Agilent Technologies

Advanced Design System 2011.01

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3GPP LTE Design Library

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The following third-party libraries are used by the NlogN Momentum solver:

"This program includes Metis 4.0, Copyright © 1998, Regents of the University of Minnesota", http://www.cs.umn.edu/~metis , METIS was written by George Karypis (karypis@cs.umn.edu).

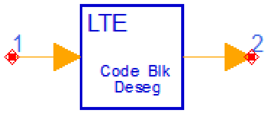
Intel@ Math Kernel Library, http://www.intel.com/software/products/mkl

3GPP LTE Channel Coding Components

The receiver models are for both downlink and uplink channel coding.

Contents

LTE_CodeBlkDeseg (LTE Code Block Desegmentation)



Description: LTE Code block de-segmentation
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

Notes/Equations

1. This model is used to perform the code block desegmentation on the input bit sequence.
2. The input bits to the code block desegmentation are denoted by c_{r0}, c_{r1}, c_{r2}, c_{r3},..., $c_{r(Kr-1)}$, where r is the code block number, and K~r~ is the number of bits for code block r.
   Number of bits in each code blocks (applicable for C ≠ 0 only):
   First segmentation size K_+ = minimum K in table 5.1.3-3 [1] such that $C \cdot K \geq B'$

   if C =1

   the number of code blocks with length K_+ is $C_+ = 1$, $K_- = 0$, $C_- = 0$

   else if $C > 1$\

   Second segmentation size K_- = maximum K in the table 5.1.3-3 [1] such that $K < K_+$

   $\Delta_K = K_+ - K_-$

   Number of segments of size K_-: $C_- = \left\lfloor \frac{C \cdot K_+ - B'}{\Delta_K} \right\rfloor$

   Number of segments of size K_+: $C_+ = C - C_-$

   end if
3. Number of filler bits F = $C_+ \cdot K_+ + C_- \cdot K_- - B'$

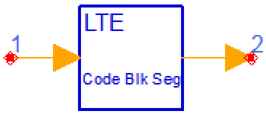
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_CodeBlkSeg (LTE Code Block Segmentation)



Description: LTE Code block segmentation
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

Notes/Equations

1. This model is used to perform downlink/uplink transport block segmentation.
2. The input bit sequence is denoted by b_0, b_1, b_2,...,b_{B-1}, where B>0. If B is larger than the maximum code block size Z, segmentation of the input bit sequence is performed and an additional CRC sequence of L = 24 bits is attached to each code block. The maximum code block size is Z = 6144.
3. If the number of filler bits F calculated below is not 0, filler bits are added to the beginning of the first block. If B < 40, filler bits are added to the beginning of the code block. The filler bits are always set to *NULL* at the input of the encoder. In this model, the value of filler bits is set to -1.
4. The total number of code blocks C is determined by:
   if $B \le Z$;

   $L = 0$

   $C = 1$

   $B' = B$

   else

   $L = 24$

   $C = \lceil B/(Z-L) \rceil$

   $B' = B + C \cdot L$

   end if
5. The bits output from code block segmentation are denoted by c_{r0}, c_{r1}, c_{r2}, c_{r3},..., $c_{r(Kr-1)}$, where r is the code block number, and K~r~ is the number of bits for code block r.
   Number of bits in each code blocks (applicable for C ≠ 0 only):
   First segmentation size K_+ = minimum K in table 5.1.3-3 [1] such that $C \cdot K \ge B'$

   if C =1

   the number of code blocks with length K_+ is $C_+ = 1$, $K_- = 0$, $C_- = 0$

   else if $C > 1$\

   Second segmentation size K_- = maximum K in the table 5.1.3-3 [1] such that $K < K_+$

   $\Delta_K = K_+ - K_-$

   Number of segments of size K_-: $C_- = \left\lfloor \frac{C \cdot K_+ - B'}{\Delta_K} \right\rfloor$

   Number of segments of size K_+: $C_+ = C - C_-$

   end if
6. Number of filler bits F = $C_+ \cdot K_+ + C_- \cdot K_- - B'$

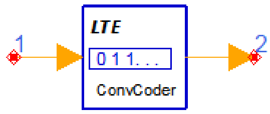
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_ConvCoder (Downlink Convolutional Coding)



Description: Downlink convolutional coding
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
InfoBitsSize	Information bits size	40	int	[7,∞)
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}	int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}	int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}	int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}	int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}	int array	[0,2e16-1]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	
ChannelType	the channel type to be coded: BCH, PDCCH, Others	BCH	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output data	int

Notes/Equations

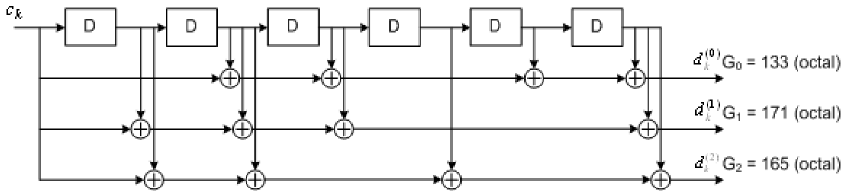
1. This model performs tail biting convolutional coding with constraint length 7 and coding rate 1/3 as defined in subclause 5.1.3.1 of 36212-880. This model can work for LTE PDCCH, LTE BCH or other input information sequence bits by setting the parameter ChannelType as PDCCH, BCH or Others.
2. Each firing, the number of tokens consumed and generated at the input and output port are decided as follows:
    - If the ChannelType is set to BCH and Others, the number of the tokens in port DataIn is defined by parameter InfoBitsSize, and the number of the tokens in port DataOut is *InfoBitsSize*3*.
    - If the ChannelType is set to PDCCH, the number of the tokens in port DataIn is

$N_{In} = \sum_{sf=0}^{sf=9} \sum_{l=0}^{l=NumOfActiveDCIs\_sf} (N_{DCIbits}(sf,l) + 16)$, and the number of the tokens in port DataOut is $N_{Out} = N_{In}*3$. Where, 16 is the number of attached CRC bits in each DCI; $N_{DCIbits}(sf,l)$ is the number of bits of the l^{th} DCI in subframe *sf* defined in 5.3.3.1 of 36212-880 and *NumOfActiveDCI_sf* is the number of active DCIs of one subframe which is same as that of the active PDCCHs. They are decided by the PDCCH corresponding parameters and system parameters. For the PDCCH default setting, N_{In} = 410 and N_{Out} = 1230.

3. Parameter details:
   - If the ChannelType is set to BCH or Others, only parameter InfoBitsSize is active. In LTE 8.9, InfoBitsSize represents the size of bits input this models.For example, if ChannelType = BCH, in LTE 8.9, set InforBitsSize=40, the number of tokens consumed in DataIn is 40.
   - If the ChannelType is set to PDCCH, the PDCCH corresponding parameters are active.

ChannelType	Active parameters
BCH or Others	InfoBitsSize
PDCCH	FrameMode TDD_Config Bandwidth NumTxAnts CyclicPrefix PDCCH_SymsPerSF PHICH_Ng PDCCH_UE_AggreLevel PDCCH_UE_DCI_Formats PDCCH_Common_AggreLevel PDCCH_Common_DCI_Formats UE_n_RNTI

4. The **configuration of the convolutional encoder** is presented in the following figure:



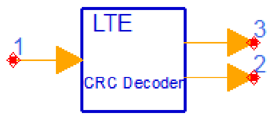
   - The initial value of the shift register of the encoder shall be set to the values corresponding to the last 6 information bits in the input stream so that the initial and final states of the shift register are the same. Therefore, denoting the shift register of the encoder by $s_0, s_1, s_2, \ldots, s_5$, then the initial value of the shift register shall be set to $s_i = c_{(K-1-i)}$
   - The encoder output streams $d_k^{(0)}$, $d_k^{(1)}$ and $d_k^{(2)}$ correspond to the first, second and third parity streams, respectively as shown in the figure above.

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).
For more details refer to *LTE_DL_DCI_Gen* (3gpplte) and *DL Control Channel Parameters* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_CRCDecoder (LTE CRC Decoder)



Description: CRC decoder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
CRC_Length	Number of parity bits: CRC_24A, CRC_24B, CRC_16, CRC_8	CRC_24A	enum	
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	CRCOut	data out	int
3	DataOut	data out	int

Notes/Equations

1. This model is used to perform CRC decoding on coded LTE transport block.
2. The parity bits are generated by one of the following cyclic generator polynomials:

CRC_Length	Number of Parity bits (L)	Cyclic generator polynomial
CRC_24A	24	$g_{CRC24A}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^{7} + D^{6} + D^{5} + D^{4} + D^{3} + D + 1]$
CRC_24B	24	$g_{CRC24B}(D) = [D^{24} + D^{23} + D^{6} + D^{5} + D + 1]$
CRC_16	16	$g_{CRC16}(D) = [D^{16} + D^{12} + D^{5} + 1]$
CRC_8	8	$g_{CRC8}(D) = [D^{8} + D^{7} + D^{4} + D^{3} + D + 1]$

3. Each firing, one radio frame is processed. For each subframe, this model performs CRC encoding on the first TransblockSize tokens of the input sequence and gets L parity tokens, which will be compared with the last L tokens of input sequence. If the result is the same, 0 is output at CRCOut, otherwise 1 is output at CRCOut.
   For more information on the calculation of number of channel bits and transport block size, please refer to *LTE_UL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).

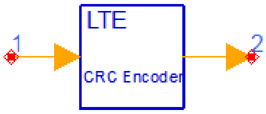
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_CRCEncoder (LTE CRC Encoder)



Description: Add CRC to each Transport Block
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
CRC_Length	Number of parity bits: CRC_24A, CRC_24B, CRC_16, CRC_8	CRC_24A	enum	
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	5640 5640 5640 5640 5640 5640 5640 5640 5640 5640	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

Notes/Equations

1. This model is used to perform CRC attachment on LTE transport block.
2. The parity bits are generated by one of the following cyclic generator polynomials:

CRC_Length	Number of Parity bits (L)	Cyclic generator polynomial
CRC_24A	24	$g_{CRC24A}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^{7} + D^{6} + D^{5} + D^{4} + D^{3} + D + 1]$
CRC_24B	24	$g_{CRC24B}(D) = [D^{24} + D^{23} + D^{6} + D^{5} + D + 1]$
CRC_16	16	$g_{CRC16}(D) = [D^{16} + D^{12} + D^{5} + 1]$
CRC_8	8	$g_{CRC8}(D) = [D^{8} + D^{7} + D^{4} + D^{3} + D + 1]$

3. The encoding is performed in a systematic form, which means that in GF(2), the polynomial:
   $a_0D^{A+23} + a_1D^{A+22} + ... + a_{A-1}D^{24} + p_0D^{23} + p_1D^{22} + ... + p_{22}D^1 + p_{23}$
   yields a remainder equal to 0 when divided by the corresponding length-24 CRC generator polynomial, $g_{CRC24A}(D)$ or $g_{CRC24B}(D)$, the polynomial

   $a_0D^{A+15} + a_1D^{A+14} + ... + a_{A-1}D^{16} + p_0D^{15} + p_1D^{14} + ... + p_{14}D^1 + p_{15}$
   yields a remainder equal to 0 when divided by $g_{CRC16}(D)$, and the polynomial:

   $a_0D^{A+7} + a_1D^{A+6} + ... + a_{A-1}D^{8} + p_0D^{7} + p_1D^{6} + ... + p_6D^1 + p_7$
   yields a remainder equal to 0 when divided by $g_{CRC8}(D)$.
4. Each firing, one radio frame is processed. For each subframe, TransBlockSize tokens are consumed in the DataIn port and TransBlockSize + L tokens are output in the DataOut port.
   For more information on the calculation of number of channel bits and transport block size, please refer to *LTE_UL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).

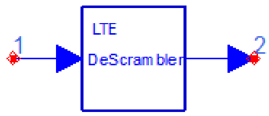
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009

LTE_DeScrambler (LTE Downlink and Uplink Descrambler)



Description: LTE Downlink and Uplink DeScrambler
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
n_RNTI	radio network temporary identifier	0	int	[0,65535]
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
q	Code word number	0	int	[0, 1]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2,	Tx1	enum	

	Tx4			
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	scrambler input	real

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	scrambler output	real

Notes/Equations

1. This model is used to perform descrambling for PDSCH/PUSCH. For more information, please refer to *LTE_Scrambler* (3gpplte).
2. For the benefit of soft decision decoding of Turbo codes, this model supports descrambling for soft information.

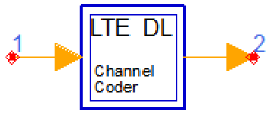
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
2. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE DL ChannelCoder (Downlink Channel Coder)



Description: Downlink channel coder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
n_RNTI	radio network temporary identifier	0	int	[0,65535]
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
CRC_Length	Number of parity bits: CRC_24A, CRC_24B, CRC_16, CRC_8	CRC_24A	enum	
RV_Idx	Redundancy Version Index	0	int	[0, 3]
UE_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1	enum	
q	Code word number	0	int	[0, 1]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	5640 5640 5640 5640 5640 5640 5640 5640 5640 5640	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	

Pin Inputs

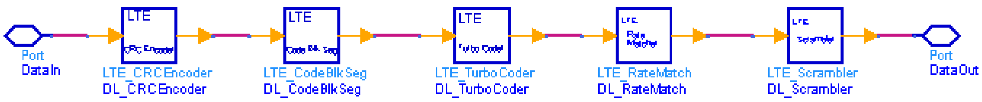
Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

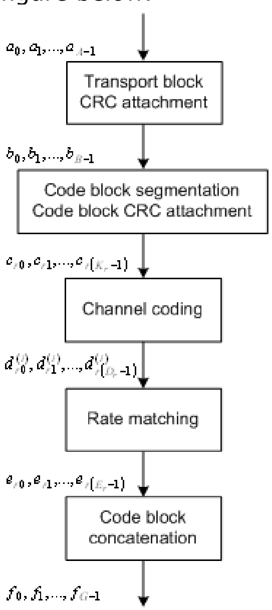
Notes/Equations:

1. This subnetwork performs LTE downlink channel coding. Data streams from MAC layer are encoded to offer transport services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting, rate matching, interleaving and transport channel mapping onto physical channels. The schematic for this subnetwork is shown in the following figure.



LTE_DL_ChannelCoder Schematic

2. The subnetwork includes LTE_CRCEncoder, LTE_CodeBlkSeg, LTE_TurboCoder, LTE_RateMatch and LTE_Scrambler, which perform CRC attachment, code block segmentation, turbo encoding, rate matching and PDSCH scrambling respectively for both FDD and TDD.
3. Data arrives to the coding unit in form of a maximum of one transport block every transmission time interval (TTI). The coding steps for DL_SCH are shown in the figure below.



4. ChBit_Config determines how to calculate the number of channel bits in each subframe.
    1. If ChBit_Config is REs per subframe, number of channel bits in each subframe is calculated from the parameters following NumChBits, and NumChBits is ignored.
        1. At first, number of REs allocated for PDSCH transmission in each subframe is calculated from those parameters. For example, suppose the following parameters configuration

Parameter	Value
FrameMode	FDD
Bandwidth	5MHz
CyclicPrefix	Normal
RB_AllocType	StartRB + NumRBs
RB_Alloc	{0, 25}
PDCCH_SymPerSF	{2,2,2,2,2,2,2,2,2,2}
NumTxAnts	1
NumOfLayers	1

- As can be seen from the table above, all 25 RBs are allocated for

        PDSCH, hence, there are NumRBs × Subcarrier_Per_RB = 25 × 12 = 300 PDSCH REs in each OFDM symbol. For more information on RB allocation, please refer to *Resource Block Allocation* (3gpplte).
        - Since CyclicPrefix is Normal, there are 7 OFDM symbols in each slot. There are 4 REs reserved for RS in each RB when NumTxAnts = 1. PDCCH occupies 2 symbols in each subframe. After the RB allocation of all other downlink physical signals and channels, number of REs available for PDSCH in each subframe is {3030, 3450, 3450, 3450, 3450, 3306, 3450, 3450, 3450, 3450}.
    2. As this codeword is mapped onto one layer (NumOfLayers = 1), suppose MappingType are QPSK in all subframes, number of channel bits of PUSCH data and control inforamtion in each subframe is { 6060, 6900, 6900, 6900, 6900, 6612, 6900, 6900, 6900, 6900}.
    3. Then, transblock size and MCS of each subframe are calculated. For more information, please refer to *Relation of Transport Block Sizes, Channel Bits and Code Rates* (3gpplte).
  2. If ChBit_Config is Channel bit size, number of channel bits in each subframe is given by NumChBits directly independent of the LTE system parameters.

5. Please note that this model doesn't check the RB allocation conflicts of physical channels and signals. It relies on other related models, for example, LTE_DL_Src, to check these potential conflicts.
6. It should also be noted that parameter "NumOfLayers" here indicates the number of layers for this codeword. If MIMO_Mode is Spatial Multiplexing, number of channel bits equals the product of number of available REs, modulation order and NumOfLayers; otherwise, for Transmit Diversity, number of channel bits equals the product of number of available REs and modulation order. For Transmit Diversity, NumOfLayers only affects rate matching, more specifically, the value of N_L, for more information, please refer to [2].

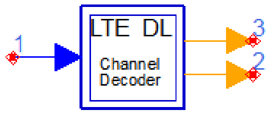
Parameter Details

- ChBit_Config: specify the calculation method of number of channel bits, it can be selected as REs per subframe and Channel bit size.
- NumChBits: number of channel bits in each subframe, it is an *Array Parameter* (3gpplte). This parameter would be ignored when ChBit_Config is selected as REs per subframe. The supported sizes are 1 × 1 and 10 × 1.
  For more information on the other parameters, please refer to *LTE_DL_Src* (3gpplte).

References

1. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_DL_ChannelDecoder (LTE Downlink Channel Decoder)



Description: Downlink channel decoder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
n_RNTI	radio network temporary identifier	0	int	[0,65535]
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
CRC_Length	Number of parity bits: CRC_24A, CRC_24B, CRC_16, CRC_8	CRC_24A	enum	
RV_Idx	Redundancy Version Index	0	int	[0, 3]
UE_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1	enum	
q	Code word number	0	int	[0, 1]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	5640 5640 5640 5640 5640 5640 5640 5640 5640 5640	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
TC_Iteration	Turbo decoder iteration number	4	int	[1,20]

Pin Inputs

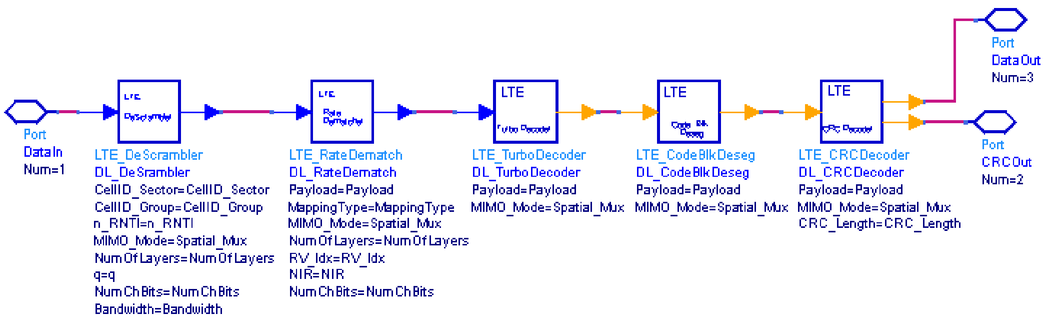
Pin	Name	Description	Signal Type
1	DataIn	data in	real

Pin Outputs

Pin	Name	Description	Signal Type
2	CRCOut	CRC out	int
3	DataOut	data out	int

Notes/Equations:

1. This subnetwork performs LTE downlink/uplink channel decoding.
   The schematic for this subnetwork is shown in the following figure.



LTE_ChannelCoder Schematic

2. The subnetwork includes LTE_Descrambler, LTE_RateDematch, LTE_TurboDecoder, LTE_CodeBlkDeseg and LTE_CRCDecoder, which perform PDSCH descrambling, rate dematch , turbo decoding, code block de-segmentation and CRC decoding respectively.
3. On the calculation of number of channel bits and transport block size, please refer to *LTE_DL_ChannelCoder* (3gpplte).

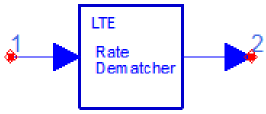
Parameter Details

For more information, please refer to *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_RateDematch (LTE Downlink and Uplink Rate Dematching)



Description: Downlink and Uplink SCH Rate Dematching
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
RV_Idx	Redundancy Version Index	0	int	[0, 3]
UE_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1	enum	
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	Data In	real

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	Data Out	real

Notes/Equations:

1. This model is used to implement rate dematching for LTE PDSCH/PUSCH.
2. This model implements the inverse operation of LTE_RateMatch. For more information, please refer to *LTE_RateMatch* (3gpplte).
3. Each firing, one radio frame is processed. For each subframe, NumChBits tokens are consumed in the DataIn port.
   For more information on the calculation of number of channel bits and transport block size, please refer to *LTE_UL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).

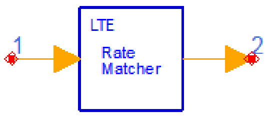
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009

LTE_RateMatch (LTE Downlink and Uplink SCH Rate Matching)



Description: Downlink and Uplink SCH Rate Matching
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
RV_Idx	Redundancy Version Index	0	int	[0, 3]
UE_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1	enum	
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

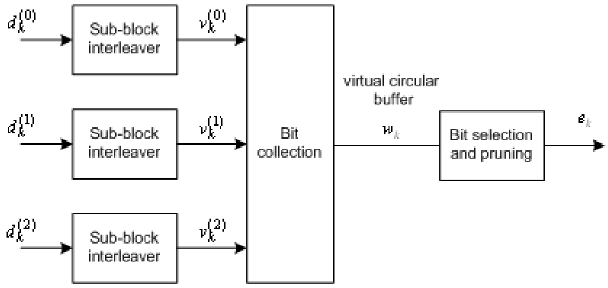
Pin	Name	Description	Signal Type
1	DataIn	Data In	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	Data Out	int

Notes/Equations:

1. This model is used to implement rate matching for turbo coded LTE PDSCH/PUSCH.
2. The rate matching for turbo coded transport channels is defined per coded block and consists of interleaving the three information bit streams $d_k^{(0)}$, $d_k^{(1)}$ and $d_k^{(2)}$, followed by the collection of bits and the generation of a circular buffer as depicted in the following figure. The output bits for each code block are transmitted as described in subclause 5.1.4.1.2 [1].



Rate matching for turbo coded transport channels

3. It should be noted that in this model, the soft buffer size N_{IR} equals the parameter NIR.
4. Each firing, one radio frame is processed. For each subframe, NumChBits tokens are output in the DataOut port.
   For more information on the calculation of number of channel bits and transport block size, please refer to *LTE_UL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).

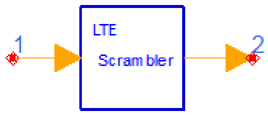
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_Scrambler (LTE Downlink and Uplink Scrambler)



Description: LTE Downlink and Uplink Scrambler
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
n_RNTI	radio network temporary identifier	0	int	[0,65535]
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
q	Code word number	0	int	[0, 1]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	

PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	scrambler input	int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	scrambler output	int

Notes/Equations

1. This model is used to perform scrambling for PDSCH/PUSCH.
2. In uplink, the block of bits $b(0)$, ..., $b(M_{bit}-1$, where M_{bit} is the number of bits transmitted on the physical uplink shared channel in one subframe, shall be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{bit}-1)$ according to pseudo code in Section 5.3.1 of [2]. M_{bit} is the sum of number of channel bits for PUSCH data and coded bits of CQI/PMI and RI. For more information on the calculation of number of channel bits, please refer to *LTE_UL_ChannelCoder* (3gpplte).
3. In downlink, For each code word q, the block of bits $b^{(q)}(0)$, ..., $b^{(q)}(M_{bits}^{(q)}-1)$, where $M_{bits}^{(q)}$ is the number of bits in code word q transmitted on the physical channel in one subframe, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{bit}^{(q)}-1)$ according to Section 6.3.1 of [2]. Up to two code words can be transmitted in one subframe, i.e., q {0,1}. In the case of single code word transmission, q is equal to zero. $M_{bit}^{(q)}$ equals the number of channel bits for PDSCH of this codeword. For more information on the calculation of number of channel bits, please refer to *LTE_DL_ChannelCoder* (3gpplte).

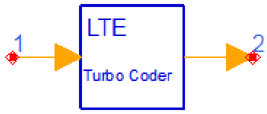
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_TurboCoder (LTE Turbo Encoder)



Description: LTE turbo encoder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

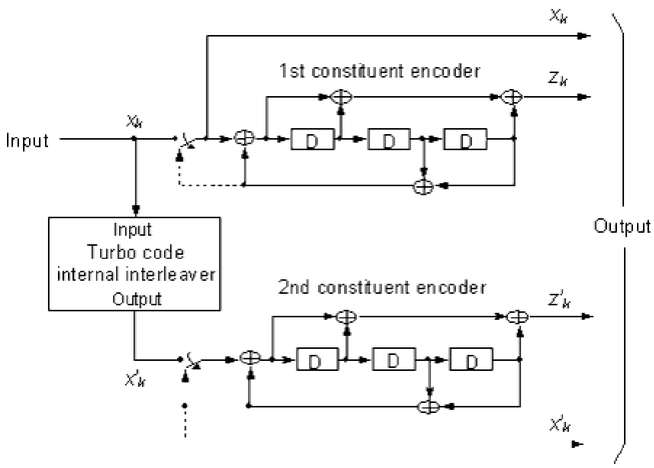
Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

Notes/Equations:

1. This model is used to implement Turbo encoding for LTE downlink/uplink each subframe.
2. The scheme of Turbo coder is a Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one turbo code internal interleaver. The coding rate of turbo coder is 1/3. The structure of turbo coder is illustrated in the following figure.



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Structure of rate 1/3 Turbo coder

3. The transfer function of the 8-state constituent code for PCCC is:

$$G(D) = \left[1, \frac{g_1(D)}{g_0(D)} \right]$$

where

$$g_0(D) = 1 + D^2 + D^3,$$

$$g_1(D) = 1 + D + D^3.$$

The initial value of the shift registers of the 8-state constituent encoders shall be all zeros when starting to encode the input bits.

4. Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded. Tail bits are padded after the encoding of information bits. The first three tail bits shall be used to terminate the first constituent encoder (upper switch of the preceding figure in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of the preceding figure in lower position) while the first constituent encoder is disabled.
5. The bits input to the turbo code internal interleaver are denoted by $x_0, x_1, \ldots, x_{(K-1)}$, where K is the number of input bits. The bits output of the turbo code internal interleaver are denoted by $x'_0, x'_1, \ldots, x'_{(K-1)}$.
The relationship between the input and output bits is as follows:
$x'_i = x_{\Pi(i)},\ i=0,1,\ldots,(K-1)$
where the relationship between the output index i and the input index $\Pi(i)$ satisfies the following quadratic form:
$\Pi(i) = \left(f_1 \cdot i + f_2 \cdot i^2\right) \bmod K$
The parameters f1 and f2 depend on the block size K and are summarized in the table illustrated below:

Turbo code internal interleaver parameters

i	K_i	f_1	f_2	i	K_i	f_1	f_2	i	K_i	f_1	f_2	i	K_i	f_1	f_2
1	40	3	10	48	416	25	52	95	1120	67	140	142	3200	111	240
2	48	7	12	49	424	51	106	96	1152	35	72	143	3264	443	204
3	56	19	42	50	432	47	72	97	1184	19	74	144	3328	51	104
4	64	7	16	51	440	91	110	98	1216	39	76	145	3392	51	212
5	72	7	18	52	448	29	168	99	1248	19	78	146	3456	451	192
6	80	11	20	53	456	29	114	100	1280	199	240	147	3520	257	220
7	88	5	22	54	464	247	58	101	1312	21	82	148	3584	57	336
8	96	11	24	55	472	29	118	102	1344	211	252	149	3648	313	228
9	104	7	26	56	480	89	180	103	1376	21	86	150	3712	271	232
10	112	41	84	57	488	91	122	104	1408	43	88	151	3776	179	236
11	120	103	90	58	496	157	62	105	1440	149	60	152	3840	331	120
12	128	15	32	59	504	55	84	106	1472	45	92	153	3904	363	244
13	136	9	34	60	512	31	64	107	1504	49	846	154	3968	375	248
14	144	17	108	61	528	17	66	108	1536	71	48	155	4032	127	168
15	152	9	38	62	544	35	68	109	1568	13	28	156	4096	31	64
16	160	21	120	63	560	227	420	110	1600	17	80	157	4160	33	130
17	168	101	84	64	576	65	96	111	1632	25	102	158	4224	43	264
18	176	21	44	65	592	19	74	112	1664	183	104	159	4288	33	134
19	184	57	46	66	608	37	76	113	1696	55	954	160	4352	477	408
20	192	23	48	67	624	41	234	114	1728	127	96	161	4416	35	138
21	200	13	50	68	640	39	80	115	1760	27	110	162	4480	233	280
22	208	27	52	69	656	185	82	116	1792	29	112	163	4544	357	142
23	216	11	36	70	672	43	252	117	1824	29	114	164	4608	337	480
24	224	27	56	71	688	21	86	118	1856	57	116	165	4672	37	146
25	232	85	58	72	704	155	44	119	1888	45	354	166	4736	71	444
26	240	29	60	73	720	79	120	120	1920	31	120	167	4800	71	120
27	248	33	62	74	736	139	92	121	1952	59	610	168	4864	37	152
28	256	15	32	75	752	23	94	122	1984	185	124	169	4928	39	462
29	264	17	198	76	768	217	48	123	2016	113	420	170	4992	127	234
30	272	33	68	77	784	25	98	124	2048	31	64	171	5056	39	158
31	280	103	210	78	800	17	80	125	2112	17	66	172	5120	39	80
32	288	19	36	79	816	127	102	126	2176	171	136	173	5184	31	96
33	296	19	74	80	832	25	52	127	2240	209	420	174	5248	113	902
34	304	37	76	81	848	239	106	128	2304	253	216	175	5312	41	166
35	312	19	78	82	864	17	48	129	2368	367	444	176	5376	251	336
36	320	21	120	83	880	137	110	130	2432	265	456	177	5440	43	170
37	328	21	82	84	896	215	112	131	2496	181	468	178	5504	21	86
38	336	115	84	85	912	29	114	132	2560	39	80	179	5568	43	174
39	344	193	86	86	928	15	58	133	2624	27	164	180	5632	45	176
40	352	21	44	87	944	147	118	134	2688	127	504	181	5696	45	178
41	360	133	90	88	960	29	60	135	2752	143	172	182	5760	161	120
42	368	81	46	89	976	59	122	136	2816	43	88	183	5824	89	182
43	376	45	94	90	992	65	124	137	2880	29	300	184	5888	323	184
44	384	23	48	91	1008	55	84	138	2944	45	92	185	5952	47	186
45	392	243	98	92	1024	31	64	139	3008	157	188	186	6016	23	94
46	400	151	40	93	1056	17	66	140	3072	47	96	187	6080	47	190
47	408	155	102	94	1088	171	204	141	3136	13	28	188	6144	263	480

6. On the calculation of number of channel bits and transport block size, please refer to *LTE_UL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).

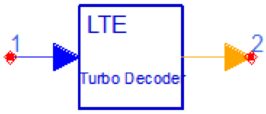
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_TurboDecoder (LTE Turbo Decoder)



Description: LTE turbo decoder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]
TC_Iteration	Turbo decoder iteration number	4	int	[1,20]

Pin Inputs

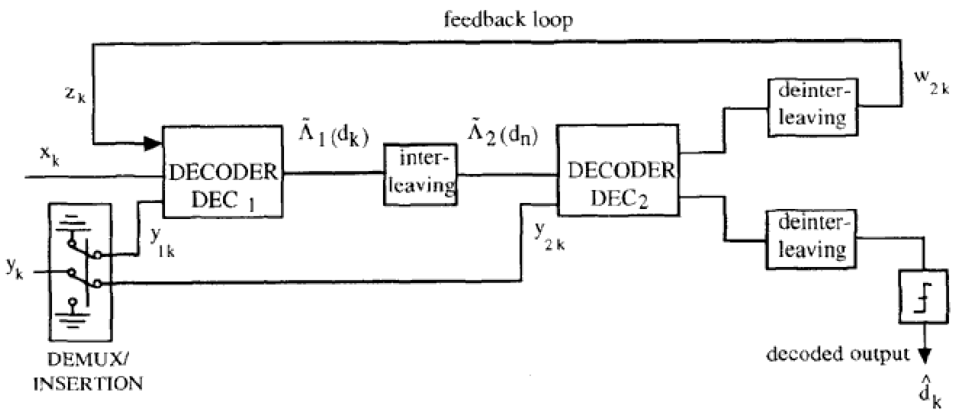
Pin	Name	Description	Signal Type
1	DataIn	data in	real

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

Notes/Equations:

1. This model is used to implement Turbo decoding for LTE downlink/uplink of each subframe.
2. An iterative decoding scheme based on the modified BAHL et al. algorithm [3][4] is used in this model. The iterative number can be set from 1 through to 20 through parameter setting. In theory, as the number of these iterations approaches infinity, the estimate at the output of decoder will approach the maximum a posteriori (MAP) solution.
3. The following figure shows the Turbo decoder structure.



Structure of Turbo decoder

The decoder 1 computes Logarithm of Likelihood Ration(LLR) associated with each decoded bit from the systematic information (X_k), redundant information of encoder 1 (y_{1k}) and extrinsic information (Z_k).

Decoder 2 takes as input the interleaved version of LLR, the redundant information of second encoder (y_{2k}). The extrinsic information from decoder 2 is interleaved to produce Z_k, which is fed back to decoder 1.

4. On the calculation of number of channel bits and transport block size, please refer to *LTE_UL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).

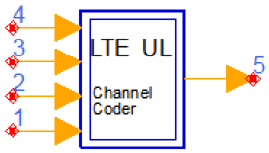
Parameter Details

For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
2. L.R. Bahl, J. Cocke, F. Jeinek and J. Raviv. "Optimal decoding of linear codes for minimizing symbol error rate." IEEE Trans. Inform. Theory, vol. IT-20. pp.248-287, March 1974.
3. C. Berrou and A. Glavieus. "Near optimum error correcting coding and decoding: turbo-codes", IEEE Trans. Comm., pp. 1261-1271, Oct. 1996.

LTE_UL_ChannelCoder (Uplink Channel Coder)



Description: uplink channel coder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
n_RNTI	radio network temporary identifier	0	int	[0,65535]
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
RV_Idx	Redundancy Version Index	0	int	[0, 3]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing,	Data_and_Control_Multiplexing	enum	

	Data_Only, Control_Only			
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0}	int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0}	int array	[0,14]
ACK_NACK_FeedbackMode	ACK/NACK feedback modes for TDD: ACK_NACK_multiplexing, ACK_NACK_bundling	ACK_NACK_multiplexing	enum	
Nbundled	Nbundled for TDD ACK/NACK bundling	{1}	int array	[1,20]

Pin Inputs

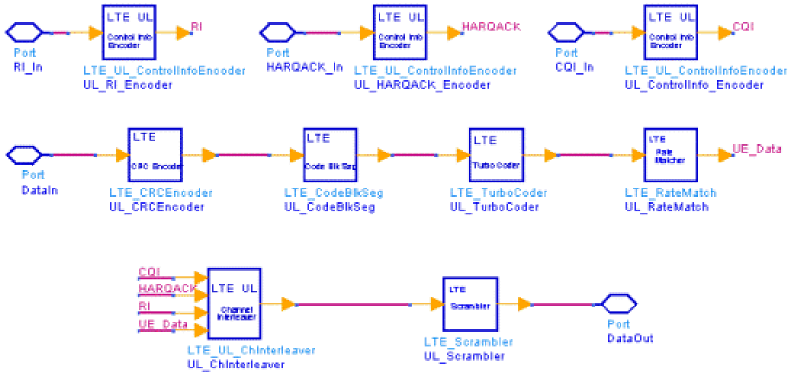
Pin	Name	Description	Signal Type
1	DataIn	data in	int
2	RI_In	rank indication in	int
3	HARQACK_In	HARQ and ACK in	int
4	CQI_In	channel quality information in	int

Pin Outputs

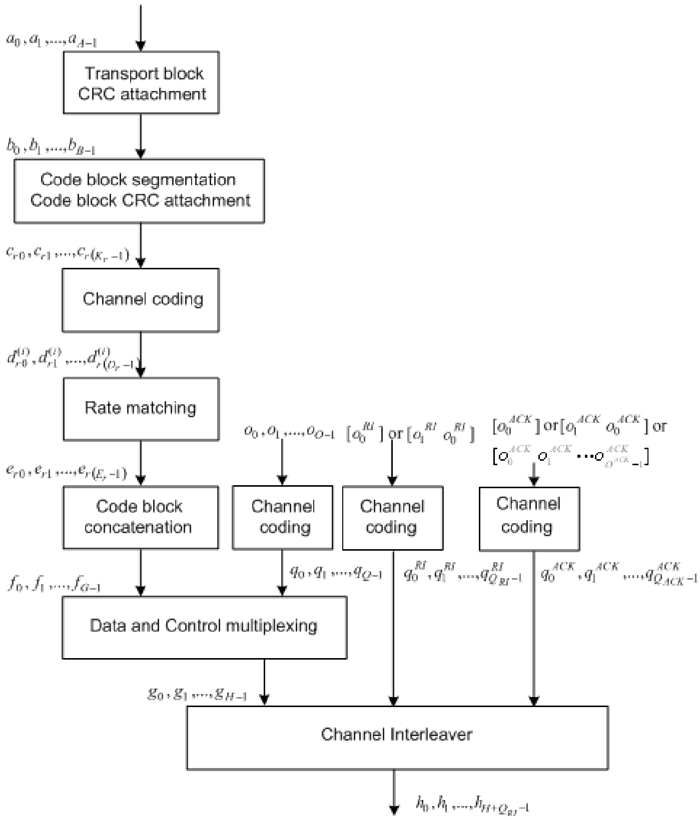
Pin	Name	Description	Signal Type
5	DataOut	data out	int

Notes/Equations

1. This subnetwork performs LTE uplink channel coding. Data and control streams from MAC layer are encoded to offer transport and control services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting, rate matching, interleaving and transport channel or control information mapping onto physical channels.
2. Each firing,
   - the number of tokens consumed at port DataIn is equal to the sum of transport block size (A) of all subframes.
   - the number of tokens consumed at port RI_In is equal to the number of RI information bits in each frame.
   - the number of tokens consumed at port HARQACK_In is equal to the number of HARQ-ACK information bits in each frame.
   - the number of tokens consumed at port CQI_In is equal to the number of CQI information bits in each frame.
   - the number of tokens produced at port DataOut is equal to the sum of the number of channel bits and the number of CQI and RI coded bits ($G + H + Q_{RI}$) in each frame. For more information, please refer to *Relation of Transport Block Sizes, Channel Bits and Code Rates* (3gpplte).
   - For the default parameter configurations, the transport block size in each subframe are [2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555], the number of channel bits in each subframe are [7200, 7200, 7200, 7200, 7200, 7200, 7200, 7200, 7200, 7200], uplink control information are not transmitted. Hence, by default, 25550 tokens are consumed at port DataIn, 72000 tokens are produced at port DataOut, 1 token is consumed at port RI_In, HARQACK_In and CQI_In.
3. The schematic **LTE_UL_ChannelCoder** is shown below:



4. The subnetwork includes LTE_CRCEncoder, LTE_CodeBlkSeg, LTE_TurboCoder, LTE_RateMatch, LTE_UL_ChInterleaver and LTE_Scrambler, which perform CRC attachment, code block segmentation and code block CRC attachment, turbo encoding, rate matching, multiplexing of data and control information as well as interleaving and PUSCH scrambling respectively for both FDD and TDD.
5. In addition, this subnetwork includes three LTE_UL_ControlInfoEncoders for channel coding of control information in the form of channel quality information(CQI and/or PMI), HARQ-ACK and rank indication respectively. Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. For more information, please refer to *LTE_UL_ControlInfoEncoder* (3gpplte).
6. Data arrives to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI). Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication. The coding steps for UL_SCH (**Transport channel processing for UL-SCH**)are shown in the figure below:



7. ChBit_Config specify the calculation method of number of channel bits (G), it can be selected as REs per subframe and Channel bit size. NumChBits indicates the number of channel bits in each subframe, it is an *Array Parameter* (3gpplte). This parameter would be ignored when ChBit_Config is selected as REs per subframe. The supported sizes are 1 × 1 and 10 × 1.
   - If ChBit_Config is selected as 0:REs per subframe, number of channel bits in each subframe is calculated from those parameters following NumChBits, and NumChBits is ignored.
      - At first, number of REs allocated for PUSCH transmission in each subframe

is calculated from those parameters. For example, suppose the following parameters configurations:

Parameter	Value
FrameMode	FDD
Bandwidth	5MHz
CyclicPrefix	Normal
RB_AllocType	StartRB + NumRBs
RB_Alloc	{0, 25}
PUCCH_PUSCH	PUSCH
SRS_Enable	YES
SRS_SF_Config	3

- As can be seen from the table above, all 25 RBs are allocated for PUSCH, hence, there are NumRBs × Subcarrier_Per_RB = 25 × 12 = 300 PUSCH REs in each SC-FDMA symbol. For more information on RB allocation, please refer to *Resource Block Allocation* (3gpplte).
- Since CyclicPrefix is Normal, there are 7 SC-FDMA symbols in each slot, among which 1 SC-FDMA symbol is allocated for DMRS for PUSCH.
- Sounding reference signals are transmitted at the last symbol of subframe 0 and subframe 5 since SRS_SF_Config = 3. Therefore, number of SC-FDMA symbols for PUSCH transmission in each subframe is {11, 12, 12, 12, 12, 11, 12, 12, 12, 12}.
- Number of REs available for PUSCH in each subframe is {3300, 3600, 3600, 3600, 3600, 3300, 3600, 3600, 3600, 3600}.
- Suppose MappingType are QPSK in all subframes, number of channel bits of PUSCH data and control inforamtion in each subframe is {6600, 7200, 7200, 7200, 7200, 6600, 7200, 7200, 7200, 7200}.
- Number of coded bits of control information in the form of CQI/PMI (H) and RI (Q_{RI}) are subtracted from the number of available REs. It should be noted that HARQ-ACK information will overwrites some of the channel interleaver entries for PUSCH data, hence, it should not be subtracted. For more information, please refer to *LTE_UL_ChInterleaver* (3gpplte).
- Then, transblock size and MCS of each subframe are calculated. For more information, please refer to *Relation of Transport Block Sizes, Channel Bits and Code Rates* (3gpplte).

- If ChBit_Config is Channel bit size, number of channel bits in each subframe is given by NumChBits directly independent of the LTE system parameters.

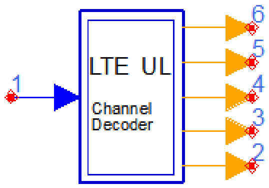
8. See *LTE_UL_ChannelDecoder* (3gpplte), *LTE_DL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelDecoder* (3gpplte).

- For more information on the channel coding of LTE uplink control information, please refer to *LTE_UL_ControlInfoEncoder* (3gpplte).
- For more information on the parameters details, please refer to *LTE_UL_Src* (3gpplte).

References

1. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_UL_ChannelDecoder (LTE Uplink Channel Decoder)



Description: uplink channel decoder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
n_RNTI	radio network temporary identifier	0	int	[0,65535]
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
RV_Idx	Redundancy Version Index	0	int	[0, 3]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	

PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0}	int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0}	int array	[0,14]
TC_Iteration	Turbo decoder iteration number	4	int	[1,20]

Pin Inputs

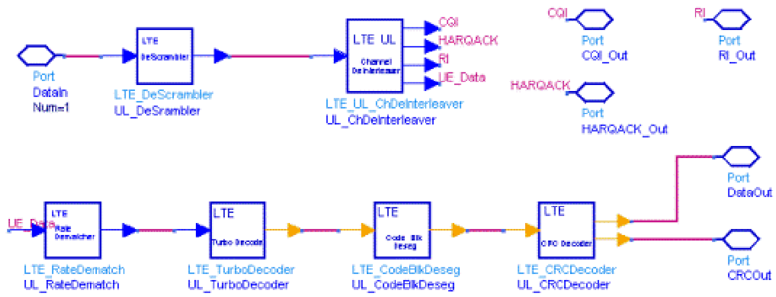
Pin	Name	Description	Signal Type
1	DataIn	data in	real

Pin Outputs

Pin	Name	Description	Signal Type
2	CRCOut	CRC out	int
3	DataOut	data out	int
4	RI_Out	rank indication out	int
5	HARQACK_Out	HARQ and ACK out	int
6	CQI_Out	channel quality information out	int

Notes/Equations

1. This subnetwork performs LTE uplink channel decoding. Data and control streams to MAC layer are decoded to offer transport and control services over the radio transmission link. Channel decoding scheme is a combination of error detection, error correcting, de-rate matching, deinterleaving and transport channel or control information splitting from physical channels.
2. Each firing
   - the number of tokens consumed at port DataIn is equal to the sum of the number of channel bits (G) and number of CQI coded bits (H) and RI coded bits (Q_{RI}) in each frame. For more information, please refer to *LTE_RateDematch* (3gpplte) and *LTE_UL_ChDeInterleaver* (3gpplte).
   - one token is produced at port CRC_Out, where '1' indicates CRC check success, '0' indicates CRC check failure.
   - the number of tokens produced at port DataOut is equal to the sum of the transport block size decoded in all subframes.
   - the number of tokens produced at port RI_Out is equal to the number of RI bits transmitted in each frame.
   - the number of tokens produced at port HARQACK_Out is equal to the number of HARQ-ACK bits transmitted in each frame.
   - the number of tokens produced at port CQI_Out is equal to the number of CQI bits transmitted in each frame.
   - For the default parameters configurations, the transport block size in each subframe are [2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555], the number of channel bits in each subframe are [7200, 7200, 7200, 7200, 7200, 7200, 7200, 7200, 7200, 7200], uplink control information are not transmitted. Hence, by default, 72000 tokens are consumed at port DataIn, 25550 tokens are produced at port DatatOut. 1 null token is produced at port RI_Out, HARQACK_Out and CQI_Out.
3. The **LTE_UL_ChannelDecoder** schematic is shown below:



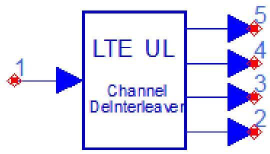
4. The subnetwork includes LTE_Descrambler, LTE_UL_ChDeinterleaver, LTE_RateDematch, LTE_TurboDecoder, LTE_CodeBlkDeseg and LTE_CRCDecoder, which performs PUSCH descrambling, deinterleaving and demultiplexing of data and control information, rate dematching , turbo decoding, code block de-segmentation and CRC decoding respectively for both FDD and TDD.
5. It should be noted that channel decoding for control information is **NOT** supported in current implementation.
6. See *LTE_UL_ChannelCoder* (3gpplte), *LTE_DL_ChannelDecoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).

- For more information on the calculation of number of channel bits, transport block size and MCS, please refer to *LTE_UL_ChannelCoder* (3gpplte).
- For more information on the parameters details, please refer to *LTE_UL_Src* (3gpplte).

References

1. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_UL_ChDeInterleaver (Uplink PUSCH Channel De-interleaver)



Description: Uplink PUSCH Channel DeInterleaver
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,14]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	Data In	real

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	Data Out	real
3	RI	Rank Indication Out	real
4	HARQACK	HARQ-ACK Out	real
5	CQI	CQI/PMI Out	real

Notes/Equations

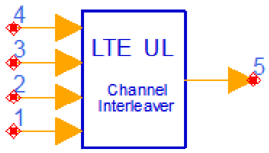
1. This model is used to deinterleave the uplink bits transported in each subframe and demultiplex the uplink control information and data.
2. Each firing,
   - the number of tokens consumed at port DataIn is equal to (*PUSCH_NumChBits* + *RI_NumCodedBits* + *CQI_NumCodedBits*), where *PUSCH_NumChBits* is the number of PUSCH channel bits in each frame, *RI_NumCodedBits* is the number of RI coded bits in each frame, *CQI_NumCodedBits* is the number of CQI coded bits in each frame;
   - the number of tokens produced at port DataOut is equal to *PUSCH_NumChBits*;
   - the number of tokens produced at port RI is equal to *RI_NumCodedBits*;
   - the number of tokens produced at port HARQACK is equal to *HARQACK_NumCodedBits*, where *HARQACK_NumCodedBits* is the number of HARQ-ACK coded bits in each frame;
   - the number of tokens produced at port CQI is equal to *CQI_NumCodedBits*;
   - For the default parameter configurations, the control information is not transmitted, *PUSCH_NumChBits* = 25RB × 12Symbols × 12SubcPerRB × 2(Q_m) × 10 subframes = 72000. 1 null token is produced at port RI, HARQACK and CQI.
3. For more information on the calculation of *RI_NumCodedBits*, *HARQACK_NumCodedBits* and *CQI_NumCodedBits*, please refer to *LTE_UL_ControlInfoEncoder* (3gpplte).
4. See *LTE_UL_ChInterleaver* (3gpplte).

- For more information on the calculation of number of channel bits, please refer to *LTE_UL_ChannelCoder* (3gpplte).
- For more information on the parameters details, please refer to *LTE_UL_Src* (3gpplte).
- For more information on channel coding for uplink control information, please refer to *LTE_UL_ControlInfoEncoder* (3gpplte).

References

1. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
3. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_UL_ChInterleaver (Uplink PUSCH Channel Interleaver)



Description: Uplink Channel Interleaver
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,14]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	Data In	int
2	RI	Rank Indication In	int
3	HARQACK	HARQ-ACK In	int
4	CQI	CQI/PMI In	int

Pin Outputs

Pin	Name	Description	Signal Type
5	DataOut	Data Out	int

Notes/Equations

1. This model is used to interleave the uplink bits transported in each subframe. If control data are sent via PUSCH with UL-SCH data, the uplink control information and data multiplexing is also implemented in this model.
2. Each firing,
   - the number of tokens consumed at port DataIn is equal to *PUSCH_NumChBits*, where *PUSCH_NumChBits* is the number of PUSCH channel bits in each frame;
   - the number of tokens consumed at port RI is equal to *RI_NumCodedBits*, where *RI_NumCodedBits* is the number of RI coded bits in each frame;
   - the number of tokens consumed at port HARQACK is equal to *HARQACK_NumCodedBits*, where *HARQACK_NumCodedBits* is the number of HARQ-ACK coded bits in each frame;
   - the number of tokens consumed at port CQI is equal to *CQI_NumCodedBits*, where *CQI_NumCodedBits* is the number of CQI coded bits in each frame;
   - the number of tokens produced at port DataOut is equal to (*PUSCH_NumChBits* + *RI_NumCodedBits* + *CQI_NumCodedBits*) in each frame;
   - For the default parameter configurations, the control information is not transmitted, *PUSCH_NumChBits* = 25RB × 12Symbols × 12SubcPerRB × 2(Q_m) × 10 subframes= 72000, *RI_NumCodedBits* = 0, *HARQACK_NumCodedBits* = 0, *CQI_NumCodedBits* = 0.
3. The control and data multiplexing is performed such that HARQ-ACK information is present on both slots and is mapped to resources around the demodulation reference signals. In addition, the multiplexing ensures that control and data information are mapped to different modulation symbols.
4. The channel interleaver in conjunction with the resource element mapping for PUSCH in [2] implements a time-first mapping of modulation symbols onto the transmit waveform while ensuring that the HARQ-ACK information is present on both slots in the subframe and is mapped to resources around the uplink demodulation reference signals.

   The input to the channel interleaver are denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, ..., \underline{g}_{H'-1}$, $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, ..., \underline{q}_{Q'_{RI}-1}^{RI}$, and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$. The number of modulation symbols in the subframe is given by $H'' = H' \_ Q'_{RI}$. The output bit sequence from the channel interleaver is derived as follows:

   1. Assign $C_{mux} = N^{PUSCH}_{symb}$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,..., $C_{mux} - 1$ from left to right. N^{PUSCH}_{symb} is determined according to section 5.2.2.6 [1].
   2. The number of rows of the matrix is $R_{mux} = (H'' \cdot Q_m) / C_{mux}$ and we define $R'_{mux} = R_{mux} / Q_m$. The rows of the rectangular matrix are numbered 0, 1, 2,..., $R_{mux} - 1$ from top to bottom.
   3. If rank information is transmitted in this subframe, the vector sequence $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, ..., \underline{q}_{Q'_{RI}-1}^{RI}$ is written onto the columns indicated by Table 5.2.2.8-1 [1], and by sets of Q_m rows starting from the last row and moving upwards according to the following pseudo code.

      Set i, j to 0.

      Set r to $R'_{mux} - 1$

      while $i < Q'_{RI}$

      $$c_{RI} = \text{Column Set}(j)$$

      $$\underline{y}_{r \times C_{mux} + c_{RI}} = \underline{q}_i^{RI}$$

      $$i = i + 1$$

      $$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$$

      $$j = (j + 3) \bmod 4$$

      end while

      Where ColumnSet is given in the following table and indexed left to right from 0 to 3.

CP configuration	Column Set
Normal	{1, 4, 7, 10}
Extended	{0, 3, 5, 8}

4. Write the input vector sequence, i.e., $\underline{y}_k = \underline{g}_k$ for k = 0, 1,..., *H*' − 1, into the ($R_{mux} \times C_{mux}$) matrix by sets of Q_m rows starting with the vector $\underline{y}_0$ in column 0 and rows 0 to (Q_m − 1) and skipping the matrix entries that are already occupied:

$$\begin{bmatrix} \underline{y}_0 & \underline{y}_1 & \underline{y}_2 & \cdots & \underline{y}_{C_{mux}-1} \\ \underline{y}_{C_{mux}} & \underline{y}_{C_{mux}+1} & \underline{y}_{C_{mux}+2} & \cdots & \underline{y}_{2C_{mux}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \underline{y}_{(R_{mux}-1)\times C_{mux}} & \underline{y}_{(R'_{mux}-1)\times C_{mux}+1} & \underline{y}_{(R_{mux}-1)\times C_{mux}+2} & \cdots & \underline{y}_{(R_{mux}\times C_{mux}-1)} \end{bmatrix}$$

5. If HARQ-ACK information is transmitted in this subframe, the vector sequence $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$ is written onto the columns indicated by the following table, and by sets of Q_m rows starting from the last row and moving upwards according to the following pseudocode. Note that this operation overwrites some of the channel interleaver entries obtained in step (4).

Set i, j to 0.

Set r to $R'_{mux} - 1$

while $i < Q'_{ACK}$

$c_{ACK} = \text{ColumnSet}(j)$

$\underline{y}_{r \times C_{mux} + c_{ACK}} = \underline{q}_i^{ACK}$

$i = i + 1$

$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$

$j = (j+3) \bmod 4$

end while

Where ColumnSet is given in the following table and indexed left to right from 0 to 3.

CP configuration	Column Set
Normal	{2, 3, 8, 9}
Extended	{1, 2, 6, 7}

6. The output of the block interleaver is the bit sequence read out column by column from the ($R_{mux} \times C_{mux}$) matrix. The bits after channel interleaving are denoted by $h_0, h_1, h_2, ..., h_{H+Q_{RI}-1}$.

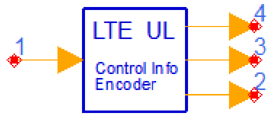
5. See *LTE_UL_ChDeInterleaver* (3gpplte).

- On the calculation of number of channel bits, please refer to *LTE_UL_ChannelCoder* (3gpplte).
- For more information on the parameters details, please refer to *LTE_UL_Src* (3gpplte).
- For more information on channel coding for uplink control information, please refer to *LTE_UL_ControlInfoEncoder* (3gpplte).

References

1. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
3. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_UL_ControlInfoEncoder (Uplink Control Information Encoder)



Description: Uplink Control Information Encoder
Library: LTE, Channel Coding

Parameters

Name	Description	Default	Type	Range
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0}	int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0}	int array	[0,14]
ControlInfoType	type of control information: CQI, HARQ ACK, Rank Indication	CQI	enum	
ACK_NACK_FeedbackMode	ACK/NACK feedback modes for TDD: ACK_NACK_multiplexing, ACK_NACK_bundling	ACK_NACK_multiplexing	enum	
Nbundled	Nbundled for TDD ACK/NACK bundling	{1}	int array	[1,20]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output data	int
3	CQI_CRCOut	output data of CRC attachment for CQI	int
4	CQI_ConvCodingOut	output data of convolutional coding for CQI	int

Notes/Equations

1. This model performs channel coding for uplink control information. Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication. Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When control data are transmitted in the PUSCH, the channel coding for HARQ-ACK, rank indication and channel quality information $o_0, o_1, o_2, o_3, \ldots, o_O$ is done independently.
2. Each firing,
   - the number of tokens consumed at port DataIn is equal to *NumInfoBits*, where *NumInfoBits* is the number of CQI/HARQ-ACK/RI information bits in each frame, which is equal to *CQI_NumInfoBits*/*HARQACK_NumInfoBits*/*RI_NumInfoBits* according to ControlInfoType;
   - the number of tokens produced at port DataOut is equal to *NumCodedBits*, where *NumCodedBits* is the number of CQI/HARQ-ACK/RI coded bits in each frame, which is calculated from the parameters according to [1];
   - the number of tokens produced at port CQI_CRCOut is equal to Σ(*CQI_NumInfoBits[subframeIndex]* + 8) when ControlInfoType is selected as CQI and *CQI_NumInfoBits[subframeIndex]* is larger than 11 in subframe#subframeIndex;
   - the number of tokens produced at port CQI_ConvCodingOut is equal to 3 × Σ(*CQI_NumInfoBits[subframeIndex]* + 8) when ControlInfoType is selected as CQI and *CQI_NumInfoBits[subframeIndex]* is larger than 11 in subframe#subframeIndex.
   - For the default parameters configurations, no control information is transmitted. Hence, one token is consumed/produced in the input/output port.
3. ControlInfoType specifies the type of control information, which can be selected from CQI, HARQ-ACK and Rank Indication. Parameters CQI_NumInfoBits/HARQACK_NumInfoBits/RI_NumInfoBits and CQI_BetaOffsetIndex/HARQACK_BetaOffsetIndex/RI_BetaOffsetIndex specify the number of information bits input to the encoder and number of output coded bits after channel coding in each subframe. These two parameters are *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
4. Uplink control information on PUSCH **with** UL-SCH data
   - When the UE transmits HARQ-ACK bits or rank indicator bits, it shall determine the number of coded symbols *Q*' for HARQ-ACK or rank indicator as

     $$Q' = \min\left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH-initial} \cdot N_{symb}^{PUSCH-initial} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C-1} K_r} \right\rceil, 4 \cdot M_{sc}^{PUSCH}\right)$$

     where *O* is the number of ACK/NACK bits or rank indicator bits, M^{PUSCH}_{sc} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, expressed as a number of subcarriers in [2], and $N^{PUSCH\text{-}initial}_{symb}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission given by $N^{PUSCH\text{-}initial}_{symb} = (2 \cdot (N^{UL}_{symb} - 1) - N_{SRS})$, where N_{SRS} is equal to 1 if UE is configured to send PUSCH and SRS in the same subframe for initial transmission or if the PUSCH resource allocation for initial transmission even partially overlaps with the cell specific SRS subframe and bandwidth configuration defined in Section 5.5.3 of [2]. Otherwise N_{SRS} is equal to 0. M^{PUSCH}_{sc}, *C* and K_r are obtained from the initial PDCCH for the same transport block. In current implementation, M^{PUSCH}_{sc}, *C* and K_r are calculated from the parameters.

     For HARQ-ACK information $Q_{ACK} = Q_m \cdot Q'$ and [$\beta^{PUSCH}_{offset} = \beta^{HARQ\text{-}ACK}_{offset}$], where $\beta^{HARQ\text{-}ACK}_{offset}$ shall be determined according to [3].

     For rank indication $Q_{RI} = Q_m \cdot Q'$ and [$\beta^{PUSCH}_{offset} = \beta^{RI}_{offset}$], where β^{RI}_{offset} shall be determined according to [3].

- When the UE transmits channel quality control information bits, it shall determine the number of coded symbols *Q*' for channel quality information as

$$Q' = \min\left(\left\lceil \frac{(O+L)\cdot M_{sc}^{PUSCH-initial}\cdot N_{symb}^{PUSCH-initial}\cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C-1} K_r} \right\rceil, M_{sc}^{PUSCH}\cdot N_{symb}^{PUSCH} - \frac{Q_{RI}}{Q_m}\right)$$

  where *O* is the number of CQI bits,

  L is the number of CRC bits given by $L = \begin{cases} 0 & O \le 11 \\ 8 & \text{otherwise} \end{cases}$,

  $Q_{CQI} = Q_m \cdot Q'$ and [$\beta^{PUSCH}_{offset} = \beta^{CQI}_{offset}$], where β^{CQI}_{offset} shall be determined according to [3]. If rank indicator is not transmitted then $Q_{RI} = 0$.

  $M^{PUSCH-initial}_{sc}$, *C* and K_r are obtained from the initial PDCCH for the same transport block (calculated from the parameters in current implementation) and $N^{PUSCH-initial}_{symb}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission.

  For UL-SCH data information $G = N^{PUSCH}_{symb} \cdot M^{PUSCH}_{sc} \cdot Q_m - Q_{CQI} - Q_{RI}$, where M^{PUSCH}_{sc} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, and N^{PUSCH}_{symb} is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N^{PUSCH}_{symb} = (2 \cdot (N^{UL}_{symb} - 1) - N_{SRS})$, where N_{SRS} is equal to 1 if UE is configured to send PUSCH and SRS in the same subframe for the current subframe or if the PUSCH resource allocation for the current subframe even partially overlaps with the cell specific SRS subframe and bandwidth configuration defined in Section 5.5.3 of [2]. Otherwise N_{SRS} is equal to 0.

5. Uplink control information on PUSCH **without** UL-SCH data
   When the UE transmits HARQ-ACK bits or rank indicator bits, it shall determine the number of coded symbols *Q*' for HARQ-ACK or rank indicator as

$$Q' = \min\left(\left\lceil \frac{O\cdot M_{sc}^{PUSCH}\cdot N_{symb}^{PUSCH}\cdot \beta_{offset}^{PUSCH}}{O_{CQI-MIN}} \right\rceil, 4\cdot M_{sc}^{PUSCH}\right)$$

   where *O* is the number of ACK/NACK bits, see also Section 5.2.2.6 [1] for the two ACK/NACK feedback modes for TDD as configured by higher layers, or rank indicator bits, $O_{CQI-MIN}$ is the number of CQI bits including CRC bits assuming rank equals to 1, M^{PUSCH}_{sc} is the scheduled bandwidth for PUSCH transmission in the current subframe expressed as a number of subcarriers in [2], and N^{PUSCH}_{symb} is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N^{PUSCH}_{symb} = (2 \cdot (N^{PUSCH}_{symb} - 1) - N_{SRS})$, where N_{SRS} is equal to 1 if UE is configured to send PUSCH and SRS in the same subframe for the current subframe or if the PUSCH resource allocation for the current subframe even partially overlaps with the cell specific SRS subframe and bandwidth configuration defined in Section 5.5.3 of [2]. Otherwise N_{SRS} is equal to 0.

   For HARQ-ACK information $Q_{ACK} = Q_m \cdot Q'$ and [$\beta^{PUSCH}_{offset} = \beta^{HARQ-ACK}_{offset} / \beta^{CQI}_{offset}$], where $\beta^{HARQ-ACK}_{offset}$ shall be determined according to [3].
   For rank indication $Q_{RI} = Q_m \cdot Q'$ and [$\beta^{PUSCH}_{offset} = \beta^{RI}_{offset} / \beta^{CQI}_{offset}$], where β^{RI}_{offset} shall be determined according to [3].
   For CQI and/or PMI information $Q_{RI} = N^{PUSCH}_{symb} \cdot M^{PUSCH}_{sc} \cdot Q_m - Q_{RI}$.
6. For HARQ-ACK information:
   - Each positive acknowledgement (ACK) is encoded as a binary '1' and each negative acknowledgement (NAK) is encoded as a binary '0'
   - If HARQ-ACK consists of 1-bit of information, i.e., [o_0^{ACK}], it is first encoded according to the **Encoding of 1-bit HARQ-ACK** table shown below:

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK}$ y]
4	$[o_0^{ACK}$ y x x]
6	$[o_0^{ACK}$ y x x x x]

- If HARQ-ACK consists of 2-bits of information, i.e., $[o_0^{ACK}\ o_1^{ACK}]$, it is first encoded according to the **Encoding of 2-bit HARQ-ACK** table shown below, where $o_2^{ACK} = (o_0^{ACK} + o_1^{ACK}) \bmod 2$.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}]$
4	$[o_0^{ACK}\ o_1^{ACK}$ x x $o_2^{ACK}\ o_0^{ACK}$ x x $o_1^{ACK}\ o_2^{ACK}$ x x]
6	[$o_0^{ACK}\ o_1^{ACK}$ x x x x $o_2^{ACK}\ o_0^{ACK}$ x x x x $o_1^{ACK}\ o_2^{ACK}$ x x x x]

- The "x" and "y" i are placeholders for [2] to scramble the HARQ-ACK bits in a way that maximizes the Euclidean distance of the modulation symbols carrying HARQ-ACK information. In this model, "x" and "y" are output as "-1" and "-2" respectively.

7. For rank indication (RI):
   - If RI consists of 1-bit of information, i.e., $[o_0^{RI}]$, it is first encoded according to **Encoding of 1-bit RI** table shown below:

Q_m	Encoded RI
2	$[o_0^{RI}$ y]
4	$[o_0^{RI}$ y x x]
6	$[o_0^{RI}$ y x x x x]

   - If RI consists of 2-bits of information, i.e., $[o_0^{RI}\ o_1^{RI}]$, it is first encoded according to **Encoding of 2-bit RI** table shown below, where $o_2^{RI} = (o_0^{RI} + o_1^{RI}) \bmod 2$.

Q_m	Encoded HARQ-ACK
2	$[o_0^{RI}\ o_1^{RI}\ o_2^{RI}\ o_0^{RI}\ o_1^{RI}\ o_2^{RI}]$
4	$[o_0^{RI}\ o_1^{RI}$ x x $o_2^{RI}\ o_0^{RI}$ x x $o_1^{RI}\ o_2^{RI}$ x x]
6	$[o_0^{RI}\ o_1^{RI}$ x x x x $o_2^{RI}\ o_0^{RI}$ x x x x $o_1^{RI}\ o_2^{RI}$ x x x x]

   - The "x" and "y" i are placeholders for [2] to scramble the HARQ-ACK bits in a way that maximizes the Euclidean distance of the modulation symbols carrying rank information. In this model, "x" and "y" are output as "-1" and "-2" respectively.
   - The bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI}, ..., q_{Q_{RI}-1}^{RI}$ is obtained by concatenation of multiple encoded RI blocks where Q_{RI} is the total number of coded bits for all the encoded RI blocks. The last concatenation of the encoded RI block may be partial so that the total bit sequence length is equal to Q_{RI}.

8. For channel quality control information (CQI and/or PMI):
   - If the payload size is less than or equal to 11 bits,
     - the channel quality information is first coded using a (32, *O*) block code with input sequence $o_0, o_1, o_2, ..., o_{O-1}$. The code words of the (32, *O*) block code are a linear combination of the 11 basis sequences denoted $M_{i,n}$ and defined in Table 5.2.2.6.4-1 [1].
     - The encoded CQI/PMI block is denoted by $b_0, b_1, b_2, ..., b_{B-1}$ where *B*=32 and
       $$b_i = \sum_{n=0}^{O-1} (o_n \cdot M_{i,n}) \bmod 2 \text{ where } i = 0, 1, 2, ..., B\text{-}1$$
     - The output bit sequence $q_0, q_1, q_2, ..., q_{Q-1}$ is obtained by circular repetition of the encoded CQI/PMI block as follows $q_i = b_{(i \bmod B)}$ where i = 0, 1, 2, ..., Q -1
   - For payload sizes greater than 11 bits,

  - the CRC attachment, channel coding and rate matching of the channel quality information is performed according to subclauses 5.1.1, 5.1.3.1 and 5.1.4.2 [1], respectively.
  - The input bit sequence to the CRC attachment is o_0, o_1, o_2, ..., o_{O-1}.
  - The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.
9. See *LTE_UL_ChInterleaver* (3gpplte) and *LTE_UL_ChDeInterleaver* (3gpplte).

It should be noted that, in current implementation, N_{SRS} is equal to 1 in all cell specific SRS subframe, and $M^{PUSCH\text{-}initial}_{sc} = M^{PUSCH}_{sc}$, $N^{PUSCH\text{-}initial}_{symb} = N^{PUSCH}_{symb}$.

- For more information on the System Parameters details please refer to *UL System Parameters* (3gpplte).
- For more information on the PUSCH Parameters details please refer to *UL PUSCH Parameters* (3gpplte).
- For more information on the Control Information Parameters details please refer to *UL Control Information Parameters* (3gpplte).

References

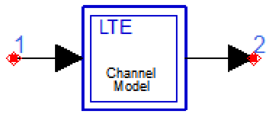
1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
3. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.

3GPP LTE Channel Model Components

The 3GPP LTE wireless design library includes LTE channel model and ITU channel model.

Contents

LTE_Channel (LTE Channel Model)



Description: LTE channel model
Library: LTE, Channel Model
Class: TSDFLTE_Channel

Parameters

Name	Description	Default	Unit	Type	Range
RIn	Input resistance	50 Ohm	Ohm	int	(0, ∞)
ROut	Output resistance	50 Ohm	Ohm	int	(0, ∞)
ModelType	the R4-070872_TR36.803.0.3.0 Channel number or User defined Channel: Extended_Pedestrian_A, Extended_Vehicular_A, Extended_TypicalUrban, UserDefined	Extended_Vehicular_A		enum	
Delay	the delay of each tap in usec, effective only when ModelType is set as UserDefined	{0.0 , 0.03, 0.15, 0.31 ,0.37, 0.71 , 1.09 , 1.73 , 2.51}	usec	real array	[0, 1000.0]
Power	the power in each tap in dB, effective only when ModelType is set as UserDefined	{0.0 dB, -1.5 dB, -1.4 dB, -3.6 dB, -0.6 dB, -9.1 dB, -7.0 dB, -12.0 dB, -16.9 dB}		real array	(-∞, 0]
Ricean_factor	the Ricean K-factor in linear scale of each tap, effective only when ModelType is set as UserDefined	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	[0.0, 1000.0]
Velocity	the velocity of mobile station	120	km/h	real	[0.001, 1000]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	channel input signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	output	channel output signal	timed

Notes/Equations

1. This model is used to generate channel models for mobile wireless applications.
2. This model is implemented following R4-070872 3GPP TR 36.803v0.3.0.
   A set of 3 channel models are implemented to simulate the multipath fading propagation conditions. The multipath fading is modeled as a tapped-delay line with a number of taps at fixed positions on a sampling grid. The gain associated with each tap is characterized by a distribution (Ricean with a K-factor>0, or Rayleigh with K-factor=0) and the maximum Doppler frequency that is determined from the mobile speed. For each tap, the method of filtered noise is used to generate channel coefficients with the specified distribution and spectral power density.
   The definition of the 3 specific channels are shown in the following tables:
   Extended Pedestrian A model (EPA)

Tap	Excess tap delay [ns]	Relative power [dB]
1	0	0.0
2	30	-1.0
3	70	-2.0
4	90	-3.0
5	110	-8.0
6	190	-17.2
7	410	-20.8

Extended Vehicular A model (EVA)

Tap	Excess tap delay [ns]	Relative power [dB]
1	0	0.0
2	30	-1.5
3	150	-1.4
4	310	-3.6
5	370	-0.6
6	710	-9.1
7	1090	-7.0
8	1730	-12.0
9	2510	-16.9

Extended Typical Urban model (ETU)

Tap	Excess tap delay [ns]	Relative power [dB]
1	0	-1.0
2	50	-1.0
3	120	-1.0
4	200	-0.0
5	230	-0.0
6	500	-0.0
7	1600	-3.0
8	2300	-5.0
9	5000	-7.0

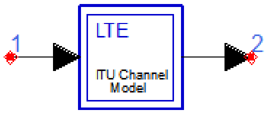
The total channel gain is normalized by adding the specified Normalization Factor to each tap.
The Doppler spectrum is modelled using the well known Clarke or Classical Doppler spectrum. The power spectral density (PSD) function is defined as follows: !3gpplte-channel-2008-1-01.gif! where !3gpplte-channel-2008-1-02.gif! is the net power, and !3gpplte-channel-2008-1-03.gif! denotes the maximum Doppler frequency, and !3gpplte-channel-2008-1-04.gif! where !3gpplte-channel-2008-1-06.gif! is the speed of the mobile, !3gpplte-channel-2008-1-05.gif! is the carrier frequency and ***c*** is the speed of light.

3. Parameter Details:
   ModelType specifies the type of ITU channel.
   The relationship of the channel type and the terrain type is shown in the following. *ModelType A* and *B* are outdoor to indoor and pedestrian environment, while Type *C* and *D* are vehicular environment. Type *User-Defined* is used to construct user defined channel model.
   Velocity specifies the mobile's velocity relative to base station.
   Delay, Power and Ricean_factor specify the delay, power and ricean factor for each path when ModelType selected as *UserDefined*.
4. Output delay
   A delay of 64 tokens is introduced in this model.

References

1. Rec.ITU-R M.1225, *Guidelines For Evaluation Of Radio Transmission Technologies For IMT-2000, 1997*.
2. 3GPP TS 36.104 v8.1.0, User Equipment (UE) radio transmission and reception, 2008-03.

LTE_Channel_ITU (ITU Downlink EVM Channel Model)



Description: ITU channel model
Library: LTE, Channel Model
Class: TSDFLTE_Channel_ITU

Parameters

Name	Description	Default	Unit	Type	Range
RIn	Input resistance	50 Ohm	Ohm	int	(0, ∞)
ROut	Output resistance	50 Ohm	Ohm	int	(0, ∞)
ModelType	the ITU-R M.1225 Channel number or User defined Channel: Pedestrian_A, Pedestrian_B, Vehicular_A, Vehicular_B, UserDefined	Vehicular_A		enum	
Delay	the delay of each tap in usec, effective only when ModelType is set as UserDefined	{0.0 , 0.31 , 0.71 , 1.09 , 1.73 , 2.51 }	usec	real array	[0, 1000.0]
Power	the power in each tap in dB, effective only when ModelType is set as UserDefined	{0.0 dB, -1.0 dB, -9.0 dB, -10.0 dB, -15.0 dB, -20.0 dB}		real array	(-∞, 0]
Ricean_factor	the Ricean K-factor in linear scale of each tap, effective only when ModelType is set as UserDefined	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	[0.0, 1000.0]
Velocity	the velocity of mobile station	120		real	[0.001, 200]
PathLoss	option for inclusion of large-scale pathloss: NO, YES	NO		enum	
PropDistance	the distance of BS and UE in meter, effective only when PassLoss is set as YES	1000	m	real	[200, 5000]
PwrNormal	option for normalization of the output power: NO, YES	NO		enum	
PwrMeasPeriod	The period of power measurement in order to normalize the output power	1 msec	sec	real	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	channel input signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	output	channel output signal	timed

Notes/Equations

1. This model is used to generate channel models for mobile wireless applications.
2. This model is implemented following Rec.ITU-R M.1225.
   A set of 4 modified International Telecommunication Union (ITU) channel models are constructed to simulate the multipath fading of the channel. The multipath fading is modeled as a tapped-delay line with 6 taps with non-uniform delays. The gain associated with each tap is characterized by a distribution (Ricean with a K-factor>0, or Rayleigh with K-factor=0) and the maximum Doppler frequency. For each tap, the method of filtered noise is used to generate channel coefficients with the specified

distribution and spectral power density.
The definition of the 4 specific ITU channels is shown in the following tables:

Outdoor to Indoor and Pedestrian Test Environment Tapped-Delay-Line Parameters

Tap	Channel A		Channel B		Doppler Spectrum
	Relative Delay (ns)	Average Power (dB)	Relative Delay (ns)	Average Power (dB)	
1	0	0	0	0	Classic
2	110	-9.7	200	-0.9	Classic
3	190	-19.2	800	-4.9	Classic
4	410	-22.8	1200	-8.0	Classic
5	oTMoTM	oTMoTM	2300	-7.8	Classic
6	oTMoTM	oTMoTM	3700	-23.9	Classic

Vehicular Test Environment Tapped-Delay-Line Parameters

Tap	Channel A		Channel B		Doppler Spectrum
	Relative Delay (ns)	Average Power (dB)	Relative Delay (ns)	Average Power (dB)	
1	0	0.0	0	-2.5	Classic
2	310	-1.0	300	0	Classic
3	710	-9.0	8900	-12.8	Classic
4	1090	-10.0	12900	-10.0	Classic
5	1730	-15.0	17100	-25.2	Classic
6	2510	-20.0	20000	-16.0	Classic

The total channel gain is normalized by adding the specified Normalization Factor to each tap.
The specified Doppler is the maximum Doppler frequency parameter (fm) of the rounded spectrum which has the power spectral density (PSD) function as follows:

$$S(f) = \begin{cases} \dfrac{1}{\pi\sqrt{1-f_0^2}} & |f_0| \le 1 \\ 0 & |f_0| > 1 \end{cases}$$

where $f_0 = \frac{f}{f_m}$ and $f_m = \frac{v}{c}f$, v is the mobile's velocity relative to base station.
The set of ITU channel models specify statistical parameters of microscopic effects. To simulate the real channel, these statistics have to be combined with macroscopic channel effects, i.e. the path loss (including shadowing) which will be introduced in the later section.
The COST 207 model with a correction term is used to simulate the path loss for both pedestrian and vehicular environments if the PathLoss is ON and other parameters are set according to the specific environment.

3. Parameter Details

- *ModelType* specifies the type of ITU channel.
  The relationship of the channel type and the terrain type is shown in the following. *ModelType A* and *B* are outdoor to indoor and pedestrian environment, while Type *C* and *D* are vehicular environment. Type *User-Defined* is used to construct user defined channel model.
- *Velocity* specifies the mobile's velocity relative to base station.
- *PropDistance* specifies the distance between base station and mobile station.
- *PathLoss* identifies whether the large-scale pathloss is included.
  If *PathLoss* = *NO*, then the path loss is not included in this model and the parameters describing the environment are unused.
  If *PathLoss* = *YES*, then the path loss for both urban and suburban environments is modeled by the COST 207 model with a correction term. There are three terms which make up the model:
  The Path Loss model for outdoor to indoor and pedestrian test environment is,
  $L = 40\log R + 30\log f + 49$
  where R is the propagation distance and f is the frequency.
  The Path Loss model for vehicular test environment is,
  $L = [40(1 - 4\times 10^{-3}\Delta h_b)]\log R - 18\log\Delta h_b + 21\log f + 80$

where R is the propagation distance and f is the frequency, Δh_b is the height between base station antenna and mobile.

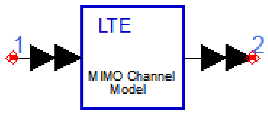
- Delay, Power and Ricean_factor specify the delay, power and ricean factor for each path when ModelType selected as *UserDefined*.

1. Output delay
   A delay of 64 tokens is introduced in this model.

References

1. Rec.ITU-R M.1225, *Guidelines For Evaluation Of Radio Transmission Technologies For IMT-2000, 1997* .

LTE_MIMO_Channel (MIMO Channel Model)



Description: LTE MIMO channel model
Library: LTE, Channel Model

Parameters

Name	Description	Default	Unit	Type	Range
Antennas_Config	the configuration of Tx and Rx antennas in term of number of Tx x number of Rx: TR_1x2, TR_2x2, TR_4x2, TR_4x4	TR_2x2		enum	
Correlation_Type	the MIMO channel correlation matrix type: Low, Medium, High	Low		enum	
ModelType	the TS 36.101 Channel number or User defined Channel: Extended_Pedestrian_A, Extended_Vehicular_A, Extended_TypicalUrban, UserDefined	Extended_Vehicular_A		enum	
Delay	the delay of each tap in usec, effective only when ModelType is set as UserDefined	{0.0 , 0.03, 0.15, 0.31 ,0.37, 0.71 , 1.09 , 1.73 , 2.51 }	sec	real array	[0,10000.0]
Power	the power in each tap in dB, effective only when ModelType is set as UserDefined	{0.0 dB, -1.5 dB, -1.4 dB, -3.6 dB, -0.6 dB, -9.1 dB, -7.0 dB, -12.0 dB, -16.9 dB}		real array	(-∞,0]
Ricean_factor	the Ricean K-factor in linear scale of each tap, effective only when ModelType is set as UserDefined	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	[0.0,1000.0]
Velocity	the velocity of mobile station	120		real	[0.001,1000]

Pin Inputs

Pin	Name	Description	Signal Type
1	TxSig	Signals supplied to transmit array	multiple timed

Pin Outputs

Pin	Name	Description	Signal Type
2	RxSig	Signals at output of receive array	multiple timed

Notes/Equations

1. The implementation in this model follows the definition in B.2 of 36.101 [1].
2. The multipath propagation conditions consist of several parts:
   - delay profile in the form of a "tapped delay-line", characterized by a number of taps at fixed positions on a sampling grid. The profile can be further characterized by the r.m.s. delay spread and the maximum delay spanned by the taps.
   - A combination of channel model parameters that include the Delay profile and the Doppler spectrum, that is characterized by a classical spectrum shape and a maximum Doppler frequency
   - A set of correlation matrices defining the correlation between the UE and eNodeB antennas in case of multi-antenna systems.
3. ModelType parameter specifies the propagation model selected from Extended Pedestrian A, Extended Vehicular A, Extended Typical Urban and user-defined model. Each pre-defined propagation model defines the number of channel taps, delay spread and Relative power for each tap, as shown in Table B.2.1-1, Table B.2.1-2, Table B.2.1-3 and Table B.2.1-4 of 36.101 [1]. For the user-defined model, the power delay profiles (PDP) is defined by the user as follows:
   - Delay, Power and Ricean_factor parameters specify the delay, power and ricean factor for each path when ModelType is selected as UserDefined.
4. Antennas_Config defines the antenna configurations at eNodeB and UE respectively. The antenna configurations are in the format of MxN, where M is the number of antennas at eNodeB, and N is the number of antennas at UE. The bus width at the

input port should be equal to M, while the bus width at the input port should be equal to M should be equal to M. Currently the allowable configurations are 1x2, 2x2, and 4x2.

5. Correlation_Type defines the spatial correlation between the antennas at the eNodeB and UE, selected from Low, Medium, and High.
   For each antenna configuration, the channel correlation matrix is shown as follows,
   1x2 case
   $$R_{spat} = R_{UE} = \begin{bmatrix} 1 & \beta \\ \beta^* & 1 \end{bmatrix}$$
   2x2 case
   $$R_{spat} = R_{eNB} \otimes R_{UE} = \begin{bmatrix} 1 & \alpha \\ \alpha^* & 1 \end{bmatrix} \otimes \begin{bmatrix} 1 & \beta \\ \beta^* & 1 \end{bmatrix} = \begin{bmatrix} 1 & \beta & \alpha & \alpha\beta \\ \beta^* & 1 & \alpha\beta^* & \alpha \\ \alpha^* & \alpha^*\beta & 1 & \beta \\ \alpha^*\beta^* & \alpha^* & \beta^* & 1 \end{bmatrix}$$
   4x2 case
   $$R_{spat} = R_{eNB} \otimes R_{UE} = \begin{bmatrix} 1 & \alpha^{1/9} & \alpha^{4/9} & \alpha \\ \alpha^{1/9*} & 1 & \alpha^{1/9} & \alpha^{4/9} \\ \alpha^{4/9*} & \alpha^{1/9*} & 1 & \alpha^{1/9} \\ \alpha^* & \alpha^{4/9*} & \alpha^{1/9*} & 1 \end{bmatrix} \otimes \begin{bmatrix} 1 & \beta \\ \beta^* & 1 \end{bmatrix}$$
   where, α and β are channel correlation factor at the eNodeB and UE respectively. α and β for different correlation types are given in the following table according to Correlation_Type parameter.

Low correlation	Medium Correlation	High Correlation
α=0, β=0	α=0.3, β=0.9	α=0.9, β=0.9

6. In this model, the channel correlation matrices are per-tap applied on each tap independently.
7. Velocity specifies the mobile unit's velocity (v) relative to the base station, in units of kilometer/hour. The specified Doppler is the maximum Doppler frequency parameter (fm) of the rounded spectrum which has the classical spectrum shape as follows:
   $$S(f) = \begin{cases} \dfrac{1}{\pi\sqrt{1-f_0^2}} & |f_0| \le 1 \\ 0 & |f_0| > 1 \end{cases}$$
   where $f_0 = \dfrac{f}{f_m}$ and $f_m = \dfrac{v}{c}f$.
8. Output delay: a delay of 64 tokens is introduced in this model.

References

1. 3GPP TS 36.101 v8.3.0 "User Equipment (UE) radio transmission and reception", Sept. 2008.

3GPP LTE Design Examples

This 3GPP LTE Wireless Design Library includes several design examples for FDD LTE/TDD LTE downlink/uplink transmitter measurement, downlink/uplink uncoded BER and coded BER performance measurement. Eight workspaces (LTE_DL_TestModel_FDD_wrk, LTE_DL_TestModel_TDD_wrk, LTE_FDD_DL_Tx_wrk, LTE_FDD_DL_Rx_wrk, LTE_FDD_UL_Tx_wrk, LTE_FDD_UL_Rx_wrk, LTE_TDD_Tx_wrk and LTE_TDD_Rx_wrk) are provided in the 3GPP LTE Wireless Design Library.

3GPP LTE Downlink FDD Test Model Examples

The LTE_DL_TestModel_FDD_wrk workspace provides E-UTRA Test Models for the 3GPP FDD LTE downlink system following 3GPP TS 36.141 V8.5.0(2009-12). The E-TM1.1, E-TM1.2, E-TM2, E-TM3.1, E-TM3.2 and E-TM3.3 are supported. The bandwidth 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz are all supported. The example links the test model with Agilent VSA89601 software.

- LTE_DL_TestModel_FDD_Tx: FDD Downlink test model connected with 89600 VSA software

Connect with 89600 VSA software

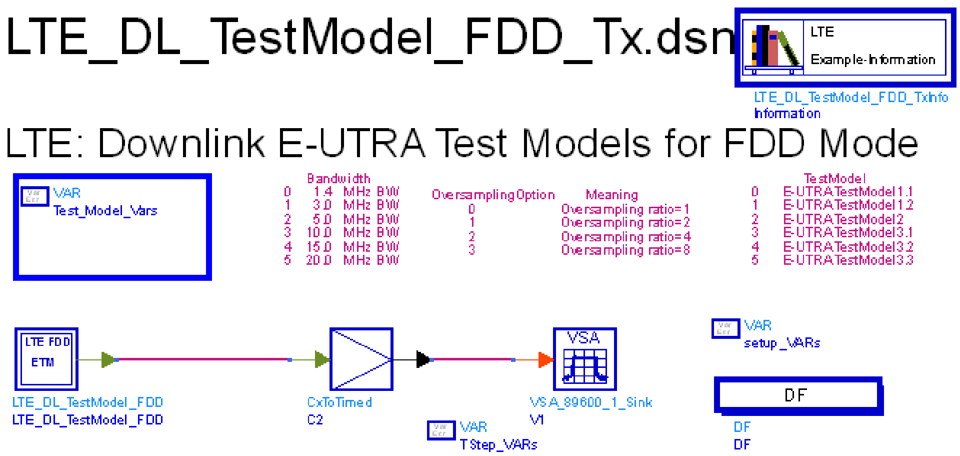
LTE_DL_TestModel_FDD_Tx Design

Features

- Demo how to connect with 89600 VSA software.

Description

LTE_DL_TestModel_FDD_Tx demo how to connect with 89600 VSA software. The schematic is shown in the following figure.



LTE_DL_TestModel_FDD_Tx Schematic

Users can change Bandwidth setting, the type of test model and set the VSA software accordingly for different system configuration.

Simulation Results

N/A

Benchmark

- Hardware Platform: Centrino 2.0GHz, 2048M memory
- Software Platform: Window XP, ADS 2011

3GPP LTE Downlink TDD Test Model Examples

The LTE_DL_TestModel_TDD_wrk workspace provides E-UTRA Test Models for the 3GPP TDD LTE downlink system following 3GPP TS 36.141 V8.5.0(2009-12). The E-TM1.1, E-TM1.2, E-TM2, E-TM3.1, E-TM3.2 and E-TM3.3 are supported. The bandwidth 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz are all supported. The example links the test model with Agilent VSA89601 software.

- LTE_DL_TestModel_TDD_Tx: TDD Downlink test model connected with 89600 VSA software

Connect with 89600 VSA software

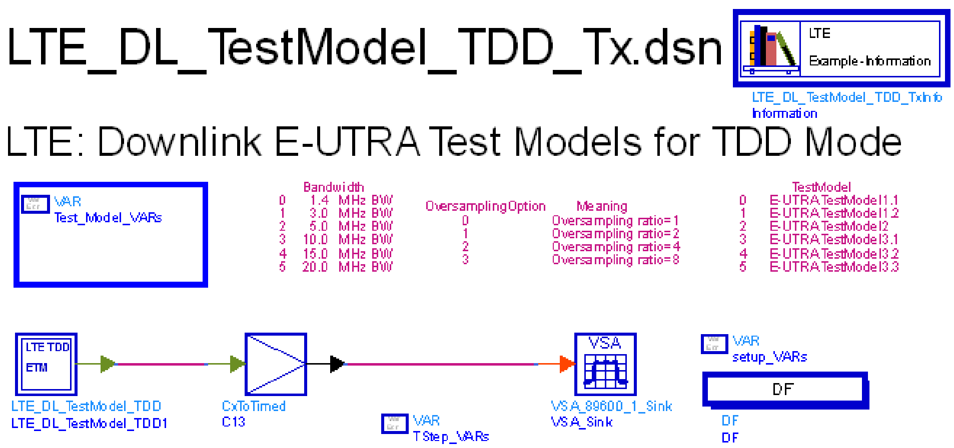
LTE_DL_TestModel_TDD_Tx Design

Features

- Demo how to connect with 89600 VSA software.

Description

LTE_DL_TestModel_TDD_Tx demos how to connect with 89600 VSA software. The schematic is shown in the following figure.



LTE_DL_TestModel_TDD_Tx Schematic

Users can change Bandwidth setting, the type of test model and set the VSA software accordingly for different system configuration.

Simulation Results

N/A

Benchmark

- Hardware Platform: Centrino 2.0GHz, 2048M memory
- Software Platform: Window XP, ADS 2011

3GPP FDD LTE Downlink Transmitter Design Examples

The LTE_FDD_DL_Tx_wrk workspace provides transmitter design examples for the 3GPP FDD LTE downlink system. The transmitter measurements include EVM, constellation, spectrum, and CCDF, link with Agilent VSA89601 software, as well as other measurements.

- LTE_DL_VSA: FDD Downlink transmitter connected with 89600 VSA software
- LTE_DL_TxSpectrum: FDD Downlink transmitter spectrum and CCDF measurements
- LTE_DL_TxEVM: FDD Downlink transmitter EVM measurement
- LTE_DL_MIMO_2x2_TxEVM: FDD Downlink 2x2 MIMO transmitter EVM measurement
- LTE_DL_MIMO_2Ant_VSA: FDD Downlink 2Ant transmitter connected with 89600 VSA software

Connect with 89600 VSA software

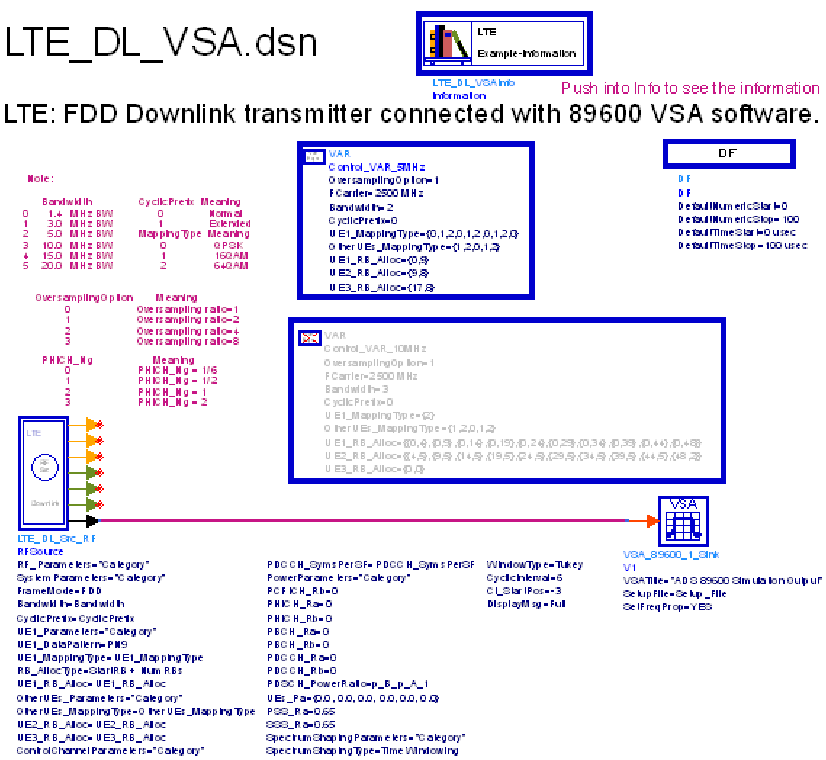
LTE_DL_VSA Design

Features

- Demo how to connect with 89600 VSA software.

Description

LTE_DL_VSA demo how to connect with 89600 VSA software. The schematic is shown in the following figure.



LTE_DL_VSA Schematic

Users can change Bandwidth setting and set the VSA software accordingly for different system configuration.

Simulation Results

N/A

Benchmark

- Hardware Platform: Centrino 2.0GHz, 2048M memory

- Software Platform: Window XP, ADS 2011

Downlink FDD Transmitter Spectrum Measurement

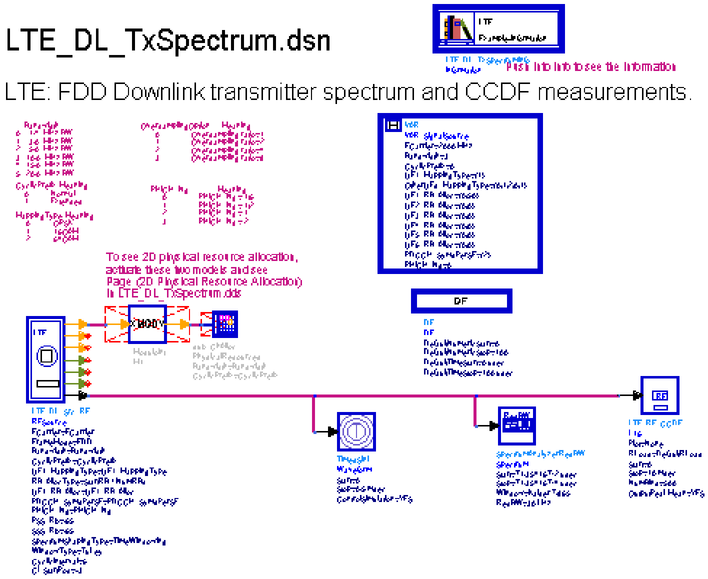
LTE_DL_TxSpectrum Design

Features

- Transmitter Spectrum Measurement
- Transmitter Waveform
- Transmitter CCDF
- Preamble Power, Mean Power and Peak Power
- 2 Dimension resource elements allocation display

Description

LTE_DL_TxSpectrum measures the transmitter spectrum, waveform, CCDF and Peak-to-Mean of downlink FDD signal. The schematic is shown in the following figure. To see 2D physical resource allocation, activate ModuloInt and sub_ChAlloc and see Page (2D Physical Resource Allocation) in the file LTE_DL_TxSpectrum.dds.



LTE_DL_TxSpectrum Schematic

In LTE_DL_SignalSrc_RF, Power is set to Average Power.

Simulation Results

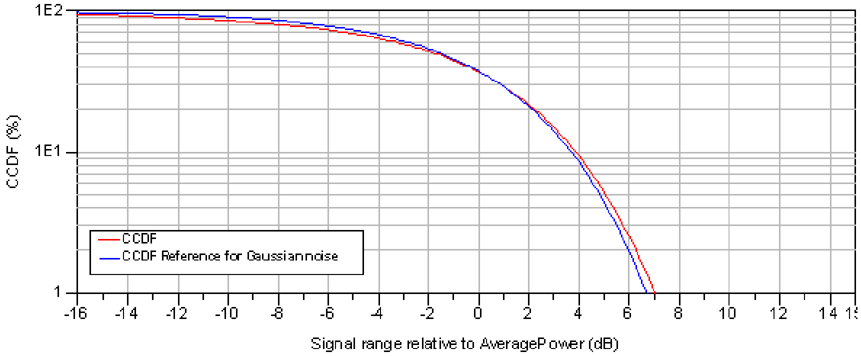
The signal power density spectrum is obtained using the spectrum analyzer. The following table shows the simulation conditions and the figure DL Transmitter Spectrum shows the spectrum.

Parameter	Value
FCarrier	2000 MHz
Bandwidth	10 MHz
NumOfRBs	50
Oversampling Option	Ratio 2
Cyclic Prefix	Normal
Mapping_Type	16QAM

DL Transmitter CCDF

CCDF Measurement
CCDF: Complementary Cumulative Distribution Function

AveragePower_dBm	PeakPower_dBm	PAPR_dB
2.313	11.134	8.820

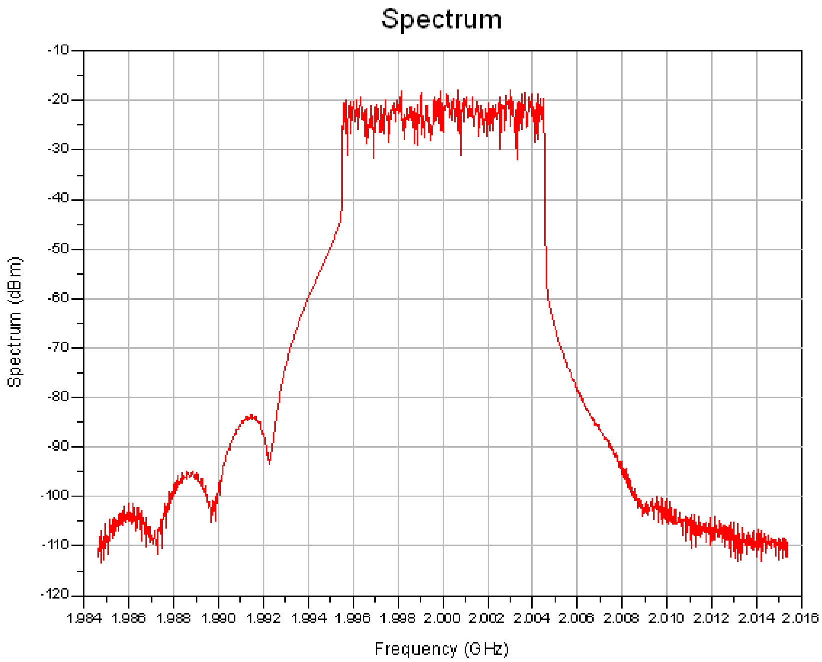


Eqn RF_CCDF_Ref=100*power_ccdf_ref(SignalRange_dB)

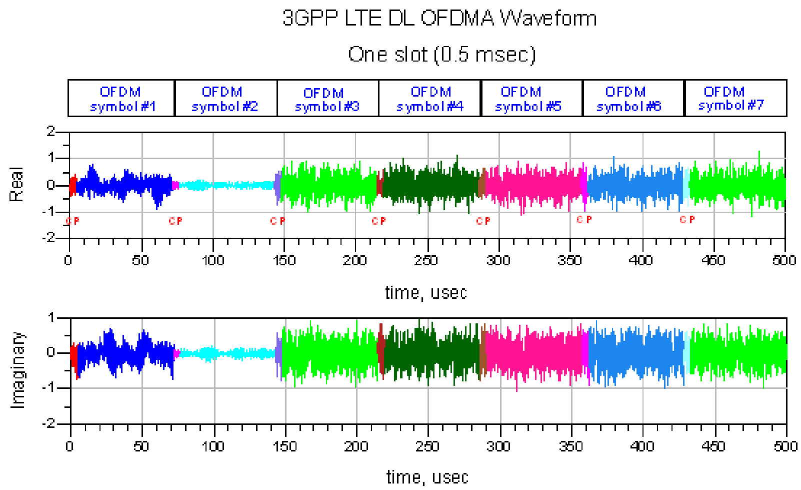
Eqn PAPR_dB=PeakPower_dBm-MeanPower_dBm

Eqn AveragePower_dBm=MeanPower_dBm

DL Transmitter Spectrum



DL Transmitter Waveform

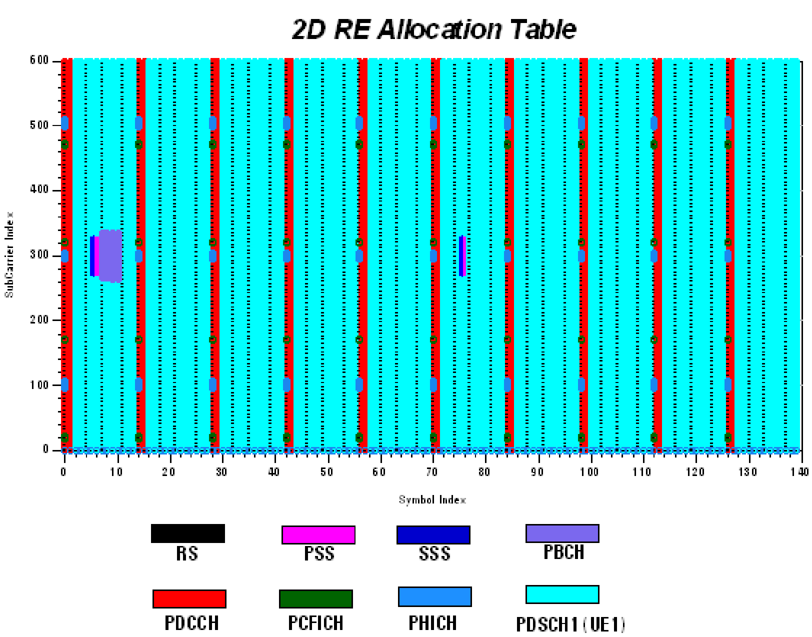


DL Transmitter Power

Eqn BS_Power=spec_power(dBm(Spectrum))

BS_Power
2.609

DL Resource Element Allocation



Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: 15 seconds

FDD Downlink Transmitter EVM Measurement

LTE_DL_TxEVM

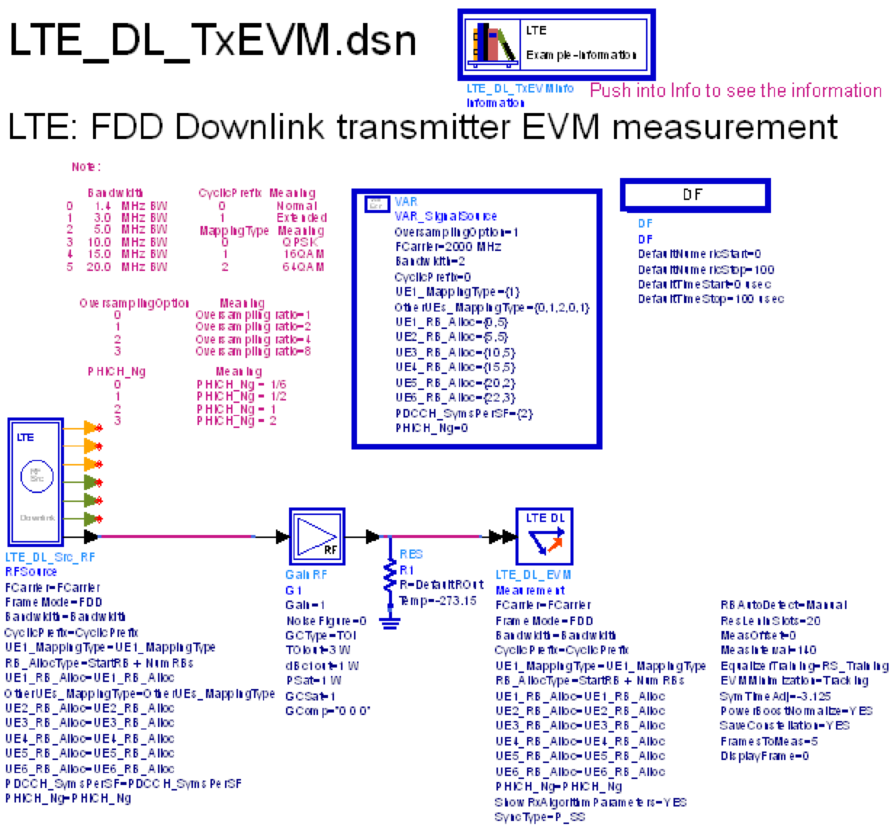
Features

- LTE DL FDD transmitter signal quality analysis, such as EVM, EVMPk, DataEVM, SyncCorr and so on.
- LTE DL FDD transmitter EVM measurements for user channels and signals: P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH and PDSCH.
- LTE DL FDD transmitter Constellation for all channels.
- LTE DL FDD transmitter normalized equalizer channel frequency response over subcarriers
- LTE DL FDD transmitter RB Error Mag Spectrum shows the EVM of each resource block (RB)

Description

LTE_DL_TxEVM measures the EVM of LTE downlink FDD signal and constellation of the signal is also provided.

The schematic for this design is shown in the following figure.



LTE_DL_TxEVM Schematic

LTE_DL_Src_RF is LTE RF downlink signal source, and the EVM of the signal is measured by EVM measurement model LTE_DL_EVM, and the constellation of the signal is also provided by this measurement model.

Simulation Results

The measurement results are shown as follows:
The following figure shows the summary of EVM measurement results which include the results of each frame.

Error Summary

Frame	EVM	SyncCorr	IQGainImbalance	IQOffset	RSTxPower
0	-68.466	1.000	1.000	5.119E-10	-24.989
1	-68.483	1.000	1.000	4.428E-10	-24.989
2	-68.660	1.000	1.000	5.415E-10	-24.989
3	-68.139	1.000	1.000	5.433E-10	-24.989

Error summary

The following figure shows the EVM measurement results of PDCCH, PCFICH, PHICH, BCH, P-SCH and S-SCH respectively, which include the EVM of each frame for each channel.

EVM vs Physical Channel

Frame	P_SSEVM	S_SSEVM	RSEVM	PBCHEVM	...FICHEVM	PHICHEVM	PDCCHEVM	PDSCHEVM
0	-69.573	-69.226	-69.220	-69.215	-72.457	-72.674	-66.706	-68.343
1	-69.388	-68.456	-69.407	-69.937	-72.978	-72.821	-66.833	-68.347
2	-69.260	-69.613	-69.335	-69.475	-73.140	-72.375	-66.763	-68.547
3	-70.263	-68.583	-69.125	-69.532	-73.305	-72.759	-66.909	-67.986
4	-70.487	-69.369	-69.071	-67.604	-73.129	-73.282	-66.906	-68.394

EVM versus Physical Channels

The following figure shows the EVM measurement results of UE1 to UE6, which include the EVM, number of RBs and the power of each frame for each UE.

EVM vs UEs

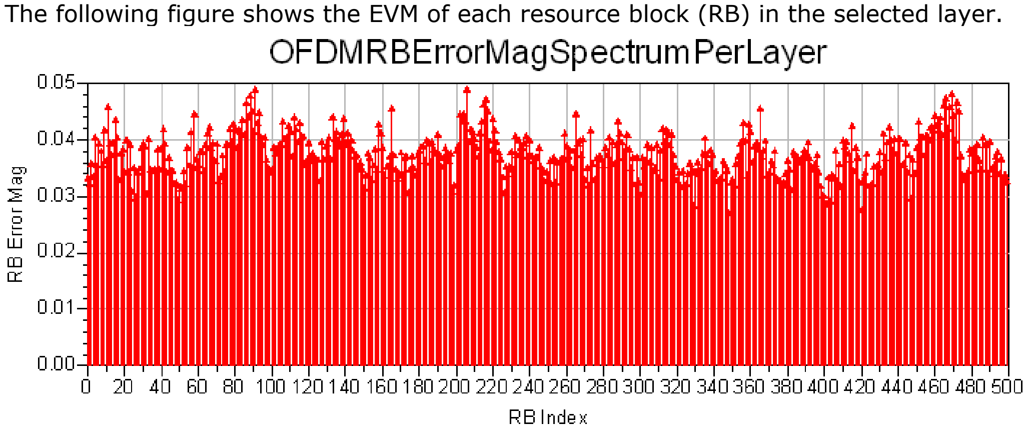
Frame	PDSCH_User0EVM	PDSCH_User1EVM	PDSCH_User2EVM	PDSCH_User3EVM	PDSCH_User4EVM	PDSCH_User5EVM
0	-68.790	-68.173	-67.876	-68.048	-68.530	-69.138
1	-68.995	-68.112	-67.787	-68.066	-68.524	-69.102
2	-69.028	-68.343	-68.060	-68.382	-68.648	-69.190
3	-68.569	-67.699	-67.417	-67.714	-68.092	-69.009
4	-68.976	-68.186	-67.874	-68.099	-68.526	-69.175

Frame	...SCH_User0NumRB	...SCH_User1NumRB	...SCH_User2NumRB	...SCH_User3NumRB	...SCH_User4NumRB	...SCH_User5NumRB
0	100.000000	100.000000	100.000000	100.000000	40.000000	60.000000
1	100.000000	100.000000	100.000000	100.000000	40.000000	60.000000
2	100.000000	100.000000	100.000000	100.000000	40.000000	60.000000
3	100.000000	100.000000	100.000000	100.000000	40.000000	60.000000
4	100.000000	100.000000	100.000000	100.000000	40.000000	60.000000

Frame	PDSCH_User0Power	PDSCH_User1Power	PDSCH_User2Power	PDSCH_User3Power	PDSCH_User4Power	PDSCH_User5Power
0	-0.002563	-0.000473	-0.003205	0.005895	-0.000429	0.009577
1	-0.002567	-0.000534	0.026935	0.015857	-0.000494	0.016230
2	-0.002602	-0.000429	-0.014038	-0.004569	-0.000483	0.007883
3	-0.002697	-0.000694	0.019304	-0.018752	-0.000633	0.045347
4	-0.002550	-0.000516	-0.043497	0.002694	-0.000624	-0.001422

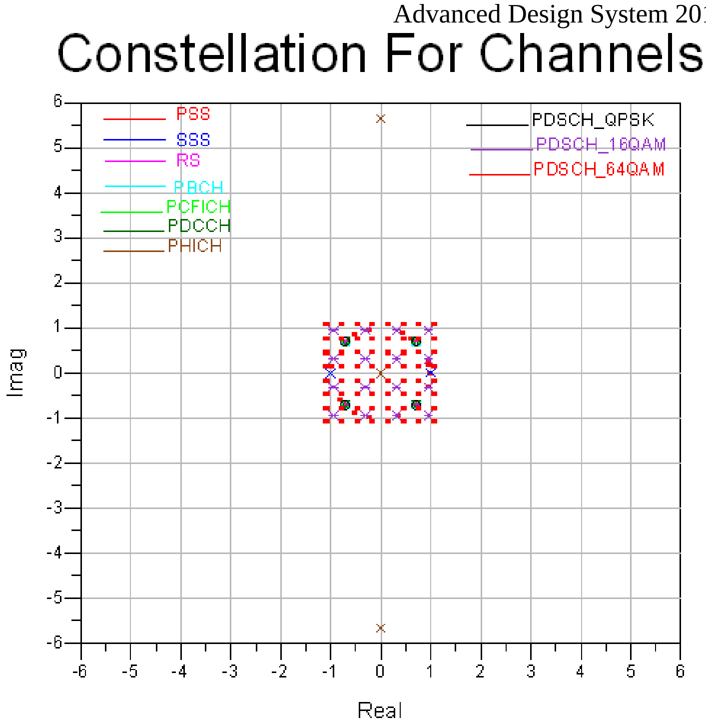
EVM versus UE

The following figure shows the EVM of each resource block (RB) in the selected layer.



OFDM RB Error Mag. Spectrum

The following figure shows the constellation of the signal to be measured of each channels.



Constellation

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: approximately 20 seconds

FDD Downlink 2x2 MIMO transmitter EVM measurement

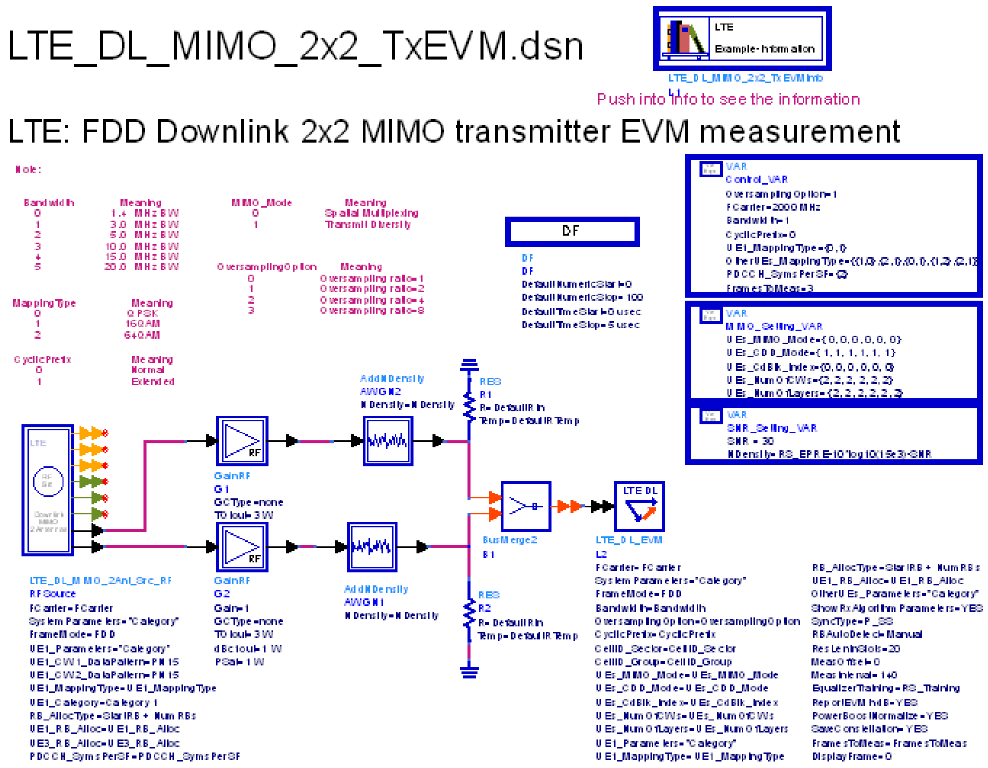
LTE_DL_MIMO_2x2_TxEVM Design

Features

- LTE DL MIMO transmitter signal quality analysis , such as EVM, EVMPk, DataEVM, SyncCorr and so on.
- LTE DL MIMO transmitter EVM measurements and display for user channels and signals: P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH and PDSCH.
- LTE DL MIMO transmitter Constellation for all channels.
- LTE DL MIMO transmitter normalized equalizer channel frequency response over subcarriers
- LTE DL MIMO transmitter RB Error Mag Spectrum shows the EVM of each resource block (RB) in the selected layer
- LTE DL MIMO transmitter other MIMO Information measurement and display.

Description

LTE_DL_MIMO_2x2_TxEVM measures EVM versus physical channels and resource blocks for downlink transmitter of MIMO 2 × 2 system. Both EVM in dB and percent can be given. The constellations of each channel are provided as well.
The schematic for this design is shown in the following figure.



LTE_DL_MIMO_2x2_TxEVM Schematic

LTE_DL_MIMO_2Ant_Src_RF is LTE downlink 2 antennas MIMO RF signal source, which generates RF signals for two transmit antennas. GainRF is used to model an amplifier with nonlinear gain compression. Then, EVM of the signals from two transmit antennas are measured by LTE_DL_EVM with 2 input ports. If the parameter SaveConstellation is set to YES, the constellation of the frame which is indicated by parameter DisplayFrame is also provided by this EVM measurement model.

Simulation Results

The simulation condition is shown in the following table, which lists the main parameters:

Simulation Condition

Parameter	Value
FrameMode	FDD
Bandwidth	3MHz
CyclicPrefix	Normal
UE1_MappingType	{0, 1}
OtherUEs_MappingType	{1,0}, {2,1}, {0,1}, {1,2}, {2,1}
UE1_RB_Alloc	{0,3}
UE2_RB_Alloc	{3,3}
UE3_RB_Alloc	{6,3}
UE4_RB_Alloc	{9,3}
UE5_RB_Alloc	{12,1}
UE6_RB_Alloc	{13,2}
UEs_MIMO_Mode	{0, 0, 0, 0, 0, 0}
UEs_NumOfCWs	{2, 2, 2, 2, 2, 2}
UEs_NumOfLayers	{2, 2, 2, 2, 2, 2}
FramesToMeas	3

Six UEs occupies different resource blocks. All 15 RBs are allocated. The mapping type are different for each UE. Spatial Multiplexing is employed.
The following figure shows the summary of EVM measurement results which include the results of each frame.

Error Summary

Frame	EVM	SyncCorr	IQGainImbalance	IQOffset	RSTxPower
0	-25.793	0.996	1.000	6.498E-6	-24.959
1	-26.693	0.997	1.001	6.138E-6	-24.959
2	-25.353	0.995	1.001	5.818E-6	-24.960

Error summary

The following figure shows the EVM measurement results of PDCCH, PCFICH, PHICH, BCH, P-SCH and S-SCH respectively, which include the EVM of each frame for each channel.

EVM vs Physical Channel

Frame	P_SSEVM	S_SSEVM	RSEVM	PBCHEVM	...FICHEVM	PHICHEVM	PDCCHEVM	PDSCHEVM
0	-28.651	-29.958	-30.218	-29.120	-28.597	-32.950	-28.306	-25.552
1	-28.747	-29.739	-30.212	-29.739	-29.555	-36.901	-29.601	-26.456
2	-28.406	-28.084	-30.094	-28.843	-28.556	-32.545	-27.811	-25.114

EVM versus Physical Channels

The following figure shows the EVM measurement results of UE1 to UE6, which include the EVM, number of RBs and the power of each frame for each UE.

EVM vs UEs

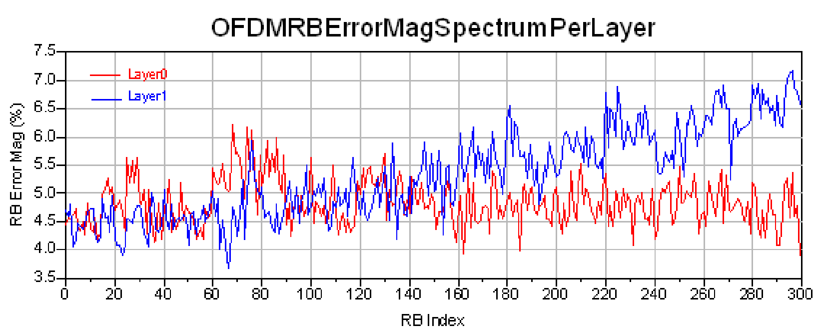
Frame	PDSCH_User0EVM	PDSCH_User1EVM	PDSCH_User2EVM	PDSCH_User3EVM	PDSCH_User4EVM	PDSCH_User5EVM
0	-25.548	-25.696	-25.642	-25.372	-25.544	-25.502
1	-26.321	-26.449	-26.626	-26.410	-26.566	-26.454
2	-25.127	-25.282	-25.234	-25.084	-24.829	-24.887

Frame	...SCH_User0NumRB	...SCH_User1NumRB	...SCH_User2NumRB	...SCH_User3NumRB	...SCH_User4NumRB	...SCH_User5NumRB
0	120.000000	120.000000	120.000000	120.000000	40.000000	80.000000
1	120.000000	120.000000	120.000000	120.000000	40.000000	80.000000
2	120.000000	120.000000	120.000000	120.000000	40.000000	80.000000

Frame	PDSCH_User0Power	PDSCH_User1Power	PDSCH_User2Power	PDSCH_User3Power	PDSCH_User4Power	PDSCH_User5Power
0	-3.011639	-2.992350	-3.016363	-3.009454	-3.023854	-3.009258
1	-3.005731	-3.007475	-3.006505	-3.010513	-2.987234	-3.000132
2	-3.007689	-3.005858	-2.998682	-3.006365	-3.035512	-2.996927

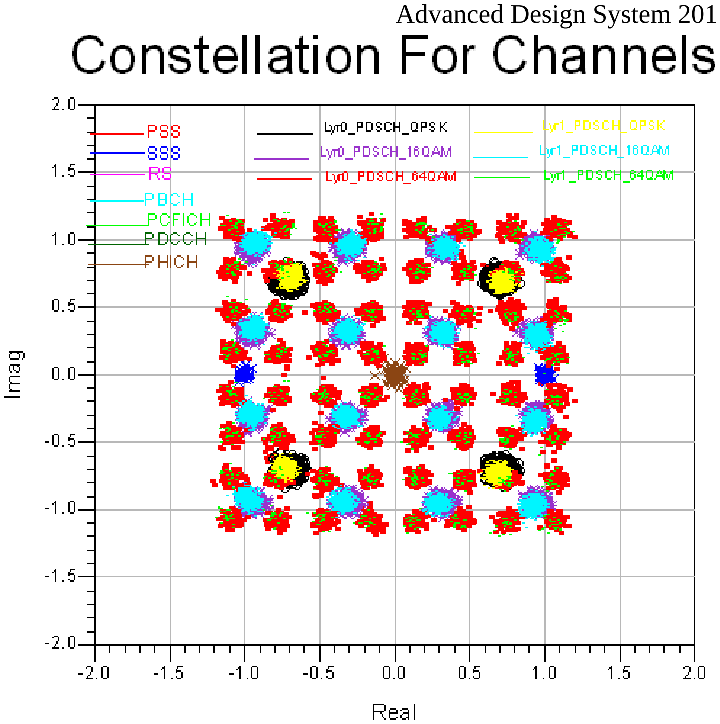
EVM versus UE

The following figure shows the EVM of each resource block (RB) in the selected layer.



OFDM RB Error Mag. Spectrum

The following figure shows the constellation of the signal to be measured of each channels.



Constellation

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2008
- Simulation Time: approximately 30 seconds

FDD Downlink 2Ant transmitter connected with 89600 VSA software

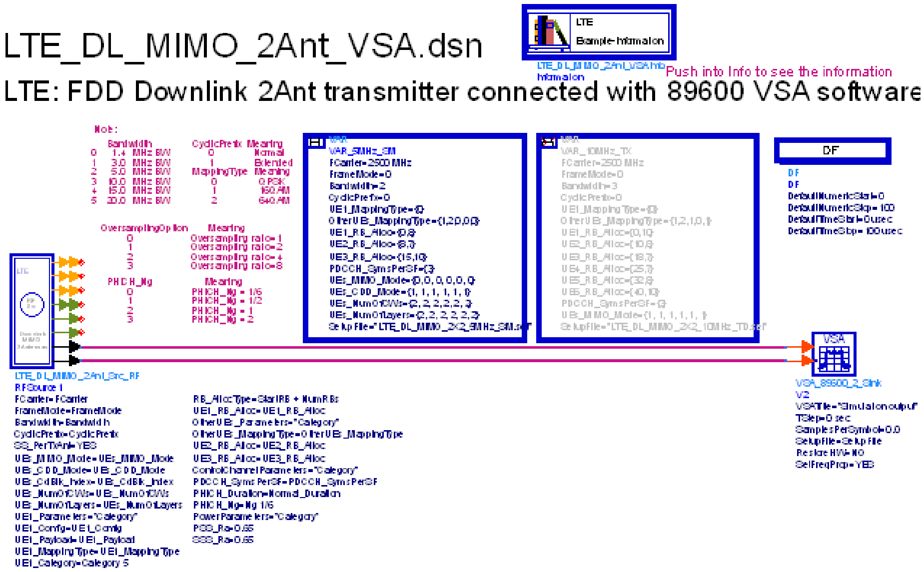
LTE_DL_MIMO_2Ant_VSA Design

Features

- Demo FDD Downlink 2Ant transmitter how to connect with 89600 VSA software.

Description

LTE_DL_MIMO_2Ant_VSA demos Downlink 2Ant transmitter how to connect with 89600 VSA software. The schematic is shown in the following figure.



LTE_ DL_MIMO_2Ant _VSA Schematic

Users can change Bandwidth setting and set the VSA software accordingly for different system configuration.

Simulation Results

N/A

Benchmark

- Hardware Platform: Centrino 2.0GHz, 2048M memory
- Software Platform: Window XP, ADS 2011

3GPP FDD LTE Downlink Receiver Design Examples

The LTE_FDD_DL_Rx_wrk workspace provides receiver design examples for the 3GPP FDD LTE downlink system. The coded BER/BLER on fading channel for SISO, SIMO and MIMO are provided.

- LTE_DL_Fading_BER: FDD Downlink BER and BLER on Fading channel
- LTE_DL_MIMO_2x2_Fading_BER: FDD Downlink MIMO 2x2 BER and BLER on Fading channel
- LTE_DL_SIMO_1x2_Fading_BER: FDD Downlink SIMO 1x2 BER and BLER on Fading channel

Downlink BER Measurement under Fading Channel

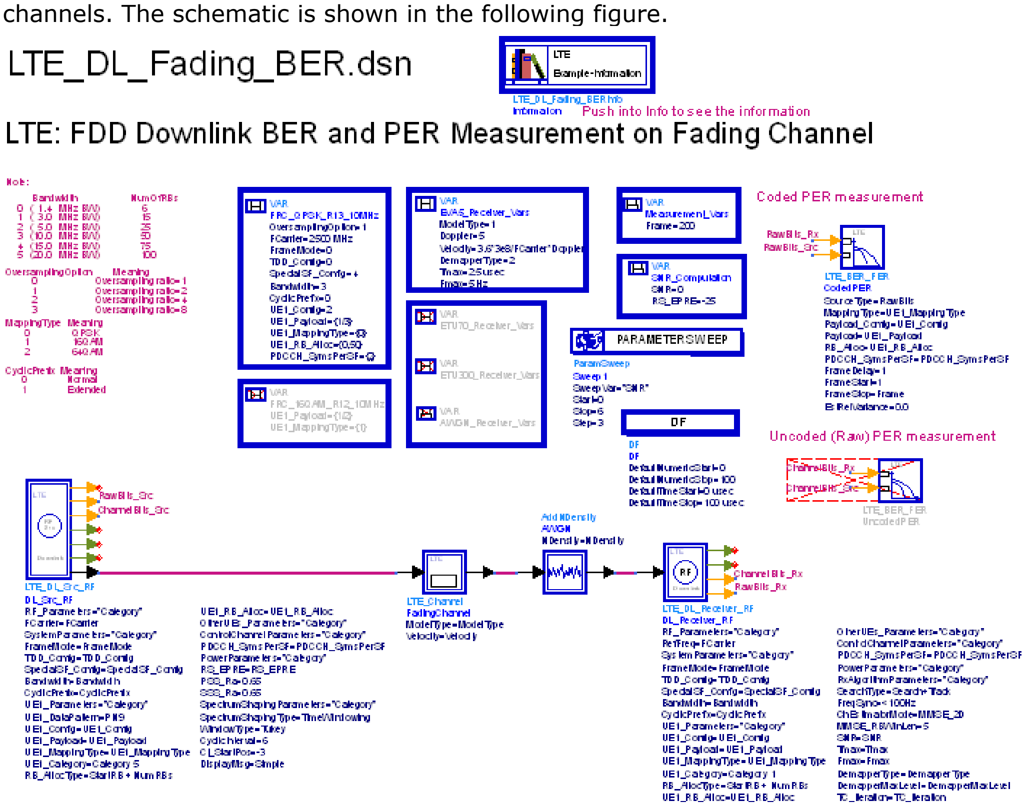
LTE_DL_Fading_BER Design

Features

- Pre-defined reference channels following TS 36.101 for DL FDD
- Fading channels following the definition in Annex B of TS 36.101
- Uncoded and coded BER/BLER measurements
- Multiple SNR measurement points

Description

LTE_DL_Fading_BER performs FDD downlink BER/BLER measurements on fading channels. The schematic is shown in the following figure.



LTE_DL_Fading_BER Schematic

The signal source refers to the definition of reference channel in A.3 of TS 36.101 with the exception that no HARQ transmissions are employed. Two are pre-configured in this example:

Signal Source Configurations
Reference channel [R.2 FDD] (10 MHz QPSK 1/3)
Reference channel [R.3 FDD] (10 MHz 16QAM 1/2)

The fading channel follows the definition in Annex B of TS 36.101. Four settings are pre-configured in this example:

Fading Channel	**Doppler**
EVA	5 Hz
ETU	70 Hz
ETU	300 Hz
AWGN	0 Hz

In this example, the uncoded (raw) BLER measurement is also provided. To measure it, activate the component UncodedPER.

The default channel estimator is the 2D MMSE with MMSE_RBWinLen = 5. The channel characters (Tmax, Fmax and SNR) needed by the channel estimator are set in *EVA5_Receiver_Vars*, *ETU70_Receiver_Vars*, *ETU300_Receiver_Vars* and *AWGN_Receiver_Vars* for EVA5, ETU70, ETU300 and AWGN respectively.

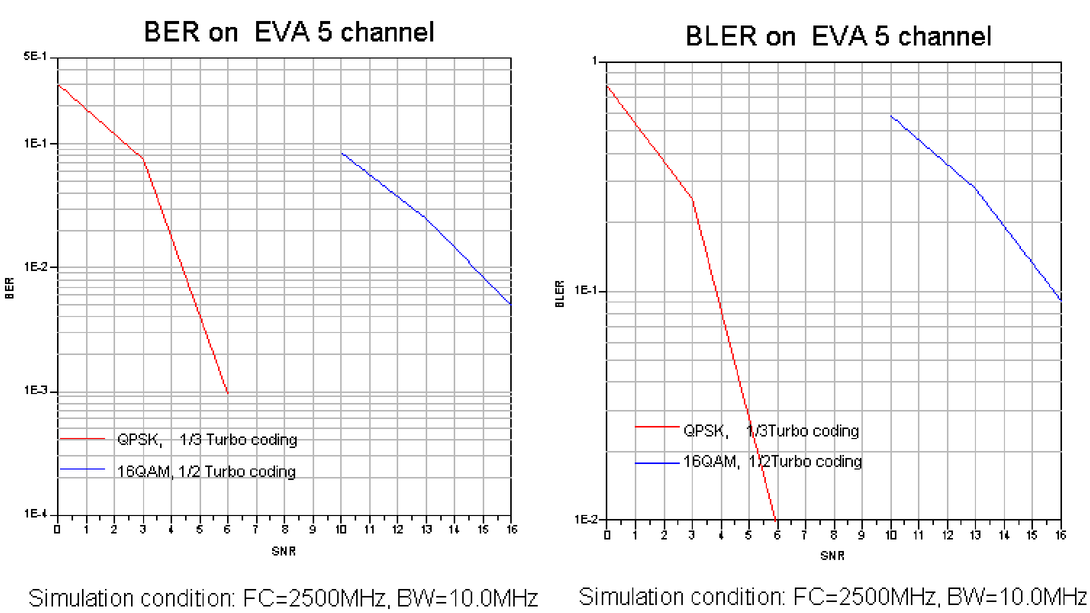
The number of frames for simulating BER/BLER is defined in *Measurement_Vars*;

Simulation Results

In this example, the performances of downlink PDSCH 1 (UE 1) on fading channel with channel coding are given. The following table shows the simulation conditions.

Parameter	**Value**
FCarrier	2500 MHz
Frame Mode	FDD
Bandwidth	10 MHz
Oversampling Option	Ratio 2
Cyclic Prefix	Normal
Fading Channel	EVA 5Hz
Reference Channels	QPSK R1/3, 16QAM R1/2

The curves have been generated averaging over 200 frames. The following figure shows the simulation results.



FDD Downlink BER/BLER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: about 2 hours

FDD Downlink SIMO 1x2 BER and BLER on Fading Channel

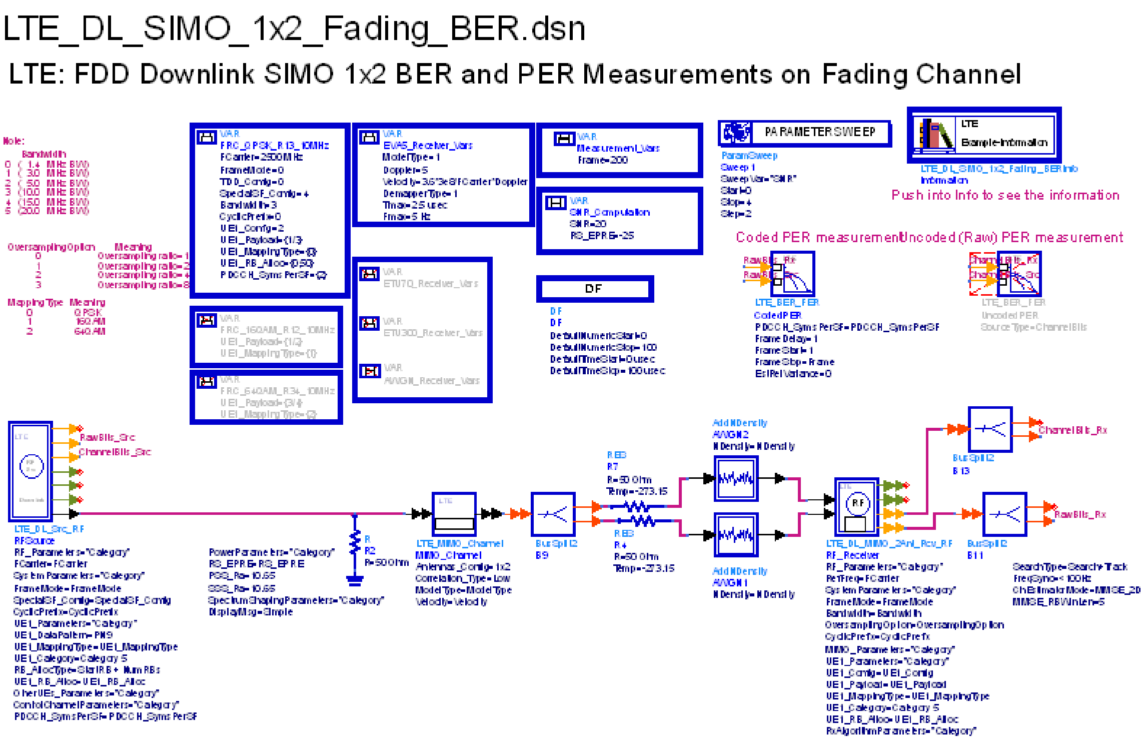
LTE_DL_SIMO_1x2_Fading_BER Design

Features

- Pre-defined reference channels following TS 36.101 for DL FDD
- MRC (Maximal Ratio Combining) receiver diversity with one transmitter antennas and 2 receiver antennas
- Fading channels following the definition in Annex B of TS 36.101
- Uncoded and coded BER/BLER measurements
- Multiple SNR measurement points

Description

LTE_DL_SIMO_1x2_Fading_BER performs FDD downlink SIMO 1x2 BER/BLER measurements on fading channels. The schematic is shown in the following figure.



LTE_DL_SIMO_1x2_Fading_BER Schematic

The signal source follows the definition of reference channel in A.3 of TS 36.101 with the exception that no HARQ transmissions are employed. Three are pre-configured in this example:

Signal Source Configurations
Reference channel [R.2 FDD] (10 MHz QPSK 1/3)
Reference channel [R.3 FDD] (10 MHz 16QAM 1/2)
Reference channel [R.7 FDD] (10 MHz 64QAM 3/4)

The fading channel follows the definition in Annex B of TS 36.101. Four settings are pre-configured in this example:

Fading Channel	Doppler
EVA	5 Hz
ETU	70 Hz
ETU	300 Hz
AWGN	0 Hz

Antenna configuration and correlation matrix support:

Antenna Configuration	Correlation Matrix
1x2	Low
1x2	Medium
1x2	High

Users may start from this example to create designs with other antenna configurations by replacing the RF source and the RF receiver with corresponding source and receiver, such as 4x4, 4x1, 1x4 or 2x4.

In this example, the uncoded (raw) BLER measurement is also provided. To measure it, activate the component UncodedPER.

The default channel estimator is the 2D MMSE with MMSE_RBWinLen = 5. The channel characters (Tmax, Fmax and SNR) needed by the channel estimator are set in *EVA5_Receiver_Vars*, *ETU70_Receiver_Vars*, *ETU300_Receiver_Vars* and *AWGN_Receiver_Vars* for EVA5, ETU70, ETU300 and AWGN respectively.

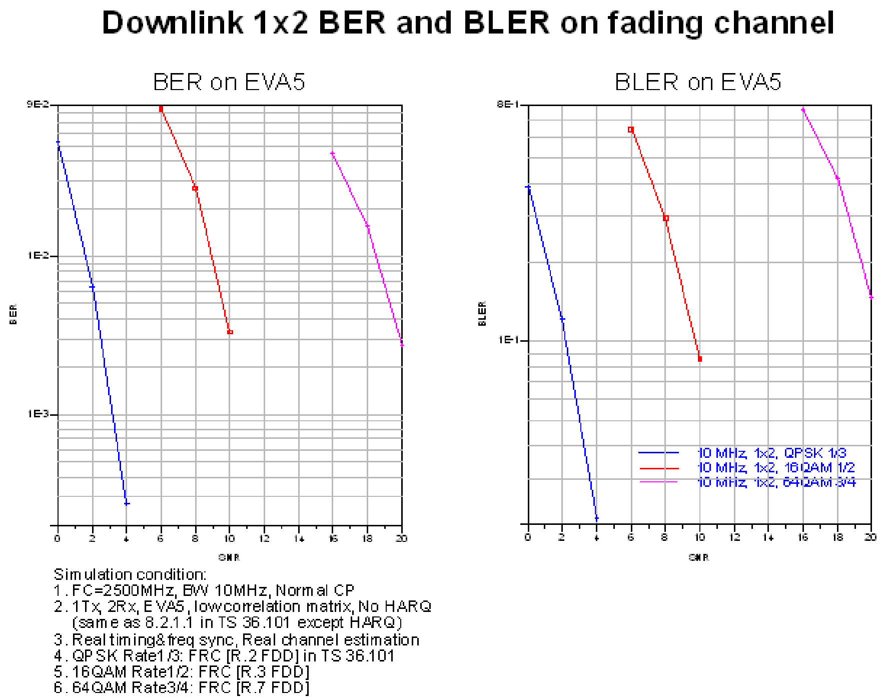
The number of frames for simulating BER/BLER is defined in *Measurement_Vars*;

Simulation Results

In this example, the performances of downlink PDSCH 1 (UE 1) on fading channel with channel coding are given. The following table shows the simulation conditions.

Parameter	Value
FCarrier	2500 MHz
Frame Mode	FDD
Bandwidth	10 MHz
Oversampling Option	Ratio 2
Cyclic Prefix	Normal
Antenna Configuration	1x2
Correlation Matrix	Low
MIMO Mode	Receiver diversity with 2 receiver antennas
Fading Channel	EVA 5Hz
Reference Channels	QPSK R1/3, 16QAM R1/2, 64QAM R3/4

The curves have been generated averaging over 200 frames. The following figure shows the simulation results.



FDD Downlink SIMO 1x2 BER/BLER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: about 3 hours

FDD Downlink MIMO 2x2 BER and BLER on Fading Channel

LTE_DL_MIMO_2x2_Fading_BER Design

Features

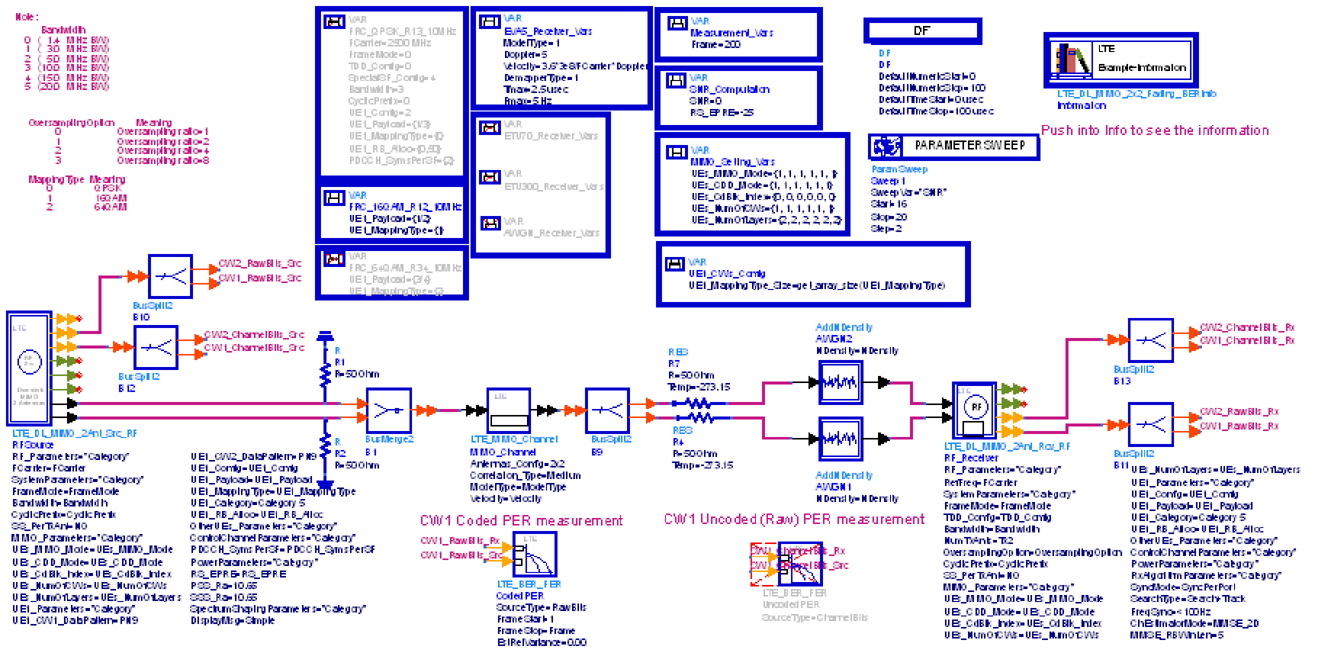
- Pre-defined reference channels following TS 36.101 for DL FDD
- Transmit diversity and Open-loop spatial multiplexing transmission modes with 2 transmitter antennas and 2 receiver antennas
- Fading channels following the definition in Annex B of TS 36.101
- Uncoded and coded BER/BLER measurements
- Multiple SNR measurement points

Description

LTE_DL_MIMO_2x2_Fading_BER performs FDD downlink MIMO 2x2 BER/BLER measurements on fading channels. The schematic is shown in the following figure.

LTE_DL_MIMO_2x2_Fading_BER.dsn

LTE: FDD Downlink MIMO (SM/Transmit Diversity Mode) BER and PER Measurements on Fading Channel



LTE_DL_MIMO_2x2_Fading_BER Schematic

The signal source follows the definition of reference channel in A.3 of TS 36.101 with the exception that no HARQ transmissions are employed. Three are pre-configured in this example:

Signal Source Configurations
Reference channel [R.10 FDD] (10 MHz QPSK 1/3)
Reference channel [R.11 FDD] (10 MHz 16QAM 1/2)
10 MHz 64QAM 3/4

The transmission mode for UE 1 is set by the parameter UEs_MIMO_Mode[1] in *MIMO_Setting_Vars*. Open-loop spatial multiplexing is selected when UEs_MIMO_Mode[1] = 0; otherwise Transmit diversity with 2 transmitter antennas is selected.

The fading channel follows the definition in Annex B of TS 36.101. Four channel settings are pre-configured in this example:

Fading Channel	Doppler
EVA	5 Hz
ETU	70 Hz
ETU	300 Hz
AWGN	0 Hz

Antenna configuration and correlation matrix support:

Antenna Configuration	Correlation Matrix
2x2	Low
2x2	Medium
2x2	High

Users may start from this example to create designs with other antenna configurations by replacing the RF source and the RF receiver with corresponding source and receiver, such as 4x4, 4x1, 1x4 or 2x4.

In this example, the uncoded (raw) BLER measurement is also provided. To measure it, activate the component UncodedPER.

The default channel estimator is the 2D MMSE with MMSE_RBWinLen = 5. The channel characters (Tmax, Fmax and SNR) needed by the channel estimator are set in *EVA5_Receiver_Vars*, *ETU70_Receiver_Vars*, *ETU300_Receiver_Vars* and *AWGN_Receiver_Vars* for EVA5, ETU70, ETU300 and AWGN respectively.

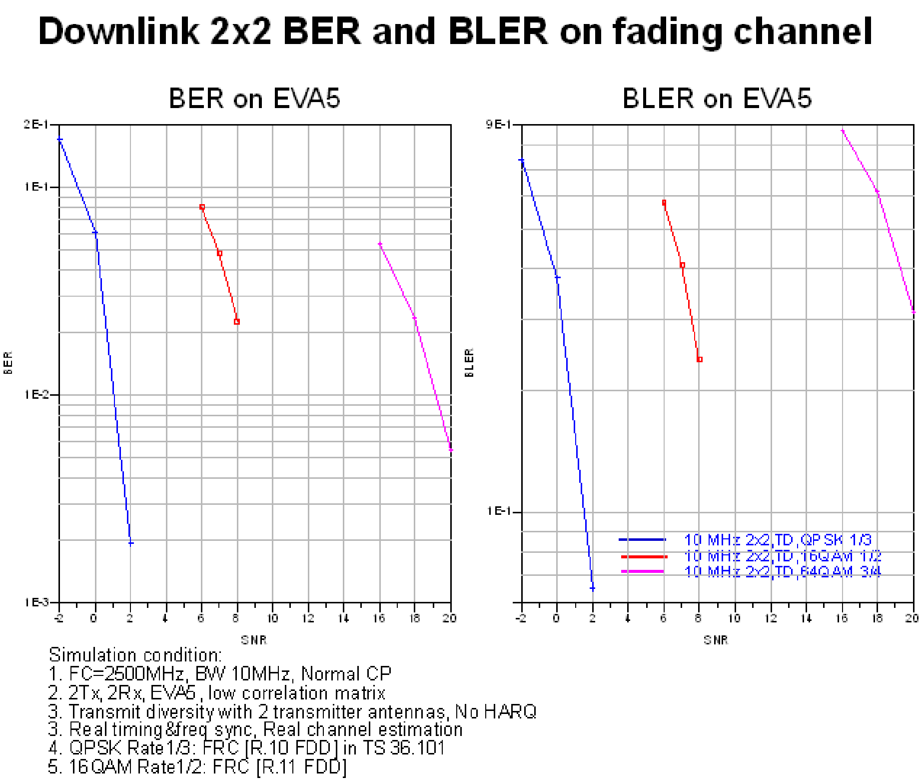
The number of frames for simulating BER/BLER is defined in *Measurement_Vars*;

Simulation Results

In this example, the performances of downlink PDSCH 1 (UE 1) on fading channel with channel coding are given. The following table shows the simulation conditions.

Parameter	Value
FCarrier	2500 MHz
Frame Mode	FDD
Bandwidth	10 MHz
Oversampling Option	Ratio 2
Cyclic Prefix	Normal
Antenna Configuration	2x2
Correlation Matrix	Medium
MIMO Mode	Transmit diversity with 2 transmitter antennas
Fading Channel	EVA 5Hz
Reference Channels	QPSK R1/3, 16QAM R1/2, 64QAM R3/4

The curves have been generated averaging over 200 frames. The following figure shows the simulation results.



FDD Downlink MIMO 2x2 BER/BLER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: about 3 hours

3GPP FDD LTE Uplink Transmitter Design Examples

The LTE_FDD_UL_Tx_wrk workspace provides transmitter design examples for the 3GPP FDD LTE uplink system. The transmitter measurements include constellation, spectrum, and CCDF, link with VSA 89601 software as well as other measurements.

- LTE_UL_TxEVM: FDD Uplink Tx EVM, constellation measurements
- LTE_UL_TxSpectrum: FDD Uplink Tx spectrum, CCDF and in-band emission measurements
- LTE_UL_VSA: FDD Uplink transmitters connected with 89600 VSA software

FDD Uplink Tx EVM Constellation Measurements

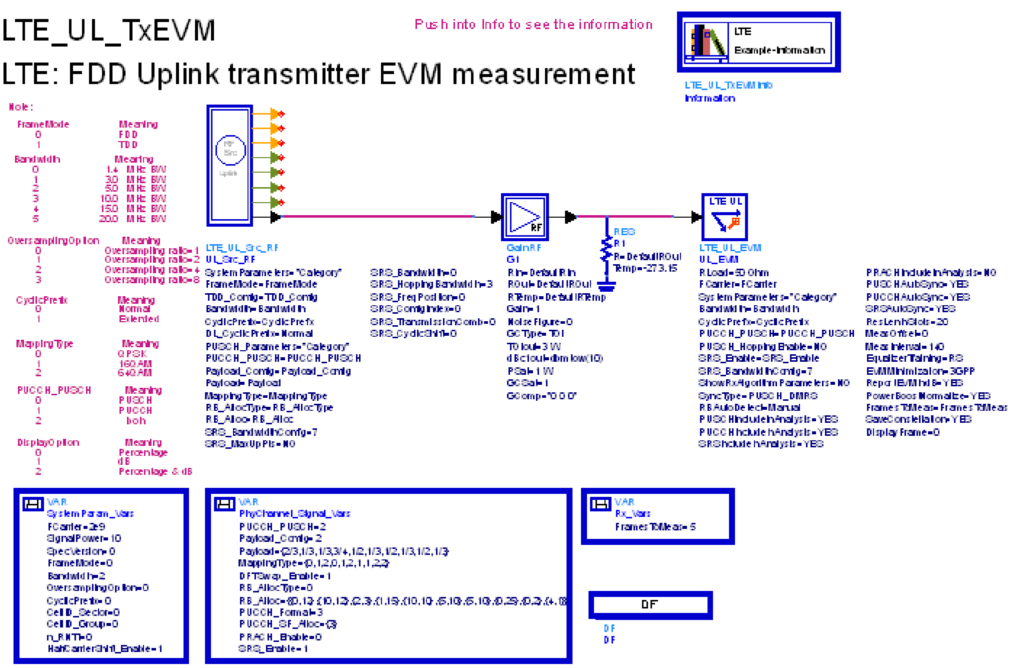
LTE_UL_TxEVM Design

Features

- LTE uplink FDD transmitter signal quality analysis, such as EVM, EVMPk, DataEVM, SyncCorr and so on.
- LTE uplink FDD transmitter EVM measurements for user channels and signals: PUCCH, PUSCH, SRS or PRACH.
- LTE uplink FDD transmitter signal Constellation for all channels.
- LTE uplink FDD transmitter normalized equalizer channel frequency response over subcarriers.
- LTE uplink FDD transmitter RB Error Mag Spectrum shows the EVM of each resource block (RB).

Description

LTE_UL_TxEVM measures EVM
The schematic for this design is shown in the following figure.



LTE_UL_TxEVM Schematic

LTE_UL_Src_RF is LTE RF uplink signal source. GainRF is used to model an amplifier with nonlinear gain compression. The EVM of the signal is measured by EVM measurement model LTE_UL_EVM.

Simulation Results

The simulation condition is shown in the following table, which lists the main parameters:

Simulation Condition

Parameter	Value
FrameMode	FDD
Bandwidth	5MHz
CyclicPrefix	Normal
PUCCH_PUSCH	both
MappingType	{0, 1, 2, 0, 1, 2, 1, 1, 2, 2}
RB_AllocType	StartRB + NumRBs
RB_Alloc	{ {0,12}, {10,12}, {2,3}, {1,15}, {10,10}, {5,10}, {5,10}, {0,25}, {0,2}, {4,1} }
PRACH_Enable	NO
SRS_Enable	YES
FramesToMeas	5

The RB allocation and mapping type for PUSCH varies from different subframes.
The measurement results are shown as follows:
The following figure shows the summary of EVM measurement results which include the results of each frame.

Error Summary

Frame	EVM	SyncCorr	IQGainImbalance	IQOffset	RSEVM	DataEVM
0	-57.946	1.000	1.000	1.104E-9	-59.852	-55.254
1	-58.134	1.000	1.000	1.079E-9	-61.962	-55.304
2	-57.685	1.000	1.000	2.138E-9	-60.635	-55.049
3	-57.855	1.000	1.000	1.293E-9	-59.821	-55.239
4	-58.080	1.000	1.000	2.131E-9	-60.756	-55.367

Error summary

The following figure shows the EVM measurement results of PUCCH and SRS respectively, which include the EVM of each frame for each channel.

EVM vs Physical Channel

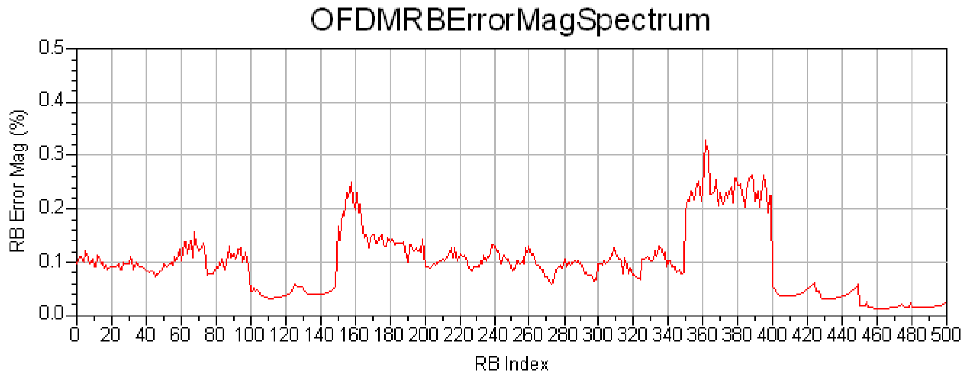
Frame	PUSCHEVM	PUCCHEVM	SRSEVM
0	-55.254	-55.849	-60.933
1	-55.304	-55.844	-61.013
2	-55.049	-52.188	-60.668
3	-55.239	-52.162	-61.476
4	-55.367	-55.433	-60.034

Frame	PUSCHNumRB	PUCCHNumRB	SRSNumRB
0	200.000	2.000	20.000
1	200.000	2.000	20.000
2	200.000	2.000	20.000
3	200.000	2.000	20.000
4	200.000	2.000	20.000

Frame	PUSCHPower	PUCCHPower	SRSPower
0	0.020	-0.014	0.020
1	-0.015	-0.014	0.020
2	-0.011	-0.014	0.020
3	-0.041	-0.014	0.020
4	0.010	-0.013	0.020

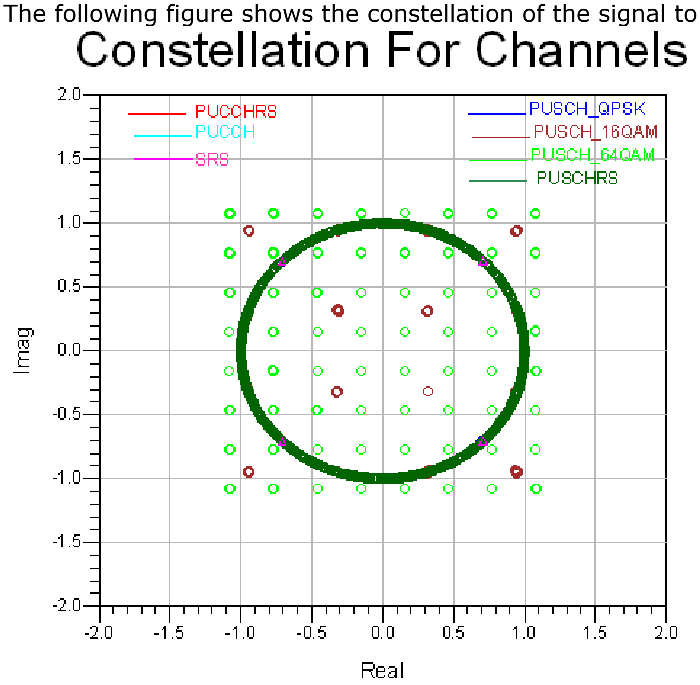
EVM versus Physical Channels

The following figure shows the EVM of each resource block (RB).



OFDM RB Error Mag. Spectrum

The following figure shows the constellation of the signal to be measured of each channel.



Constellation

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2008
- Simulation Time: approximately 25 seconds

FDD Uplink Tx Spectrum, CCDF and In Band Emission Measurements

LTE_UL_TxSpectrum: Design

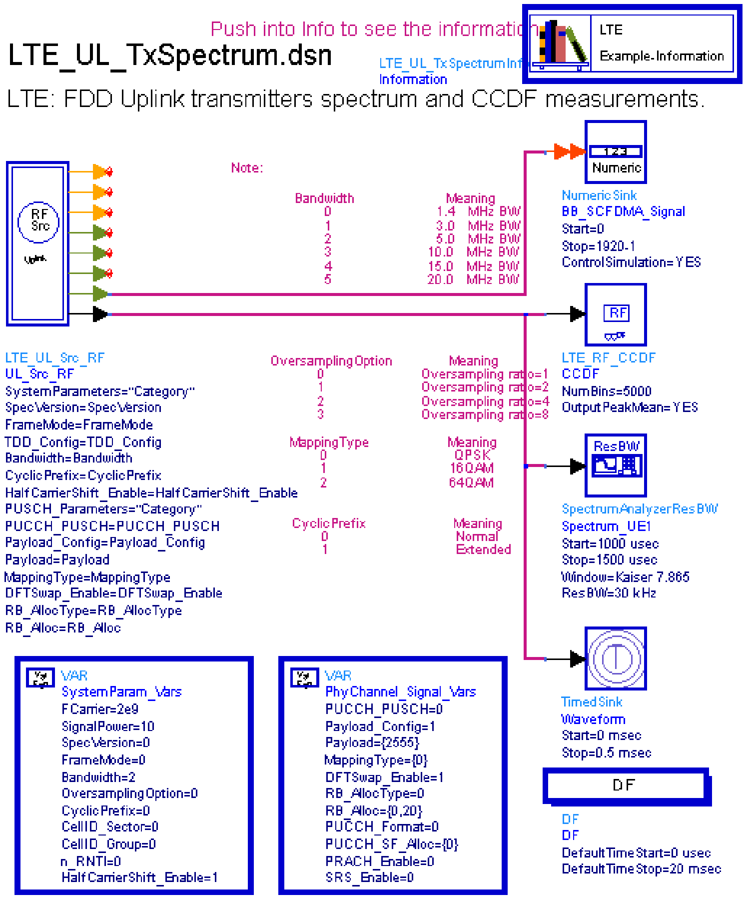
Features

- Transmitter Waveform
- Transmitter Spectrum measurement
- Transmitter CCDF, Peak-to_Average Ratio
- In-band emission

Description

This example measures spectrum, waveform, CCDF, Peak-to-Average ratio and in-band emission of uplink. The in-band emission is measured as the relative UE output power of

any non-allocated RB(s) and the total UE output power of all the allocated RB(s). The in-band emission measurement is only effective when "RB_AllocType" is set to "RB_Start + NumRBs" in current ADS implementation. In LTE_UL_TxSpectrum.dds, the "NonAllocRBIndex" should be set as the index of a non-allocated RB.
The schematic for this design is shown in the following figure.



LTE_UL_ TxSpectrum Schematic

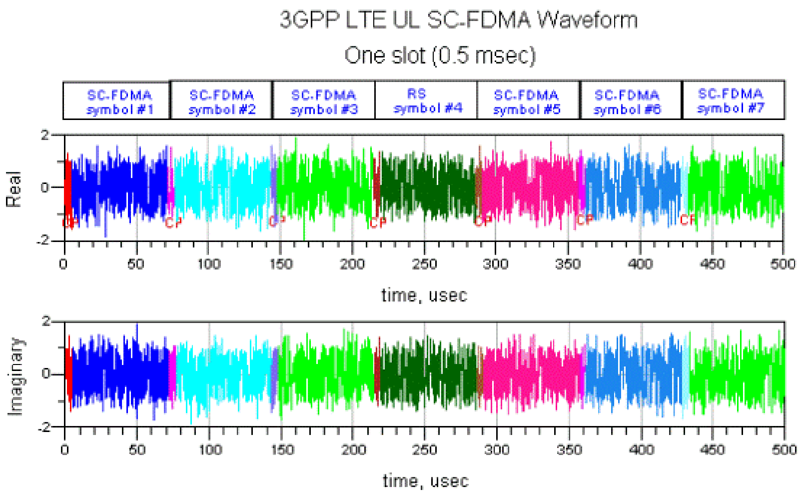
In LTE_UL_Src_RF, parameter "Power" is set to Average Power.

Simulation Results

The following table shows the simulation conditions.

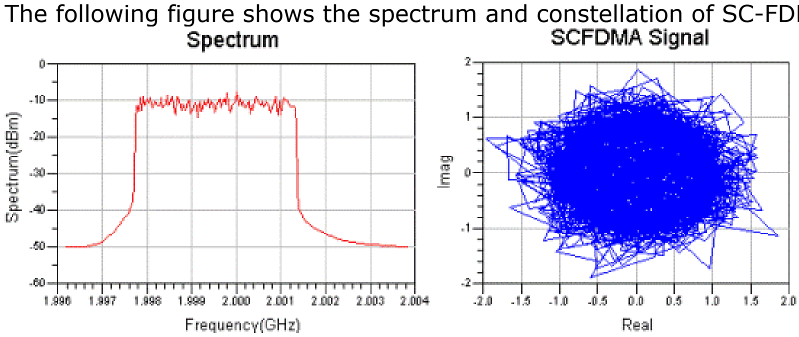
Parameter	Value
FCarrier	2000 MHz
Power	10 dBm
Bandwidth	5.0 MHz
Oversampling Option	Ratio 1
Cyclic Prefix Mode	Normal
PUCCH_PUSCH	PUSCH
HalfCarrierShift_Enable	YES
RB_AllocType	RBStart + NumRBs
RB_Alloc	{0,20}
PRACH_Enable	0
SRS_Enable	0

The signal power density spectrum is obtained using the spectrum analyzer.
The following figure shows the waveform of the signal. Each slot is 0.5ms long and consists of seven SC-FDMA symbols in Normal CP. The cyclic-prefix length for the first SC-FDMA symbol of a slot is somewhat larger, compared to the remaining SC-FDMA symbols.



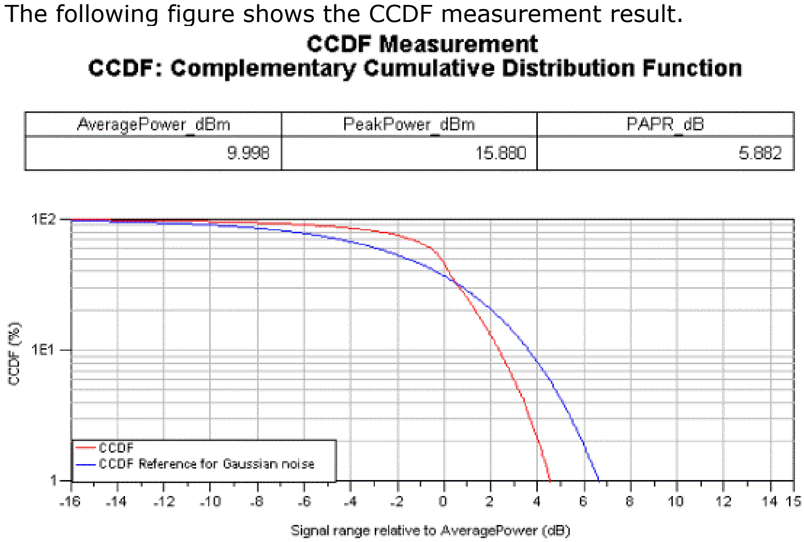
UL Transmitter Waveform

The following figure shows the spectrum and constellation of SC-FDMA signal.



UL Transmitter Spectrum

The following figure shows the CCDF measurement result.



UL Transmitter CCDF measurement

The following tables show the in-band emission measurement results with the 21th RB selected, which is the first non-allocated RB. The average in-band emission is also provided, which is calculated as the relative UE average output power of all non-allocated RBs and the total UE output power of all the allocated RBs.

Power

UE_Power_All	UE_Power_AllocRB
9.99547	9.99484

Average in-band emission

NumNonAllocRBs	AvgInBandEmission
5.000	-45.420

In-band emission of the selected non-allocated RB

NonAllocRBIndex	InBandEmission_NonAllocRB
21	-45.325

UL Transmitter In-band emissions

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2008
- Simulation Time: 6 seconds

FDD Uplink Transmitters Connected with 89600 VSA Software

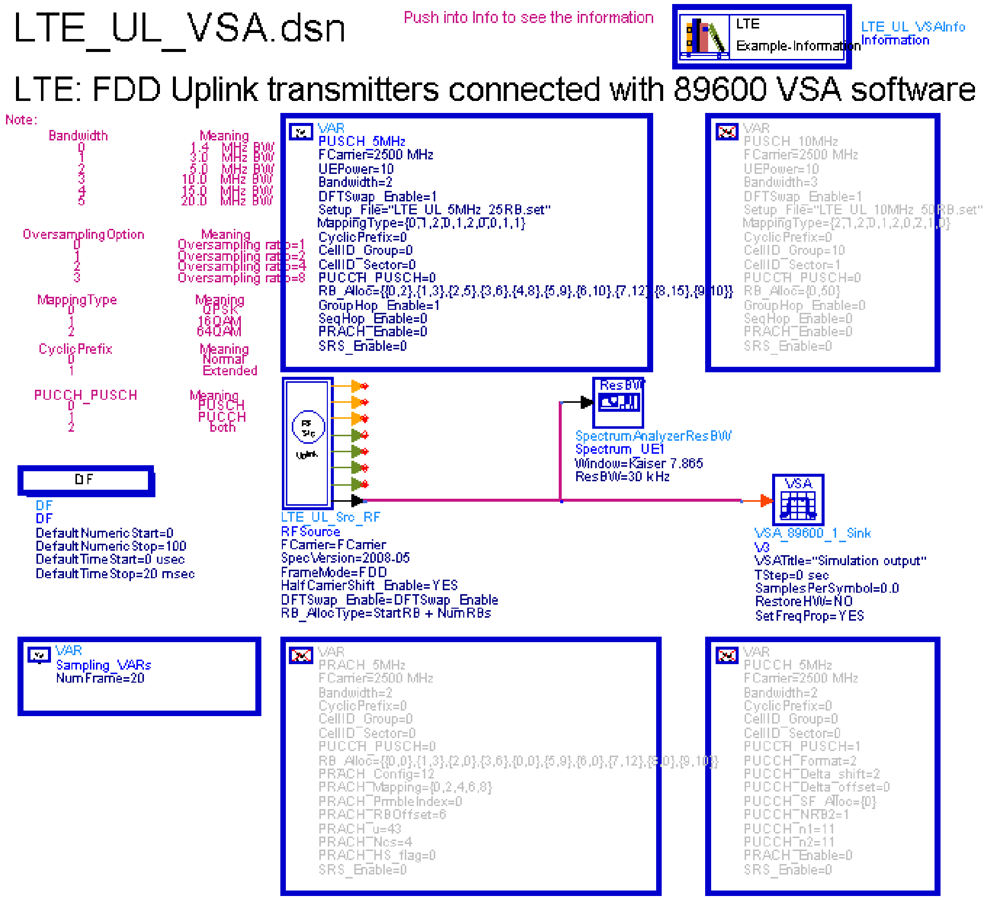
LTE_UL_VSA Design

Features

- Demo how to connect uplink transmitters with 89600 VSA software.

Description

This example connects the LTE uplink transmitter in ADS with 89600 VSA software. Var PUSCH_5MHz and Var PUSCH_10MHz are provided to test PUSCH in Bandwidth 5MHz and 10MHz respectively. PRACH_5MHz and PUCCH_5MHz are provided to test PRACH and PUCCH respectively. Users can enable one of the four vars each time for different transmitter configurations. Users can also change the var settings to test any other valid transmitter configuration, and the .set file for VSA should be modified accordingly. The schematic is shown in the following figure.



LTE_UL_VSA Schematic

Simulation Results

N/A

Benchmark

- Hardware Platform: Centrino 2.0GHz, 2048M memory
- Software Platform: Window XP, ADS 2008

3GPP FDD LTE Uplink Receiver Design Examples

The LTE_FDD_UL_Rx_wrk workspace provides receiver design examples for the 3GPP FDD LTE uplink system. est benches on AWGN and fading channel are provided.

- LTE_UL_AWGN_BER: Uplink FDD coded BER and PER Measurement on AWGN Channel
- LTE_UL_Fading_BER: Uplink FDD coded BER and PER Measurement on fading Channel

Uplink FDD Coded BER and BLER Measurement on AWGN Channel

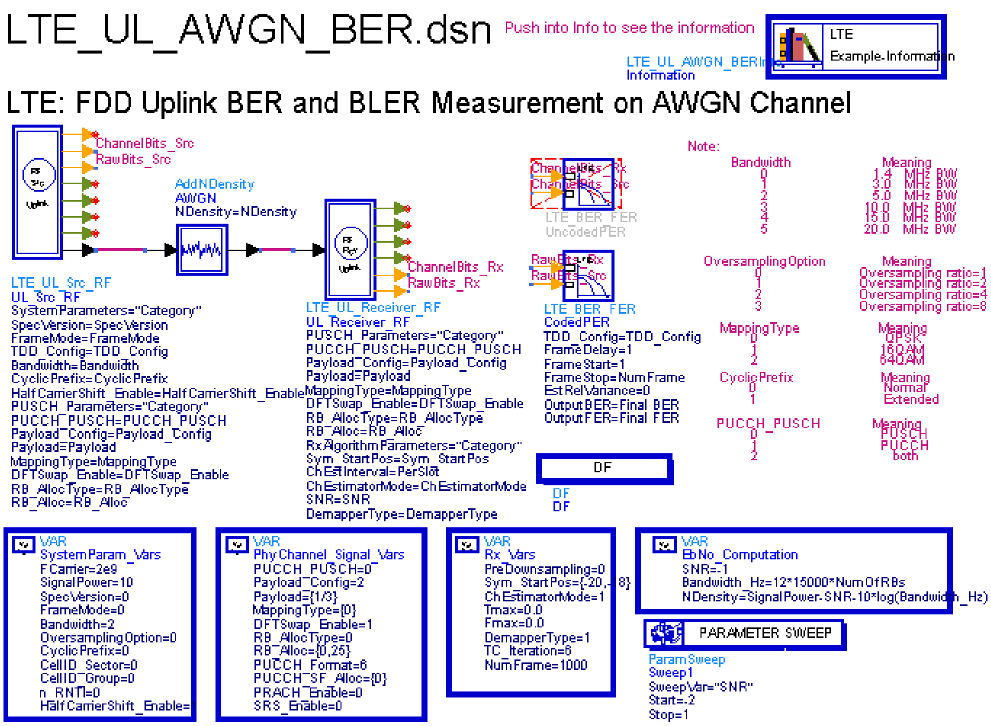
LTE_UL_AWGN_BER Design

Features

- Uncoded and coded BER/BLER measurement under AWGN channel
- Multiple SNR measurement points

Description

LTE_UL_AWGN_BER performs uplink BER/BLER measurements under AWGN, including both uncoded and coded BER/BLER. The schematic is shown in the following figure.



LTE_UL_AWGN_BER Schematic

The SNR used in this example is defined as
SNR = S / N
Where:
S is the total signal energy in the subframe on a single antenna port.
N is the noise energy in a bandwidth corresponding to the allocated bandwidth over the duration of a subframe.
There is only one antenna in the receiver in this example, and no HARQ retransmission is employed.
Users can change the parameter configurations to simulate different system configurations. For example, users can change MappingType from 0 to 2 in PhyChannel_Signal_VARs and get BER/BLER results of different modulation schemes (QPSK, 16QAM and 64QAM). DemappingType can be selected from Hard and Soft in Rx_Vars, generally speaking, soft demapper improves the performance compared to hard

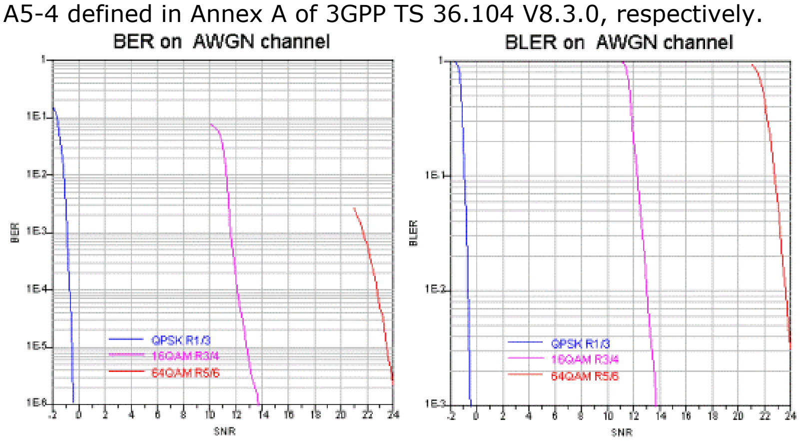
demapper. ChEstimationMode can be selected as Linear and MMSE, utilizing a linear interpolator and MMSE interpolator in the channel estimator respectively. In AWGN channel, for MMSE channel estimation, Tmax can be set to 0.0.

Simulation Results

In this example, the performance of PUSCH under AWGN for different modulation schemes is given. The following table shows the simulation conditions.

Parameter	Value
FCarrier	2000 MHz
Bandwidth	5 MHz
Cyclic Prefix	Normal
PUCCH_PUSCH	PUSCH
RB_AllocType	StartRB + NumRBs
RB_Alloc	{0, 25}
ChEstimatorMode	MMSE
Tmax	0.0
DemapperType	Soft
Number of Measured Frames	1000

The following figure shows the simulation results. The curves have been generated averaging over 1000 frames under AWGN channel. It should be noted that ideal timing and frequency synchronization are used to get the following results. The code rates for QPSK, 16QAM, 64QAM are 1/3, 3/4, 5/6 corresponding to FRC A3-4, FRC A4-5 and FRC A5-4 defined in Annex A of 3GPP TS 36.104 V8.3.0, respectively.



Uplink AWGN BER/BLER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2008
- Simulation Time: about 5 hours for QPSK

Uplink FDD Coded BER and PER Measurement on Fading Channel

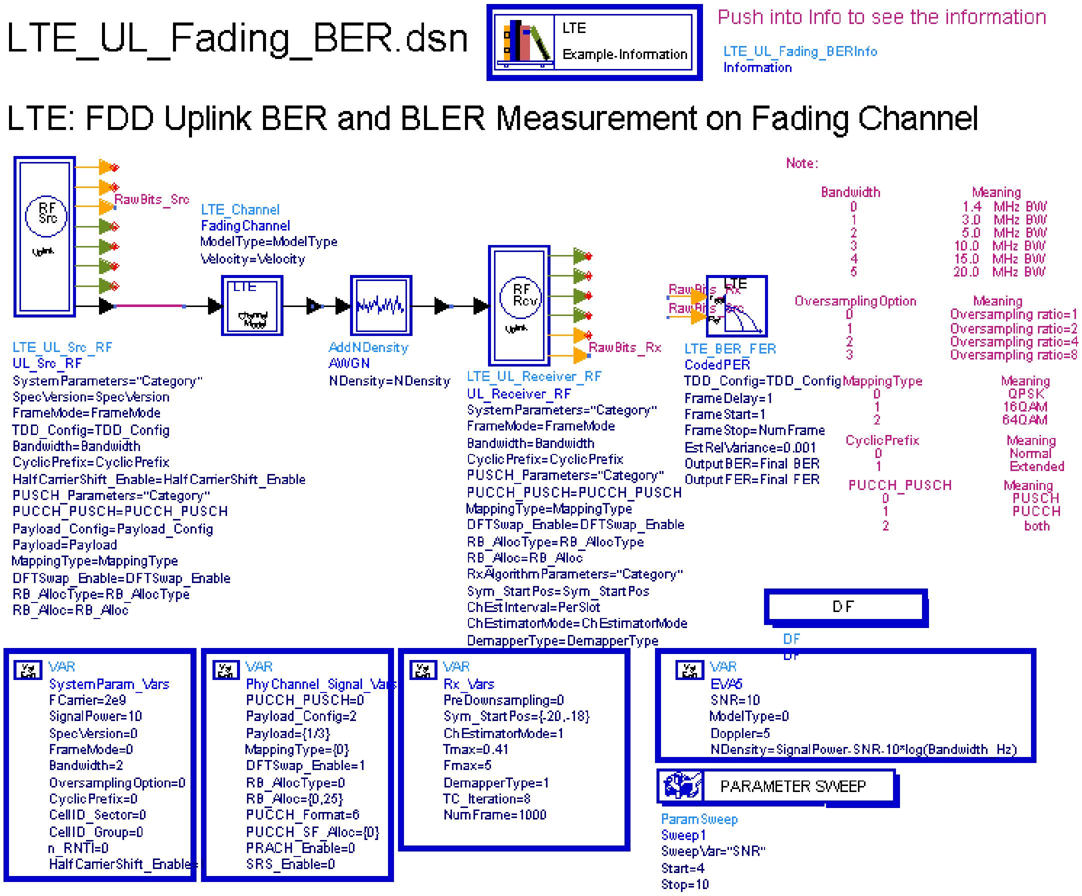
LTE_UL_Fading_BER Design

Features

- coded BER/BLER measurement under fading channel
- Multiple SNR measurement points

Description

This example measures uplink FDD coded BER/BLER performance on fading channel. The supported channel models are Extended Pedestrian A, Extended Vehicular A and Extended Typical Urban. Users also can define other channel models by directly set the channel parameters. The schematic is shown in the following figure.



LTE_UL_Fading_BER Schematic

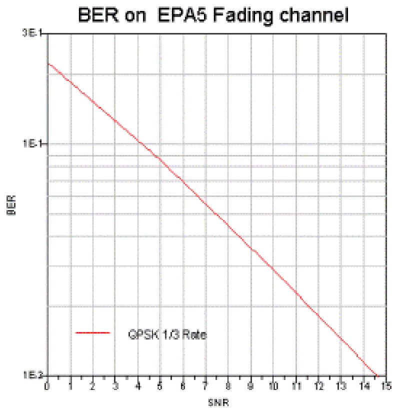
Users can change the parameter configurations to simulate different system configurations. For example, users can change MappingType from 0 to 2 in PhyChannel_Signal_VARs and get BER/BLER results for different modulation schemes (QPSK, 16QAM and 64QAM). Also DemappingType can be selected from Hard and Soft in Rx_Vars. The ChEstimationMode can be selected from Linear and MMSE. ChEstInterval can be selected from Per Slot and Per Subframe.

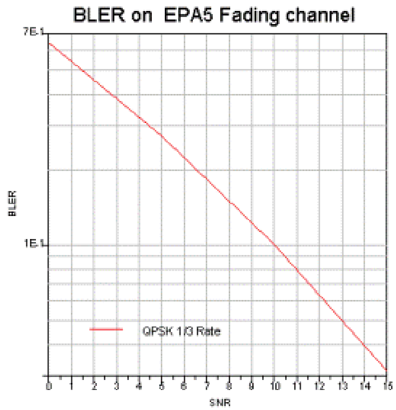
Simulation Results

In this example, the performance of uplink PUSCH under EVA5 fading channel for QPSK is given. The following table shows the simulation conditions.

Parameter	Value
FCarrier	2000 MHz
Bandwidth	5 MHz
Cyclic Prefix	Normal
PUCCH_PUSCH	PUSCH
MappingType	QPSK
Payload_Config	Code rate
Payload	{ 1/3 }
RB_AllocType	StartRB + NumRBs
RB_Alloc	{0, 25}
ChEstimatorMode	MMSE
Tmax	0.41 μ s
DemapperType	Soft
Number of Measured Frames	1000

The curves have been generated averaging over 1000 frames under EPA5 fading channel. The following figure shows the simulation results.





Uplink Fading BER/BLER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: about 70 hours for QPSK

3GPP LTE TDD Transmitter Design Examples

The LTE_TDD_Tx_wrk workspace provides transmitter design examples for the 3GPP TDD LTE system. The transmitter measurements include EVM, constellation, spectrum, and waveform measurements.

- LTE_TDD_DL_TxEVM: TDD Downlink transmitter EVM measurement
- LTE_TDD_UL_TxEVM: TDD Uplink transmitter EVM measurement
- LTE_TDD_DL_4Ant_TxSpectrum: TDD DL 4 antennas transmitter spectrum and CCDF measurements

TDD LTE Downlink Transmitter EVM Measurement

LTE_TDD_DL_TxEVM

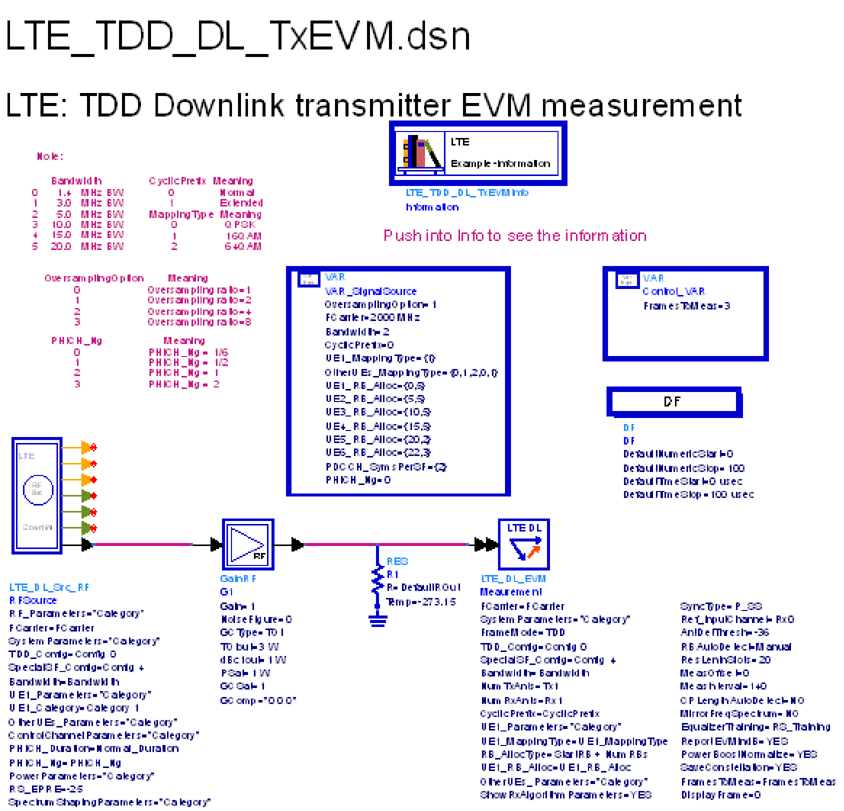
Features

- LTE DL TDD transmitter signal quality analysis, such as EVM, EVMPk, DataEVM, SyncCorr and so on.
- LTE DL TDD transmitter EVM measurements for user channels and signals: P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH and PDSCH.
- LTE DL TDD transmitter Constellation for all channels.
- LTE DL TDD transmitter normalized equalizer channel frequency response over subcarriers
- LTE DL TDD transmitter RB Error Mag Spectrum shows the EVM of each resource block (RB)

Description

LTE_TDD_DL_TxEVM measures EVM versus physical channels and resource blocks for TDD LTE downlink transmitter system. Both EVM in dB and percent can be given. The constellations of each channel and signals are provided as well.

The schematic for this design is shown in the following figure.



LTE_TDD_DL_TxEVM Schematic

LTE_TDD_DL_TxEVM Schematic

LTE_DL_Src_RF is TDD-LTE RF downlink signal source, which generates RF signal. GainRF is used to model an amplifier with nonlinear gain compression. Then, EVM of the signals from two transmit antennas are measured by LTE_DL_EVM, and the constellation of the signal and other measurement are also provided by this measurement model.

Simulation Results

The simulation condition is shown in the following table, which lists the main parameters:

Simulation Condition

Parameter	**Value**
FrameMode	TDD
Bandwidth	5MHz
CyclicPrefix	Normal
UE1_MappingType	{1}
OtherUEs_MappingType	{0, 1, 2, 0, 1}
UE1_RB_Alloc	{0,5}
UE2_RB_Alloc	{5,5}
UE3_RB_Alloc	{10,5}
UE4_RB_Alloc	{15,5}
UE5_RB_Alloc	{20,2}
UE6_RB_Alloc	{22,3}
FramesToMeas	3

Six UEs occupies different resource blocks. All 15 RBs are allocated. The mapping types are different for each UE. Spatial Multiplexing is employed.

The measurement results are shown as follows:
The following figure shows the summary of EVM measurement results which include the results of each frame.

Error Summary

Frame	EVM	SyncCorr	IQGainImbalance	IQOffset	RSTxPower
0	-57.006	1.000	1.000	7.398E-9	-24.989
1	-57.847	1.000	1.000	6.100E-9	-24.989
2	-57.752	1.000	1.000	5.639E-9	-24.989

Error summary

The following figure shows the EVM measurement results of PDCCH, PCFICH, PHICH, BCH, P-SCH and S-SCH respectively, which include the EVM of each frame for each channel.

EVM vs Physical Channel

Frame	P_SSEVM	S_SSEVM	RSEVM	PBCHEVM	...FICHEVM	PHICHEVM	PDCCHEVM	PDSCHEVM
0	-58.870	-56.467	-57.802	-59.250	-61.457	-61.135	-62.570	-56.811
1	-55.164	-57.439	-58.172	-58.930	-61.576	-61.472	-63.014	-57.817
2	-57.981	-58.618	-59.214	-55.137	-61.864	-61.537	-63.481	-57.705

EVM versus Physical Channels

The following figure shows the EVM measurement results of UE1 to UE6, which include the EVM, number of RBs and the power of each frame for each UE.

EVM vs UEs

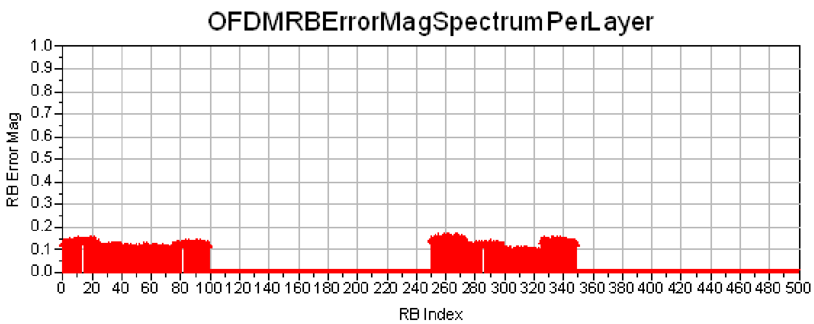
Frame	PDSCH_User0EVM	PDSCH_User1EVM	PDSCH_User2EVM	PDSCH_User3EVM	PDSCH_User4EVM	PDSCH_User5EVM
0	-56.992	-56.745	-56.402	-56.779	-56.987	-57.163
1	-58.003	-57.683	-57.709	-57.651	-57.893	-58.122
2	-57.918	-57.581	-57.728	-57.507	-57.741	-57.844

Frame	...SCH_User0NumRB	...SCH_User1NumRB	...SCH_User2NumRB	...SCH_User3NumRB	...SCH_User4NumRB	...SCH_User5NumRB
0	40.000000	40.000000	40.000000	40.000000	16.000000	24.000000
1	40.000000	40.000000	40.000000	40.000000	16.000000	24.000000
2	40.000000	40.000000	40.000000	40.000000	16.000000	24.000000

Frame	PDSCH_User0Power	PDSCH_User1Power	PDSCH_User2Power	PDSCH_User3Power	PDSCH_User4Power	PDSCH_User5Power
0	-0.033971	-0.000729	-0.002512	0.006334	-0.000778	-0.019137
1	-0.034015	-0.000742	0.021074	0.003258	-0.000860	0.012871
2	-0.034120	-0.000922	0.017642	0.023174	-0.000844	0.044790

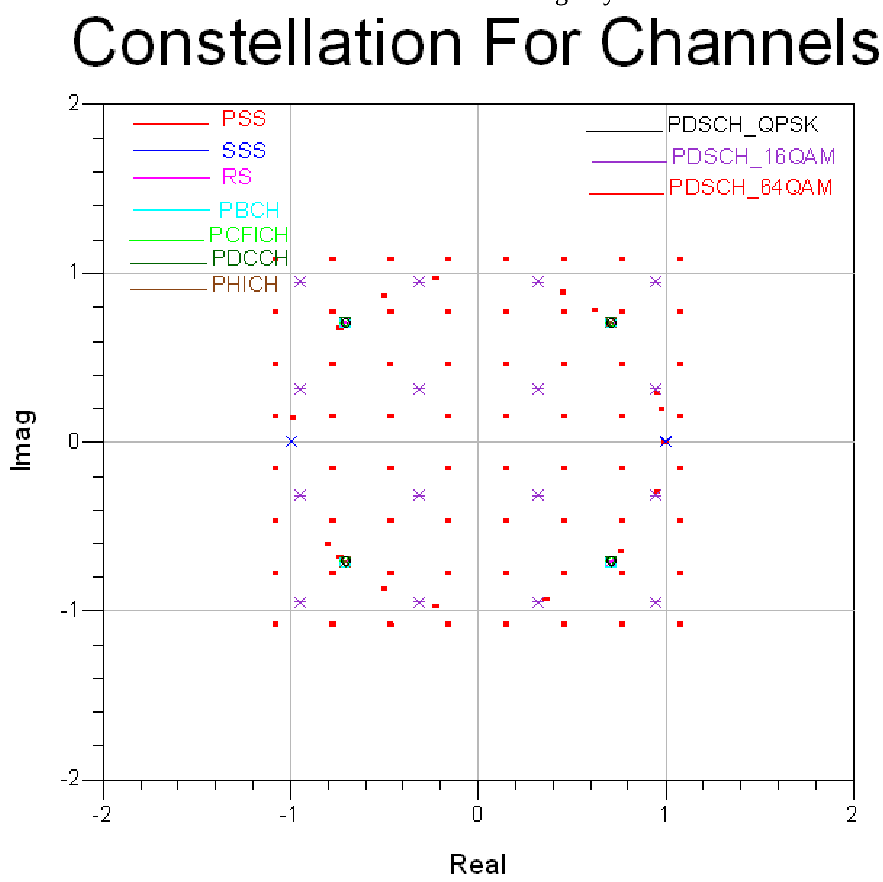
EVM versus UE

The following figure shows the EVM of each resource block (RB) in the selected layer.



OFDM RB Error Mag. Spectrum

The following figure shows the constellation of the signal to be measured of each channels.



Constellation

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: approximately 40 seconds

TDD Uplink Transmitter EVM Measurement

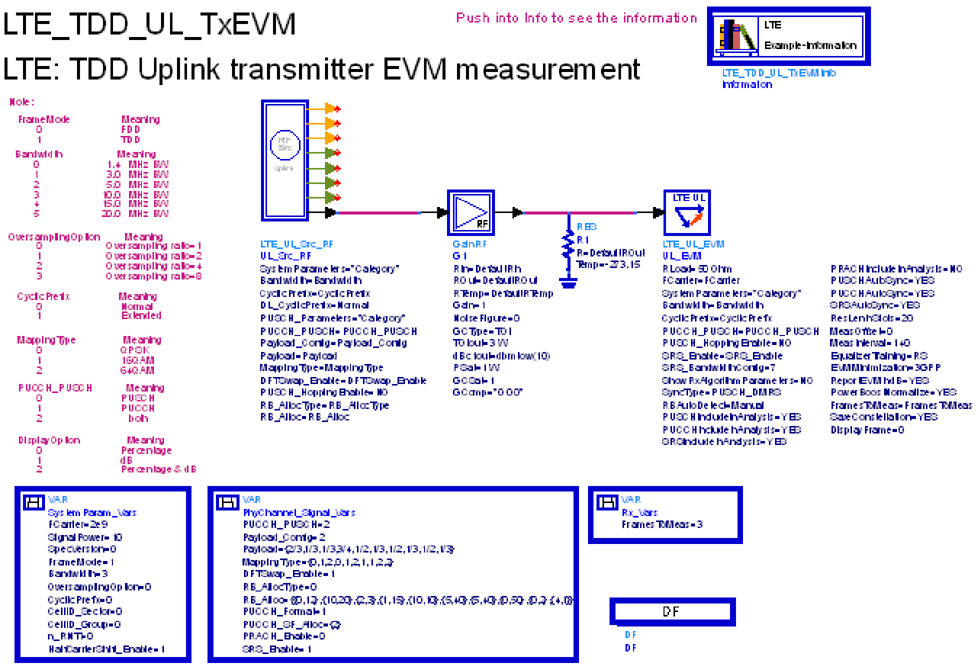
LTE_TDD_UL_TxEVM

Features

- LTE uplink TDD transmitter signal quality analysis, such as EVM, EVMPk, DataEVM, SyncCorr and so on.
- LTE uplink TDD transmitter EVM measurements for user channels and signals: PUCCH, PUSCH, SRS or PRACH.
- LTE uplink TDD transmitter signal Constellation for all channels.
- LTE uplink TDD transmitter normalized equalizer channel frequency response over subcarriers.
- LTE uplink TDD transmitter RB Error Mag Spectrum shows the EVM of each resource block (RB).

Description

LTE_TDD_UL_TxEVM measures EVM
The schematic for this design is shown in the following figure.



LTE_TDD_UL_TxEVM Schematic

LTE_UL_Src_RF is LTE RF uplink signal source. GainRF is used to model an amplifier with nonlinear gain compression. The EVM of the signal is measured by EVM measurement model LTE_UL_EVM.

Simulation Results

The simulation condition is shown in the following table, which lists the main parameters:

Simulation Condition

Parameter	**Value**
FrameMode	TDD
Bandwidth	10MHz
CyclicPrefix	Normal
PUCCH_PUSCH	both
MappingType	{0, 1, 2, 0, 1, 2, 1, 1, 2, 2}
RB_AllocType	StartRB + NumRBs
RB_Alloc	{ {0,12}, {10,20}, {2,3}, {1,15}, {10,10}, {5,40}, {5,40}, {0,50}, {0,2}, {4,1} }
PRACH_Enable	NO
SRS_Enable	YES
FramesToMeas	3

The RB allocation and mapping type for PUSCH varies from different subframes.
The measurement results are shown as follows:
The following figure shows the summary of EVM measurement results which include the results of each frame.

Error Summary

Frame	EVM	SyncCorr	...GainImbalance	IQOffset	RSEVM	DataEVM
0	-59.241	1.000	1.000	8.161E-10	-67.483	-52.979
1	-58.879	1.000	1.000	6.664E-10	-64.164	-52.766
2	-59.127	1.000	1.000	1.053E-9	-63.097	-52.888

Error summary

The following figure shows the EVM measurement results of PUCCH and SRS respectively, which include the EVM of each frame for each channel.

EVM vs Physical Channel

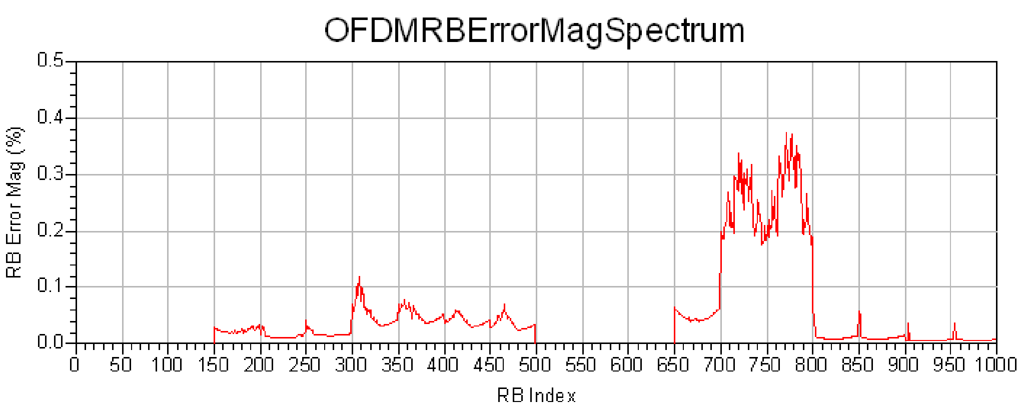
Frame	PUSCHEVM	PUCCHEVM	SRSEVM
0	-52.979	-68.444	-67.347
1	-52.766	-60.362	-65.394
2	-52.888	-64.424	-68.600

Frame	PUSCHNumRB	PUCCHNumRB	SRSNumRB
0	162.000	2.000	32.000
1	162.000	2.000	32.000
2	162.000	2.000	32.000

Frame	PUSCHPower	PUCCHPower	SRSPower
0	-0.007	0.026	0.025
1	-0.026	0.026	0.025
2	-0.002	0.026	0.025

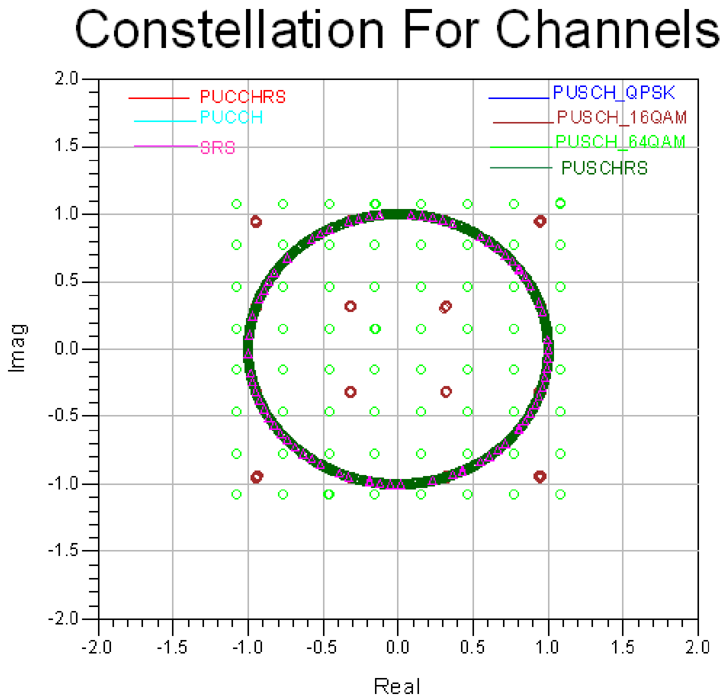
EVM versus Physical Channels

The following figure shows the EVM of each resource block (RB).



OFDM RB Error Mag. Spectrum

The following figure shows the constellation of the signal to be measured of each channel.



Constellation

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2008
- Simulation Time: approximately 25 seconds

TDD DL 4 Antenna Transmitter Spectrum and CCDF Measurements

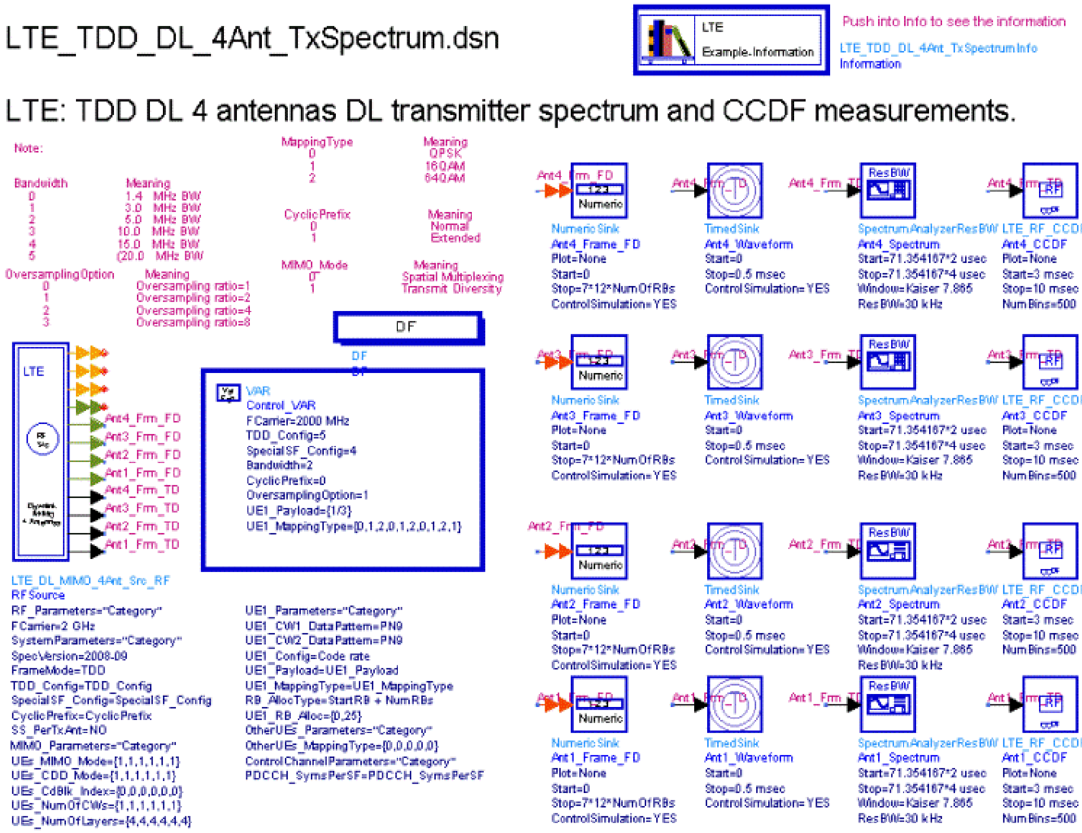
LTE_TDD_DL_4Ant_TxSpectrum Design

Features

- 4 Antennas Transmitter Spectrum Measurement
- 4 Antennas Transmitter Power
- 4 Antennas Transmitter CCDF and Waveform

Description

LTE_TDD_DL_4Ant_TxSpectrum measures spectrum, waveform, CCDF and Peak-to-Mean ratio of TDD LTE downlink 4 antenna transmitter. The schematic is shown in the following figure.



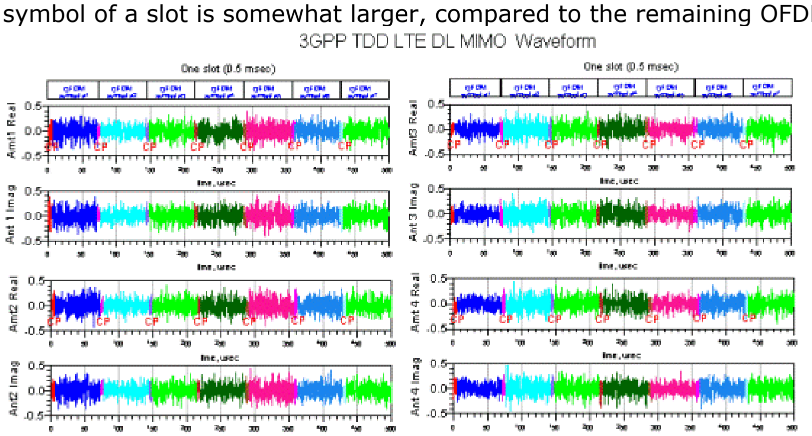
LTE_TDD_DL_4Ant_TxSpectrum Schematic

Simulation Results

The signal power density spectrum is obtained using the spectrum analyzer. The following table shows the simulation conditions.

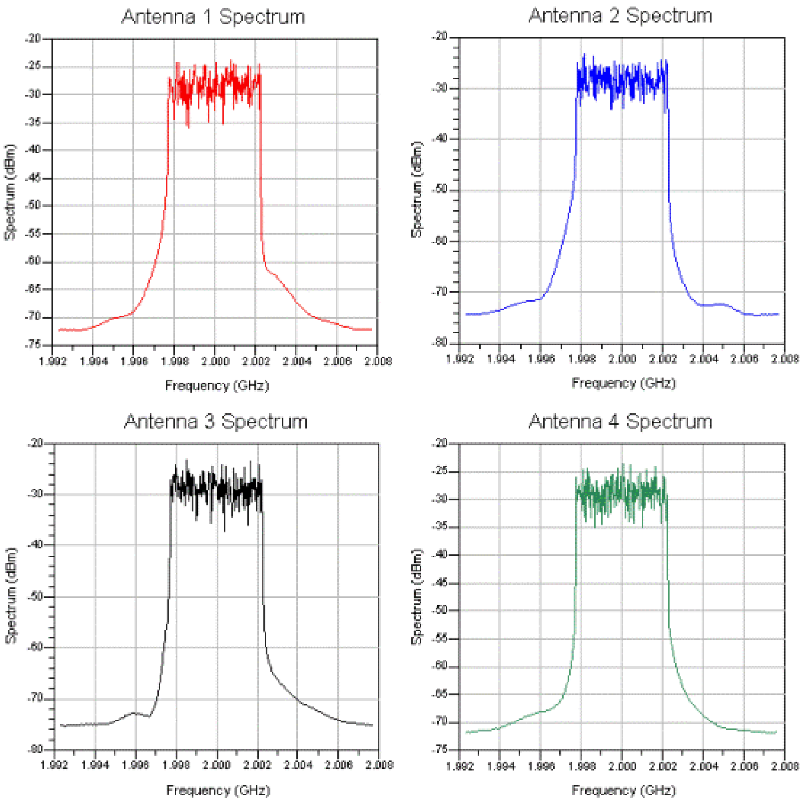
Parameter	Value
FCarrier	2000 MHz
Bandwidth	5 MHz
CyclicPrefix	Normal
UE1_MappingType	{0, 1, 2, 0, 1, 2, 0, 1, 2, 1}
UE1_RBAllocType	StartRB + NumRBs
UE1_RBAlloc	{0, 25}
Oversampling Option	Ratio 2

The measurement results are shown as follows:
The following figure shows the waveform of the signal. Each slot is 0.5ms long and consists of seven OFDM symbols in Normal CP. The cyclic-prefix length for the first OFDM symbol of a slot is somewhat larger, compared to the remaining OFDM symbols.



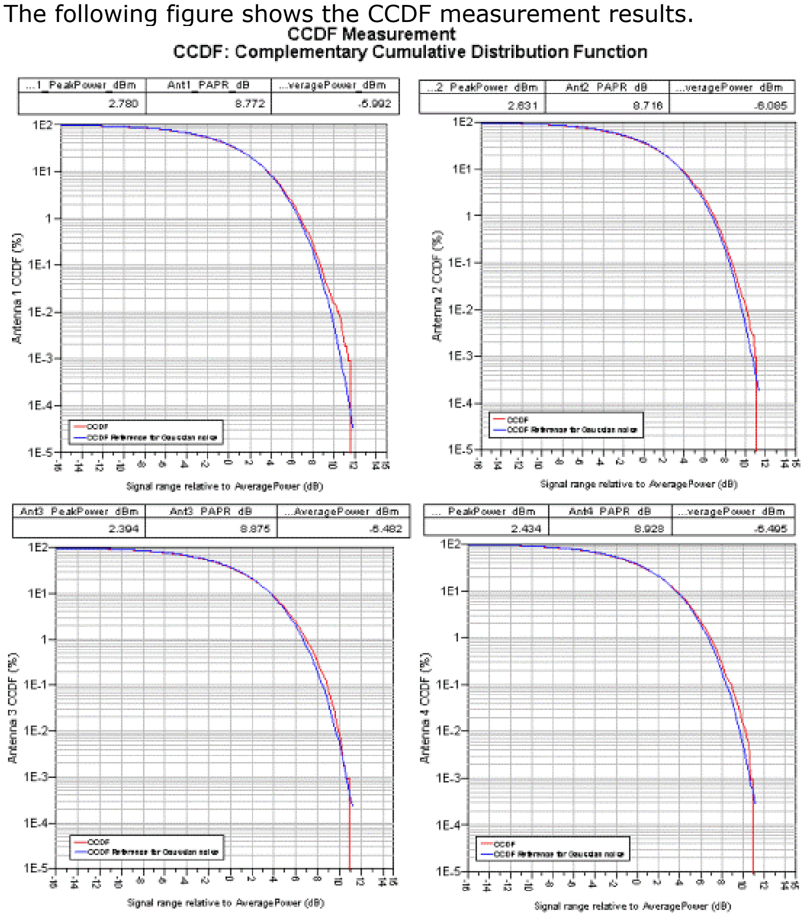
LTE TDD Downlink 4 Antennas Transmitter Waveform

The following figure shows the spectrum of each antenna.



LTE TDD Downlink 4 Antennas Transmitter Spectrum

The following figure shows the CCDF measurement results.



LTE TDD Downlink 4 Antennas Transmitter CCDF measurement

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: 10 seconds

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: 10 seconds

3GPP TDD LTE Receiver Design Examples

The LTE_TDD_Rx_wrk workspace provides downlink and uplink receiver design examples for the 3GPP TDD System. The receiver measurements include TDD uplink BER/BLER on AWGN, TDD Downlink SISO, SIMO and MIMO BER/BLER on AWGN and fading channel.

- LTE_TDD_DL_AWGN_BER: TDD DL AWGN BER/BLER measurements
- LTE_TDD_UL_AWGN_BER: TDD UL AWGN BER/BLER measurements
- LTE_TDD_DL_1x2_Fading_BER: TDD DL SIMO 1x2 BER and BLER on Fading Channel
- LTE_TDD_DL_4x2_Fading_BER: TDD DL MIMO 4x2 BER and BLER on Fading Channel

TDD Downlink BER Measurement under AWGN

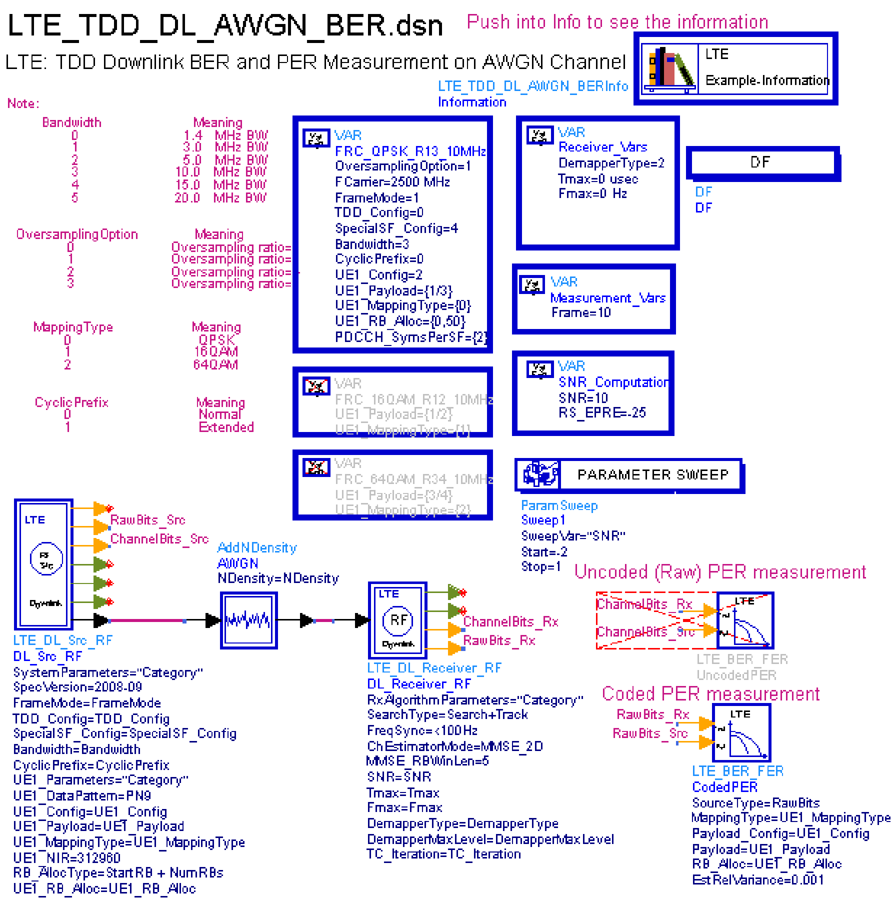
LTE_TDD_DL_AWGN_BER Design

Features

- uncoded and coded BER/BLER measurement under AWGN channel
- Multiple SNR measurement points

Description

LTE_TDD_DL_AWGN_BER performs downlink uncoded/coded BER/BLER measurements under AWGN channel. The schematic is shown in the following figure.



LTE_TDD_DL_AWGN_BER Schematic

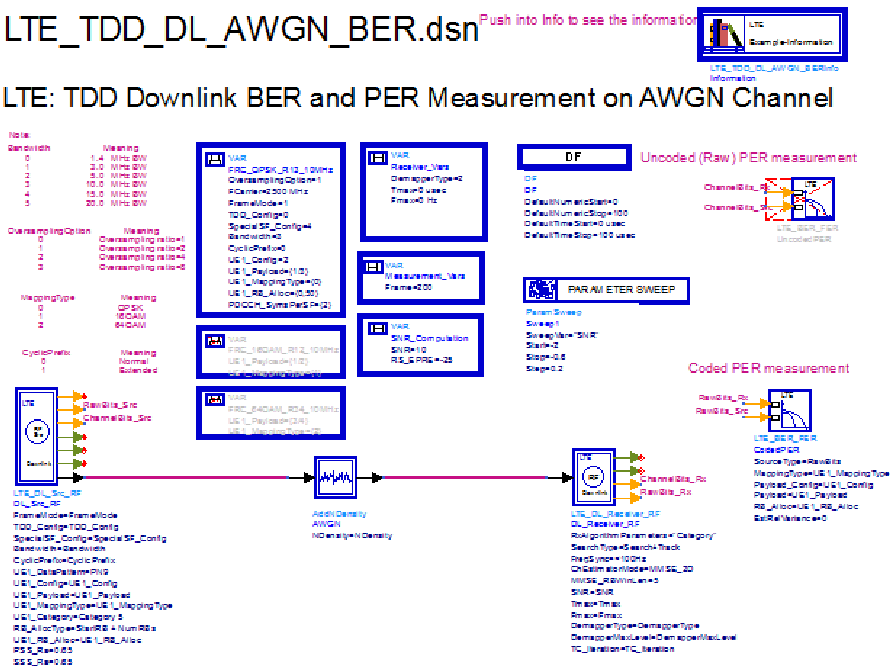
The three VARs FRC_QPSK_R13_10MHz, FRC_16QAM_R12_10MHz and FRC_64QAM_R34_10MHz configure the signal source according to definition of reference channel [R.2 FDD], [R.3 FDD] and [R.7 FDD]in Section A.3 of 3GPP TS 36.101 V8.3.0, respectively. It should be noted that no HARQ retransmission is employed.

Simulation Results

The performances of downlink PSCH under AWGN channel for QPSK with code rate 1/3, 16QAM with code rate 1/2 and 64QAM with code rate 3/4 are given. The following table shows the simulation conditions.

Parameter	Value
FCarrier	2500 MHz
TDD_Config	Config 0
Bandwidth	10 MHz
CyclicPrefix	Normal
ChEstimatorMode	MMSE_2D
DemapperType	CSI
Number of Measured Frames	1000

The curves have been generated averaging over 1000 frames under AWGN. The following figure shows the simulation results. It should be noted that ideal timing and frequency synchronization are used to get the following results.



TDD Downlink AWGN BER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: about 1 hours for QPSK

TDD Uplink BER Measurement under AWGN

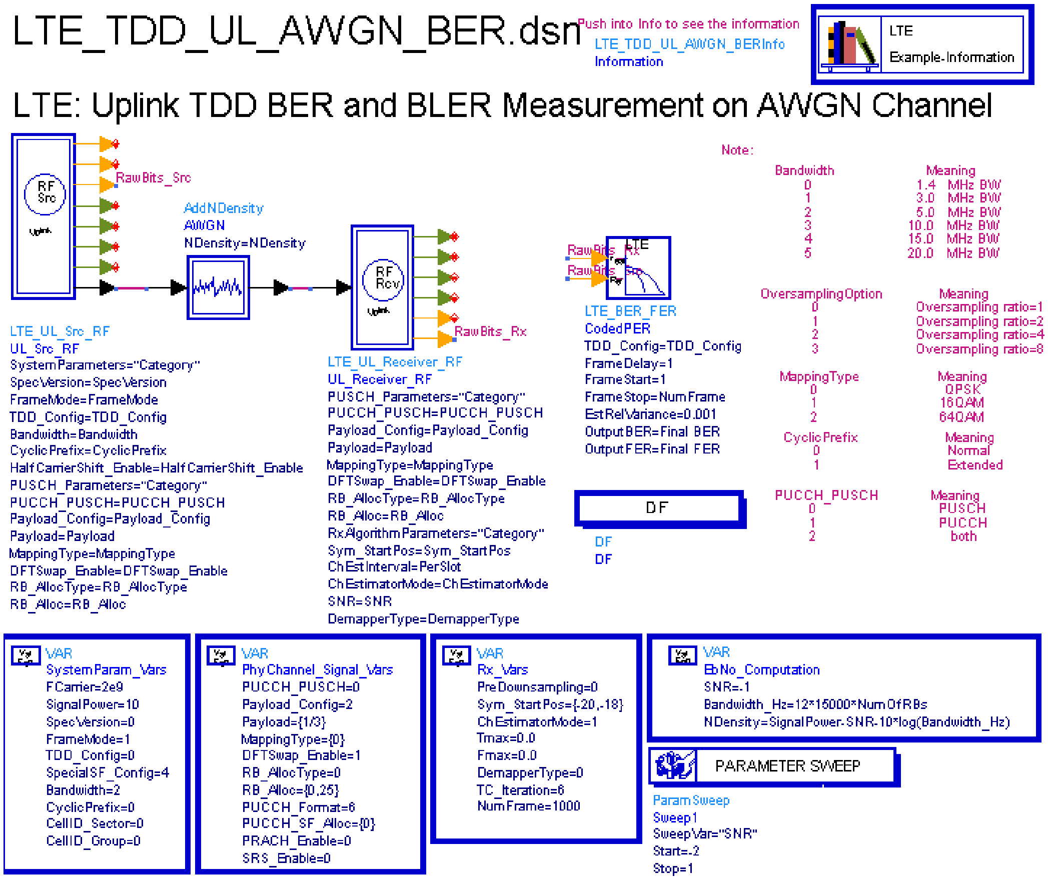
LTE_TDD_UL_AWGN_BER Design

Features

- coded BER/BLER measurement under AWGN
- Multiple SNR measurement points

Description

LTE_TDD_UL_AWGN_BER performs uplink BER measurements with channel coding/decoding under AWGN. The schematic is shown in the following figure.



LTE_TDD_UL_AWGN_BER Schematic

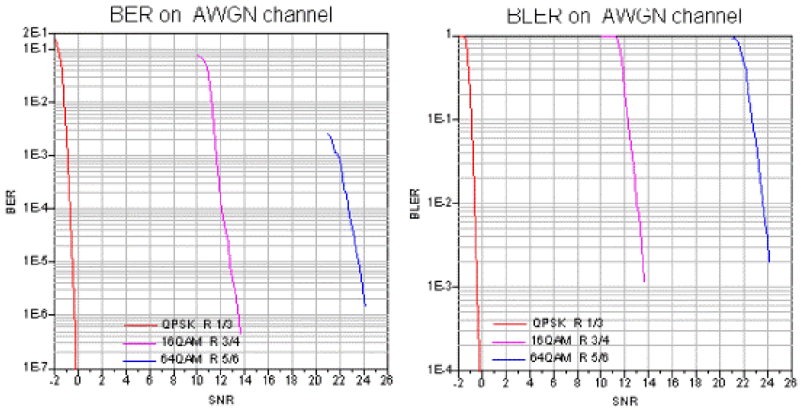
There is only one antenna in the receiver in this example, and no HARQ retransmission is employed.
Users can change the parameter configurations to simulate different system configurations. For example, users can select TDD_Config from Config 0 to Config 6 to simulate different uplink-downlink configurations.

Simulation Results

In this example, the performance of PUSCH under AWGN for different modulation schemes is given. The following table shows the simulation conditions.

Parameter	Value
FCarrier	2000 MHz
TDD_Config	Config 0
Bandwidth	5 MHz
Cyclic Prefix	Normal
PUCCH_PUSCH	PUSCH
RB_AllocType	StartRB + NumRBs
RB_Alloc	{0, 25}
ChEstimatorMode	MMSE
Tmax	0.0
DemapperType	Soft
Number of Measured Frames	1000

The following figure shows the simulation results. The curves have been generated averaging over 1000 frames under AWGN channel. It should be noted that ideal timing and frequency synchronization are used to get the following results. The code rates for QPSK, 16QAM, 64QAM are 1/3, 3/4, 5/6 corresponding to FRC A3-4, FRC A4-5 and FRC A5-4 defined in Annex A of 3GPP TS 36.104 V8.3.0, respectively.



TDD Uplink AWGN BER/BLER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2008
- Simulation Time: about 5 hours for QPSK

TDD Downlink SIMO 1x2 BER and BLER on Fading Channel

LTE_TDD_DL_1x2_Fading_BER Design

Features

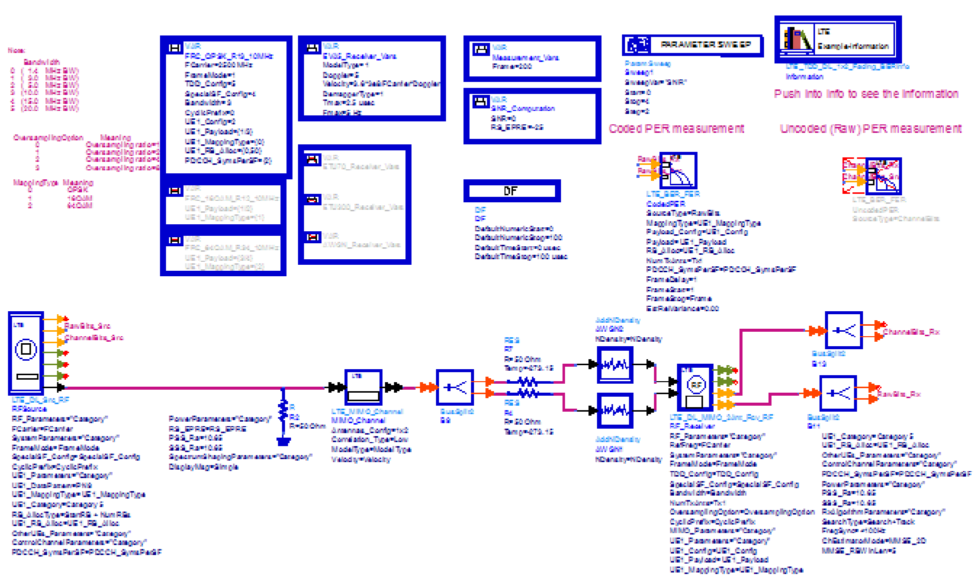
- Pre-defined reference channels following TS 36.101 for DL TDD
- MRC (Maximal Ratio Combining) receiver diversity with one transmitter antennas and 2 receiver antennas
- Fading channels following the definition in Annex B of TS 36.101
- Uncoded and coded BER/BLER measurements
- Multiple SNR measurement points

Description

LTE_TDD_DL_1x2_Fading_BER performs TDD downlink SIMO 1x2 BER/BLER measurements on fading channels. The schematic is shown in the following figure.

LTE_DL_TDD_1x2_Fading_BER.dsn

LTE: TDD Downlink SIMO 1x2 BER and PER Measurements on Fading Channel



LTE_TDD_DL_1x2_Fading_BER Schematic

The signal source follows the definition of reference channel in A.3 of TS 36.101 with the exception that no HARQ transmissions are employed. Three are pre-configured in this example:

Signal Source Configurations
Reference channel [R.2 TDD] (10 MHz QPSK 1/3)
Reference channel [R.3 TDD] (10 MHz 16QAM 1/2)
Reference channel [R.7 TDD] (10 MHz 64QAM 3/4)

The fading channel follows the definition in Annex B of TS 36.101. Four settings are pre-configured in this example:

Fading Channel	Doppler
EVA	5 Hz
ETU	70 Hz
ETU	300 Hz
AWGN	0 Hz

Antenna configuration and correlation matrix support:

Antenna Configuration	Correlation Matrix
1x2	Low
1x2	Medium
1x2	High

Users may start from this example to create designs with other antenna configurations by replacing the RF source and the RF receiver with corresponding source and receiver, such as 4x4, 4x1, 1x4 or 2x4.

In this example, the uncoded (raw) BLER measurement is also provided. To measure it, activate the component UncodedPER.

The default channel estimator is the 2D MMSE with MMSE_RBWinLen = 5. The channel characters (Tmax, Fmax and SNR) needed by the channel estimator are set in *EVA5_Receiver_Vars*, *ETU70_Receiver_Vars*, *ETU300_Receiver_Vars* and *AWGN_Receiver_Vars* for EVA5, ETU70, ETU300 and AWGN respectively.

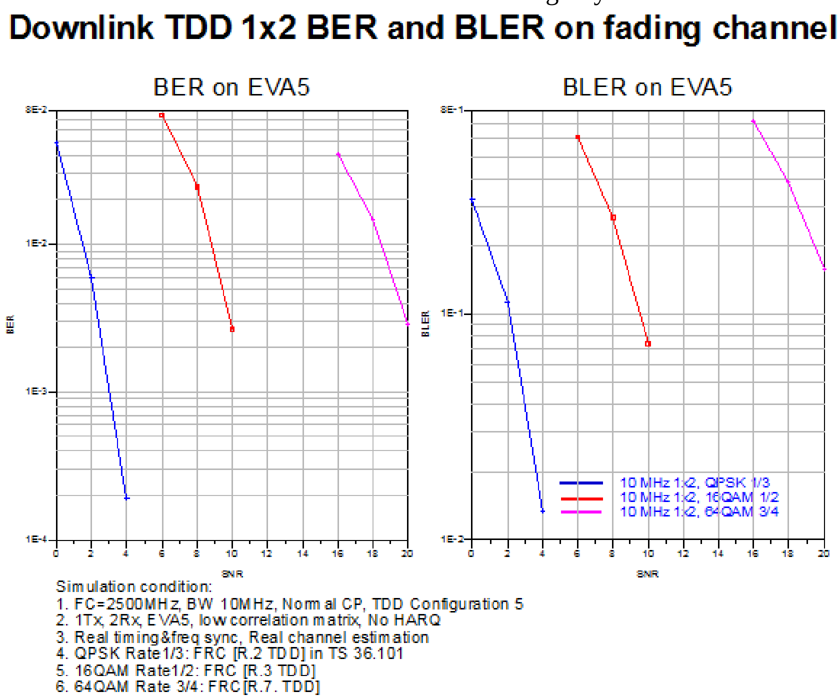
The number of frames for simulating BER/BLER is defined in *Measurement_Vars*;

Simulation Results

In this example, the performances of downlink PDSCH 1 (UE 1) on fading channel with channel coding are given. The following table shows the simulation conditions.

Parameter	Value
FCarrier	2500 MHz
Frame Mode	TDD Configuration 5
Bandwidth	10 MHz
Oversampling Option	Ratio 2
Cyclic Prefix	Normal
Antenna Configuration	1x2
Correlation Matrix	Low
MIMO Mode	Receiver diversity with two receiver antennas
Fading Channel	EVA 5Hz
Reference Channels	QPSK R1/3, 16QAM R1/2, 64QAM R3/4

The curves have been generated averaging over 200 frames. The following figure shows the simulation results.



TDD Downlink SIMO 1x2 BER/BLER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: about 2 hours

TDD Downlink MIMO 4x2 BER and BLER on Fading Channel

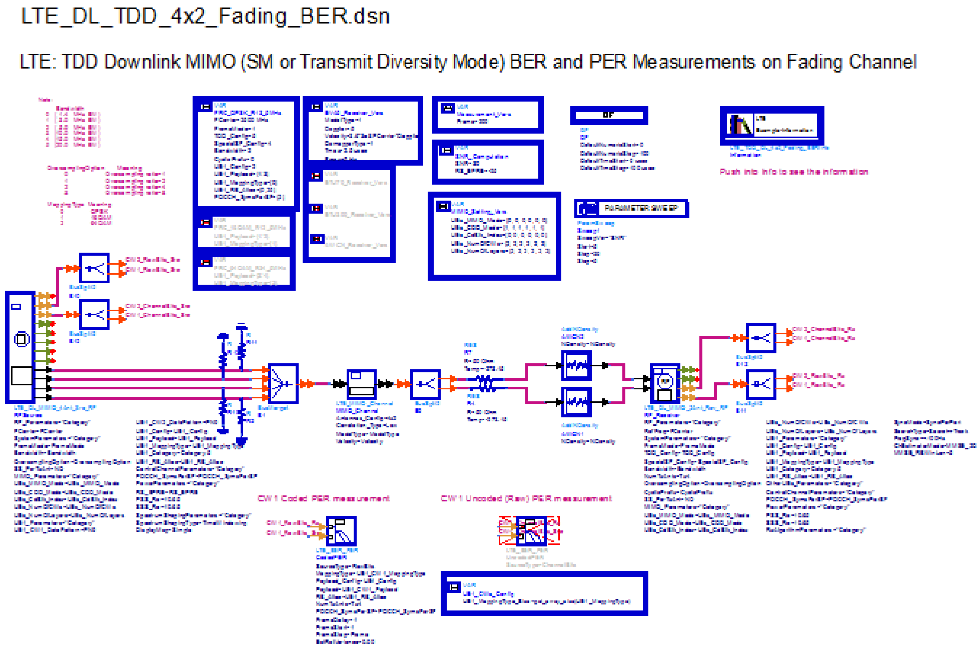
LTE_TDD_DL_4x2_Fading_BER Design

Features

- Pre-defined reference channels following TS 36.101 for DL TDD
- Transmit diversity and Open-loop spatial multiplexing transmission modes with 4 transmitter antennas and 2 receiver antennas
- Fading channels following the definition in Annex B of TS 36.101
- Uncoded and coded BER/BLER measurements
- Multiple SNR measurement points

Description

LTE_TDD_DL_4x2_Fading_BER performs TDD downlink MIMO 4x2 BER/BLER measurements on fading channels. The schematic is shown in the following figure.



LTE_TDD_DL_4x2_Fading_BER Schematic

The signal source follows the definition of reference channel in A.3 of TS 36.101 with the exception that 1. No HARQ transmissions are employed; 2. BW 5 MHz is employed. Three are pre-configured in this example:

Signal Source Configurations
Reference channel [R.13 FDD] (5 MHz QPSK 1/3)
Reference channel [R.14 FDD] (5 MHz 16QAM 1/2)
5 MHz 64QAM 3/4

The transmission mode for UE 1 is set by the parameter UEs_MIMO_Mode[1] in *MIMO_Setting_Vars*. Open-loop spatial multiplexing is selected when UEs_MIMO_Mode[1] = 0; otherwise Transmit diversity with 4 transmitter antennas is selected.

The fading channel follows the definition in Annex B of TS 36.101. Four channel settings are pre-configured in this example:

Fading Channel	Doppler
EVA	5 Hz
ETU	70 Hz
ETU	300 Hz
AWGN	0 Hz

Antenna configuration and correlation matrix support:

Antenna Configuration	Correlation Matrix
4x2	Low
4x2	Medium
4x2	High

Users may start from this example to create designs with other antenna configurations by replacing the RF source and the RF receiver with corresponding source and receiver, such as 4x4, 4x1, 1x4 or 2x4.

In this example, the uncoded (raw) BLER measurement is also provided. To measure it, activate the component UncodedPER.

The default channel estimator is the 2D MMSE with MMSE_RBWinLen = 5. The channel characters (Tmax, Fmax and SNR) needed by the channel estimator are set in *EVA5_Receiver_Vars*, *ETU70_Receiver_Vars*, *ETU300_Receiver_Vars* and *AWGN_Receiver_Vars* for EVA5, ETU70, ETU300 and AWGN respectively.

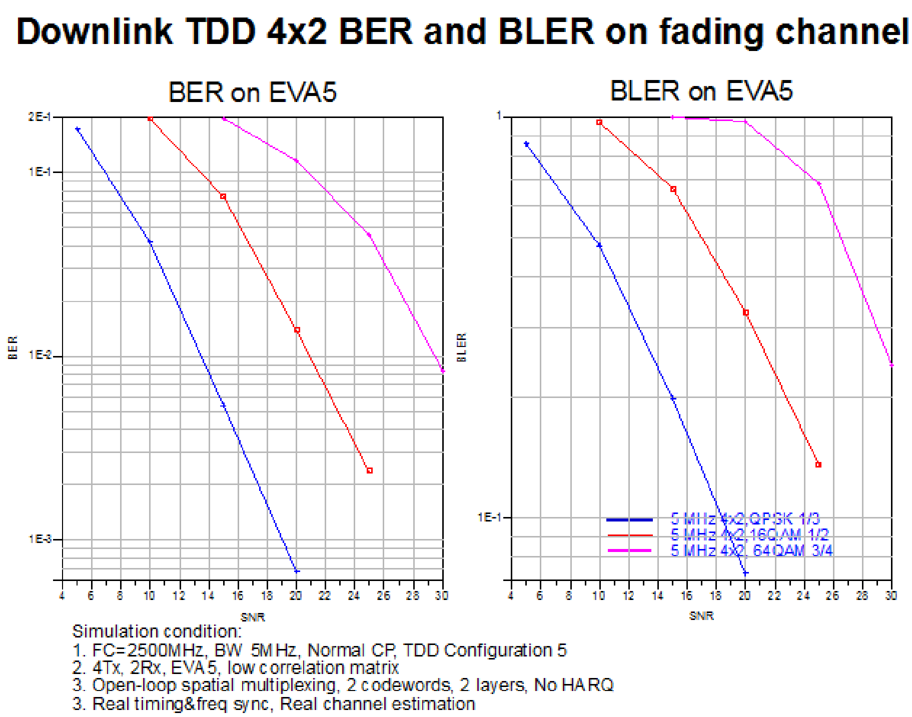
The number of frames for simulating BER/BLER is defined in *Measurement_Vars*;

Simulation Results

In this example, the performances of downlink PDSCH 1 (UE 1) on fading channel with channel coding are given. The following table shows the simulation conditions.

Parameter	**Value**
FCarrier	2500 MHz
FrameMode	TDD Configuration 5
Bandwidth	10 MHz
Oversampling Option	Ratio 2
Cyclic Prefix	Normal
Antenna Configuration	4x2
Correlation Matrix	Low
MIMO Mode	Open-loop spatial multiplexing with 2 code words and 2 layers
Fading Channel	EVA 5Hz
Reference Channels	QPSK R1/3, 16QAM R1/2, 64QAM R3/4

The curves have been generated averaging over 200 frames. The following figure shows the simulation results.



TDD Downlink MIMO 4x2 BER/BLER Simulation Curve

Benchmark

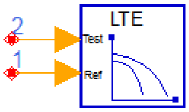
- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2011
- Simulation Time: about 4 hours

3GPP LTE Measurement Components

The 3GPP LTE measurement models provide basic measurements such as EVM and CCDF.

Contents

LTE_BER_FER (Bit Error Rate and Frame Error Rate Estimation)



Description: Bit Error Rate and Frame Error Rate estimation in LTE library
Library: LTE, Measurement

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
SourceType	The source is including channel coding or not: RawBits, ChannelBits	RawBits	enum	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
Plot	Plot data when set to 'Rectangular' and Simulation Setup set to 'Open Data Display when simulation completes':	None	enum	

	None, Rectangular			
FrameDelay	Delay frame numbers for ref input pin	1	int	[0,∞)
FrameStart	Data collection start frame index	1	int	[0,∞)
FrameStop	Data collection stop frame index when EstRelVariance is not met	10	int	[FrameStart,∞)
ControlSimulation	Let sink control how long the simulation will run?: NO, YES	YES	enum	
EstRelVariance	BER estimation relative variance	0.01	real	[0,1)
OutputBER	BER output: BER vs index, BER vs index every 10 bits, BER vs index every 100 bits, BER vs index every 1000 bits, BER vs index every BitsPerFrame bits, Final BER	Final BER	enum	
OutputFER	FER output: FER vs frame, FER vs frame every 10 frames, Final FER, No FER	Final FER	enum	
StatusUpdatePeriod	Status update period in number of bits	1000	int	[1,∞)
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	ref	reference bit stream	int
2	test	test bit stream	int

Notes/Equations

1. This model can be used to measure the bit error rate (BER) and frame error rate (FER) of the input data streams for both LTE downlink and uplink. FER is sometimes referred to as PER (packet error rate) or BLER (block error rate). Here FER actually stands for subframe error rate. A subframe is considered to be in error if at least one of the bits in the subframe is detected incorrectly.
2. If LinkDir is Downlink, only subframes which contain PDSCH are processed, while if LinkDir is Uplink, only subframes which contain PUSCH are processed.
3. Both raw BER/FER and coded BER/FER can be reported. Number of bits in each subframe is calculated from LTE system parameters.
   - If SourceType is RawBits, the input data streams to ref and test are taken as information bit streams before encoding and decoded bit streams respectively, number of bits in each subframe equals the transport block size in each subframe.
   - If SourceType is ChannelBits, the input data streams to ref and test are taken as channel bit streams after encoding and undecoded bit streams after demapping, number of bits in each subframe equals the number of channel bits in each subframe.
4. The input signals to the reference (ref) and test (test) inputs must be bit streams. The bit streams to the reference (ref) inputs will be delayed FrameDelay frames before being compared with test (test) inputs.
5. The FrameStart parameter defines when data processing starts. The end of data processing depends on the settings of the parameters ControlSimulation, FrameStop, and EstRelVariance:
   - If ControlSimulation is NO, then FrameStop and EstRelVariance are ignored. Data processing ends when the simulation ends. In this case, the end of the simulation is determined by other sink or source components that control the simulation.

- If ControlSimulation is YES and EstRelVariance is 0.0, then data processing ends when FrameStop is reached.
- If ControlSimulation is YES and EstRelVariance is greater than 0.0, then data processing ends when EstRelvariance is met or when FrameStop is reached. In this case, FrameStop acts as an upper bound on how long the simulation runs just in case the simulation takes too long for EstRelVariance to be met. In this mode of operation, messages are printed in the simulation status window showing the value of estimation relative variance as the simulation progresses. The EstRelVariance parameter can be used to control the quality of the BER estimate LTE_BER_FER generates. The lower the value of EstRelVariance the more accurate the estimate is.
  For more details, refer to *PE Measurement Concepts* (sinks). Note that the equation for the estimation relative variance described above assumes that the errors happen randomly (as in the case of an AWGN channel) and not in bursts (as in the case of a fading channel).

6. If the bit errors are independent identically distributed events then BER and FER are related through the equation FER = 1 − (1 − BER)$^{\text{BitsPerSubFrame}}$.
   To estimate BER/FER over an exact number of frames set ControlSimulation to YES, EstRelVariance to 0.0, and FrameStop to FrameStart + N − 1, where FrameStart is the value of the FrameStart parameter and N is the number of frames to be simulated.
7. The OutputBER parameter determines how often BER values are written in the dataset.
   - Final BER - writes the final BER value.
   - BER vs index - writes BER values as a function of index. You can see how BER changes throughout the simulation.
   - BER vs index every 10 bits, BER vs index every 100 bits, BER vs index every 1000 bits, and BER vs index every BitsPerFrame bits - behave similar to BER vs index but BER values are written every 10, 100, 1000, and BitsPerFrame bits, respectively. You can see how BER changes throughout the simulation while keeping the dataset at a reasonable size.
8. The OutputFER parameter determines how often FER values are written in the dataset.
   - No FER - does not write any FER values.
   - Final FER - writes the final FER value.
   - FER vs frame - writes FER values as a function of frame. You can see how FER changes throughout the simulation.
   - FER vs frame every 10 frames - behaves similar to FER vs frame but FER values are written every 10 frames. You can see how FER changes throughout the simulation while keeping the dataset at a reasonable size.
9. The StatusUpdatePeriod parameter can be used to control how often estimation relative variance status messages are reported to the simulation status window.
10. Lengthy BER simulation times can be shortened significantly by using the *Parallel BER* option in the *Simulate* > *Simulation Setup* window > *Parallel* tab (To use this option, your computer must have LSF client installed and it must be connected to an LSF cluster.) In the *Parallel* tab *Simulation Mode*, choose *Parallel Hosts* to activate the *Parallel BER* field.
    For more information, see the description of the *Parallel BER option* (sinks) in the *berMC* component documentation.

Parameter Details

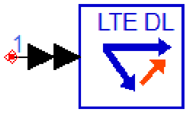
- LinkDir: link direction, it can be selected as Downlink and Uplink, indicating the measurement is for LTE downlink and uplink respectively.
- SourceType: type of the input data streams, it can be selected as RawBits and ChannelBits, indicating coded BER/FER and uncoded (raw) BER/FER are measured respectively.
- If LinkDir is Downlink, for more information on parameters FrameMode, TDD_Config, SpecialSF_Config, Bandwidth, CyclicPrefix, MappingType, Payload_Config, Payload, RB_AllocType, RB_Alloc, NumTxAnts, NumOfLayers and PDCCH_SymsPerSF, please refer to *LTE_DL_Src* (3gpplte).
- If LinkDir is Uplink, for more information on parameters FrameMode, TDD_Config, SpecialSF_Config, Bandwidth, CyclicPrefix, MappingType, Payload_Config, Payload, RB_AllocType, RB_Alloc, PUCCH_PUSCH, SRS_Enable and SRS_SF_Config, please refer to *LTE_UL_Src* (3gpplte).
- Plot: plot data when set to 'Rectangular' and Simulation Setup set to 'Open Data Display when simulation completes'.
- FrameDelay: the input data streams to ref will be delayed FrameDelay frames.
- FrameStart: data collection start frame index.

- FrameStop: data collection stop frame index when EstRelVariance is not met.
- ControlSimulation: Let sink control how long the simulation will run?
- EstRelVariance: BER estimation relative variance, it must be in range [0.0,1.0].
- OutputBER: determines how often BER values are written in the dataset, it can be selected as BER vs index, BER vs index every 10 bits, BER vs index every 100 bits, BER vs index every 1000 bits, BER vs index every BitsPerFrame bits and Final BER.
- OutputFER: determines how often FER values are written in the dataset, it can be selected as FER vs frame, FER vs frame every 10 frames, Final FER and No FER.
- StatusUpdatePeriod: status update period in number of bits.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_EVM (Downlink EVM Measurement with RF De-modulator)



Description: Downlink EVM measurement
Library: LTE, Measurement

Parameters

Name	Description	Default	Unit	Type	Range
RLoad	load resistance. DefaultRLoad will inherit from the DF controller.	DefaultRLoad	Ohm	real	(0,∞)
FCarrier	carrier frequency	2500 MHz	Hz	real	(0,∞)
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1		enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO		enum	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CDD_Mode	CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{1, 1, 1, 1, 1, 1}		int array	[1,2]
UEs_NumOfLayers	number of layers for each UE	{1, 1, 1, 1, 1, 1}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of	{0, 25}		int array	

	RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]				
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6		enum	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
ShowRxAlgorithmParameters	show parameters for LTE downlink EVM measurement algorithm: NO, YES	YES		enum	
SyncType	Initial synchronization type: P_SS, RS	P_SS		enum	
PDSCHIncludeInAnalysis	whether or not PDSCH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	

P_SSIncludeInAnalysis	whether or not P_SS is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
S_SSIncludeInAnalysis	whether or not S_SS is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
PBCHIncludeInAnalysis	whether or not PBCH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
PHICHIncludeInAnalysis	whether or not PHICH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
PCFICHIncludeInAnalysis	whether or not PCFICH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
PDCCHIncludeInAnalysis	whether or not PDCCH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
RSIncludeInAnalysis	whether or not RS is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
CellIDDetectMode	Cell ID detect mode: CellIDAuto, CellIDManual	CellIDAuto		enum	
Ref_TxAnt	determines the Tx antenna port and works with Ref_InputChannel to determine which Tx/Rx path to use for initial equalization: Autodetect, Port0, Port1, Port2, Port3	Autodetect		enum	
Ref_InputChannel	determines the Rx antenna port and works with Ref_TxAnt to determine which Tx/Rx path to use for initial equalization: Rx0, Rx1, Rx2, Rx3	Rx0		enum	
AntDetThresh	specify threshold level of RS power level in dB relative to that of a reference antenna port for automatic detection of active antenna	-36		int	[-100,100]
IncludeInactiveAntennaPaths	means only Tx/Rx antenna paths that have an average RS power above the threshold will be displayed on the MIMO traces: NO, YES	NO		enum	
MIMODecoding	specifies the MIMO decoding: NoDecoding, Decoding	Decoding		enum	
RBAutoDetect	defines the RB allocation and modulation format detection mode: RBDetManual, RBDetAuto	RBDetAuto		enum	
ResLenInSlots	Result length in slots. Specifically, this is the number of slots to be analyzed and demodulated	20		int	[1,100]
MeasOffset	specifies measurement offset in symbols, from which EVM is computed.	0		int	[0,ResLenInSlots*NumSymsPerSlot)
MeasInterval	specifies measurement interval in symbols used for EVM computation, starting from the slot and symbol offset specified by MeasOffset	140		int	[1,ResLenInSlots*NumSymsPerSlot - MeasOffset)
AnalysisBoundary	analysis start boundary: ANALYSIS_BOUNDARY_FRAME, ANALYSIS_BOUNDARY_HALFFRAME, ANALYSIS_BOUNDARY_SUBFRAME	ANALYSIS_BOUNDARY_FRAME		enum	

CPLengthAutoDetect	specifies Cyclic Prefix length auto detect or not: NO, YES	NO		enum	
MirrorFreqSpectrum	whether or not the entire frequency spectrum be flipped around the carrier frequency: NO, YES	NO		enum	
EqualizerTraining	specify how equalizer is trained: EqTraingOff, RS_Training	RS_Training		enum	
EqualizerTrainingMovingAvgLength	specify window length of the equalizer moving average for subcarrier smoothing.	19		int	[1,399]
EVMMinimization	specifies the amplitude err, timing err and frequency and phase err tracking and compensation mode: Off, Tracking	Tracking		enum	
EVMMinimizationAmp	whether or not tracking the amplitude err: NO, YES	NO		enum	
EVMMinimizationTiming	whether or not tracking the timing err: NO, YES	NO		enum	
EVMMinimizationFreqPhase	whether or not tracking the freq and phase err: NO, YES	NO		enum	
SymTimeAdjMode	symbol timing adjust mode: MAX_EVMWIN_START_END, MIN_EVMWIN_START_END, EVMWIN_START, EVMWIN_START_End, EVMWIN_Center, PERCENT_FFT_SIZE	MAX_EVMWIN_START_END		enum	
SymTimeAdj	specify how much data in cyclic prefix portion, backing up from the exact symbol timing are included for FFT computation in percentage of FFT length. This value must be zero or a negative value, down to a whole cyclic prefix length -7.125 to 0% (Normal CP length), -25% to 0% (Extended CP length)	-3.125		real	[-25,0]
ReportEVMIndB	specifies the EVM units in dB or not: NO, YES	NO		enum	
PowerBoostNormalize	whether or not the constellation be normalized: NO, YES	YES		enum	
SaveConstellation	if set YES, the measured vector used for EVM calculation shall be saved to Data File: NO, YES	NO		enum	
FramesToMeas	number of frames that will be measured	10		int	[1,100]
DisplayFrame	the Frame number for display some vector measurement results	0		int	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	multiple timed

Parameters Details

- For System Parameters details please refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.
- For UE1 Parameters details details refer to *DL UE1 Parameters* (3gpplte).
- For OtherUEs Parameters details please refer to *DL OtherUEs Parameters* (3gpplte).
- For Control Channel Parameters details please refer to *DL Control Channel Parameters* (3gpplte).
- For MIMO Parameters details please refer to *DL MIMO Parameters* (3gpplte).
- For Power Parameters details please refer to *DL Power Parameters* (3gpplte).

> For more information on parameters details, please refer to *LTE_DL_Src* (3gpplte).

Rx Algorithm Parameters:

- SyncType: Sets the channel or signal to be used for synchronization. The LTE demodulator can be set to use either the Primary Sync Signal (P_SS) or the reference signal (RS) to synchronize the downlink signal.
  This synchronization is performed at the frame level. For smaller scale adjustments (such as at the symbol or slot level), see the EVM Minimization parameter.
  P-SS is normally used for downlink synchronization. However, when P-SS is impaired in some way (for example, P-SS has a different CellID than RS), RS can be used for

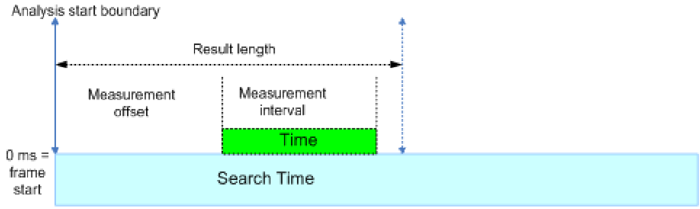
synchronization so that the signal can be demodulated. S-SS must be present in the time capture for demodulation to occur, since finding S-SS is the only way to distinguish between the beginning and the middle of a frame.
When Sync Type is set to RS the measurement result SyncCorr shows which Tx antenna port's reference signal was used for synchronization to the right of the correlation value. The Error Summary data result SyncCorr shows which Tx antenna port's reference signal was used for synchronization to the right of the correlation value. The reference Tx antenna port must be specified, since the demodulator does not automatically search the reference input channel for all Tx antenna ports when Sync Type is set to RS. Autodetection of CellID is not supported.

- These parameters listed below are used to set whether these channels or signals are included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum.
  PDSCHIncludeInAnalysis, P_SSIncludeInAnalysis, S_SSIncludeInAnalysis, PBCHIncludeInAnalysis, PHICHIncludeInAnalysis, PCFICHIncludeInAnalysis, PDCCHIncludeInAnalysis and RSIncludeInAnalysis.
- CellIDDetectMode: Sets Cell ID detect mode. When SyncType is set to RS, the Auto detect is not supported and CellIDDetectMode must be specified manually. This is because the demodulator needs to know the values of the RS sequence to use for synchronization and because Cell ID determines these values.
- Ref_TxAnt and Ref_InputChannel: These two parameters determine which Tx/Rx path to use for initial equalization and to show on certain non-MIMO traces (OFDMRBErrorMagSpectrum, OFDMRBPowerSpectrum, OFDMErrVectSpectrum and OFDMFrequencyError). The Ref_TxAnt determines the Tx antenna port and the Ref_InputChannel parameter determines the Rx antenna port of the reference path.
  When Ref_TxAnt is set to Autodetect, the Tx antenna signal path with the strongest reference signal on the reference Rx antenna port (determined by Ref_InputChannel) is used.
  When Ref_TxAnt is selected and set to Port(x), Tx antenna port(x) is used as the reference Tx antenna port. The reference Rx antenna port is determined by Ref_InputChannel.
  The RS power of the current Tx/Rx path is used to set the reference level for the other Tx/Rx RS power levels. For example, when Tx port 0 and Rx port 0 (Input Channel 1) are selected, the Tx0/Rx0 section of the MIMO Info Talbe will show 0 dB for RSPwr and the other Tx/Rx paths' RSPwr will be expressed in dB relative to this 0 dB point.
  In the absence of cross-channel paths (when connecting directly to the Tx antenna ports), make sure that the Tx/Rx path selected is present; otherwise, the signal will not be demodulated. This is not a problem when SyncType is set to P-SS and the Ref_TxAnt set to Autodetect since the demodulator will automatically detect the strongest Tx/Rx path to use for the reference path. However, when Sync Type is set to RS, reference path autodetection is not supported and the reference Tx/Rx antenna path must be specified manually using Ref_TxAnt and Ref_InputChannel. When the reference signal (RS) for the reference Tx-to-Rx path is not present in the signal, demodulation will fail.
  P-SS and S-SS must be present in the time capture of one of the channels connected to the analyzer for successful demodulation to occur. For example, in a two-channel transmit diversity signal that has P-SS and S-SS transmitted only on Tx port 1,the demodulator could analyze Tx port 1 without Tx port 0 connected, but not vice versa.
- AntDetThresh: sets the threshold for transmit antenna port signal detection. The signal from a Tx antenna port has to be above the Antenna Detection Threshold to be detected by the demodulator. The threshold is relative to the average RS subcarrier power level of the reference antenna path, which is determined by the parameters Ref_TxAnt and Ref_InputChannel.
- IncludeInactiveAntennaPaths: is used to show information for all Tx/Rx antenna paths on the MIMO Info results. If IncludeInactiveAntennaPaths = NO, only Tx/Rx antenna paths that that have an average RS power above the antenna detection threshold will be shown.
- MIMODecoding: determines how much of the transmit chain is decoded by the demodulator. The selection of this parameter directly affects what values are shown on the IQ Measurement data and all other Measurement data that depend on the IQ Measurement data (error vector traces). MIMO Decoding applies to multi-antenna signals only.
  When MIMO Decoding is selected, the data points shown on the IQ Measurement data are equivalent to the data points before precoding was applied in the transmit chain. In other words, the demodulated signal will be decoded and then shown on IQ Measurement data. Although the data points are mapped onto "subcarriers" when being shown on the layer traces, the data points do not have a one-to-one correspondence to the subcarrier that they are mapped onto. For instance, when

there is a frequency null that affects a subcarrier, there will be several (depending on the precoding) data points in IQ Measurement data that are affected. Another way of looking at this is that each subcarrier contains information from multiple data points after precoding is performed (this does not apply to RS, P-SS, and S-SS which do not undergo precoding).
For channels that undergo transmit diversity, the demodulator will undo transmit diversity precoding, undo codeword-to-layer mapping, and show the resulting codeword data points in their respective resource elements, copied on all layer traces. That is, constellation points on layer traces for transmit diversity-precoded channels will be the same for all layer traces.
When a signal uses Tx Diversity, the amount of data transmitted is not increased, but the reliability of the signal is increased by transmitting multiple copies of the data.
For channels that undergo spatial multiplexing, the demodulator will only undo Spatial Multiplexing precoding and show the layer data points in their respective resource elements on the appropriate layer traces.
For precoded channels, subcarrier points on the layer traces do not have a one-to-one correspondence to on-air subcarriers. Rather, each subcarrier point is actually the demodulated value of a codeword data point that was present prior to the codeword-to-layer mapping at the transmitter.
RS subcarriers from the reference Tx/Rx path are copied to all layer traces. P-SS and S-SS subcarriers from the P-SS/S-SS Antenna Port are also copied to all layer traces.
When No Decoding is selected, no decoding or cross-channel equalization will be performed on the measured IQ data. This means that, for LTE signals that have been precoded (multi-antenna signals), subcarrier points shown on measured IQ trace will actually be an addition of multiple modulation points, resulting in non-standard constellations.
For example, in a two antenna port signal, there will be subcarrier points that are an addition of two QPSK points. The resulting diagram will be a 9QAM constellation. These are effectively the points that were transmitted on the OFDM subcarriers.
Reference antenna path equalization will still be performed when Equalizer Training is enabled (set to RS or RS+Data). Only one input channel is analyzed. The signal from the reference input antenna port will be equalized using the reference antenna path RS. The points on layer traces will correspond to actual subcarriers, and each set of layer traces will be identical.
The No Decoding selection is useful for the case that you have four antenna signals, and you want to isolate channel effects from transmit chain effects (filters, mixers, etc.). You could connect each transmit port directly to your measurement instrument with identical cables. That way, any observed anomalies would come primarily from the RF transmit chain.

- RBAutoDetect: enables autodetection of user allocations .
When RB Auto Detect is selected, the demodulator will autodetect PDSCH user allocations. The codeword powers (needed for EVM calculations) and Precoding type are not autodetected and need to be specified. And these parameters are assumed to apply to all autodetected PDSCH channels. When RB Auto Detect is selected, the demodulator groups resource blocks that contain the same modulation type into a user so that there are three possible users: QPSK, QAM16, and QAM64. RB Autodetection can detect allocations which use either Spatial Multiplexing (SpMux) or Transmit Diversity (TxDiv) precoding, but not both. The Precoding parameter determines which type of precoding the demodulator looks for.
When RBAutoDetect is set to Manual, all user’s allocation is set by the system parameters and the RB allocation corresponding parameters.
- ResLenInSlots: determines how many slots will be available for demodulation. Measurement Interval and Measurement Offset specify which part of the time capture is demodulated.
- MeasOffset: specifies the offset from the Analysis Start Boundary to the beginning of the Measurement Interval (the data sent to the demodulator). Measurement Offset is specified in slots plus symbol-times.
*MeasInterval: determines how much data is sent to the demodulator and can be specified in slots plus symbol-times. The beginning of the measurement interval is specified as an offset from the Analysis Start Boundary. The offset is specified by the Measurement Offset parameter.
- AnalysisBoundary: specifies the alignment boundary of the Result Length time data. To ensure that this alignment can be achieved, the total amount of data acquired by the analyzer is equal to the Result Length plus the length of the alignment boundary specified by Analysis Start Boundary. For example, when Analysis Start Boundary is set to Half-Frame, the total acquisition is equal to Result Length + 10 slots (and the data available for analysis would start at a Half-Frame boundary). Once the Result Length data is located within the time capture, Measurement Offset and Measurement Interval determine what part of the Result Length data is to be

analyzed. The Measurement Interval data is shown on the Time trace. See image below for more information.



- CPLengthAutoDetect: indicates the CP length (Normal or Extended) that was autodetected or specified by the CyclicPrefix parameter. When the CP length is autodetected, the text "(auto)" will be displayed to the right of the value.
- MirrorFreqSpectrum: whether or not the entire frequency spectrum will be flipped around the carrier frequency.
- EqualizerTraining: tells the demodulator whether or not to equalize the signal (compensate for the measured channel frequency response). When Off is selected, no equalization will be applied to the signal. When RS is selected, equalization will be performed using the frequency response calculated from the reference signal for the reference antenna path. The channel frequency response for subcarriers between reference signals will be linearly interpolated.
- EqualizerTrainingMovingAvgLength: specifies window length of the equalizer moving average (frequency smoothing) on the reference signals during equalization, as well as the number of RS subcarriers to use in each average. When EqualizerTraining is set to RS, a value of 5 RS means the value of an RS subcarrier is calculated as the average of the value of that subcarrier and the values of the next two and previous two RS subcarriers in frequency. For RS subcarrier locations that do not have enough RS subcarriers to one side or the other (those near the edge of the frequency spectrum), the average is taken over available reference signal subcarriers.
- EVMMinimization: whether or not uses the reference signal to correct the signal. When Tracking is selected, the demodulator applies corrections on a symbol-by-symbol basis and the Equalizer Training parameter determines whether data subcarriers are included in calculating corrections. When Equalizer Training is set to RS+Data, EVM Minimization Tracking is performed using the reference signal and the PDSCH data subcarriers. When Equalizer Training is set to RS or Off, EVM Minimization Tracking is performed using only the reference signal.When Off is selected, EVM minimization corrections are not applied to the signal.
  There are four types of corrections that can be applied to the signal to minimize the EVM. They are Amplitude, Frequency/Phase and Timing which are set by these 3 parameters as follows.
- EVMMinimizationAmp: When selected, the average reference signal amplitude error will be used to correct the amplitudes of the subcarriers
- EVMMinimizationTiming: When selected, the average slope (average rate of change) of the RS phase in the frequency domain is used to correct the timing
- EVMMinimizationFreqPhase: When selected, the average reference signal phase difference will be used to adjust subcarrier phase
- SymTimeAdjMode and SymTimeAdj: determines where the FFT used for EVM and demodulation results is located within the symbol + cyclic prefix time data.
- ReportEVMIndB: specifies the EVM units for all result data.
- PowerBoostNormalize: When Power Boost Normalize is selected, whether or not the constellation be normalized.
- SaveConstellation: if set YES, the measured vector used for EVM calculation shall be saved to Data File
- FramesToMeas: number of measured frames.
- DisplayFrame: the Frame number for display some vector measurement results.

Notes/Equations

1. This component performs an EVM measurement for a LTE downlink signal (including single transmit antenna and multiple transmit antennas). The input signal must be a complex signal. The available results from this measurement are:
   - Error summary
     These measurement results contain information about the quality of the signal being analyzed (in the Measurement Interval). Measurement Interval determines how much data is sent to the demodulator and can be specified in symbol-times by parameter MeasInterval. The beginning of the measurement interval is specified as an offset from the AnalysisBoundary. The offset is specified by the MeasOffset parameter. Notes: this need add link.
     Below is a list of available data results.

- EVM: Overall RMS Error Vector Magnitude for all selected channels.
- EVMPk, EVMPkIdx and EVMSubcarPkIdx: The peak EVM value and location of the peak EVM.
- DataEVM: RMS Error Vector Magnitude of the user channels.
- QPSKEVM: RMS average EVM of PDSCH QPSK allocations, calculated according to the standard
- QAM16EVM: RMS average EVM of PDSCH 16QAM allocations, calculated according to the standard.
- QAM64EVM: RMS average EVM of PDSCH 64QAM allocations, calculated according to the standard.
- RSEVM: RMS Error Vector Magnitude of the reference signal.
- RSTxPower: Average (dBm) reference signal power, can be used to calculate RSTP as defined by the standard.
- OFDMSymTxPower: Average power (dBm) for OFDM data subcarriers, can be used to calculate OSTP as defined by the standard.
- FreqErr: Average carrier frequency error (unit: Hz).
- SyncCorr: Correlation between the measured P-SS signal and the reference P-SS signal.
- CommonTrackingError: Rms averaged common pilot error result (unit: %).
- SymClkErr: Frequency error of the measured signal's symbol clock (unit: ppm).
- TimeOffset: The distance from the start of the Search Time trace to the beginning of the Measurement Interval (unit:sec).
- IQOffset: IQ offset result is computed as a power ratio of dc power to total averaged power.
- IQGainImbalance: I vs Q amplifier gain imbalance (ratio of I-gain to Q-gain).
- IQQuadError: Amount of angle skew between I and Q (unit: deg).
- IQTimingSkew: Time difference between the I and Q parts of the signal (unit: sec).
  Only EVM and EVM Pk are calculated from the channels that are selected for. The other Error Summary data results are not dependent on which channels are selected for analysis. The ReportEVMIndB parameter affects the units of EVM result.

- Frame summary
  The Frame Summary trace shows the EVM, power, and number of resource blocks occupied for the channels and signals that are present in the Measurement Interval.
  EVM is the RMS value of error vector magnitudes for the channel. The ReportEVMIndB parameter affects the units of EVM result. Power is the per-subcarrier power received at the reference input channel, averaged over all the subcarriers belonging to the physical layer channel. The power values are reported in dB relative to the reference signal power. For PDSCH channels, the Power data result also shows the average power for each layer.
  NumRB shows the number of resource blocks (1 RB x 1 slot) within the Measurement Interval that contain subcarriers belonging to the channel
  - P_SSEVM: EVM result of P_SS.
  - P_SSPower: power of P_SS in dB relative to the reference signal power.
  - P_SSNumRB: number of RBs of P_SS.
  - S_SSEVM: EVM result of S_SS.
  - S_SSPower: power of S_SS in dB relative to the reference signal power.
  - S_SSNumRB: number of RBs of S_SS.
  - PBCHEVM: EVM result of PBCH.
  - PBCHPower: power of PBCH in dB relative to the reference signal power.
  - PBCHNumRB: The number of RBs of PBCH.
  - PCFICHEVM: EVM result of PCFICH.
  - PCFICHPower: power of PCFICH in dB relative to the reference signal power
  - PCFICHNumRB: number of RBs of PCFICH.
  - PHICHEVM: EVM result of PHICH.
  - PHICHPower: power of PHICH in dB relative to the reference signal power
  - PHICHNumRB: number of RBs of PHICH.
  - PDCCHEVM: EVM result of PDCCH.
  - PDCCHPower: power of PDCCH in dB relative to the reference signal power.
  - PDCCHNumRB: number of RBs of PDCCH.
  - RSEVM: EVM result of RS.
  - RSPower: power of RS in dB relative to the reference signal power
  - RSNumRB: number of RBs of RS.
  - PDSCHEVM: EVM result of PDSCH.
  - PDSCHPower: power of PDSCH in dB relative to the reference signal power

- PDSCHNumRB: number of RBs of PDSCH.
- PDSCH_UsersEVM: EVM result of PDSCH for each user.
- PDSCH_UsersPower: power of PDSCH for each user in dB relative to the reference signal power
- PDSCH_UsersNumRB: number of RBs of PDSCH for each user.
  The user mappings for downlink users (PDSCH) and the downlink control channel and signal are specified by the corresponding parameters same as the downlink signal sources.

* Vector measurement output
  If parameter SaveConstellation set to YES, the available vector measurement output for the displayed frame (specified by the parameter DisplayFrame) are listed below:
  - MeasuredVector: IQ measured vector result after FFT of all layers, and the FFT window starts from the center of CP.
  - MeasuredModFormat: Modulation format per subcarrier and symbol. Enum values used in this result are defined as follows:

0	MOD_NONE	null subcarrier
1	MOD_QPSK	QPSK modulation
2	MOD_QAM16	16QAM modulation
3	MOD_QAM64	64QAM modulation
4	MOD_BPSK	BPSK modulation
8	MOD_BPSK_CDM_45DEG	PHICH BPSK +45deg ROTATED plus CDM (code domain modulation) combination. Multiple users have the same PHICH allocation, but their data are separated by orthogonal codes.
9	MOD_DL_RS	modulation of RS
10	MOD_PSCH	modulation of PSCH, Zadoff-Chu sequence

  - MeasuredChanType: Channel type per subcarrier and symbol of layer 0. Enum values used in this result are defined as follows:

0	null subcarrier
1	PSCH
2	SSCH
3	RS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
21	unused DC
22	unused subcarriers at edges of central 72 PSCH/SSCH sync subcarriers
23	unused subcarriers reserved for Antenna Port 0 RS subcarrier transmission
24	unused subcarriers reserved for Antenna Port 1 RS subcarrier transmission
25	unused subcarriers reserved for Antenna Port 2 RS subcarrier transmission
26	unused subcarriers reserved for Antenna Port 3 RS subcarrier transmission
27	unused subcarriers within PBCH channel symbols (i.e. inactive Null subcarriers)
28	unused subcarriers within PCFICH channel symbols (i.e. inactive Null subcarriers)
29	unused subcarriers within PHICH channel symbols (i.e. inactive Null subcarriers)
30	unused subcarriers within PXCCH control channel symbols (i.e. inactive Null subcarriers)
32	unused subcarriers for partial RB in Subframe 0 (all sym) and Subframe 10 (just sync sym) when Odd #Tx RB
34	allocated for PXSCH, but disabled
35	unused reserved RS subcarriers within PBCH channel symbols (i.e. inactive Null subcarriers)
100~	PDSCH, use numbers after this for multiple data bursts, such as 100, 101, 102, …

  - OFDMRBErrorMagSpectrum: EVM result (%), rms averaged over subcarrier and symbol for each RB and Slot of each layer for the reference TxRx path which is decided by the parameters Ref_TxAnt and Ref_InputChannel. It is a 2 dimensional result of RB and slot but shown as a 1 dimensional vector in such alignment as (Slot0, RB0), (Slot0, RB1), (Slot0, RB2), …, (Slot1, RB0), (Slot1, RB1), (Slot1, RB2), …(Slot2, RB0), (Slot2, RB1), …etc. Where the number of slots is decided by MeasOffset and MeasInterval . Because average is computed slot by slot in time, odd symbols after slot boundary at the end are averaged to add an additional result at the end. Likewise, when MeasOffset in symbols is not 0, odd symbols before slot boundary at

the beginning are averaged to add an additional result at the beginning. So, when MeasOffset in symbols = 0 and MeasInterval in symbols = 0, then, the number of slots is equal to MeasInterval in slots. When MeasOffset in symbols > 0 and MeasInterval in symbols = 0, the number of slots is equal to MeasInterval in slots + 1. When MeasOffset in symbols = 0 and MeasInterval in symbols > 0, the number of slots is equal to MeasInterval in slots + 1, too.
  - OFDMRBPowerSpectrum: Normalized relative power result in linear scale, rms averaged over subcarrier and symbol for each RB and slot of each layer for the reference TxRx path which is decided by the parameters Ref_TxAnt and Ref_InputChannel. The data format is same as OFDMRBErrorMagSpectrum.
  - OFDMErrVectSpectrum: a comlex vector with length: the actual number of symbols analyzed * numOfSubcarriers. Error vector result, which is the difference between IQ measured vector result and IQ reference vector result for the reference TxRx path which is decided by the parameters Ref_TxAnt and Ref_InputChannel.
  - OFDMFrequencyError: a real vector with length: the number of measurement slot. Each element is the frequency error estimated over each slot for the reference TxRx path which is decided by the parameters Ref_TxAnt and Ref_InputChannel.
  - TxRxEqChanFreqResp: Each row vector is a normalized equalizer channel frequency response over subcarriers of each path.
  - Constellation for all channels
    The displayed constellation of each channel and each layer are listed below:
  - PDSCHConst_QPSK: Constellation of PDSCH with QPSK modulation.
  - PDSCHConst_16QAM: Constellation of PDSCH with 16QAM modulation.
  - PDSCHConst_64QAM: Constellation of PDSCH with 64QAM modulation.
  - PSSConst: Constellation of PSS.
  - SSSConst: Constellation of SSS.
  - RSConst: Constellation of RS.
  - PBCHConst: Constellation of PBCH.
  - PCFICHConst: Constellation of PCFICH.
  - PHICHConst: Constellation of PHICH.
  - PDCCHConst: Constellation of PDCCH.
- MIMO information printed in the Simulation Log
  The MIMO information about Tx/Rx antenna paths present in the signal is printed in the simulation log. This information is calculated from the reference signals. The items are listed below:
  - RSPwr(dB): Average (RMS) RS signal power. It shows the average power of the reference signal from a Tx/Rx antenna path. RSPwr is expressed in dB relative to the power of RS on the reference Tx/Rx antenna path and is calculated from the data in the Measurement Interval.
  - RSEvm(% or dB): Average (RMS) RS EVM. It shows the average error vector magnitude of the reference signal for each Tx/Rx antenna path and is calculated from the data in the Measurement Interval. The RS subcarrier EVMs are calculated and expressed relative to the average power of the signal. Then the EVMs are RMS averaged, and the result is expressed in dB or percentage depending on the Report EVM in dB parameter
  - RSTiming(second): RS timing error. It shows the average timing error of the reference signal for a Tx/Rx antenna path. RSTiming is expressed in nanoseconds relative to the RS timing error of the reference Tx/Rx antenna path and is calculated from the data in the Measurement Interval.
  - RSPhase(degress): Average(RMS) RS phase error. It shows the average phase error of the reference signal for each Tx/Rx antenna path. RSPhase is expressed in degrees relative to the RS phase error of the reference Tx/Rx antenna path and is calculated from the data in the Measurement Interval.
  - RSSymClk(ppm): Average RS symbol clock error. It shows the symbol clock error of the reference signal for a Tx/Rx antenna path.RSSymClk is expressed in ppm (parts-per-million) relative to the symbol clock error of the reference Tx/Rx antenna path and is calculated from the data in the Measurement Interval.
  - RSFreq(Hz): RS frequency shift error. It shows the frequency error of the reference signal for each Tx/Rx antenna path.RSFreq is expressed in Hz relative to the RS frequency error of the reference Tx/Rx antenna path and is calculated from the data in the Measurement Interval.
  - IQGainImb: shows the amount of amplifier gain imbalance between I and Q for a transmit antenna port over all receive antenna ports. IQGainImb is

computed by calculating the ratio of I to Q for each pair of PDSCH subcarriers symmetric about the DC axis and then linearly averaging the ratios. IQGainImb is calculated over all PDSCH subcarriers in the Measurement Interval. IQGainImb is calculated for each transmit antenna port. When a Tx/Rx antenna path is present, the MIMO Info Table printed in the simulation log will show the IQ gain imbalance for the corresponding transmit antenna port. Antenna paths with the same Tx antenna port but different Rx ports will show the same value.

    - IQQuadErr(deg): IQ quadrature error. It shows the IQ quadrature error, or angle error between I and Q for a transmit antenna, averaged over the PDSCH subcarriers on a transmit antenna port for all Rx antenna ports. IQQuadErr is expressed in number of degrees. Positive values indicate that the angle between I and Q is greater than 90 degrees. Negative values indicate that the angle between I and Q is less than 90 degrees. IQQuadErr is calculated for each transmit antenna port. When a Tx/Rx antenna path is present, the MIMO Info Table will show the IQ quadrature error for the corresponding transmit antenna port. Antenna paths with the same Tx antenna port but different Rx ports will show the same value.
    - IQTimSkew(second): IQ timing skew. It shows the amount of IQ time skew, or delay between the I and Q channels, averaged over the PDSCH subcarriers on a transmit antenna port for all Rx antenna ports. IQTimSkew is expressed in nanoseconds and is calculated from the data in the Measurement Interval. IQTimSkew is calculated for each transmit antenna port. When a Tx/Rx antenna path is present, the MIMO Info Table will show the IQ timing skew for the corresponding transmit antenna port. Antenna paths with the same Tx antenna port but different Rx ports will show the same value.

    RSPwr, RSTiming, RSPhase, RSSymClk and RSFreq are set to zero for the Tx/Rx antenna path determined by the Ref Input Channel and Ref Tx Antenna parameters. The values of these data results for other Tx/Rx antenna paths are reported relative to the reference antenna path.
    Cases where the IQ metrics cannot be calculated are as follows:

    - The signal has the MIMO_Mode set to (SM) Spatial Multiplexing, CDD_Mode set to W/o CDD, and the number of layers is less than the number of transmit antennas.
    - The signal in the Measurement Interval does not contain at least one PDSCH subcarrier that has a corresponding PDSCH subcarrier in the frequency-mirrored location on the other side of the DC axis.

    RSPwr, RSTiming, RSPhase, RSSymClk and RSFreq are set to zero for the Tx/Rx antenna path determined by the Ref_TxAnt and Ref_InputChannel parameters. The values of these data results for other Tx/Rx antenna paths are reported relative to the reference antenna path.

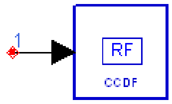
2. The algorithm used here is the same as the one used in Agilent 89600 software. Following is a brief description of the algorithm.
   Starting at the beginning of the frame, a signal segment of length SearchLength is acquired. The SearchLength is longer than the result length (which is decided by parameter ResLenInSlots) by approximately the length of the AnalysisBoundary (frame = 10 ms, slot = 0.5 ms, etc.) to allow for location of the analysis boundary within the time capture. ResLenInSlots determines how many slots will be available for demodulation. MeasOffset and MeasInterval specify which part of the time capture is demodulated.
   To ensure that this alignment can be achieved, the total amount of data acquired by the analyzer is larger than the result length plus the length of the alignment boundary specified by AnalysisBoundary. For example, when AnalysisBoundary is set to Half-Frame, the total acquisition is larger than result length + 10 slots (and the data available for analysis would start at a Half-Frame boundary).
   The acquired complex signal is passed to a complex algorithm that performs synchronization, demodulation, and EVM analysis. The algorithm that performs the synchronization, demodulation, and EVM analysis is the same as the one used in the Agilent 89600 VSA.
   If for any reason a measurement is misdetected (in this model, if synchronization correlation coefficient is less than 0.4, the measurement shall be discarded) the results from its analysis are discarded.
3. See *LTE_DL_Receiver* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception",

September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
4. Agilent 89600 VSA Online Help, Optional Measurement Software, 3G Cellular Comms Modulation Analysis, LTE Modulation Analysis, version 12.00.

LTE_RF_CCDF (CCDF Measurement)



LTE_RF_CCDF

Description: CCDF measurement
Library: LTE, Measurements
Class: TSDF_LTE_RF_CCDF
Derived From: baseAnalysis

Parameters

Name	Description	Default	Unit	Type	Range
Plot	If simulation is setup to open data display after simulation and if Plot is not set to 'None', then plot the data for this sink: None, Rectangular	None		enum	
RLoad	Load resistance. DefaultRLoad will inherit from the DF controller.	DefaultRLoad	Ohm	real	(0, ∞)
RTemp	Resistor physical temperature, in degrees C. DefaultRTemp will inherit from the DF controller.	DefaultRTemp	Celsius	real	[-273.15, ∞)
Start	Start time for data recording. DefaultTimeStart will inherit from the DF Controller.	DefaultTimeStart	sec	real	[0, ∞)
Stop	Stop time for data recording. DefaultTimeStop will inherit from the DF Controller.	DefaultTimeStop	sec	real	[Start, ∞)
NumBins	Number of points in the CCDF curve	100		int	
OutputPeakMean	Output signal peak and mean values: NO, YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	timed sink input signal	timed

Notes/Equations

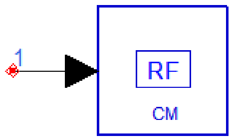
1. This model measures the complementary cumulative distribution function (CCDF) of the RF signal, PeakPower and AvgPower.
2. $Samples_{Frame}$ (explained in item 4 below) tokens are consumed at pin input and *SymLen x SymNum* tokens are used for measurement. The distribution range is divided into segments and the corresponding distribution probability is calculated based on these segments. Peak power of 99.9% probability and average power of input signals are calculated. These results are collected by the PeakPower and AvgPower NumericSinks.
3. Note that the units of PeakPower and AvgPower are dBm; SignalRange is the transient absolute signal power minus AvgPower, so the unit of SignalRange is dB.
4. $Samples_{Frame}$ is the total sample of one downlink frame including zero padding and calculated as follows:
   $$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$
   where $Samples_{idle}$ is the samples of IdleInterval and calculated as follows:
   $$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$
   F_s is the sampling frequency decided by Bandwidth; these are listed in the following table.

Bandwidth BW	Sampling Frequency Fs
1.4MHz	1.92MHz
3.0MHz	3.84MHz
5MHz	7.68MHz
10MHz	15.36MHz
15MHz	23.04MHz
20MHz	30.72MHz

References

1. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
2. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
3. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.

LTE_RF_CM (Cubic Metric (CM) Measurement)



Description: Cubic Metric (CM) measurement
Library: LTE, Measurements
Class: TSDF_LTE_RF_CM
Derived From: baseAnalysis

Parameters

Name	Description	Default	Unit	Type	Range
Plot	If simulation is setup to open data display after simulation and if Plot is not set to 'None', then plot the data for this sink: None, Rectangular	None		enum	
RLoad	Load resistance. DefaultRLoad will inherit from the DF controller.	DefaultRLoad	Ohm	real	(0, ∞)
RTemp	Resistor physical temperature, in degrees C. DefaultRTemp will inherit from the DF controller.	DefaultRTemp	Celsius	real	[-273.15, ∞)
Start	Start time for data recording. DefaultTimeStart will inherit from the DF Controller.	DefaultTimeStart	sec	real	[0, ∞)
Stop	Stop time for data recording. DefaultTimeStop will inherit from the DF Controller.	DefaultTimeStop	sec	real	[Start, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	timed sink input signal	timed

Notes/Equations

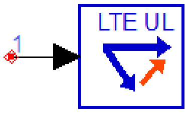
1. This model measures the cubic metric (CM) of the RF signal.
2. $Samples_{\text{Frame}}$ (explained in item 5 below) tokens are consumed at pin input and *SymLen x SymNum* tokens are used for measurement.
3. Note that the units of CM is dB.
4. Data has been collected on several devices for a variety of signals that will show how well the de-rating of LTE signals is predicted by CM. The CM can be computed as,
$$CM = \frac{20\log\{rms[v_{norm}{}^3(t)]\} - 20\log\{rms[vre_{norm}{}^3(t)]\}}{K}$$
Where $20\log\{rms[v_{norm}{}^3(t)]\}$ is the called *raw cubic metric* (in dB) of a signal
$20\log\{rms[vre_{norm}{}^3(t)]\} = 1.52dB$ is the raw cubic metric of the W-CDMA voice reference signal
to clarify $rms(x) = \sqrt{\frac{x^H x}{N}}$, and $v_{norm}(t) = \frac{|v(t)|}{rms[v(t)]}$
And *K* is empirically determined to be 1.85.
5. $Samples_{\text{Frame}}$ is the total sample of one downlink frame including zero padding and calculated as follows:
$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$
where $Samples_{\text{idle}}$ is the samples of *IdleInterval* and calculated as follows:
$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$
Fs is the sampling frequency decided by *Bandwidth*; these are listed in the table below.

Bandwidth BW	Sampling Frequency Fs
1.4MHz	1.92MHz
3.0MHz	3.84MHz
5MHz	7.68MHz
10MHz	15.36MHz
15MHz	23.04MHz
20MHz	30.72MHz

References

1. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
2. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
3. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.

LTE_UL_EVM (Uplink EVM (RCE) Measurement)



Description: Uplink EVM measurement
Library: LTE, Measurement

Parameters

Name	Description	Default	Unit	Type	Range
RLoad	load resistance. DefaultRLoad will inherit from the DF controller.	DefaultRLoad	Ohm	real	(0,∞)
FCarrier	carrier frequency	2500 MHz	Hz	real	(0,∞)
SystemParameters	system parameters for LTE uplink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0, 2]
CellID_Group	the index of cell identity group	0		int	[0, 167]
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES		enum	
FrameNum	frame number	0		int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO		enum	
PUSCH_Parameters	PUSCH parameters for LTE uplink signals	Category		string	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
MappingType	the modulation orders for the PUSCH in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	NO		enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO		enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame		enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0		int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1		int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	

RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}		int array	
GroupHop_Enable	whether enable group hopping for DMRS on PUCCH and PUSCH or not: NO, YES	NO		enum	
SeqHop_Enable	whether enable sequence hopping for DMRS on PUSCH or not: NO, YES	NO		enum	
PUSCH_Delta_ss	used in determining the sequence-shift pattern for PUSCH	0		int	[0, 29]
PUSCH_n_DMRS1	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUSCH_n_DMRS2	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUCCH_Parameters	PUCCH parameters for LTE uplink signals	Category		string	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1		enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2		int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1		int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11		int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11		int	[0, 12*PUCCH_NB2-1]
PRACH_Parameters	PRACH parameters for LTE uplink signals	Category		string	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO		enum	
PRACH_Config	PRACH configuration index	0		int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{0}		int array	[0, 9]
PRACH_PrmbleIndex	preamble indexes, used to select preamble sequences from 64 preambles available in this cell	{0}		int array	[0, 63]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0		int	[0, 94]
PRACH_LogicalIndex	logical index of root ZC sequence	0		int	[0, 837]
PRACH_Ncs	cyclic shifts of ZC sequence	0		int	[0, 15]
PRACH_HS_flag	high speed flag: NO, YES	NO		enum	
SRS_Parameters	SRS parameters for LTE uplink signals	Category		string	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO		enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7		int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0		int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO		enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0		int	[0, 3]
SRS_HoppingBandwidth	the SRS hopping bandwidth	3		int	[0, 3]
SRS_FreqPosition	the SRS frequency domain position	0		int	[0, 23]
SRS_ConfigIndex	the UE-specific SRS configuration	0		int	[0, 1023]
SRS_TransmissionComb	transmission comb	0		int	[0, 1]

SRS_CyclicShift	used in computing the cyclic shift of SRS	0		int	[0, 7]
PowerParameters	power-related parameters	Category		string	
PUSCH_PwrOffset	the power offset in dB for PUSCH	0		real	(-∞, +∞)
PUSCH_RS_PwrOffset	the power offset in dB for PUSCH RS	0		real	(-∞, +∞)
PUCCH_PwrOffset	the power offset in dB for PUCCH	0		real	(-∞, +∞)
PUCCH_RS_PwrOffset	the power offset in dB for PUCCH RS	0		real	(-∞, +∞)
PRACH_PwrOffset	the power offset in dB for PRACH	0		real	(-∞, +∞)
SRS_PwrOffset	the power offset in dB for SRS	0		real	(-∞, +∞)
ShowRxAlgorithmParameters	show parameters for LTE uplink EVM measurement algorithm: NO, YES	NO		enum	
SyncType	Initial synchronization type: PUSCH_DMRS, PUCCH_DMRS, S_RS, PRACH	PUSCH_DMRS		enum	
RBAutoDetect	defines the RB allocation and modulation format detection mode: RBDetManual, RBDetAuto	RBDetAuto		enum	
PUSCHIncludeInAnalysis	whether or not PUSCH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	YES		enum	
PUCCHIncludeInAnalysis	whether or not PUCCH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	NO		enum	
SRSIncludeInAnalysis	whether or not SRS is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	NO		enum	
PRACHIncludeInAnalysis	whether or not PRACH is included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum: NO, YES	NO		enum	
PUSCHAutoSync	specify the sync slot type for PUSCH: NO, YES	YES		enum	
PUSCHSyncSlot	specify a slot index in a radio frame used for initial synchronization	6		int	[0,19]
PUCCHAutoSync	specify the sync slot type for PUCCH: NO, YES	YES		enum	
PUCCHSyncSlot	specify the slot to use as the sync slot	0		int	[0,19]
SRSAutoSync	specify the sync slot type for SRS: NO, YES	YES		enum	
SRSSyncSlot	specify the slot to use as the sync slot	1		int	[0,19]
ResLenInSlots	Result length in slots. Specifically, this is the number of slots to be analyzed and demodulated.	20		int	[1,100]
MeasOffset	specifies measurement offset in symbols, from which EVM is computed.	0		int	[0,ResLenInSlots*NumSymsPerSlot)
MeasInterval	specifies measurement interval in symbols used for EVM computation, starting from the slot and symbol offset specified by MeasOffset	140		int	[1,ResLenInSlots*NumSymsPerSlot - MeasOffset]
AnalysisBoundary	analysis start boundary: ANALYSIS_BOUNDARY_FRAME, ANALYSIS_BOUNDARY_HALFFRAME, ANALYSIS_BOUNDARY_SUBFRAME, ANALYSIS_BOUNDARY_SLOT	ANALYSIS_BOUNDARY_FRAME		enum	
CPLengthAutoDetect	specifies Cyclic Prefix length auto detect or not: NO, YES	NO		enum	
MirrorFreqSpectrum	whether or not the entire frequency spectrum be flipped around the carrier frequency: NO, YES	NO		enum	
EqualizerTraining	Specify how equalizer is trained:	RS_Training		enum	

	TrainingOff, RS_Training, RS_DataTraining				
EVMMinimization	specifies the amplitude err, timing err and frequency and phase err tracking and compensation mode: EVMMiniOff, EVMMini3GPP, EVMMiniTracking	EVMMini3GPP		enum	
EVMMinimizationAmp	whether or not tracking the amplitude err: NO, YES	NO		enum	
EVMMinimizationTiming	whether or not tracking the timing err: NO, YES	NO		enum	
EVMMinimizationFreqPhase	whether or not tracking the freq and phase err: NO, YES	NO		enum	
EVMMinimizationIQOffset	whether or not tracking the IQ offset: NO, YES	NO		enum	
SymTimeAdjMode	symbol timing adjust mode: MAX_EVMWIN_START_END, MIN_EVMWIN_START_END, EVMWIN_START, EVMWIN_START_End, EVMWIN_Center, PERCENT_FFT_SIZE	MAX_EVMWIN_START_END		enum	
SymTimeAdj	specify how much data in cyclic prefix portion, backing up from the exact symbol timing are included for FFT computation in percentage of FFT length. This value must be zero or a negative value, down to a whole cyclic prefix length -7.125 to 0% (Normal CP length), -25% to 0% (Extended CP length)	-3.125		real	[-25,0]
ReportEVMIndB	specifies the EVM units in dB or not: NO, YES	NO		enum	
PowerBoostNormalize	whether or not the constellation be normalized: NO, YES	YES		enum	
FramesToMeas	number of frames that will be averaged if AverageType is RMS (Video)	10		int	[1,100]
SaveConstellation	if set YES, the measured vector used for EVM calculation shall be saved to Data File: NO, YES	NO		enum	
DisplayFrame	the Frame number for display some vector measurement results	0		int	[0,FramesToMeas-1]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	timed

Parameters Details

- For System Parameters details please refer to *UL System Parameters* (3gpplte).
- For more information on the PUSCH Parameters details please refer to *UL PUSCH Parameters* (3gpplte).
- For more information on the PUCCH Parameters details please refer to *UL PUCCH Parameters* (3gpplte).
- For more information on the PRACH Parameters details please refer to *UL PRACH Parameters* (3gpplte).
- For more information on the SRS Parameters details please refer to *UL SRS Parameters* (3gpplte).
- For more information on the Power Parameters details please refer to *UL Power Parameters* (3gpplte).

Rx Algorithm Parameters

- PUCCH_PUSCH, PRACH_Enable and SRS_Enable set which channels or signals are present for the current user. PRACH analysis is done separately from the other channels and signals. Selecting Present in Signal for PRACH by setting PRACH_Enable to YES, will clear the Present for the other channels and signals, i.e. SRS_Enable should be set to NO, and PUCCH_PUSCH should be set to PUSCH and none RB allocated to PUSCH.
- SyncType: Sets the channel or signal to be used for synchronization. The demodulator can use PUSCH DM-RS, PUCCH DM-RS, S-RS, or PRACH for synchronization. Only the channels or signals that are present for the current user

will be available as synchronization options. PUSCH, PUCCH, PUSCH DM-RS, PUCCH DM-RS, and SRS powers are specified relative to the 0 dB level determined by the power of the channel/signal chosen for synchronization.
Sync Type also determines which channel/signal's Sync Slot parameter is used for frame boundary calculation.

- RBAutoDetect: enables autodetection of user allocations .
  When RBAutoDetect is set to Auto, the demodulator can autodetect PUSCH, PUCCH, SRS, or PRACH when the necessary parameters are defined.
  For PUSCH, PUCCH, and SRS autodetection, channel parameters include a Sync Slot parameter. There must be a unique sync slot in the channel/signal corresponding to the Sync Type setting in order for the frame boundary to be determined successfully. The signal will still demodulate when there is no unique sync slot, but the time indexes (slot, symbol, etc.) may be incorrect.
  To configure the demodulator to automatically detect the sync slot, select the Auto Sync parameter for the channel or signal.
  To specify a sync slot for a channel or signal, make sure the this channel or signal is active, then specify the Channel Parameters or Signal Parameters, and Per-slot Parameters for the sync slot.
  When RBAutoDetect is set to Manual, all user’s allocation is set by the system parameters and the RB allocation corresponding parameters.
- These parameters listed below are used to set whether these channels or signals are included in computing composite results such as EVM, EVMPk and OFDMRBErrorMagSpectrum.
  PUSCHIncludeInAnalysis, PUCCHIncludeInAnalysis, SRSIncludeInAnalysis and PRACHIncludeInAnalysis work with PUCCH_PUSCH, PRACH_Enable and SRS_Enable to decide whether or not the presented signal is included in computing composite results.
- PUSCHAutoSync and PUSCHSyncSlot
  AutoSync sets the demodulator to automatically find a sync slot.
  - When RBAutoDetect is set to Auto,
    - Auto Sync set YES: the sync slot will be chosen automatically given channel parameters and channel powers. The resource block allocation of the sync slot does not need to be specified.
    - Auto Sync set NO: the sync slot index is specified by the Sync Slot parameter. The sync slot will be found within the frame given the sync slot's resource block allocation and channel parameters.
  - When RBAutoDetect is set to Manual,
    - Auto Sync set YES: the sync slot will be automatically chosen from the list of slot allocations. A unique slot with the highest correlation will be chosen as the sync slot. When there is no unique slot, the slot with the highest correlation will be chosen as the sync slot.
    - Auto Sync set NO: the sync slot index is specified by the Sync Slot parameter. The sync slot index determines which of the slot allocations defined for the current user to use as the sync slot.
      SyncSlot specifies the index of the slot to use for initial synchronization when PUSCH DM-RS is selected as the Sync Type. The demodulator searches for the slot with the characteristics specified in Per-slot Parameters, and the slot that matches the Per-slot Parameters with the highest correlation will be assigned the slot number given in the Sync Slot parameter.
      To specify a sync slot for PUSCH, make sure the PUSCH is presented, then specify Sync Slot, Channel Parameters, and Per-slot Parameters for the sync slot.
- PUCCHAutoSync, PUCCHSyncSlot
  Auto Sync sets the demodulator to automatically find a sync slot. This parameter does not have any effect when Sync Type is set to a channel/signal other than PUCCH DMRS.
  - When RBAutoDetect is set to Auto,
    - Auto Sync set YES: the sync slot will be chosen automatically given the Auto-calculate parameters (when Auto-calculate is selected) and Per-slot Parameters.
    - Auto Sync set NO: the sync slot index is specified by the Sync Slot parameter.
  - When RBAutoDetect is set to Manual,
    - Auto Sync set YES: the sync slot will be automatically chosen from the list of subframe allocations. A unique slot with the highest correlation will be chosen as the sync slot.
    - Auto Sync set NO: the sync slot index is specified by the Sync Slot

parameter. The sync slot index determines which of the subframe allocations defined for the current user is used as the sync slot.
SyncSlot specifies the index of the slot to use for initial synchronization when PUCCH DM-RS is selected as the Sync Type. The demodulator searches for the slot with the characteristics specified in Per-slot Parameters, and the slot that matches the Per-slot Parameters with the highest correlation will be assigned the slot number given in the Sync Slot parameter.
To specify a sync slot for PUCCH, make sure the PUCCH is presented, and then specify Sync Slot, Channel Parameters, and Per-slot Parameters for the sync slot.

- SRSAutoSync and SRSSyncSlot
  AutoSync sets the demodulator to automatically find a sync slot.
  - Auto Sync set YES: the sync slot will be chosen automatically using the SRS Signal Parameters.
  - Auto Sync set NO: the sync slot index is specified by the Sync Slot parameter. The sync slot will be located within the frame using the SRS Signal Parameters. SyncSlot specifies the index of the slot to use for initial synchronization when SRS is selected as the Sync Type.
  - The demodulator searches for the slot with the characteristics specified in the Signal Parameters, and the slot that matches the Signal Parameters with the highest correlation will be assigned the slot number given in the Sync Slot parameter.
  - To specify a sync slot for SRS, make sure the SRS tab is presented, then specify Sync Slot and Signal Parameters for the sync slot.
- ResLenInSlots: determines how many slots will be available for demodulation. Measurement Interval and Measurement Offset specify which part of the time capture is demodulated.
- MeasOffset: specifies the offset from the Analysis Start Boundary to the beginning of the Measurement Interval (the data sent to the demodulator). Measurement Offset is specified in slots plus symbol-times.
- MeasInterval: determines how much data is sent to the demodulator and can be specified in slots plus symbol-times. The beginning of the measurement interval is specified as an offset from the Analysis Start Boundary. The offset is specified by the Measurement Offset parameter.
- AnalysisBoundary: specifies the alignment boundary of the Result Length time data. To ensure that this alignment can be achieved, the total amount of data acquired by the analyzer is equal to the Result Length plus the length of the alignment boundary specified by Analysis Start Boundary. For example, when Analysis Start Boundary is set to Half-Frame, the total acquisition is equal to Result Length + 10 slots (and the data available for analysis would start at a Half-Frame boundary). Once the Result Length data is located within the time capture, Measurement Offset and Measurement Interval determine what part of the Result Length data is to be analyzed. The Measurement Interval data is shown on the Time trace. See image *EVM Measment Interval* (3gpplte)for more information.
- CPLengthAutoDetect: indicates the CP length (Normal or Extended) that was autodetected or specified by the CyclicPrefix parameter.
- MirrorFreqSpectrum: whether or not the entire frequency spectrum will be flipped around the carrier frequency.
- EqualizerTraining: tells the demodulator whether or not to equalize the signal (compensate for the measured channel frequency response).
  When RS+Data is selected for uplink, the LTE demodulator calculates the equalizer channel frequency response according to the standard using the DM-RS subcarriers and the DFT-spread (SC-FDMA) subcarriers (PUSCH). The LTE standard specifies that an RS+Data equalization should be performed for uplink signals.
  When RS is selected, the signal will be equalized using the channel frequency response calculated using the DM-RS subcarriers in the signal.
  When Off is selected, the channel frequency response will still be calculated from the DM-RS subcarriers but will not be applied to the signal.
  PRACH equalization is done differently from the other uplink channels' equalization. First, the channel frequency response is calculated for a PRACH transmission by comparing the received preamble sequence to the reference preamble sequence. Then, the channel frequency response is averaged to a single correction value and this correction is applied to all subcarriers in the PRACH preamble. Each PRACH transmission is equalized separately from the other PRACH transmissions.
  PRACH equalization is done this way because if each PRACH subcarrier were corrected individually, the equalization would simply remove the error from the PRACH transmission (resulting in near zero EVM) since the channel frequency response would be calculated from the same subcarriers that were being equalized.

- EVMMinimization: whether or not uses the reference signal to correct the signal. When Tracking is selected, the demodulator applies corrections on a symbol-by-symbol basis and the Equalizer Training parameter determines whether data subcarriers are included in calculating corrections. When Equalizer Training is set to RS+Data, EVM Minimization Tracking is performed using the reference signal and the data subcarriers. When Equalizer Training is set to RS or Off, EVM Minimization Tracking is performed using only the reference signal.When Off is selected, EVM minimization corrections are not applied to the signal.
  There are four types of corrections that can be applied to the signal to minimize the EVM. They are Amplitude, Frequency/Phase, Timing, and IQ Offset which are set by these 4 parameters as follows.
- EVMMinimizationAmp: When selected, the average reference signal amplitude error will be used to correct the amplitudes of the subcarriers.
- EVMMinimizationTiming: When selected, the average slope (average rate of change) of the RS phase in the frequency domain is used to correct the timing.
- EVMMinimizationFreqPhase: When selected, the average reference signal phase difference will be used to adjust subcarrier phase.
- EVMMinimizationIQOffset: When selected, the average reference signal phase difference will be used to adjust the IQ offset.
- SymTimeAdjMode and SymTimeAdj: determines where the FFT used for EVM and demodulation results is located within the symbol + cyclic prefix time data.
- ReportEVMIndB: specifies the EVM units for all result data.
- PowerBoostNormalize: When Power Boost Normalize is selected, whether or not the constellation is normalized.
- SaveConstellation: if set YES, the measured vector used for EVM calculation shall be saved to Data File.
- FramesToMeas: number of measured frames.
- DisplayFrame: the Frame number for display some vector measurement results.

Notes/Equations

1. This component performs an EVM measurement for a LTE uplink signal. The input signal must be a complex signal. The available results from this measurement are:
   - Error summary
     These measurement results contain information about the quality of the signal being analyzed (in the Measurement Interval). Measurement Interval determines how much data is sent to the demodulator and can be specified in symbol-times by parameter MeasInterval. The beginning of the measurement interval is specified as an offset from the AnalysisBoundary. The offset is specified by the MeasOffset parameter. Notes: this need add link.
     Below is a list of available data results.
     - EVM: Overall RMS Error Vector Magnitude for all selected channels.
     - EVMPk, EVMPkIdx and EVMSubcarPkIdx: The peak EVM value and location of the peak EVM.
     - DataEVM: RMS Error Vector Magnitude of the user channels.
     - QPSKEVM: RMS average EVM of PDSCH QPSK allocations, calculated according to the standard
     - QAM16EVM: RMS average EVM of PDSCH 16QAM allocations, calculated according to the standard.
     - QAM64EVM: RMS average EVM of PDSCH 64QAM allocations, calculated according to the standard.
     - RSEVM: RMS Error Vector Magnitude of the reference signal.
     - FreqErr: Average carrier frequency.
     - SyncCorr: Correlation between the measured P-SS signal and the reference P-SS signal.
     - CommonTrackingError: Rms averaged common pilot error result (unit: %).
     - SymClkErr: Frequency error of the measured signal's symbol clock. (unit: ppm)
     - TimeOffset: The distance from the start of the Search Time trace to the beginning of the Measurement Interval
     - IQOffset: IQ offset result is computed as a power ratio of dc power to total averaged power.
     - IQGainImbalance: I vs Q amplifier gain imbalance (ratio of I-gain to Q-gain).
     - IQQuadError: Amount of angle skew between I and Q (unit: deg).
     - IQTimingSkew: Time difference between the I and Q parts of the signal (unit: sec).
     - CPLengthMode: Current CP Length (normal or extended).
       Only EVM and EVM Pk are calculated from the channels that are selected

for. The other Error Summary data results are not dependent on which channels are selected for analysis. The ReportEVMIndB parameter affects the units of EVM result.

- Frame summary
  The Frame Summary trace shows the EVM, power, and number of resource blocks occupied for the channels and signals that are present in the Measurement Interval.
  EVM is the RMS value of error vector magnitudes for the channel. The ReportEVMIndB parameter affects the units of EVM result. Power is the per-subcarrier power received averaged over all the subcarriers belonging to the physical layer channel. The power values are reported in dB relative to the signal’s 0dB point power which determined by the sync signal's power for uplink Num. RB shows the number of resource blocks (1 RB x 1 slot) within the Measurement Interval that contain subcarriers belonging to the channel
  - PUSCHEVM: EVM result of PUSCH.
  - PUSCHPower: power of PUSCH in dB relative to the reference signal power.
  - PUSCHNumRB: number of RBs of PUSCH.
  - PUCCHEVM: EVM result of PUCCH.
  - PUCCHPower: power of PUCCH in dB relative to the reference signal power.
  - PUCCHNumRB: number of RBs of PUCCH.
  - PUCCHDMRSEVM: EVM result of PUCCH Demodulation Reference Signal (DMRS).
  - PUCCHDMRSPower: power of PUCCH Demodulation Reference Signal (DMRS) in dB relative to the reference signal power.
  - PUCCHDMRSNumRB: number of RBs of PUCCH Demodulation Reference Signal (DMRS).
  - SRS: EVM result of SRS.
  - SRSPower: power of SRS in dB relative to the reference signal power
  - SRSNumRB: number of RBs of SRS.
  - PRACHEVM: EVM result of PRACH.
  - PRACHPower: power of PRACH in dB relative to the reference signal power
  - PRACHNumRB: number of RBs of PRACH.
    The user mappings for uplink users (PUSCH) and the uplink control channel and signal are specified by the corresponding parameters same as the uplink signal sources.
- Vector measurement output
  If parameter SaveConstellation set to YES, the available vector measurement output for the displayed frame (specified by the parameter DisplayFrame) are listed below:
  - MeasuredVector: IQ measured vector result after IDFT.
  - MeasuredModFormat: Modulation format per subcarrier and symbol. Enum values used in this result are defined as follows:

0	MOD_NONE	null subcarrier
1	MOD_QPSK	QPSK modulation
2	MOD_QAM16	16QAM modulation
3	MOD_QAM64	64QAM modulation
11	MOD_UL_RS	modulation of RS
12	MOD_PUCCH_FORMAT1	PUCCH format 1
13	MOD_PUCCH_FORMAT1a	PUCCH format 1a
14	MOD_PUCCH_FORMAT1b	PUCCH format 1b
15	MOD_PUCCH_FORMAT2a	PUCCH format 2a
16	MOD_PUCCH_FORMAT2b	PUCCH format 2b

  - MeasuredChanType: Channel type per subcarrier and symbol of layer 0. Enum values used in this result are defined as follows:

0	null subcarrier
3	RS
4	PBCH
5	PCFICH
6	PHICH
7	PUCCH
8	PUCCH_RS
9	SRS
10	PRACH
21	unused DC
30	unused subcarriers within PUCCH/PDCCH control channel symbols (i.e. inactive Null subcarriers)
32	unused subcarriers for partial RB in Subframe 0 (all sym) and Subframe 10 (just sync sym) when Odd #Tx RB
34	allocated for PUSCH/PDSCH, but disabled
36	unused reserved SRS subcarriers
37	unused subcarriers in opposite link in TDD mode
100~	PDSCH, use numbers after this for multiple data bursts, such as 100, 101, 102, …

- OFDMEqChanFreqResp: Normalized equalizer channel frequency response over subcarriers. It's a complex vector of length with the length of numOfSubcarriers.
- OFDMErrVectSpectrum: a comlex vector with length: the actual number of symbols analyzed * numOfSubcarriers. Error vector result, which is the difference between IQ measured vector result and IQ reference vector result.
- OFDMFrequencyError: shows the average frequency error for each slot in the Measurement Interval. The frequency error is expressed as an offset in Hz from the current center frequency setting. It's a real vector with length: the number of measurement slot.
- OFDMIQOffset: shows the average IQ offset for each slot in the Measurement Interval. See the IQ Offset topic in the Error Summary for more information about IQ offset calculation. The IQ Offset Per Slot trace is calculated and is valid for active slots only (slots that contain channel allocations.
- OFDMRBErrorMagSpectrum: EVM result (%), rms averaged over subcarrier and symbol for each RB and Slot. It is a 2 dimensional result of RB and slot but shown as a 1 dimensional vector in such alignment as (Slot0, RB0), (Slot0, RB1), (Slot0, RB2), …, (Slot1, RB0), (Slot1, RB1), (Slot1, RB2), …(Slot2, RB0), (Slot2, RB1), …etc. Where the number of slots is decided by MeasOffset and MeasInterval . Because average is computed slot by slot in time, odd symbols after slot boundary at the end are averaged to add an additional result at the end. Likewise, when MeasOffset in symbols is not 0, odd symbols before slot boundary at the beginning are averaged to add an additional result at the beginning. So, when MeasOffset in symbols = 0 and MeasInterval in symbols = 0, then, the number of slots is equal to MeasInterval in slots. When MeasOffset in symbols > 0 and MeasInterval in symbols = 0, the number of slots is equal to MeasInterval in slots + 1. When MeasOffset in symbols = 0 and MeasInterval in symbols > 0, the number of slots is equal to MeasInterval in slots + 1, too.
- OFDMRBPowerSpectrum: Normalized relative power result in linear scale, rms averaged over subcarrier and symbol for each RB and slot. The data format is same as OFDMRBErrorMagSpectrum.
- Constellation for all channels
  The displayed constellation of each channel and each layer are listed below:
- PUSCHConst_QPSK: Constellation of PUSCH with QPSK modulation.
- PUSCHConst_16QAM: Constellation of PUSCH with 16QAM modulation.
- PUSCHConst_64QAM: Constellation of PUSCH with 64QAM modulation.
- PUSCHRSConst: Constellation of PUSCH RS.
- PUCCHConst: Constellation of PUCCH.
- PUCCHRSConst: Constellation of PUCCH RS.
- SRSConst: Constellation of SRS.
- PRACHConst: Constellation of PRACH.

2. The algorithm used here is the same as the one used in Agilent 89600 software. Following is a brief description of the algorithm.
   Starting at the beginning of the frame, a signal segment of length SearchLength is acquired. The SearchLength is longer than the result length (which is decided by

parameter ResLenInSlots) by approximately the length of the AnalysisBoundary (frame = 10 ms, slot = 0.5 ms, etc.) to allow for location of the analysis boundary within the time capture. ResLenInSlots determines how many slots will be available for demodulation. MeasOffset and MeasInterval specify which part of the time capture is demodulated.
To ensure that this alignment can be achieved, the total amount of data acquired by the analyzer is larger than the result length plus the length of the alignment boundary specified by AnalysisBoundary. For example, when AnalysisBoundary is set to Half-Frame, the total acquisition is larger than result length + 10 slots (and the data available for analysis would start at a Half-Frame boundary).
The acquired complex signal is passed to a complex algorithm that performs synchronization, demodulation, and EVM analysis. The algorithm that performs the synchronization, demodulation, and EVM analysis is the same as the one used in the Agilent 89600 VSA.
If for any reason a measurement is misdetected (in this model, if synchronization correlation coefficient is less than 0.4, the measurement shall be discarded) the results from its analysis are discarded.
3. See *LTE_UL_Receiver* (3gpplte) and *LTE_UL_Src* (3gpplte).

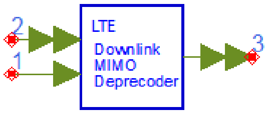
References

1. 3GPP TS 36.101 v8.6.0 "User Equipment (UE) radio transmission and reception", September 2009.
2. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
4. Agilent 89600 VSA Online Help, Optional Measurement Software, 3G Cellular Comms Modulation Analysis, LTE Modulation Analysis, version 12.00.

3GPP LTE MIMO Precoder Components

Contents

LTE_DL_MIMO_Deprecoder (Downlink MIMO Deprecoder)



Description: Downlink MIMO Deprecoder
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
CDD_Mode	cyclic delay diversity (CDD) mode, valid when MIMO_Mode is Spatial_Mux: Large-Delay, Zero-Delay	Large-Delay	enum	
CdBlk_Index	codebook index for precoding, valid when MIMO_Mode is Spatial_Mux	0	int	[0, 15]
NumOfLayers	number of layers	1	int	[1,4]
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	
ChannelType	Physical Channel Type: PDSCH, PCFICH, PDCCH, PBCH, SS	PDSCH	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	CIR	Channel Impulse Response	complex
2	MIMO_Symbol	input of modulation symbols	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	Layer_Symbol	output of layer mapping symbols	multiple complex

Notes/Equations

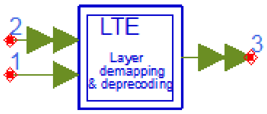
1. This model is to implement MIMO deprecoding for both spatial multiplexing and transimit diversity. It is the inverse of LTE_DL_MIMO_Precoder.
2. The bus width of MIMO_Symbol is is equal to the number of antenna ports (determined by *NumTxAnts*). The bus width of Layer_Symbol port is equal to *NumOfLayers*.

3. Each firing, the number of tokens consumed at the MIMO_Symbol port donated *B* and consumed at CIR port should be equal to *NumTxPorts*NumRxPorts*B* when this port is connected, where *NumTxPorts* and *NumRxPorts* are the number of transmit antenna ports and the number of receiver antenna ports respectively. The number of tokens produced at the Layer_Symbol port is same as the Layer_Symbol port in *LTE_DL_MIMO_Precoder* (3gpplte).
4. When this CIR port is connected, the H matrix is constructed from this port, with the size of *NumRxPorts* by *NumTxPorts*. Otherwise, the identity matrix is constructed for H matrix.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MIMO_LayDemapDeprecoder (Downlink Layer Demapping and Deprecoding)



Description: Downlink layer demapping and deprecoding
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
CDD_Mode	cyclic delay diversity (CDD) mode, valid when MIMO_Mode is Spatial_Mux: Large-Delay, Zero-Delay	Large-Delay	enum	
CdBlk_Index	codebook index for precoding, valid when MIMO_Mode is Spatial_Mux	0	int	[0, 15]
NumOfCWs	number of code words	1	int	[1,2]
NumOfLayers	number of layers	1	int	[1,4]
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	
ChannelType	Physical channel type that this model works on: PDSCH, PCFICH, PDCCH, PBCH	PDSCH	enum	

Pin Inputs

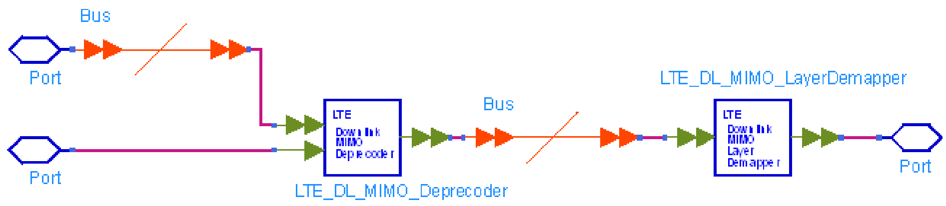
Pin	Name	Description	Signal Type
1	CIR	Channel impulse response for PHICH	complex
2	input	layer mapping and precoding signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	output	mapping signal	multiple complex

Notes/Equations

1. This sub-network model is used to implement layer de-mapping (section 6.3.3 in [1]) and de-precoding (section 6.3.4 in [1]). It consists of LTE_DL_MIMO_LayerDemapper and LTE_DL_MIMO_Deprecoder. It can support both spatial multiplexing and transmit diversity MIMO mode. It also can support PDSCH as well as PMCH, PBCH, PDCCH and PCFICH. The schematic is shown in the following figure.



LTE_DL_MIMO_LayDemapDeprecoder Schematic

2. Each firing, the tokens consumed at the input port and the CIR port refer to *LTE_DL_MIMO_Deprecoder* (3gpplte) for more information on input ports.
   The tokens produced at the output port refer to *LTE_DL_MIMO_LayerDemapper* (3gpplte) for more information on output ports.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MIMO_LayerDemapper (Downlink MIMO Layer Demapper)

Description: Downlink MIMO Layer Demapper
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
NumOfCWs	number of code words	1	int	[1,2]
NumOfLayers	number of layers	1	int	[1,4]

Pin Inputs

Pin	Name	Description	Signal Type
1	Layer_Symbol	input of layer mapping symbols	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	Mod_Symbol	output of modulation symbols	multiple complex

Notes/Equations

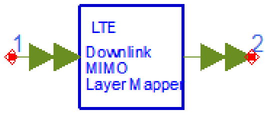
1. This model is used to implement MIMO layer de-mapping for both spatial multiplexing (SM) and transmit diversity (TD). It is the inverse of LTE_DL_MIMO_LayerDemapper.
2. Each firing, the tokens consumed at the input port whose bus width is equal to *NumOfLayers* is denoted by *B*.
   The tokens produced at the output port whose bus width is equal to *NumOfCWs* denoted by *A(i)*, which shown in the following table.

NumOfCWs	NumOfLayers	A(i)
1	1	B
1	2	2*B
2	2	Codeword#1:B Codeword#2: B
2	3	Codeword#1: B Codeword#2: 2*B
2	4	Codeword#1: 2*B Codeword#2: 2*B

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MIMO_LayerMapper (Downlink MIMO Layer Mapper)



Description: Downlink MIMO Layer Mapper
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
NumOfCWs	number of code words	1	int	[1,2]
NumOfLayers	number of layers	1	int	[1,4]

Pin Inputs

Pin	Name	Description	Signal Type
1	Mod_Symbol	input of modulation symbols	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	Layer_Symbol	output of layer mapping symbols	multiple complex

Notes/Equations

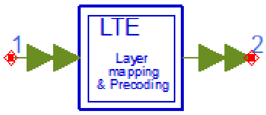
1. This model is used to implement MIMO layer mapping for both spatial multiplexing (SM) and transmit diversity (TD). The complex-valued modulation symbols for each of the code words to be transmitted are mapped onto one or several layers.
2. Each firing, the tokens consumed at the input port whose bus width is equal to *NumOfCWs* is denoted by *A* with the exception that, in case *NumOfCWs* = 2, *NumOfLayers*=3, the size in Codeword#1 is A, the size in Codeword#2 is 2A.
   the tokens produced at the output port whose bus width is equal to *NumOfLayers* is denoted by *B*, which shown in the following table.

NumOfCWs	NumOfLayers	B
1	1	A
1	2	A/2
2	2	A
2	3	A
2	4	A/2
3. Layer mapping for spatial multiplexing: For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1 in [1]. The case of a single codeword mapped to two layers is only applicable when the number of antenna ports is 4.
4. Layer mapping for transmit diversity: For transmit diversity, the layer mapping shall be done according to Table 6.3.3.3-1 in [1]. The case of a single codeword mapped to two layers is only applicable when the number of antenna ports is 4.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MIMO_LayMapPrecoder (Downlink Layer Mapping and Precoding)



Description: Downlink layer mapping and precoding
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
CDD_Mode	cyclic delay diversity (CDD) mode, valid when MIMO_Mode is Spatial_Mux: Large-Delay, Zero-Delay	Large-Delay	enum	
CdBlk_Index	codebook index for precoding, valid when MIMO_Mode is Spatial_Mux	0	int	[0, 15]
NumOfCWs	number of code words	1	int	[1,2]
NumOfLayers	number of layers	1	int	[1,4]
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	
ChannelType	Physical channel type that this model works on: PDSCH, PCFICH, PDCCH, PBCH	PDSCH	enum	

Pin Inputs

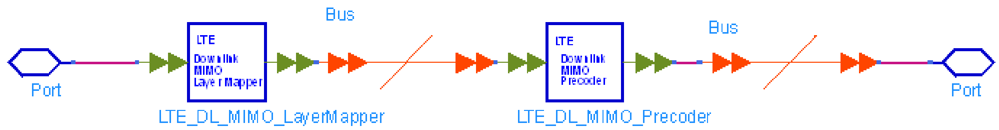
Pin	Name	Description	Signal Type
1	input	mapping signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	layer mapping and precoding signal	multiple complex

Notes/Equations

1. This sub-network model is used to implement layer mapping (section 6.3.3 in [1]) and precoding (section 6.3.4 in [1]). It consists of LTE_DL_MIMO_LayerMapper and LTE_DL_MIMO_Precoder. It can support both spatial multiplexing and transmit diversity MIMO mode. It also can support PDSCH as well as PMCH, PBCH, PDCCH and PCFICH. The schematic is shown in the following figure.



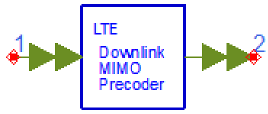
LTE_DL_MIMO_LayMapPrecoder Schematic

2. Each firing, the tokens consumed at the input port refer to *LTE_DL_MIMO_LayerMapper* (3gpplte) for more information on input ports. The tokens produced at the output port refer to *LTE_DL_MIMO_Precoder* (3gpplte) for more information on output ports.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MIMO_Precoder (Downlink MIMO Precoder)



Description: Downlink MIMO Precoder
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
CDD_Mode	cyclic delay diversity (CDD) mode, valid when MIMO_Mode is Spatial_Mux: Large-Delay, Zero-Delay	Large-Delay	enum	
CdBlk_Index	codebook index for precoding, valid when MIMO_Mode is Spatial_Mux	0	int	[0, 15]
NumOfLayers	number of layers	1	int	[1,4]
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	
ChannelType	Physical Channel Type: PDSCH, PCFICH, PDCCH, PBCH	PDSCH	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Layer_Symbol	output of layer mapping symbols	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	MIMO_Symbol	input of modulation symbols	multiple complex

Notes/Equations

1. The precoder takes as input a block of vectors from the layer mapping and generates a block of vectors to be mapped onto resources on each of the antenna ports according to Section 6.3.4 in reference 1.
2. Each firing, the tokens consumed at the input port whose bus width is equal to *NumOfLayers* is donated by A.
   The tokens produced at the output port whose bus width is equal to the number of antenna ports (determined by *NumTxAnts*) is donated by B, which is shown in the following table.

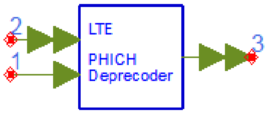
MIMO_Mode	NumTxAnts	B
Spatial_Mux	Tx1	A
Spatial_Mux	Tx2	A
Spatial_Mux	Tx4	A
Tx_Div	Tx1	A
Tx_Div	Tx2	A/2
Tx_Div	Tx4	A/4

3. Precoding for spatial multiplexing: When set parameter MIMO_Mode to Spatial_Mux, precoding for spatial multiplexing is used in combination with layer mapping for spatial multiplexing as described in Section 6.3.4.2 in [1]. Spatial multiplexing supports two or four antenna ports.
    - Precoding without CDD: The values of the precoding matrix shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restriction. The configured codebook shall be selected by parameter Codebook_Index from Table 6.3.4.2.3-1 or 6.3.4.2.3-2 in [1]. For transmission on two antenna ports, the precoding matrix shall be selected from Table 6.3.4.2.3-1 in [1]. For the closed-loop spatial multiplexing transmission mode defined in [1], the codebook index 0 is not used when the number layers is 2.
    - Precoding for large delay CDD: For large-delay CDD, precoding for spatial multiplexing is defined by Section 6.3.4.2.2 in [1]. This can be set parameter CDD_Mode to Large-delay CDD.
        - For Precoding for large delay CDD, for 2 antenna ports, the precoder is selected according to W(i) = C1, where C1 denotes the precoding matrix corresponding to precoder index 0 in Table 6.3.4.2.3-1. For transmission on four antenna ports, the precoding matrix shall be selected from Table 6.3.4.2.3-2 in [1], which means the CdBlk_Index parameter is ignored in this case.
        - For 4 antenna ports, the UE may assume that the eNB cyclically assigns different precoders to different vectors as defined in 6.3.4.2.2 in [1]. In this case, the CdBlk_Index parameter is also ignored.
4. Precoding for transmit diversity: When set parameter MIMO_Mode setting to Tx_Div, precoding for transmit diversity is used in combination with layer mapping for transmit diversity as described in Section 6.3.4.3 in [1].
   The precoding operation for transmit diversity is defined for two and four antenna ports. Note that for transmit diversity precoding, the number of layers set by parameter NumOfLayers should be equal to number of transmit antenna ports set by parameter NumTxAnts.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_PHICH_Deprecoder (PHICH Deprecoder)



Description: PHICH Deprecoder
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	CIR	Channel Impulse Response	complex
2	MIMO_Symol	input of Rx antenna signals	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	Layer_Symbol	output of layer mapping symbols	multiple complex

Notes/Equations

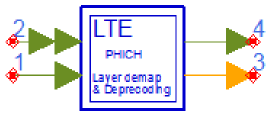
1. This model is used to implement PHICH pre-decoding. It is the inverse of LTE_PHICH_Precoder.
2. The input port MIMO_Symbol and output port Layer_Symbol are all multiple ports. The bus width connected to Layer_Symbol should be equal to the number of layers which is equal to the number of Tx antenna ports; the bus width connected to MIMO_Symbol should be equal to the number of Rx antenna ports. The input port CIR used to input the channel impulse response for PHICH.
   Each firing,
   - for each antenna port, the tokens consumed at MIMO_Symbol is $N\_MIMOSymbol = c*3*N_{SF}^{PHICH}*N\_PHICH\_Group(0) + \ldots +c*3*N_{SF}^{PHICH} *N\_PHICH\_Group(9)$.
   - the tokens consumed at CIR is *N_MIMOSymbol*NumOfTxAnts*NumOfRxAnts*.
   - for each antenna port, the tokens generated at Layer_Symbol is $N\_LyrSymbol = (c*3*N_{SF}^{PHICH}*N\_PHICH\_Group(0) + \ldots + c*3*N_{SF}^{PHICH} *N\_PHICH\_Group(9))/NumOfLayers$.
   - Where $N_{SF}^{PHICH}=4$, $c=1$ for normal cyclic prefix and $N_{SF}^{PHICH}=2$, $c=2$ for extended cyclic prefix. *N_PHICH_Group(sf)* is the number of PHICH groups in this subframe as defined in Section 6.9 of 36.211. These system parameters are used to decide the *N_PHICH_Group(sf)* of each subframe. *NumOfTxAnts* and *NumOfRxAnts* are defined by parameter NumTxAnts and NumRxAnts.
3. Parameter details:
   - System parameters
     - FrameMode: frame mode of LTE, the type is enum and it can be selected as

FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2.
    - TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6.Hidden when FrameMode = FDD.
    - Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
    - CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
    - NumTxAnts: number of Tx antenna ports.
    - NumRxAnts: number of Rx antenna ports.
    - SubframeIgnored: number of subframe that are ignored at the beginning due to system delay.
  - Control channel parameters
    - PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211-890. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe.
    - PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
    - ETM_Support: whether to support PHICH m=1 in all transmitted subframes for TDD E-TM defined in 36.141 6.1.2.6.
  - For the system parameters, refer to *DL System Parameters* (3gpplte).
    For PDCCH corresponding parameters, refer to *DL Control Channel Parameters* (3gpplte).
4. See *LTE_PHICH_LayerDemapper* (3gpplte) and *LTE_PHICH_Precoder* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.141 v8.5.0, "Base Station (BS) conformance testing", December 2009.

LTE_PHICH_LayDemapDeprecoder (PHICH Layer Demapping and Deprecoding)



Description: PHICH layer demapping and deprecoding
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
NumOfLayers	number of layers	1	int	[1,4]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

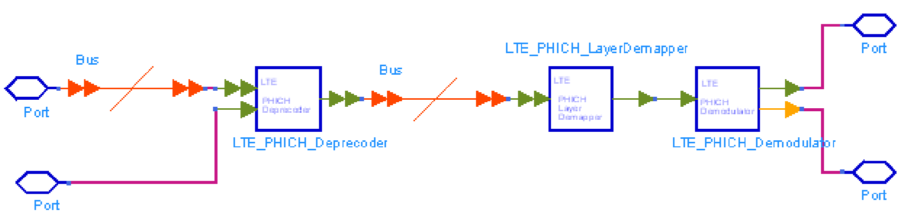
Pin	Name	Description	Signal Type
1	CIR	Channel impulse response for PHICH	complex
2	input	PHICH layer mapping and precoding signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	HI	output of HI bits	int
4	Constellation	output of PHICH constellation	complex

Notes/Equations

1. This sub-network model is used to implement PHICH pre-decoding, PHICH de-mapping and de-modulator. It consists of PHICH_Demodulator, PHICH_LayerDemapper and PHICH_Predecoder. The schematic is shown in the following figure.



LTE_PHICH_LayDemapDeprecoder Schematic

2. Each firing,
   - the number of tokens consumed at the input port refer to *LTE_PHICH_Deprecoder* (3gpplte) for more information on input ports.

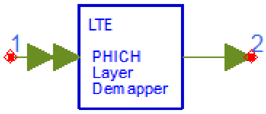
- for each antenna port, the number of tokens produced at the output port refer to *LTE_PHICH_Demodulator* (3gpplte) for more information on output ports.

3. It consists of LTE_PHICH_Deprecoder, LTE_PHICH_LayerDemapper and LTE_PHICH_Demodulator.
4. It can support transmit diversity MIMO mode for PHICH.
5. Parameter details:
    - FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2.
    - TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6.Hidden when FrameMode = FDD.
    - Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
    - NumTxAnts: number of Tx antennas.
    - CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
    - CellID_Sector: the index of cell identity within the physical-layer cell-identity group.
    - CellID_Group: index of cell identity group, its value range is [0,167]. CellID_Sector and CellID_Group are used to initialize the scrambling sequence in LTE_PHICH_Modulator.
    - NumOfLayers: number of layers for PHICH which is equal to the number of antenna ports.
    - PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211-860. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe.
    - PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
    - ETM_Support: whether to support PHICH m=1 in all transmitted subframes for TDD E-TM defined in 36.141 6.1.2.6.
6. See *LTE_PHICH_Deprecoder* (3gpplte), *LTE_PHICH_LayerDemapper* (3gpplte) and *LTE_PHICH_Demodulator* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.141 v8.5.0, "Base Station (BS) conformance testing", December 2009.

LTE_PHICH_LayerDemapper (PHICH Layer Demapper)



Description: PHICH Layer Demapper
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
NumOfLayers	number of layers	1	int	[1,4]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	PHICH_Layer	input of layer mapping PHICH symbols	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	PHICH	out of PHICH symbols	complex

Notes/Equations

1. This model is used to implement PHICH layer de-mapping according to section 6.3.3.3 in [1]. It is the inverse of LTE_PHICH_LayerMapper.

2. The input port PHICH_Layer is multiple ports. The bus width connected to it should be equal to the NumOfLayers parameter which is equal to the number of Tx antenna ports.
   Each firing,
   - For each antenna port, the tokens consumed at PHICH_Layer is $N\_LyrSymbol = (c*3*N_{SF}^{PHICH}*N\_PHICH\_Group(0) + ... + c*3*N_{SF}^{PHICH}*N\_PHICH\_Group(9))/NumOfLayers$.
   - the number of tokens generated at PHICH is $3*N_{SF}^{PHICH}*N\_PHICH\_Group(0) +... + 3*N_{SF}^{PHICH}*N\_PHICH\_Group(9)$.
   - Where $N_{SF}^{PHICH}=4, c=1$ for normal cyclic prefix and $N_{SF}^{PHICH}=2, c=2$ for extended cyclic prefix. *N_PHICH_Group(sf)* is the number of PHICH groups in this subframe as defined in Section 6.9 of 36.211. These system parameters are used to decide the *N_PHICH_Group(sf)* of each subframe.
3. Parameter details:
   - FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2.
   - TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and

Config 6.Hidden when FrameMode = FDD.

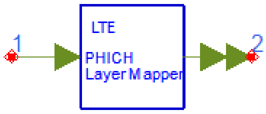
- Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
- CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
- NumOfLayers: number of layers for PHICH which is equal to the number of antenna ports.
- PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211-860. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe.
- PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
- ETM_Support: whether to support PHICH m=1 in all transmitted subframes for TDD E-TM defined in 36.141 6.1.2.6.

4. See *LTE_PHICH_LayerMapper* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.141 v8.5.0, "Base Station (BS) conformance testing", December 2009.

LTE_PHICH_LayerMapper (PHICH Layer Mapping)



Description: PHICH Layer Mapper
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
NumOfLayers	number of layers	1	int	[1,4]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	PHICH	input of PHICH symbols	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	PHICH_Layer	output of layer mapping PHICH symbols	multiple complex

Notes/Equations

1. This model is used to implement PHICH layer mapping according to section 6.3.3.3 in ref 1.

2. The output port PHICH_Layer is multiple ports. The bus width connected to it should be equal to the NumOfLayers parameter which is equal to the number of Tx antenna ports.
   Each firing,
   - the number of tokens consumed at PHICH is $3*N_{SF}^{PHICH}*N\_PHICH\_Group(0) +... + 3*N_{SF}^{PHICH}*N\_PHICH\_Group(9)$.
   - for each antenna port, the tokens generated at PHICH_Layer is $N\_LyrSymbol = (c*3*N_{SF}^{PHICH}*N\_PHICH\_Group(0) + ... + c*3*N_{SF}^{PHICH}*N\_PHICH\_Group(9))/NumOfLayers$.
   - Where $N_{SF}^{PHICH}=4$, $c=1$ for normal cyclic prefix and $N_{SF}^{PHICH}=2$, $c=2$ for extended cyclic prefix. *N_PHICH_Group(sf)* is the number of PHICH groups in this subframe as defined in Section 6.9 of 36.211. These system parameters are used to decide the *N_PHICH_Group(sf)* of each subframe.
3. Parameter details:
   - FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2.
   - TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6.Hidden when FrameMode = FDD.
   - Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.

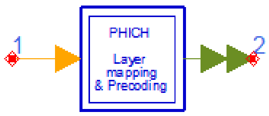
- CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
- NumOfLayers: number of layers for PHICH which is equal to the number of antenna ports.
- PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211-860. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe.
- PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
- ETM_Support: whether to support PHICH m=1 in all transmitted subframes for TDD E-TM defined in 36.141 6.1.2.6.

4. See *LTE_PHICH_LayerMapper* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.141 v8.5.0, "Base Station (BS) conformance testing", December 2009.

LTE_PHICH_LayMapPrecoder (PHICH Layer Mapping and Precoding)



Description: PHICH layer mapping and precoding
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
NumOfLayers	number of layers	1	int	[1,4]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

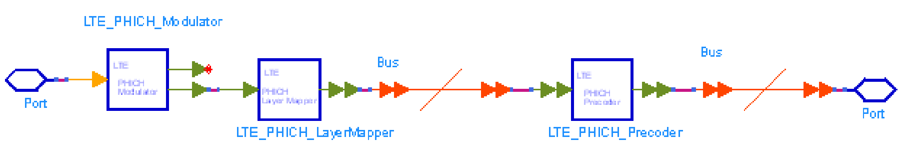
Pin	Name	Description	Signal Type
1	input	PHICH bits	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	PHICH layer mapping and precoding signal	multiple complex

Notes/Equations

1. This sub-network model is used to implement PHICH modulator, PHICH mapping and precoding. It consists of PHICH_Modulator, PHICH_LayerMapper and PHICH_Precoder. The schematic is shown in the following figure.



LTE_PHICH_LayMapPrecoder Schematic

2. Each firing,
   - the number of tokens consumed at the input port refer to *LTE_PHICH_Modulator* (3gpplte) for more information on input ports.
   - for each antenna port, the number of tokens produced at the output port refer to *LTE_PHICH_Precoder* (3gpplte) for more information on output ports.
3. It consists of LTE_PHICH_Modulator, LTE_PHICH_LayerMapper and LTE_PHICH_Precoder.
4. It can support transmit diversity MIMO mode for PHICH.
5. Parameter details:
   - FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure

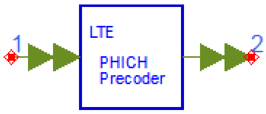
type 2.
- TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6.Hidden when FrameMode = FDD.
- Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
- NumTxAnts: number of Tx antennas.
- CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
- CellID_Sector: the index of cell identity within the physical-layer cell-identity group.
- CellID_Group: index of cell identity group, its value range is [0,167]. CellID_Sector and CellID_Group are used to initialize the scrambling sequence in LTE_PHICH_Modulator.
- NumOfLayers: number of layers for PHICH which is equal to the number of antenna ports.
- PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211-860. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe.
- PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
- ETM_Support: whether to support PHICH m=1 in all transmitted subframes for TDD E-TM defined in 36.141 6.1.2.6.

6. See *LTE_PHICH_Modulator* (3gpplte), *LTE_PHICH_LayerMapper* (3gpplte) and *LTE_PHICH_Precoder* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.141 v8.5.0, "Base Station (BS) conformance testing", December 2009.

LTE_PHICH_Precoder (PHICH Precoding)



Description: PHICH Precoder
Library: LTE, MIMO Precoder

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Layer_Symbol	output of layer mapping symbols	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	MIMO_Symol	input of modulation symbols	multiple complex

Notes/Equations

1. This model is used to precode PHICH symbols for each of the transimit antenna port.
   - For transmission on two antenna ports, precoding are defined by 6.3.4.3 in ref 1.
   - For transmission on four antenna ports, precoding are defined by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mathrm{Re}\{x^{(0)}(i)\} \\ \mathrm{Re}\{x^{(1)}(i)\} \\ \mathrm{Re}\{x^{(2)}(i)\} \\ \mathrm{Re}\{x^{(3)}(i)\} \\ \mathrm{Im}\{x^{(0)}(i)\} \\ \mathrm{Im}\{x^{(1)}(i)\} \\ \mathrm{Im}\{x^{(2)}(i)\} \\ \mathrm{Im}\{x^{(3)}(i)\} \end{bmatrix}$$

   if (i+PHICH group number)mod2=0 for normal cyclic prefix, or (i + int(PHICH group number/2))mod2 = 0 for extended cyclic prefix, and by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \mathrm{Re}\{x^{(0)}(i)\} \\ \mathrm{Re}\{x^{(1)}(i)\} \\ \mathrm{Re}\{x^{(2)}(i)\} \\ \mathrm{Re}\{x^{(3)}(i)\} \\ \mathrm{Im}\{x^{(0)}(i)\} \\ \mathrm{Im}\{x^{(1)}(i)\} \\ \mathrm{Im}\{x^{(2)}(i)\} \\ \mathrm{Im}\{x^{(3)}(i)\} \end{bmatrix}$$

otherwise.

2. The input and output port are all multiple ports. The bus width connected to Layer_Symbol should be equal to the number of layers which is equal to the number of Tx antenna ports; the bus width connected to MIMO_Symbol should be equal to the number of Tx antenna ports.
3. Each firing,
   - for each layer, the number of tokens consumed at Layer_Symbol is *N_LyrSymbol = (c*3**N_{SF}^{PHICH}**N_PHICH_Group(0) + … + c*3**N_{SF}^{PHICH} **N_PHICH_Group(9))/NumOfLayers*.
   - the number of tokens generated at MIMO_Symbol is *c*3**N_{SF}^{PHICH} **N_PHICH_Group(0) + … + c*3**N_{SF}^{PHICH}**N_PHICH_Group(9)*.
   - Where $N_{SF}^{PHICH}=4$, *c=1* for normal cyclic prefix and $N_{SF}^{PHICH}=2$, *c=2* for extended cyclic prefix. *N_PHICH_Group(sf)* is the number of PHICH groups in this subframe as defined in Section 6.9 of 36.211. These system parameters are used to decide the *N_PHICH_Group(sf)* of each subframe.
4. Parameter details:
   - System parameters
     - FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2.
     - TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6.Hidden when FrameMode = FDD.
     - Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
     - CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
     - NumTxAnts: number of Tx antenna ports.
   - Control channel parameters
     - PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211-860. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe.
     - PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
     - ETM_Support: whether to support PHICH m=1 in all transmitted subframes for TDD E-TM defined in 36.141 6.1.2.6.
   - For the system parameters, refer to *DL System Parameters* (3gpplte). For PDCCH corresponding parameters, refer to *DL Control Channel Parameters* (3gpplte).
5. See *LTE_PHICH_LayerMapper* (3gpplte) and *LTE_PHICH_Deprecoder* (3gpplte).

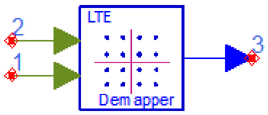
References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.141 v8.5.0, "Base Station (BS) conformance testing", December 2009.

3GPP LTE Modulation Components

Contents

LTE_Demapper (De-mapper)



Description: De-mapper
Library: LTE, Modulation

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]
DemapperType	demodulator type: Hard, Soft, CSI	Hard	enum	
DemapperMaxLevel	the maximum level for soft demapping output when DemapperType is Soft or CSI	1.0	real	(0,∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signals to be demapped	complex
2	CIR	channel impulse response	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	output	decision bits	real

Notes/Equations

1. This model de-maps uniform QPSK, 16-QAM and 64-QAM to bits used for channel decoding. When MappingType equals to 0, QPSK demapper is used. When MappingType equals to 1, 16QAM demapper is used. When MappingType equals to 2, 64QAM demapper is used.
2. Each firing, the data of each subframe are produced. On the calculation of number of channel bits and transport block size, please refer to *LTE_UL_ChannelCoder* (3gpplte) and *LTE_DL_ChannelCoder* (3gpplte).
3. Decision equations:
   - If MappingType is 2 input is multiplied by sqrt(42) and I is the real part of product and Q is the imaginary part, the decision equations for 64QAM are: b0 = 2.0-|b1|; b1 = 4 - |Q|; b2 = -Q; b3 = 2.0-|b4|; b4 = 4 - |I|; b5 = -I.
   - If MappingType is 1 input is multiplied by sqrt(10) and I is the real part of product and Q is the imaginary part, the decision equations for 16QAM are: b0 = 2.0-|b1|; b1 = -Q; b2 = 2.0-|b3|; b3 = -I.
   - If MappingType is 0 input is multiplied by sqrt(2) and I is the real part of product and Q is the imaginary part, the decision equations for QPSK are: b0 = -Q; b1 = -I.
4. Based on the above calculations, let any one of decision bits equal b:
   - when DecoderType is set to Hard, if b < 0, -1.0 is output, otherwise 1.0 is output.
   - when DecoderType is set to Soft, if b < -DemapperMaxLevel, -DemapperMaxLevel is output; if b > DemapperMaxLevel, DemapperMaxLevel is output, otherwise, b is output directly.
   - when DecoderType is set to CSI, after the steps of soft decision, the channel estimation of each subcarrier is considerated for the output.

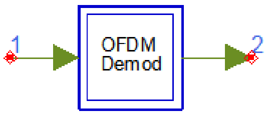
Parameter Details

- DemapperMaxLevel: the maximum level for soft demapping output when DemapperType is Soft or CSI.
- For more information, please refer to *LTE_UL_Src* (3gpplte) and *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_OFDM_Demodulator (Downlink OFDM De-modulator)



Description: Downlink MIMO OFDM De-modulator
Library: LTE, Modulation

Parameters

Name	Description	Default	Type
Bandwidth	bandwidth: BW 1.4 MHz, BW 3.2 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz	enum
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2	enum
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum

Pin Inputs

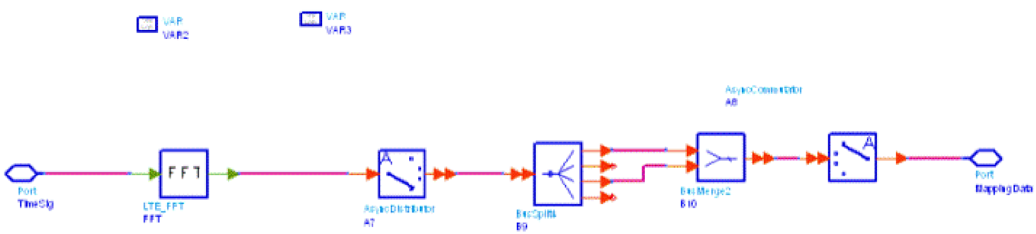
Pin	Name	Description	Signal Type
1	TimeSig	time domain signal before FFT	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	MappingData	demodulated mapping signal after FFT	multiple complex

Notes/Equations

1. This model is used to complete 3GPP LTE downlink OFDM demodulator.
2. This is a sub-network model and the schematic is shown in the following figure.



LTE_DL_OFDM_Demodulator Schematic

After removing cyclic prefix, the time domain OFDM signals are input into FFT (LTE_FFT). After LTE_FFT, the frequency domain mapping signals are output after removing NULL subcarriers and reordering. The FFT procedure is completed in LTE_FFT. The FFT size is N_{FFT}. One downlink OFDM symbol consists of $N_{BW}{}^{DL}$. Resource Block's (RB) mapping signals (the index is from 0 to $12 \times N_{BW}{}^{DL} - 1$) and one DC-NULL signal. In the ADS implementation, the input of LTE_DL_OFDM_Modulator is $N = 12 \times N_{BW}{}^{DL}$ (it does not include DC NULL subcarrier). These N mapping signals in one OFDM symbol are output as follows:

$$d[i] = \begin{cases} x\left[i + N_{FFT} - \frac{N}{2}\right] & i = 0, 1, \ldots, \frac{N}{2} - 1 \\ x\left[i - \frac{N}{2} + 1\right] & i = \frac{N}{2}, \ldots, N - 1 \end{cases}$$

where input signals of LTE_DL_OFDM_Demodulator are $x[0], \ldots, x[N_{FFT} - 1]$. The output signals of LTE_DL_OFDM_Demodulator are $d[0], \ldots, d[N-1]$. The FFT size N_{FFT} is determined by Bandwidth and OversamplingOption. If Bandwidth is selected, the basic FFT size (!3gpplte-6-06-34.gif!) is also determined (see the following table).

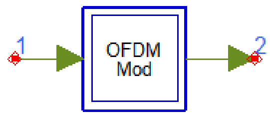
Bandwidth (MHz)	FFT Size ($N_{basic-FFT}$)
1.4	128
3	256
5	512
10	1024
15	1536
20	2048

The FFT size (!3gpplte-6-06-35.gif!) of LTE_FFT is as follows:
$N_{FFT} = N_{basic-FFT} \times 2^{OversamplingOption}$
Please note the length of cyclic prefix per each OFDM in one slot is not the same. The CP is always set to zeros and the cyclic prefix inserting is completed in LTE_DL_MuxSlot.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_OFDM_Modulator (Downlink OFDM Modulator)



Description: Downlink OFDM modulator
Library: LTE, Modulation

Parameters

Name	Description	Default	Type
Bandwidth	bandwidth: BW 1.4 MHz, BW 3.2 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz	enum
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2	enum

Pin Inputs

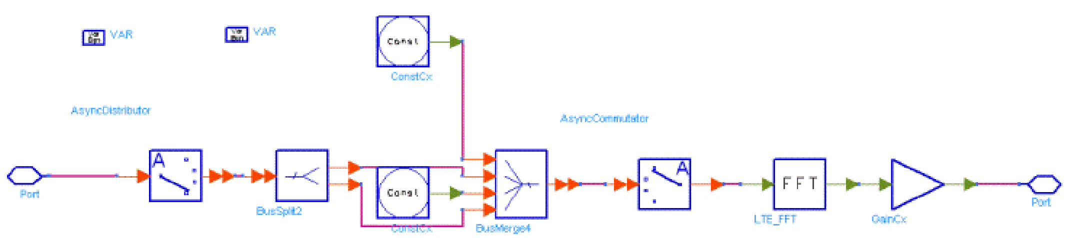
Pin	Name	Description	Signal Type
1	MappingData	mapping signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	OFDMSig	output of one OFDM signal	complex

Notes/Equations

1. This model is used to complete 3GPP LTE downlink OFDM modulator.
2. This is a sub-network model and the schematic is shown in the following figure.



LTE_DL_OFDM_Modulator Schematic

The inverse FFT procedure is completed in LTE_FFT. The inverse IFFT size is N_{FFT}. One downlink OFDM symbol consists of N_{BW}^{DL} . Resource Block (RB)'s mapping signals (the index is from 0 to $12 \times N_{BW}^{DL} - 1$) and one DC-NULL signal. In the ADS implementation, the input of LTE_DL_OFDM_Modulator is $N = 12 \times N_{BW}^{DL}$ (it does not include DC NULL subcarrier). These $12 \times N_{BW}^{DL}$ mapping signals are mapped into inverse FFT buffer as follows:

$$x[i] = \begin{cases} 0 & i = 0, \frac{N}{2}+1, \ldots, N_{FFT} - \frac{N}{2} - 1 \\ d\left[\frac{N}{2} + i - 1\right] & i = 1, 2, 3, \ldots, \frac{N}{2} \\ d\left[i - N_{FFT} + \frac{N}{2}\right] & i = N_{FFT} - \frac{N}{2}, \ldots, (N_{FFT} - 1) \end{cases}$$

where input signals of LTE_DL_OFDM_Modulator are $d[0], \ldots, d[N-1]$. The input signals of

LTE_FFT are $x[0], \ldots, x[N_{FFT}-1]$. After LTE_FFT (inverse IFFT), the time domain signal (the length is N_{FFT}) is generated. After adding cyclic prefix (By AddGuard), one time domain OFDM symbol is generated.

The FFT size N_{FFT} is determined by Bandwidth and OversamplingOption. If Bandwidth is selected, the basic FFT size ($N_{basic-FFT}$) is also determined (see the following table).

Bandwidth (MHz)	**FFT Size ($N_{basic-FFT}$)**
1.4	128
3.0	256
5	512
10	1024
15	1536
20	2048

The FFT size (N_{FFT}) of LTE_FFT is as follows:

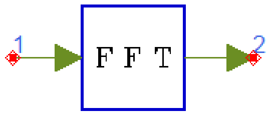
$N_{FFT} = N_{basic-FFT} \times 2^{OversamplingOption}$

Please note the length of cyclic prefix per each OFDM in one slot is not the same. The CP is always set to zeros and the cyclic prefix inserting is completed in LTE_DL_MuxSlot.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_FFT (Complex Fast Fourier Transform)



Description: Complex fast Fourier transform
Library: LTE, Modulation

Parameters

Name	Description	Default	Type	Range
InputSize	number of input samples to read	256	int	[1,∞)
FFTSize	number of the transform size	256	int	[InputSize,∞)
Direction	direction of transform: Inverse, Forward	Forward	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output signal	complex

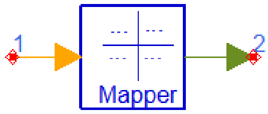
Notes/Equations

1. FFT algorithms are based on the fundamental principle of decomposing the computation of the discrete Fourier transform of a sequence of length N into successively smaller DFT.
2. A single firing of LTE_FFT consumes *InputSize* inputs and produces *FFTSize* outputs.
3. LTE_FFT calculates the DFT or IDFT of a complex input using the fast Fourier transform (FFT) algorithm. LTE_FFT reads *InputSize* (default 256) complex samples, zero pads the data if necessary, then takes an FFT of length *FFTSize* (default 256) where *InputSize* <= *FFTSize* .
4. *Direction* specifies a forward or inverse FFT.

References

1. A. V. Oppenheim and R. W. Schafer, Discrete-Time Signal Processing, Prentice-Hall: Englewood Cliffs, NJ, 1989.

LTE_Mapper (Mapper)



Description: Mapper
Library: LTE, Modulation

Parameters

Name	Description	Default	Type	Range
LinkDir	link direction: Downlink, Uplink	Downlink	enum	
Payload_Config	the configuration mode of input data for payload: MCS_index, Transport_block_size, Code_rate	Transport_block_size	enum	
Payload	the input payload, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}	real array	
MappingType	the modulation orders for the UE in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES	enum	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
NumOfLayers	number of layers for one codeword can be up to 2 for DL (for transmit diversity, it should be set to 1), and be up to 1 for UL.	1	int	[1,4]
ChBit_Config	the configuration mode of code word size.: REspersubframe, Channelbitsize	REspersubframe	enum	
NumChBits	the number of channel bits	{5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640, 5640}	int array	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	SRS subframe configuration	0	int	[0,14]
RI_NumInfoBits	RI information bits size	{0}	int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}	int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}	int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}	int array	[2,15]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data bits	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after constellation mapping	complex

Notes/Equations

1. This model takes binary digits, 0 or 1, as input and produces complex-valued modulation symbols, x=I+jQ, as output. When *MappingType* equals to 0, QPSK mapping is used. When *MappingType* equals to 1, 16QAM mapping is used. When *MappingType* equals to 2, 64QAM mapping is used.
2. Each firing,
   - 2 tokens for QPSK, 4 tokens for 16QAM, or 6 tokens for 64QAM are consumed at pin input each firing;
   - The output pin generates 1 token each firing.
3. QPSK mapping.
   In case of QPSK modulation, pairs of bits, b(n)b(n+1), are mapped to complex-valued modulation symbols x=I+jQ according to the following table.

QPSK Modulation Mapping

$b(n), b(n+1)$	*I*	*Q*
00	$1/\sqrt{2}$	$1/\sqrt{2}$
01	$1/\sqrt{2}$	$-1/\sqrt{2}$
10	$-1/\sqrt{2}$	$1/\sqrt{2}$
11	$-1/\sqrt{2}$	$-1/\sqrt{2}$

4. 16QAM mapping.
   In case of 16QAM modulation, pairs of bits, b(n)b(n+1)b(n+2)b(n+3), are mapped to complex-valued modulation symbols x=I+jQ according to the following table.

16QAM Modulation Mapping

$b(n), b(n+1), b(n+2), b(n+3)$	*I*	*Q*
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

5. 64QAM mapping.
   In case of QPSK modulation, pairs of bits, b(n)b(n+1)b(n+2)b(n+3)b(n+4)b(n+5), are mapped to complex-valued modulation symbols x=I+jQ according to the following table.

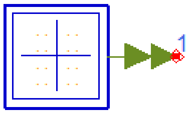
64QAM Modulation Mapping

$b(n),b(n+1),b(n+2),b(n+3),b(n+4),b(n+5)$	I	Q	$b(n),b(n+1),b(n+2),b(n+3),b(n+4),b(n+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_MIMO_Mapper (MIMO mapping for two codewords)



Description: MIMO mapping for two codewords
Library: LTE, Modulation

Parameters

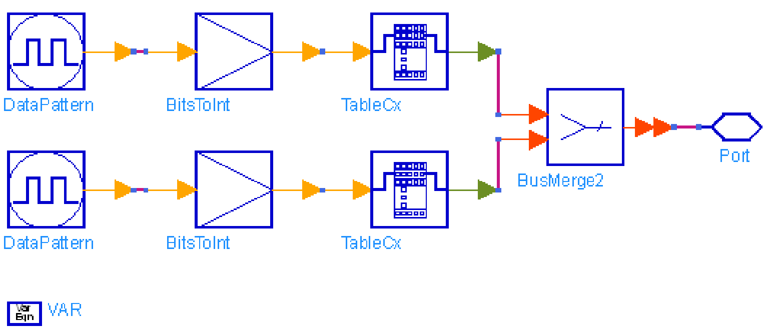
Name	Description	Default	Type
CW1_DataPattern	data pattern for codeword 1: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9	enum
CW2_DataPattern	data pattern for codeword 2: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9	enum
CW1_MappingType	modulation type for codeword 1: QPSK, QAM16, QAM64	QPSK	enum
CW2_MappingType	modulation type for codeword 2: QPSK, QAM16, QAM64	QPSK	enum

Pin Outputs

Pin	Name	Description	Signal Type
1	output	mapping signal for two codewords	multiple complex

Notes/Equations

1. This subnetwork model generates mapping signals (QPSK, 16-QAM and 64-QAM) for up to two codewords. It is only for 3GPP FDD and TDD LTE MIMO usage. The schematic for this subnetwork is shown in the following figure.



LTE_DL_MIMO_2Ant_Src Schematic

2. Each firing,
    - 2 tokens for QPSK, 4 tokens for 16QAM, or 6 tokens for 64QAM are consumed at pin input each firing;
    - The output pin generates 1 token each firing.
3. For the mapping of QPSK, 16QAM and 64QAM, the details can be found in the document for LTE Mapper.
4. Parameter Details:
    - CW1_DataPattern: data pattern for codeword 1. For the CW1_DataPattern parameter:
      if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
      if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
      if FIX4 is selected, a zero-stream is generated
      if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2 × x. In one period, the first x bits are 1s and the second x bits are 0s.
    - CW2_DataPattern: data pattern for codeword 2.
      For the DataPattern parameter:
      if PN9 is selected, a 511-bit pseudo-random test pattern is generated according

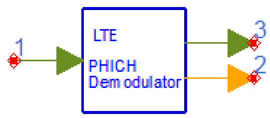
to CCITT Recommendation O.153
if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
if FIX4 is selected, a zero-stream is generated
if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2 × x. In one period, the first x bits are 1s and the second x bits are 0s.

- CW1_MappingType: modulation type for codeword 1. It can be selected as QPSK, 16_QAM and 64-QAM mapping type.
- CW2_MappingType: modulation type for codeword 2. It also can be selected as QPSK, 16_QAM and 64-QAM mapping type.

References

1. CCITT, Recommendation O.151(10/92).
2. CCITT, Recommendation O.153(10/92).
3. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_PHICH_Demodulator (LTE PHICH Demodulator)



Description: Downlink PHICH Demodulator
Library: LTE, Modulation

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	PHICH	input of PHICH symbols	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	HI	output of HI bits	int
3	Constellation	output of PHICH constellation	complex

Notes/Equations

1. This model is used to implement PHICH De-mouulation and its the inverse of LTE_PHICH_Modulator.

1. Each firing,
   - the number of tokens consumed at PHICH is $3*N_{SF}^{PHICH}*N\_PHICH\_Group(0)$ + ... + $3*N_{SF}^{PHICH}*N\_PHICH\_Group(9)$, where $N_{SF}^{PHICH}=4$ for normal cyclic prefix and $N_{SF}^{PHICH}=2$ for extended cyclic prefix.
   - the number of tokens generated at HI and Constellation is the number of HI bits: *3*NumPHICHs*N_PHICH_Group(0) + ... + 3*NumPHICHs*N_PHICH_Group(9)*, where *NumPHICHs=8* for normal cyclic prefix and *NumPHICHs=4* for extended cyclic prefix is the number of PHICHs of one PHICH group; *N_PHICH_Group(sf)* is the number of PHICH groups in this subframe as defined in Section 6.9 of 36.211. These system parameters are used to decide the *N_PHICH_Group(sf)* of each subframe.
2. Parameter details:

System Parameters	FrameMode TDD_Config Bandwidth CyclicPrefix CellID_Sector CellID_Group
PDCCH corresponding parameters	PDCCH_SymsPerSF PHICH_Ng ETM_Support

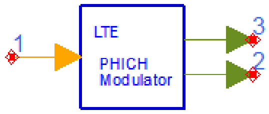
   For the system parameters, refer to *DL System Parameters* (3gpplte).
   For PDCCH corresponding parameters, refer to *DL Control Channel Parameters*

(3gpplte).
3. See *LTE_PHICH_Modulator* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.141 v8.5.0, "Base Station (BS) conformance testing", December 2009.

LTE_PHICH_Modulator (LTE PHICH Modulator)



Description: Downlink PHICH Modulator
Library: LTE, Modulation

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	HI	input of HI bits	int

Pin Outputs

Pin	Name	Description	Signal Type
2	PHICH	output of PHICH symbols	complex
3	Constellation	output of PHICH constellation	complex

Notes/Equations

1. This model is used to modulate the HI bits into PHICH symbols including constellation mapping, scrambling and spreading, and then these sequences of different PHICH in the same PHICH group are summed and output at port PHICH. The constellations of the HI bits are output at port Constellation.
   - The modulation mappings applicable for the physical hybrid ARQ indicator channel is BPSK defined in Section 7.1.1 [1]. The modulation symbols are output at Constellation.
   - The block of modulation symbols shall be bit-wise multiplied with an PN sequence and a spreading sequence, resulting in a sequence of modulation symbols. The PN sequence generated according to Section 7.2 in [1] and initialized with cinit = (slot number/2 + 1)*(2*Cell_ID + 1)*2^9 + Cell_ID in Section 6.9.1 [1].
   - The spreading sequence is given by Table 6.9.1-2 in [1] and can be set by parameter CyclicPrefix.
     In our implementation, the port PHICH is not output the data only including scrambling and spreading. These sequences of different PHICH in the same PHICH group are summed and out put at port PHICH.
2. Each firing, the number of tokens consumed and generated at HI, PHICH and Constellation as follows:
   - HI and Constellation: *3*NumPHICHs*N_PHICH_Group(0)* + ... + *3*NumPHICHs*N_PHICH_Group(9)*, where *NumPHICHs=8* for normal cyclic prefix and *NumPHICHs=4* for extended cyclic prefix is the number of PHICHs of one PHICH group; *N_PHICH_Group(sf)* is the number of PHICH groups in this subframe as defined in Section 6.9 of 36.211. These system parameters are used to decide the *N_PHICH_Group(sf)* of each subframe.
   - PHICH: $3*N_{SF}^{PHICH}$*N_PHICH_Group(0)* + ... + $3*N_{SF}^{PHICH}$*N_PHICH_Group(9)*,
     PHICH PHICH

where N_{SF} =*4* for normal cyclic prefix and N_{SF} =*2* for extended cyclic prefix.

3. Parameter details:

System Parameters	FrameMode TDD_Config Bandwidth CyclicPrefix CellID_Sector CellID_Group
PDCCH corresponding parameters	PDCCH_SymsPerSF PHICH_Ng ETM_Support

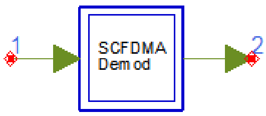
For the system parameters, refer to *DL System Parameters* (3gpplte).
For PDCCH corresponding parameters, refer to *DL Control Channel Parameters* (3gpplte).

4. See *LTE_DL_HI* (3gpplte) and *LTE_PHICH_LayerMapper* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_SCFDMA_Demodulator (Uplink SC-FDMA De-modulator)



Description: Uplink SC-FDMA de-modulator
Library: LTE, Modulation

Parameters

Name	Description	Default	Type
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz	enum
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2	enum

Pin Inputs

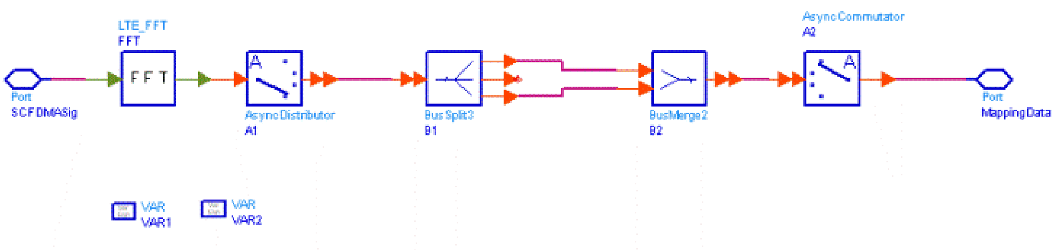
Pin	Name	Description	Signal Type
1	SCFDMASig	SC-FDMA signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	MappingData	mapping signal	complex

Notes/Equations

1. This subnetwork performs LTE uplink SC-FDMA demodulation. The schematic for this subnetwork is shown in the following figure.



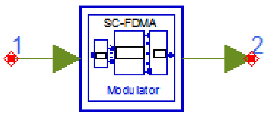
LTE_SCFDMA_Demodulator Schematic

2. See *LTE_SCFDMA_Modulator* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_SCFDMA_Modulator (Uplink SC-FDMA Modulator)



Description: Uplink SC-FDMA modulator
Library: LTE, Modulation

Parameters

Name	Description	Default	Type
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz	enum
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2	enum

Pin Inputs

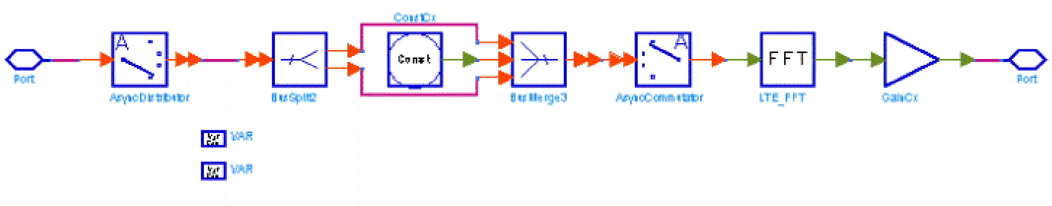
Pin	Name	Description	Signal Type
1	MappingData	mapping signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	SCFDMASig	output of SC-FDMA signal	complex

Notes/Equations

1. This subnetwork performs LTE uplink SC-FDMA modulation. The schematic for this subnetwork is shown in the following figure.



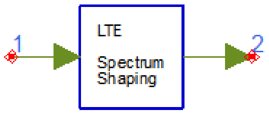
LTE_SCFDMA_Modulator Schematic

2. See *LTE_SCFDMA_Demodulator* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_SpecShaping (Spectrum Shaping)



Description: LTE Spectrum Shaper
Library: LTE, Modulation

Parameters

Name	Description	Default	Unit	Type	Range
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing		enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised_cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6		int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19		int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO		enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal_Lowpass	RRC		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22		real	[0,1.0]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input signal in one frame	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output signal in one frame	complex

Notes/Equations

1. This model is used to shape the spectrum of the transmitting signal by FIR filtering or time domain windowing.
2. Each firing,
   - the number of tokens consumed at port DataIn equals the number of samples in each frame, which is determined by Bandwidth and OversamplingOption, $NumSamplesPerFrame = F_s * 2^{\text{OversamplingOption}} *$ 10ms.
   - the number of tokens produced at port DataOut equals the number of tokens consumed at port DataIn.
   - For the default parameter configurations, each firing, the number of tokens consumend at port DataIn and produced at port DataOut would be 7.68MHz * 2 * 10ms = 153600.
3. For Time Windowing, Tukey window and Raised Cosine window is provided.

- To make the spectrum goes down more rapidly, windowing can be applied to the individual OFDM symbols. Windowing on OFDM symbol makes the amplitude go smoothly to zero at the symbol boundaries. As a result, the inter-channel interference can be reduced.
- The **Time Windowing** figure shown below depicts the principle of the windowing function, whereby an extended cyclic prefix and/or postfix are/is inserted to cover an overlap of the windowing functions for adjacent OFDM symbols.

- The length of prefix is equal to the absolute value of *CI_StartPos*. *CI_StartPos* is a negative value indicating that the prefix is inserted before CP.
- The number of *CyclicInterval* samples from the beginning of the extended cyclic prefix is multiplied by the raising half of the Tukey window or RC window, and the last *CyclicInterval* samples including postfix is multiplied by the falling half of the Tukey window or RC window. The samples in the roll-off region of the adjacent symbols are overlapped.

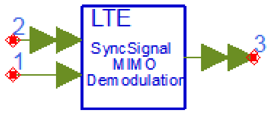
4. For FIR filtering, Square-Root Raised Cosine filter and ideal lowpass filter are provided. The number of taps of the filter is determined by FIR_Taps, while whether perform interpolation or not is determined by FIR_withInterp. RRC_Alpha is the roll-off factor for root raised-cosine filter.
5. For Time Windowing, this model would cause |*CI_StartPos*| samples delay (without oversampling) to the input signal; for FIR filtering, there is no delay to the input signal.

> For more information on the parameters, please refer to *UL Spectrum Shaping Parameters* (3gpplte) and *DL Spectrum Shaping Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.
4. Harris, F. J. "On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform" Proceedings of the IEEE. Vol. 66 (January 1978).

LTE_SS_MIMO_Demod (MIMO Demodulation for Sync Signals)



Description: MIMO demodulatio for Sync signals (PSS and SSS)
Library: LTE, Modulation

Parameters

Name	Description	Default	Type
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum

Pin Inputs

Pin	Name	Description	Signal Type
1	H	CIR for Sync signals	complex
2	RxSync	received Sync signals	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	DemodSignal	demodulated Syn signals	multiple complex

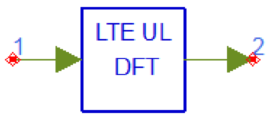
Notes/Equations

1. This model is used to perform the MIMO decoding for P-SCH and S-SCH in MIMO transmission.
2. The bus width at port RxSync should be equal to the NumRxAnts parameter.
   The bus width at port DemodSignal should be equal to the NumTxAnts parameter.
   The input at port H should be the serial CIRs for received signals.
3. Each firing,
   - One token with the bus width of NumRxAnts is consumed at port RxSync
   - NumTxAnts*NumRxAnts tokens are consumed at port H
   - One token with the bus width of NumTxAnts is produced at port DemodSignal
4. Firstly, the H matrix with the size NumRxAnts by NumTxAnts is constructed read from port H, and the Y matrix with the size NumRxAnts by 1 is constructed read from port RxSync. Then the following is performed to get the decoded DemodSignal (X) matrix with the size NumTxAnts by 1:
   $$X = (H^* H)^{-1} H^* Y$$
   The matrix X is output at port DemodSignal.
5. Note that, when the matrix (H^*H) is singular, the output DemodSignal is set to RxSync/NumRxAnts.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_DFT (Complex Discrete Fourier Transform for Uplink)



Description: Complex discrete Fourier transform for uplink
Library: LTE, Modulation

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}	int array	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	the cell-specific SRS subframe configuration	0	int	[0, 14]
Direction	direction of transform: Inverse, Forward	Forward	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output signal	complex

Notes/Equations

1. This model performs DFT or IDFT of LTE uplink signal using the fast Fourier transform (FFT) algorithm.
2. Each firing, the number of tokens consumed at input and produced at output are equal to the number of REs allocated for PUSCH in the each frame, which is determined by FrameMode, Bandwidth, CyclicPrefix, RB_AllocType, RB_Alloc, PUCCH_PUSCH, SRS_Enable and SRS_SF_Config, for more details, please refer to *Resource Block Allocation* (3gpplte). When SRS_Enable is YES, the last symbol of SRS cell specific subfames would be reserved for SRS transmission. For the default parameter configurations, the size of the matrix token in each frame is 25 RBs * 120 Symbols = 36000.
3. The direction of DFT is determined by Direction, which can be selected as Inverse and Forward.
4. The number of REs allocated for PUSCH in each subframe also determines the length of FFT. FFT algorithms are based on the fundamental principle of decomposing the computation of the discrete Fourier transform of a sequence of length N into successively smaller DFT. Many different algorithms are generated based on the decomposing principle, all with comparable improvements in computational speed.

   For more information on the parameters, please refer to *UL PUSCH Parameters* (3gpplte).

References

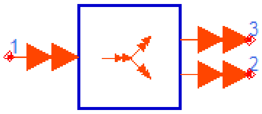
1. A. V. Oppenheim and R. W. Schafer, Discrete-Time Signal Processing, Prentice-Hall: Englewood Cliffs, NJ, 1989.

2. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA)", V7.0.0, June 2006.

3GPP LTE Multiplex Components

Contents

LTE_BusFork2 (Copy particles from an input bus to each output bus)



Description: Copy particles from an input bus to each output bus
Library: LTE, Multiplex

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	multiple anytype

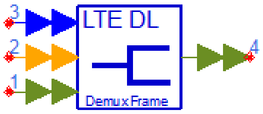
Pin Outputs

Pin	Name	Description	Signal Type
2	outputA	outputA signal	multiple anytype
3	outputB	outputB signal	multiple anytype

Notes/Equations

1. This model is used to explicitly connect a multi-port output pin of a component to 2 multi-port input pins of other components.
2. The bus width of input pin and output pins should be same in order for the model to work properly.
3. LTE_BusFork2 is typically used with numeric signals.
4. When forced to connect with timed signals, it assumes infinite equivalent input resistances and zero equivalent output resistances.

LTE_DL_DemuxFrame (Downlink Radio Frame De-multiplexer with Frequency Offset Compensator)



Description: Downlink Radio Frame De-multiplexer with Frequency Offset Compensator
Library: LTE, Multiplex

Parameters

Name	Description	Default	Unit	Type	Range
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
PreDownsampling	pre-downsampling to 1X symbol rate ?: NO, YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	multiple complex
2	index	propagation delay in samples	multiple int
3	DeltaF	frequency offset	multiple real

Pin Outputs

Pin	Name	Description	Signal Type
4	DataOut	data out	multiple complex

Notes/Equations

1. This model is used to demultiplex LTE downlink frame, which includes removing idle interval, pre-downsampling, and compensating time and carrier frequency offsets.
2. All the input and output ports are multiple ports whose bandwidth should be equal to the NumRxAnts parameter.
3. Each firing, 1 token is consumed at index and DeltaF respectively, and *SamplingFreq* $* 2^{\text{OversamplingOption}} *$ *(0.01 + IdleInterval)* tokens are consumed at DataIn, which is the number of samples 20 slots and idle interval contain. 0.01 is the time duration of the 20 time slots which constitute one radio frame, and IdleInterval is the time duration of the idle interval. SamplingFreq is sampling frequency, which is denoted as Fs and determined by Bandwidth as follows:

$$F_s = \begin{cases} 1.92MHz & BW = 1.4MHz \\ 3.84MHz & BW = 3MHz \\ 7.68MHz & BW = 5MHz \\ 15.36MHz & BW = 10MHz \\ 23.04MHz & BW = 15MHz \\ 30.72MHz & BW = 20MHz \end{cases}$$

   And each firing, *SamplingFreq * 0.01* tokens are exported if PreDownsampling is set to YES, otherwise *SamplingFreq* $* 2^{\text{OversamplingOption}} *$ *0.01* tokens are exported if PreDownsampling is set to NO.
4. Because of the transmission delay, a detected frame usually falls into 2 consecutive received blocks, so the buffer length for DataIn is *SamplingFreq * 2OversamplingOption * (0.01 + IdleInterval) * 2*. The start point of the detected frame is determined by the token consumed at index. Only after receiving the second input block, this model can output one actual frame. So this model causes one frame delay.
5. The DeltaF inputs the estimated frequency offset (Δf_i) of each received frame. The i-

th estimated frequency offset (Δf_i) compensates for the phase in the current frame only. Assume $x_0, x_1, \ldots, x_N$ sequences are the input signals from DataIn, $y_0, y_1, \ldots, y_N$ are the sequences, whose phase caused by frequency offset are removed, where N is the number of samples within one radio frame. Then:

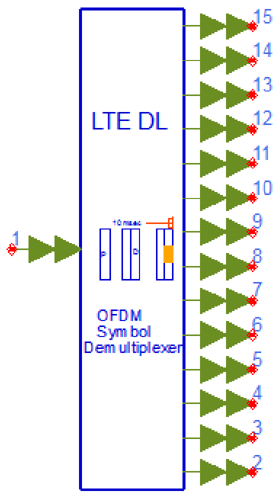
$$y_k = x_k \times e^{-j2\pi\Delta f_i k T_{Step}}$$

where Δf_i is frequency offset of the i-th received frame which is the input at DeltaF, $T_{Step} = \frac{1}{F_s \times 2^{OversamplingOption}}$ is the sample time interval in the system.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_DemuxOFDMSym (Downlink OFDM Symbol De-multiplexer in One Radio Frame)



Description: Downlink OFDM Symbol De-multiplexer in one radio frame
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized	enum	
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO	enum	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}	int array	[0,1]
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration	enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1	enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}	real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

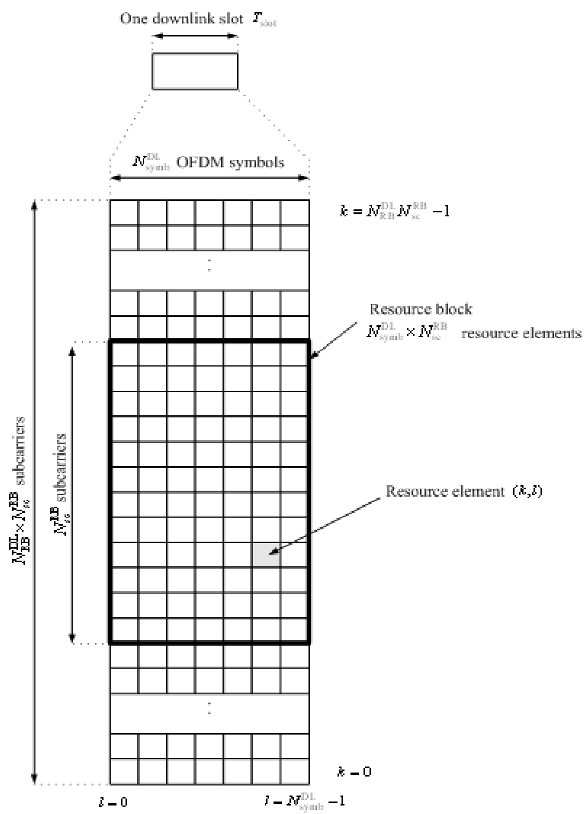
Pin	Name	Description	Signal Type
1	DataIn	downlink OFDM symbols in one frame	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	Pilots	output pilots	multiple complex
3	PSCH	output P-SCH mapping signal	multiple complex
4	SSCH	output S-SCH mapping signal	multiple complex
5	BCH	output CCPCH mapping signal	multiple complex
6	PCFICH	output mapping signal of PCFICH	multiple complex
7	PHICH	output mapping signal of PHICH	multiple complex
8	PDCCH	output mapping signal of PDCCH	multiple complex
9	Data_UE6	output signal data for UE6	multiple complex
10	Data_UE5	output signal data for UE5	multiple complex
11	Data_UE4	output signal data for UE4	multiple complex
12	Data_UE3	output signal data for UE3	multiple complex
13	Data_UE2	output signal data for UE2	multiple complex
14	Data_UE1	output signal data for UE1	multiple complex
15	StdOut	downlink OFDM symbols without scale factor in one frame	multiple complex

Notes/Equations

1. This model is used to de-multiplex 3GPP LTE FDD and TDD downlink OFDM Symbol into various physical channels (PDCCH, PCFICH, PHICH and PBCH), synchronization signals (RS, PSCH, SSCH) and users information (PDSCH1, PDSCH2,..., PDSCH6) and etc.
2. For all the input and output multiple ports, the bandwidth should be equal to the NumRxAnts parameter.
3. The transmitted UEs signal in each subframe is described by a resource grid of !LTE_DL_NSC.gif! subcarriers and !LTE_DL_NSym.gif! OFDM symbols. The resource grid and structure is illustrated in the following figure. Each element in the resource grid is called a resource atom and each resource atom corresponds to one complex-valued modulation symbol. Resource atoms not used for transmission of a physical channel or a physical signal in a subframe shall be set to zero.

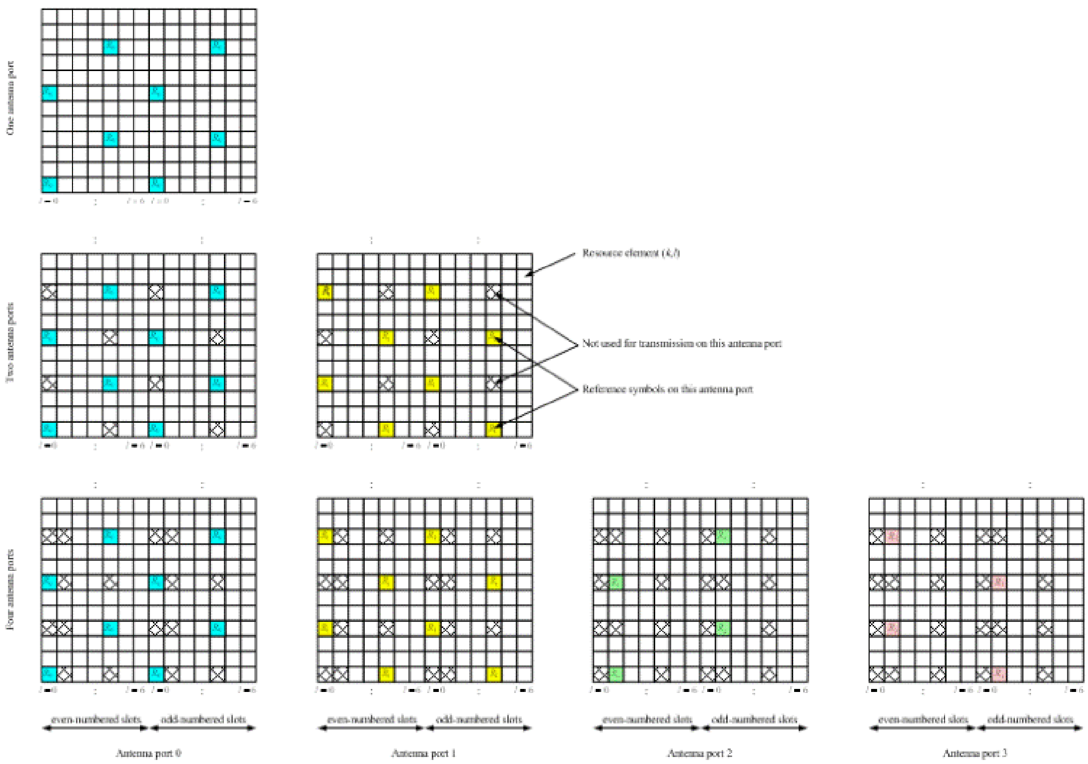


Downlink Resource Grid

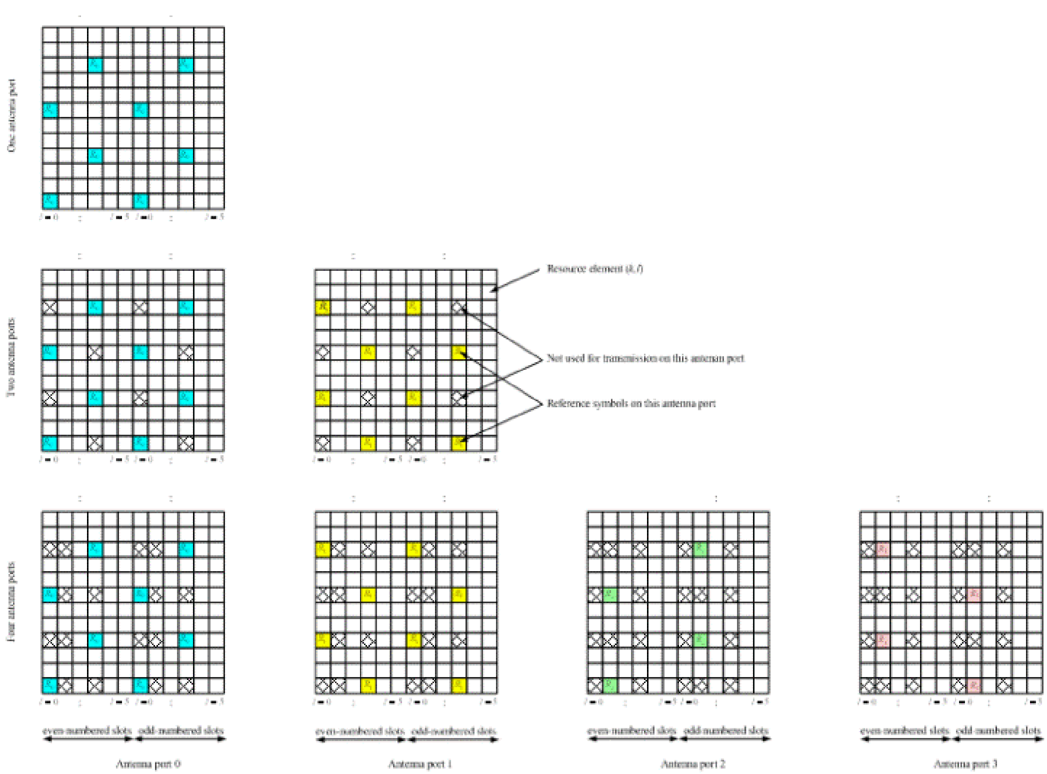
The value of !LTE_DL_NSC.gif! depends on the transmission bandwidth. Note that

!LTE_DL_NSC.gif! does not include the DC subcarrier.

4. The downlink reference signal (RS) are always transmitted in the first OFDM symbol and the last third symbol in one slot. The RS are mapped according to Section 6.10.1.2 in [1]. Resource elements (*k*,*l*) used for reference signal transmission on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero. The following figures illustrate the resource elements used for reference signal transmission according to the definition.



Mapping of downlink reference signals (normal cyclic prefix)



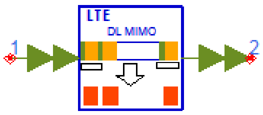
Mapping of downlink reference signals (extended cyclic prefix)

5. The primary synchronization signal (PSS) is transmitted in the last OFDM symbol in slot 0 and slot 10 for FDD and is transmitted in the third OFDM symbol in subframe 1 and 6 for TDD. The secondary synchronization signal (SSS) is transmitted in the last second OFDM symbol in slot 0 (subframe 0) and slot 10 (subframe 5) for FDD and is transmitted in the last OFDM symbols in slot 1 (subframe 0) and slot 11 (subframe 5) for TDD. Both PSCH and SSS occupy centeral 6 resource blcoks (RB, 72 subcarriers). The SS_PerTxAnt parameter determines whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.
6. The PCFICH, PHICH and PDCCCH are transmitted in each subframe according to PDCCH_SymsPerSF and parameters related to PHICH mapping including PHICH_Ng, PHICH_Duration and CyclicPrefix. PDCCH_SymsPerSF[i] determines how many OFDM symbols are used to transmit control information in the ith subframe. The value range of PDCCH_SymsPerSF[i] is 0, 1, 2 and 3 except subframe 1 and 6 for TDD which is 0, 1 and 2. Note that PDCCH_SymsPerSF is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1.
   If PDCCH_SymsPerSF[i]>0, the PCFICH is mapped in the first OFDM symbol of the *i*th subframe according to section 6.7.4 in [1]. After the PCFICH mapping, the PHICH is mapped according to section 6.9.3 in [1] and then the PDCCH is mapped to the remnent resource-element groups in the first PDCCH_SymsPerSF[i] OFDM symbols of ith subframe according to section 6.8.5 in [1].
7. PBCH is always transmitted in the first 4 OFDM symbols in slot 1(subframe 0). PBCH occupies centeral 6 RBs (same as PSCH and SSCH) in spectrum. The mapping operation shall assume cell-specific reference signals for antenna ports 0-3 being present irrespective of the actual configuration. Resource elements assumed to be reserved for reference signals in the mapping operation above but not used for transmission of reference signal shall not be used for transmission of any physical channel.
8. Parameters Details
   - System Parameters Details:
     - For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
     - SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.
   - UE1 Parameters Details:
     - Refer to *DL UE1 Parameters* (3gpplte).
   - OtherUEs Parameters Details:
     - Refer to *DL OtherUEs Parameters* (3gpplte).
   - Control Channel Parameters Details:
     - Refer to *DL Control Channel Parameters* (3gpplte).
   - Power Parameters
     - Refer to *DL Power Parameters* (3gpplte).
     - Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Rb), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Rb-10log10(P)), where P is the number of antenna ports.
     - For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_DemuxSlot (Downlink Slot De-multiplexer)



Description: Downlink Slot De-multiplexer for LTE DL receiver
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum
Sym_StartPos	start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP	{-3,-3}	int array

Pin Inputs

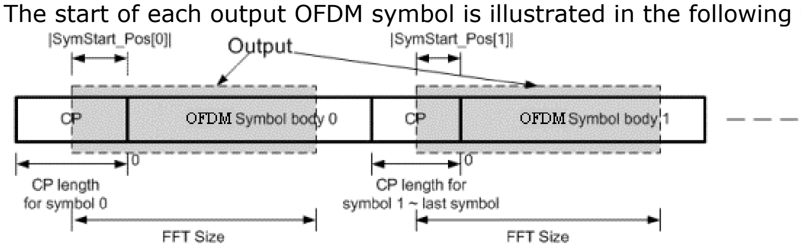
Pin	Name	Description	Signal Type
1	FrameData	input downlink frame symbol	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	OFDMSig	OFDM signal	multiple complex

Notes/Equations

1. This model is used to demultiplex 3GPP LTE downlink slot.
2. Each 10 ms radio frame consists of 20 slots of length, numbered from 0 to 19. Each 0.5 ms slot consists of 7 OFDM symbols for normal cyclic prefix or 6 OFDM symbols for extended cyclic prefix.
   The cyclic prefix of each OFDM symbol is removed in this model. For normal cyclic prefix, the first OFDM symbol within a slot has different cyclic prefix lengths from other 6 OFDM symbols. For extended cyclic prefix, the 6 OFDM symbols have same cyclic prefix lengths.
3. The start of each output OFDM symbol is illustrated in the following figure.



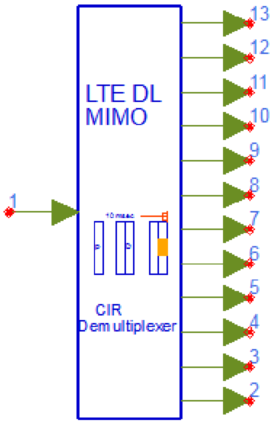
4. Sym_StartPos is an array of two elements, indicating the start position (without oversampling) of the first output OFDM symbol and other output OFDM symbols in each slot respectively. Here the "start position" is compared to the first sample of the input OFDM symbol body excluding the cyclic prefix. Hence the value is negative indicating the start position locates in the CP duration of the input symbol as shown in the figure.
5. It would be better set Sym_StartPos to a certain value so that the "Output" in the above figure is a whole SC-FDMA symbol which is not affected by the spectrum shaping in the transmitter. Hence, the value of Sym_StartPos depends on the CP length (samples) and the spectrum shaping employed in *LTE_DL_Src* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.

3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_MIMO_DemuxCIR (Downlink CIR Demultiplexer)



Description: Downlink CIR De-multiplexer in one radio frame
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized	enum	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}	int array	[0,1]
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration	enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1	enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}	real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

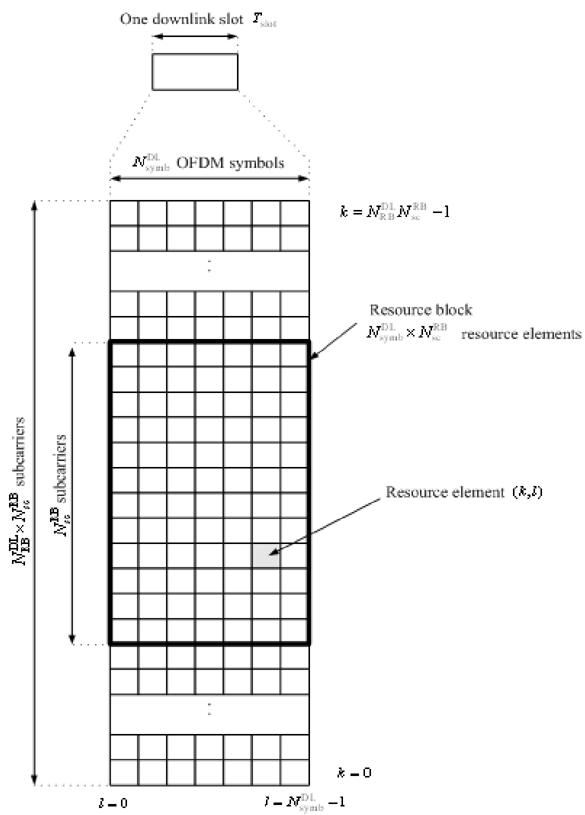
Pin	Name	Description	Signal Type
1	H_DataIn	CIR of downlink OFDM symbols in one frame	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	H_PSCH	CIR of P-SCH mapping signal	complex
3	H_SSCH	CIR of S-SCH mapping signal	complex
4	H_BCH	CIR of BCH mapping signal	complex
5	H_PDCCH	CIR of PDCCH mapping signal	complex
6	H_PCFICH	CIR of PCFICH mapping signal	complex
7	H_PHICH	CIR of PHICH mapping signal	complex
8	H_Data_UE6	CIR of signal data from UE	complex
9	H_Data_UE5	CIR of signal data from UE	complex
10	H_Data_UE4	CIR of signal data from UE	complex
11	H_Data_UE3	CIR of signal data from UE	complex
12	H_Data_UE2	CIR of signal data from UE	complex
13	H_Data_UE1	CIR of signal data from UE	complex

Notes/Equations

1. This model is used to de-multiplex the CIR of 3GPP LTE FDD and TDD downlink signal according to various physical channels (PDCCH, PCFICH, PHICH and PBCH), synchronization signals (RS, PSCH, SSCH) and users information (PDSCH1, PDSCH2,..., PDSCH6) and etc.
2. For all the input and output ports, the channel estimation of each subcarrier H_i should be expressed by NumRxAnts * NumTxAnts tokens and with the same order of LTE_DL_ChEstimator's output.
3. The transmitted UEs signal in each subframe is described by a resource grid of !LTE_DL_NSC.gif! subcarriers and !LTE_DL_NSym.gif! OFDM symbols. The resource grid and structure is illustrated in the following figure. Each element in the resource grid is called a resource atom and each resource atom corresponds to one complex-valued modulation symbol. Resource atoms not used for transmission of a physical channel or a physical signal in a subframe shall be set to zero.

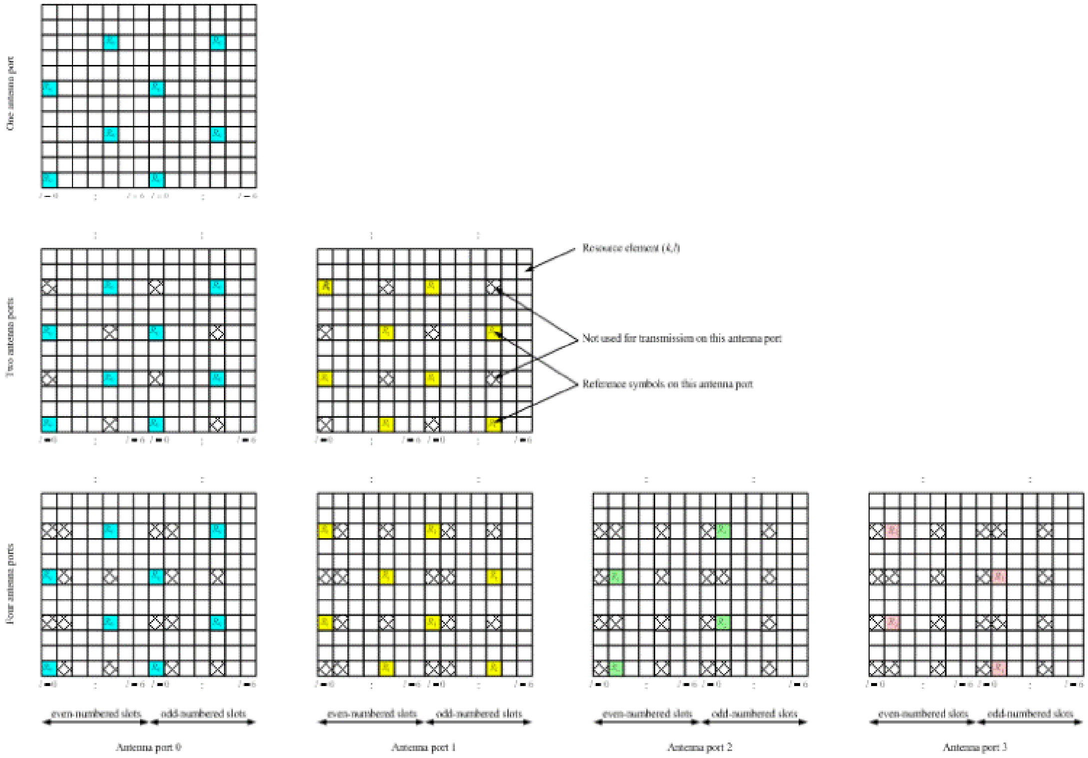


Downlink Resource Grid

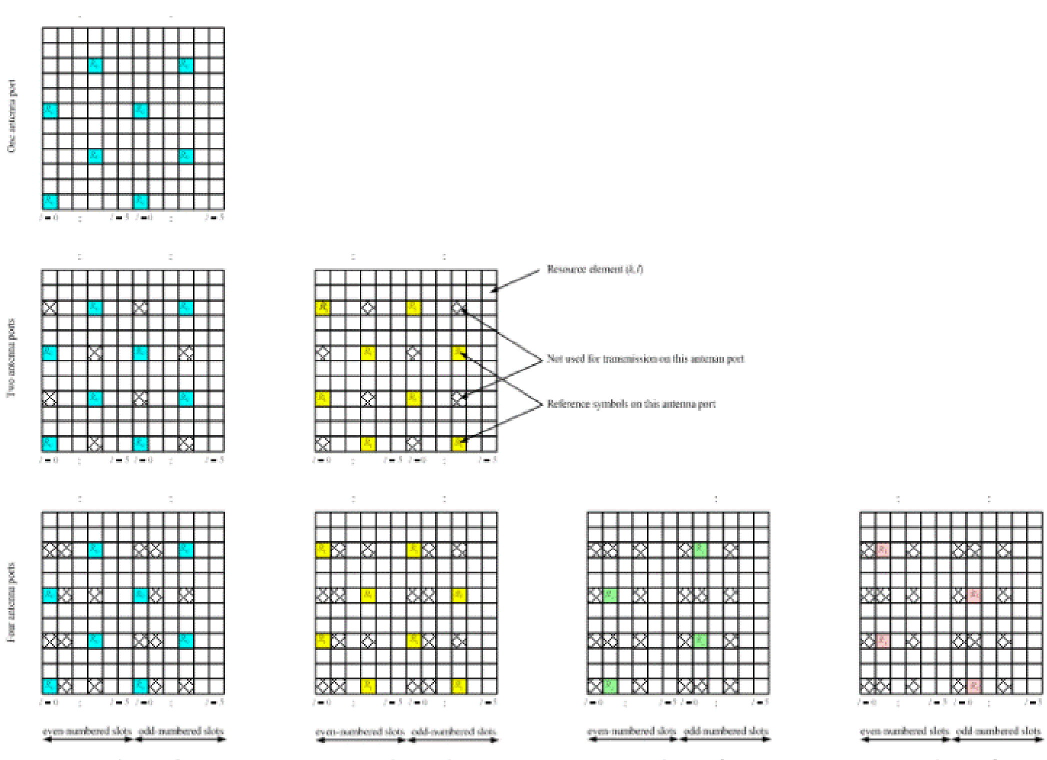
The value of !LTE_DL_NSC.gif! depends on the transmission bandwidth. Note that !LTE_DL_NSC.gif! does not include the DC subcarrier.

4. The downlink reference signal (RS) are always transmitted in the first OFDM symbol and the last third symbol in one slot. The RS are mapped according to Section 6.10.1.2 in [1]. Resource elements (k,l) used for reference signal transmission on

any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero. The following figures illustrate the resource elements used for reference signal transmission according to the definition.



Mapping of downlink reference signals (normal cyclic prefix)



Mapping of downlink reference signals (extended cyclic prefix)

5. The primary synchronization signal (PSS) is transmitted in the last OFDM symbol in slot 0 and slot 10 for FDD and is transmitted in the third OFDM symbol in subframe 1 and 6 for TDD. The secondary synchronization signal (SSS) is transmitted in the last second OFDM symbol in slot 0 (subframe 0) and slot 10 (subframe 5) for FDD and is

transmitted in the last OFDM symbols in slot 1 (subframe 0) and slot 11 (subframe 5) for TDD. Both PSCH and SSS occupy central 6 resource blcoks (RB, 72 subcarriers).

6. The PCFICH, PHICH and PDCCCH are transmitted in each subframe according to PDCCH_SymsPerSF and parameters related to PHICH mapping including PHICH_Ng, PHICH_Duration and CyclicPrefix. PDCCH_SymsPerSF[i] determines how many OFDM symbols are used to transmit control information in the ith subframe. The value range of PDCCH_SymsPerSF[i] is 0, 1, 2 and 3 except subframe 1 and 6 for TDD which is 0, 1 and 2. Note that PDCCH_SymsPerSF is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1.
If PDCCH_SymsPerSF[i]>0, the PCFICH is mapped in the first OFDM symbol of the *i*th subframe according to section 6.7.4 in [1]. After the PCFICH mapping, the PHICH is mapped according to section 6.9.3 in [1] and then the PDCCH is mapped to the remnent resource-element groups in the first PDCCH_SymsPerSF[i] OFDM symbols of ith subframe according to section 6.8.5 in [1].
7. PBCH is always transmitted in the first 4 OFDM symbols in slot 1(subframe 0). PBCH occupies the center 6 RBs (same as PSCH and SSCH) in spectrum. Resource elements assumed to be reserved for reference signals in the mapping operation above but not used for transmission of reference signal shall not be used for transmission of any physical channel.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

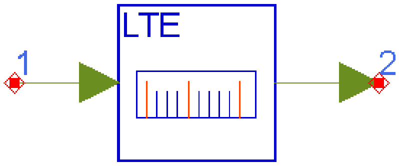
Power Parameters

- Refer to *DL Power Parameters* (3gpplte).
- Note that for PSS_Rb, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Rb), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Rb-10log10(P)), where P is the number of antenna ports.
- For SSS_Rb, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MuxFrame (Downlink Radio Frame Multiplexer)



Description: Downlink radio frame multiplexer
Library: LTE, Multiplex

Parameters

Name	Description	Default	Unit	Type	Range
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	complex

Notes/Equations

1. This model is used to multiplex 20 slots into one radio frame (10 ms) and insert idle interval (time duration is IdleInterval) between two consecutive radio frames. Each firing, *SamplingFreq x* $2^{OversamplingOption}$ *x 0.01* tokens are consumed, which is the number of samples 20 slots contain. *SamplingFreq* is sampling frequency, which is denoted as F_s and determined by Bandwidth as follows:

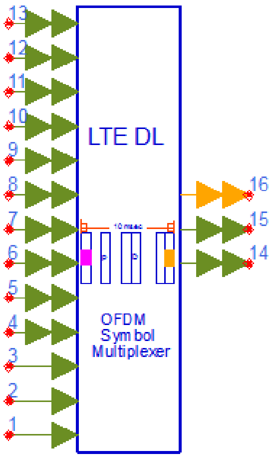
$$F_s = \begin{cases} 1.92MHz & BW = 1.4MHz \\ 3.84MHz & BW = 3.0MHz \\ 7.68MHz & BW = 5MHz \\ 15.36MHz & BW = 10MHz \\ 23.04MHz & BW = 15MHz \\ 30.72MHz & BW = 20MHz \end{cases}$$

And each firing, *SamplingFreq x* $2^{OversamplingOption}$ *x (0.01 + IdleInterval)* tokens are exported, which is the number of samples 20 slots and idle interval contain. The 0.01 is the time duration of the 20 time slots which constitute one radio frame, and *IdleInterval* is the time duration of the idle.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_MuxOFDMSym (Downlink OFDM Symbol Multiplexer in One Radio Frame)



Description: Downlink OFDM Symbol Multiplexer in one radio frame
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized	enum	
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO	enum	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}	int array	[0,1]
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}	int array	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration	enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
RS_EPRE	transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz	-25	real	(-∞,∞)
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0	real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1	enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}	real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0	real	(-∞,∞)
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

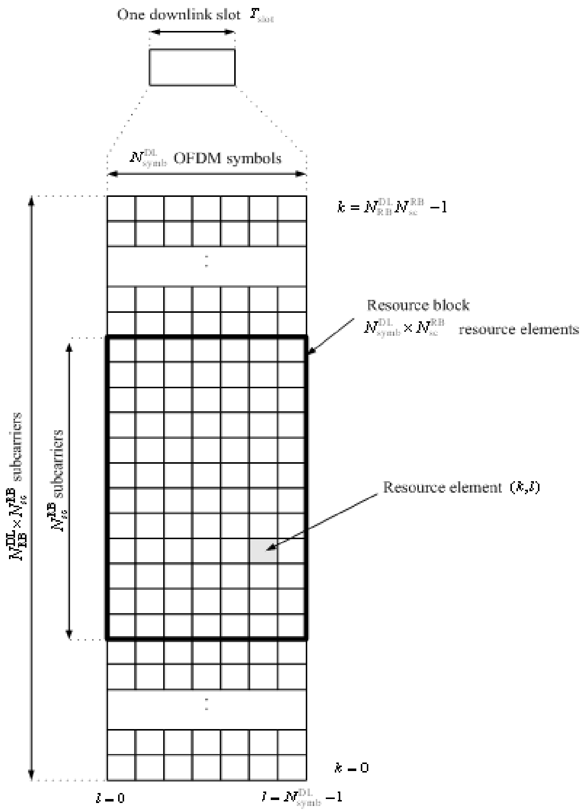
Pin	Name	Description	Signal Type
1	Pilots	input pilots	complex
2	PSCH	input P-SCH mapping signal	complex
3	SSCH	input S-SCH mapping signal	complex
4	BCH	input CCPCH mapping signal	multiple complex
5	PCFICH	input mapping signal of PCFICH	multiple complex
6	PHICH	input mapping signal of PHICH	multiple complex
7	PDCCH	input mapping signal of PDCCH	multiple complex
8	Data_UE6	input signal data from UE6	multiple complex
9	Data_UE5	input signal data from UE5	multiple complex
10	Data_UE4	input signal data from UE4	multiple complex
11	Data_UE3	input signal data from UE3	multiple complex
12	Data_UE2	input signal data from UE2	multiple complex
13	Data_UE1	input signal data from UE1	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
14	DataOut	downlink OFDM symbols in one frame	multiple complex
15	StdOut	downlink OFDM symbols without scale factor in one frame	multiple complex
16	SC_Status	downlink subcarrier (resource element) status in one frame	multiple int

Notes/Equations

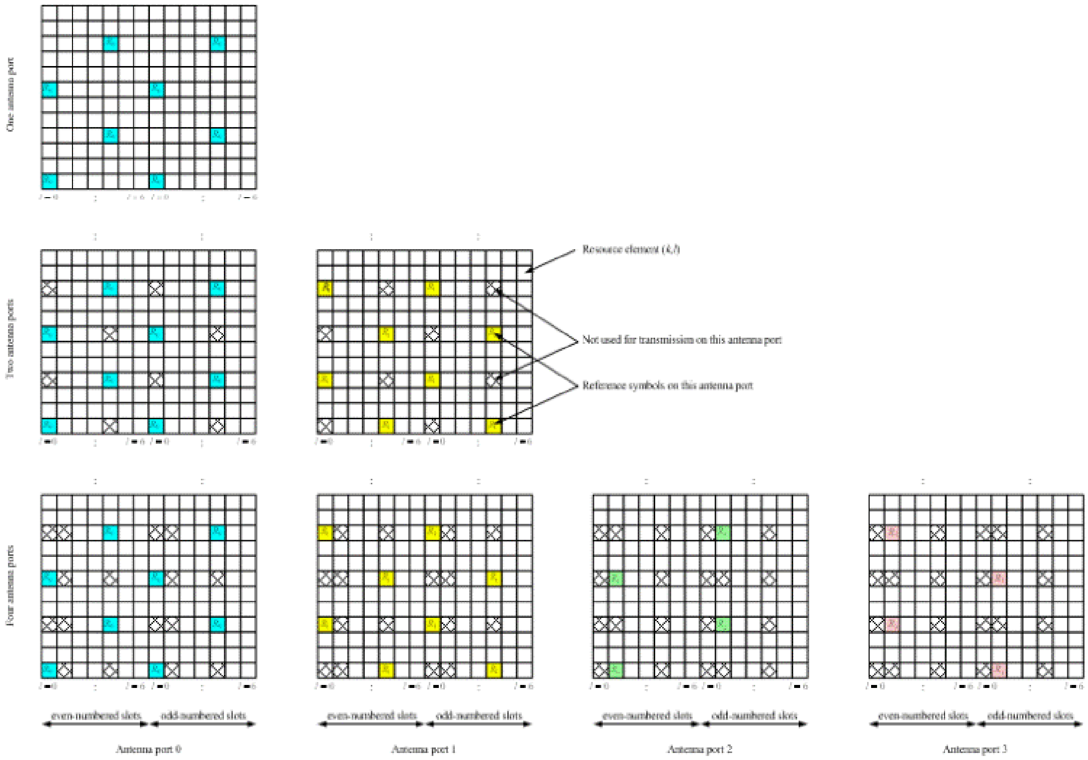
1. This model is used to constitute 3GPP LTE FDD and TDD downlink OFDM Symbol. It multiplex control channels PCFICH, PHICH PDCCH and PBCH), synchronization signals(PSS, SSS, RS) and data channels PUSCH1 to PUSCH6 into one OFDM frame.
2. For all the input and output multiple ports, the bandwidth should be equal to the NumTxAnts parameter.
3. Each firing,
   For each antenna port, the number of tokens consumed at ports Data_UEx (x is 1~6) are equal to the number of resource elements (REs) allocated to this UE (PDSCH) in one radio frame (10 subframes), which are shown in ADS Status/Summary window when the DisplayMsg parameter is set to Simple or Full. For more information on how to get the number of allocated REs given the UEx_RB_Alloc parameter (x is 1~6), refer to *Resource Block Allocation* (3gpplte) and *Channel Bits Calculation* (3gpplte).
4. The transmitted UEs signal in each subframe is described by a resource grid of $N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{DL}}$ OFDM symbols. The resource grid and structure is illustrated in the following figure. Each element in the resource grid is called a resource atom and each resource atom corresponds to one complex-valued modulation symbol. Resource atoms not used for transmission of a physical channel or a physical signal in a subframe shall be set to zero.



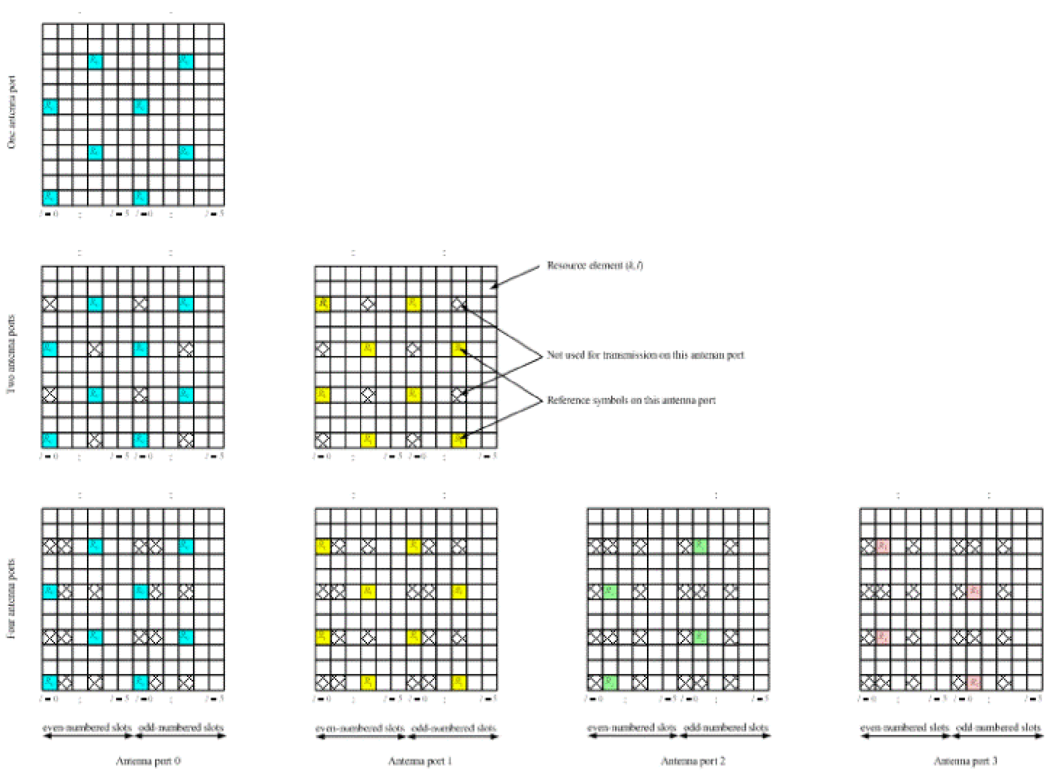
Downlink Resource Grid

The value of $N_{RB}^{DL} N_{sc}^{RB}$ depends on the transmission bandwidth. Note that $N_{RB}^{DL} N_{sc}^{RB}$ does not include the DC subcarrier.

5. The downlink reference signal (RS) are always transmitted in the first OFDM symbol and the last third symbol in one slot. The RS are mapped according to Section 6.10.1.2 in [1]. Resource elements (*k*,*l*) used for reference signal transmission on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero. The following figures illustrate the resource elements used for reference signal transmission according to the definition.



Mapping of downlink reference signals (normal cyclic prefix)



Mapping of downlink reference signals (extended cyclic prefix)

6. The primary synchronization signal (PSS) is transmitted in the last OFDM symbol in slot 0 and slot 10 for FDD and is transmitted in the third OFDM symbol in subframe 1 and 6 for TDD. The secondary synchronization signal (SSS) is transmitted in the last second OFDM symbol in slot 0 (subframe 0) and slot 10 (subframe 5) for FDD and is transmitted in the last OFDM symbols in slot 1 (subframe 0) and slot 11 (subframe 5) for TDD. Both PSCH and SSS occupy centeral 6 resource blcoks (RB, 72 subcarriers). The SS_PerTxAnt parameter determines whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

7. The PCFICH, PHICH and PDCCCH are transmitted in each subframe according to PDCCH_SymsPerSF and parameters related to PHICH mapping including PHICH_Ng, PHICH_Duration and CyclicPrefix. PDCCH_SymsPerSF[i] determines how many OFDM symbols are used to transmit control information in the ith subframe. The value range of PDCCH_SymsPerSF[i] is 0, 1, 2 and 3 except subframe 1 and 6 for TDD which is 0, 1 and 2. Note that PDCCH_SymsPerSF is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1.
   If PDCCH_SymsPerSF[i]>0, the PCFICH is mapped in the first OFDM symbol of the *i*th subframe according to section 6.7.4 in [1]. After the PCFICH mapping, the PHICH is mapped according to section 6.9.3 in [1] and then the PDCCH is mapped to the remnent resource-element groups in the first PDCCH_SymsPerSF[i] OFDM symbols of ith subframe according to section 6.8.5 in [1].
8. PBCH is always transmitted in the first 4 OFDM symbols in slot 1(subframe 0). PBCH occupies centeral 6 RBs (same as PSCH and SSCH) in spectrum. The mapping operation shall assume cell-specific reference signals for antenna ports 0-3 being present irrespective of the actual configuration. Resource elements assumed to be reserved for reference signals in the mapping operation above but not used for transmission of reference signal shall not be used for transmission of any physical channel.
9. The output at port SC_Status is the status for each subcarrier (resource element). The first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol. When the last subcarrier (resource element) in the first OFDM symbol is output, then next the first subcarrier (resource element) in the second OFDM symbol is output, and so on. The 8 LSB bits of each status value represent the channel type allocated on each subcarrier (resource element). The **meaning of the 8 LSB bits** is shown in the table below:

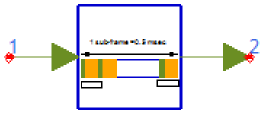
Value	ChannelType
0	EMPTY
1	RS
2	PSS
3	SSS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
8	PDSCH 1 (UE 1)
9	PDSCH 2 (UE 2)
10	PDSCH 3 (UE 3)
11	PDSCH 4 (UE 4)
12	PDSCH 5 (UE 5)
13	PDSCH 6 (UE 6)

10. Parameters Details
    - System Parameters Details:
        - For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
        - SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.
    - UE1 Parameters Details:
        - Refer to *DL UE1 Parameters* (3gpplte).
    - OtherUEs Parameters Details:
        - Refer to *DL OtherUEs Parameters* (3gpplte).
    - Control Channel Parameters Details:
        - Refer to *DL Control Channel Parameters* (3gpplte).
    - Power Parameters
        - Refer to *DL Power Parameters* (3gpplte).
        - Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Rb), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Rb-10log10(P)), where P is the number of antenna ports.
        - For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MuxSlot (Downlink Slot Multiplexer)



Description: Downlink slot multiplexer
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum

Pin Inputs

Pin	Name	Description	Signal Type
1	OFDMSig	input OFDM symbol	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	FrameData	downlink frame signal	complex

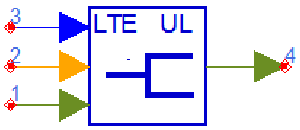
Notes/Equations

1. This model is used to multiplex 3GPP LTE downlink slot.
2. Each 10 ms radio frame consists of 20 slots, numbered from 0 to 19. Each 0.5 ms slot consists of 7 OFDM symbols for normal cyclic prefix or 6 OFDM symbols for extended cyclic prefix. The cyclic prefix of each OFDM symbol is added in this model. For normal cyclic prefix, the first OFDM symbol within a slot has different cyclic prefix lengths from other 6 OFDM symbols. For extended cyclic prefix, the 6 OFDM symbols have same cyclic prefix lengths.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_DemuxFrame (Uplink Radio Frame De-multiplexer with Frequency Offset Compensator)



Description: Uplink radio frame de-multiplexer with frequency offset compensator
Library: LTE, Multiplex

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0, 1.0e-3]
PreDownsampling	pre-downsampling to 1X symbol rate or not: NO, YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	complex
2	index	propagation delay in samples	int
3	DeltaF	frequency offset	real

Pin Outputs

Pin	Name	Description	Signal Type
4	DataOut	data out	complex

Notes/Equations

1. This model is used to demultiplex LTE uplink frame, which includes pre-downsampling and compensating time and carrier frequency offsets.
2. Each firing,
   - 1 token is consumed at index and DeltaF respectively.
   - *NumberSamplesPerFrame* tokens are consumed at DataIn.
   - If PreDownsampling is set to YES, *NumberSamplesPerFrame* tokens are produced at DataOut;
   - If PreDownsampling is set to NO, *NumberSamplesPerFrame* / $2^{OversamplingOption}$ tokens are produced at DataOut.
   - wherein *NumberSamplesPerFrame* is the number of samples (take oversampling into consideration) in 1 frame, and *NumberSamplesPerFrame* = *SamplingFreq* * $2^{OversamplingOption}$ * 0.01s.
   - where *SamplingFreq* is sampling frequency, which is denoted as F_s and determined by Bandwidth as follows:

Bandwidth	F_s
1.4 MHz	1.92 MHz
3.0 MHz	3.84 MHz
5.0 MHz	7.68 MHz
10.0 MHz	15.36 MHz
15.0 MHz	23.04 MHz
20.0 MHz	30.72MHz

   - For the default parameter configurations, *NumberSamplesPerFrame* = 153600.
3. Because of the transmission delay, a detected block usually falls into 2 consecutive

received blocks, so the buffer length for DataIn is *NumberSamplesPerFrame* * 2. The start point of the detected block is determined by the token read from index. Only after receiving the second input block, this model can output one actual block. So this model causes one frame delay.

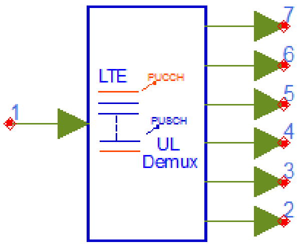
4. The DeltaF inputs the estimated frequency offset Δf_i of each received block. The i-th estimated frequency offset Δf_i compensates for the phase in the current block only. Assume $x_0, x_1, \ldots, x_N$ sequences are the input signals from DataIn, $y_0, y_1, \ldots, y_N$ are the sequences whose phase caused by frequency offset are removed, where N is the number of samples within one block. Then:
$$y_k = x_k \times e^{-j2\pi\Delta f_i k T_{Step}}$$
where Δf_i is frequency offset of the i-th received frame which is the input at DeltaF,
$$T_{Step} = \frac{1}{F_s \times 2^{OversamplingOption}}$$
is the sample time interval in the system.
5. See *LTE_UL_MuxFrame* (3gpplte).

For more information on the parameters, please refer to *UL System Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_DemuxSCFDMASym (Uplink SC-FDMA Symbol De-multiplexer in one Radio Frame)



Description: Uplink SC-FDMA symbol Demultiplexer
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0, 2]
CellID_Group	the index of cell identity group	0	int	[0, 167]
FrameNum	frame number	0	int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO	enum	
DL_CyclicPrefix	type of cyclic prefix in downlink: DL_Normal, DL_Extended	DL_Normal	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	NO	enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO	enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame	enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0	int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1	int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}	int array	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1	enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2	int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}	int array	[0, 9]

PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1	int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11	int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11	int	[0, 12*PUCCH_NB2-1]
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO	enum	
PRACH_Config	PRACH configuration index	0	int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}	int array	[0, 9]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0	int	[0, 94]
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7	int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0	int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO	enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0	int	[0, 3]
SRS_HoppingBandwidth	the SRS hopping bandwidth	3	int	[0, 3]
SRS_FreqPosition	the SRS frequency domain position	0	int	[0, 23]
SRS_ConfigIndex	the UE-specific SRS configuration	0	int	[0, 1023]
SRS_TransmissionComb	transmission comb	0	int	[0, 1]
PUSCH_PwrOffset	the power offset in dB for PUSCH	0	real	(-∞, +∞)
PUSCH_RS_PwrOffset	the power offset in dB for PUSCH RS	0	real	(-∞, +∞)
PUCCH_PwrOffset	the power offset in dB for PUCCH	0	real	(-∞, +∞)
PUCCH_RS_PwrOffset	the power offset in dB for PUCCH RS	0	real	(-∞, +∞)
SRS_PwrOffset	the power offset in dB for SRS	0	real	(-∞, +∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Input	uplink SCFDMA symbols in one frame	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	PUSCH_Sym	uplink Shared Channel Symbol	complex
3	PUCCH_Sym	uplink Control Channel Symbol	complex
4	PUSCH_RS	uplink Shared Channel DMRS	complex
5	PUCCH_RS	uplink Control Channel DMRS	complex
6	SRS	uplink sounding RS	complex
7	RBOut	valid RB output without RS	complex

Notes/Equations

1. This model is used to demultiplex UL frames into physical channels and physical signals. PUSCH, PUCCH, DMRS for PUSCH, DMRS for PUCCH and Sounding reference signals are output.
2. Each firing,
   - *NumberREsPerFrame* tokens are consumed at port Input, where *NumberREsPerFrame* is the total number of REs in each Frame. *NumberREsPerFrame* = *NumOfTotalRBs* * 12 (subcarriers per RB) * *NumberOfSymbolsPerFrame*.
   - the number of tokens produced at port PUSCH_Sym is equal to the number of REs allocated for PUSCH transmission in each frame. If PUSCH is not transmitted, 1 null token is output.
   - the number of tokens produced at port PUCCH_Sym is equal to the number of REs allocated for PUCCH transmission in each frame. If PUCCH is not transmitted, 1 null token is output.

- the number of tokens produced at port PUSCH_RS is equal to the number of REs allocated for PUSCH DMRS transmission in each frame. If PUSCH is not transmitted, 1 null token is output.
- the number of tokens produced at port RS_PUCCH is equal to the number of REs allocated for PUCCH DMRS transmission in each frame. If PUCCH is not transmitted, 1 null token is output.
- the number of tokens produced at port SRS is equal to the number of REs allocated for SRS transmission in each frame. If SRS is not transmitted, 1 null token is output.
- the number of tokens produced at port RBOut is equal to the number of REs allocated for PUSCH and PUCCH transmission.
- For the default parameter configurations, *NumberREsPerFrame* = 72000; the number of tokens produced at port Sym_PUSCH is 36000; the number of tokens produced at RS_PUSCH is 6000; the number of tokens produced at RBOut is 36000.

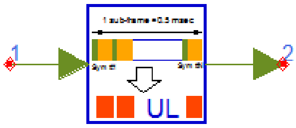
3. Port RBout output data symbols transmitted in each allocated RB for PUSCH and PUCCH. Reference signals are not output from this port.
4. It should be noted that the parameter DFTSwap_Enable should be set to **NO** according to the LTE specifications.
5. See *LTE_UL_MuxSCFDMASym* (3gpplte).

- For more information on the mapping of UL physical channels and signals, please refer to *LTE_UL_MuxSCFDMASym* (3gpplte).
- For more information on the System Parameters details please refer to *UL System Parameters* (3gpplte).
- For more information on the PUSCH Parameters details please refer to *UL PUSCH Parameters* (3gpplte).
- For more information on the PUCCH Parameters details please refer to *UL PUCCH Parameters* (3gpplte).
- For more information on the PRACH Parameters details please refer to *UL PRACH Parameters* (3gpplte).
- For more information on the SRS Parameters details please refer to *UL SRS Parameters* (3gpplte).
- For more information on the Power Parameters details please refer to *UL Power Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_DemuxSlot (Uplink Slot De-multiplexer)



Description: Uplink slot de-multiplexer
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES	enum
Sym_StartPos	start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP	{-3,-3}	int array

Pin Inputs

Pin	Name	Description	Signal Type
1	SlotData	slot signal	complex

Pin Outputs

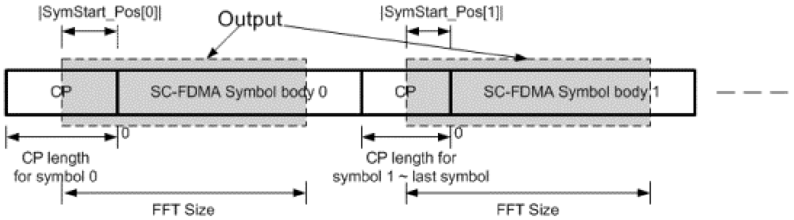
Pin	Name	Description	Signal Type
2	DemuxSlotData	SC-FDMA data symbol	complex

Notes/Equations

1. This model is used to demultiplex each slot into seven and six SC-FDMA symbols for normal cyclic prefix and extended cyclic prefix respectively, where the start of each output SC-FDMA symbol is calculated from Sym_StartPos.
2. Each firing,
   - *NumberSamplesPerSlot* tokens are consumed at SlotData , where $NumberSamplesPerSlot = SamplingFreq * 2^{OversamplingOption} * 0.0005$. *SamplingFreq* is sampling frequency, which is denoted as F_s and determined by Bandwidth as follows:

Bandwidth	F_s
1.4 MHz	1.92 MHz
3.0 MHz	3.84 MHz
5.0 MHz	7.68 MHz
10.0 MHz	15.36 MHz
15.0 MHz	23.04 MHz
20.0 MHz	30.72MHz

   - *NumberSymsPerSlot* × *FFTSize* tokens are produced at DemuxSlotData, where *NumberSymsPerSlot* is the number of SC-FDMA symbols in each slot, *FFTSize* is the FFT length.
   - For the default parameter configurations, *NumberSymsPerSlot* = 7, *FFTSize* = 1024, hence, each firing, 7680 tokens are consumed at SlotData, 7168 tokens are produced at DemuxSlotData.
3. The start of each output SC-FDMA symbol is illustrated in the **UL demux Slot** structure below:



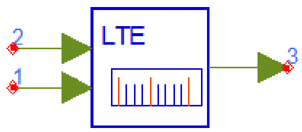
4. Sym_StartPos is an array of two elements, indicating the start position (without oversampling) of the first output SC-FDMA symbol and other output SC-FDMA symbols in each slot respectively. Here the "start position" is compared to the first sample of the input SC-FDMA symbol body excluding the cyclic prefix. Hence the value is negative indicating the start position locates in the CP duration of the input symbol as shown in the figure.
5. It would be better set Sym_StartPos to a certain value so that the “Output” in the above figure is a whole SC-FDMA symbol which is not affected by the spectrum shaping in the transmitter. Hence, the value of Sym_StartPos depends on the CP length (samples) and the spectrum shaping employed in *LTE_UL_Src* (3gpplte).
6. The negative half carrier shift is performed if HalfCarrierShift_Enable = YES.
7. It should be noted that the parameter HalfCarrierShift_Enable should be set to **YES** according to the LTE specifications.
8. See *LTE_UL_MuxSlot* (3gpplte).

For more information on Bandwidth, CyclicPrefix, OversamplingOption and HalfCarrierShift_Enable, please refer to *UL System Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_MuxFrame (Uplink Frame Multiplexer)



Description: Uplink radio frame multiplexer
Library: LTE, Multiplex

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0, 1.0e-3]
FrameNum	frame number	0		int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO		enum	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO		enum	
PRACH_Config	PRACH configuration index	0		int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}		int array	[0, 9]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	complex
2	RACHIn	RACH in	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	DataOut	data out	complex

Notes/Equations

1. This model is used to multiplex slots and PRACH signal into one uplink radio frame for both FDD and TDD mode. PRACH signal is added into the frame in time domain.
2. Each firing,
   - *NumberSamplesPerFrame* tokens are consumed at DataIn.
   - *NumberPRACHSamples* tokens are consumed at RACHIn.
   - *NumberSamplesPerFrame* tokens are produced at DataOut.
   - *NumberSamplesPerFrame* = *SamplingFreq* $* \ 2^{\text{OversamplingOption}} *$ 0.01s, wherein *SamplingFreq* is sampling frequency, which is denoted as F_s and determined by Bandwidth as follows:

Bandwidth	F_s
1.4 MHz	1.92 MHz
3.0 MHz	3.84 MHz
5.0 MHz	7.68 MHz
10.0 MHz	15.36 MHz
15.0 MHz	23.04 MHz
20.0 MHz	30.72MHz

OversamplingOption

- *NumberPRACHSamples* = *SamplingFreq* * 2 * *PreambleLength* * *NumberOfPreambles*, wherein *PreambleLength* and *NumberOfPreambles* is determined by FrameMode and PRACH_Config, for more information, please refer to *LTE_RACH* (3gpplte).
- For the default parameter configuraions, *NumberSamplesPerFrame* = 153600.

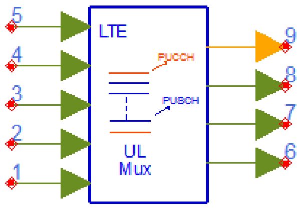
3. See *LTE_UL_DemuxFrame* (3gpplte) and *LTE_RACH* (3gpplte).

For more information on the parameters, please refer to *UL System Parameters* (3gpplte) and *UL PRACH Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_MuxSCFDMASym (Uplink SC-FDMA Symbol Multiplexer in one radio frame)



Description: Uplink SC-FDMA symbol multiplexer
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0, 2]
CellID_Group	the index of cell identity group	0	int	[0, 167]
FrameNum	frame number	0	int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO	enum	
DL_CyclicPrefix	type of cyclic prefix in downlink: DL_Normal, DL_Extended	DL_Normal	enum	
Printf_RB_SF_Alloc	print the RB_SF allocation to file: NO, YES	NO	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	NO	enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO	enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame	enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0	int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1	int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}	int array	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1	enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2	int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than	{2}	int array	[0, 9]

	PUSCH			
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1	int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11	int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11	int	[0, 12*PUCCH_NB2-1]
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO	enum	
PRACH_Config	PRACH configuration index	0	int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}	int array	[0, 9]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0	int	[0, 94]
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7	int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0	int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO	enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0	int	[0, 3]
SRS_HoppingBandwidth	the SRS hopping bandwidth	3	int	[0, 3]
SRS_FreqPosition	the SRS frequency domain position	0	int	[0, 23]
SRS_ConfigIndex	the UE-specific SRS configuration	0	int	[0, 1023]
SRS_TransmissionComb	transmission comb	0	int	[0, 1]
PUSCH_PwrOffset	the power offset in dB for PUSCH	0	real	(-∞, +∞)
PUSCH_RS_PwrOffset	the power offset in dB for PUSCH RS	0	real	(-∞, +∞)
PUCCH_PwrOffset	the power offset in dB for PUCCH	0	real	(-∞, +∞)
PUCCH_RS_PwrOffset	the power offset in dB for PUCCH RS	0	real	(-∞, +∞)
SRS_PwrOffset	the power offset in dB for SRS	0	real	(-∞, +∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Sym_PUCCH	uplink Control Channel Symbol	complex
2	RS_PUCCH	uplink PUCCH Reference Signal	complex
3	Sym_PUSCH	uplink Shared Channel Symbol	complex
4	RS_PUSCH	uplink PUSCH Reference Signal	complex
5	SRS	uplink Sounding Reference Signal	complex

Pin Outputs

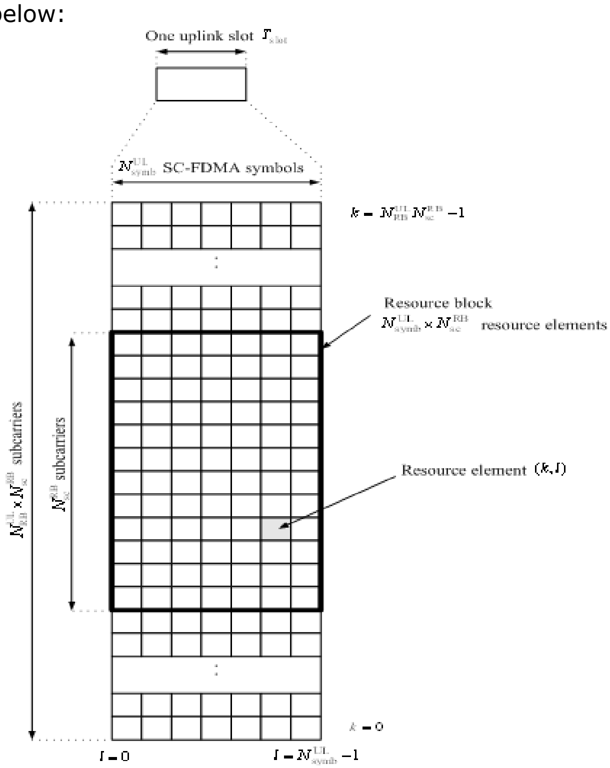
Pin	Name	Description	Signal Type
6	Output	uplink SCFDMA symbols in one frame	complex
7	Out	uplink SCFDMA symbols without scale factor and gain in one frame	complex
8	RBOut	valid RB output without RS	complex
9	Channel_Type	Output the channel and RS type for each output data	int

Notes/Equations

1. This model is used to multiplex uplink SC-FDMA symbols of one radio frame. Data for PUSCH, PUCCH and reference signals are mapped onto the allocated physical resources.
2. Each firing,
    - the number of tokens consumed at port Sym_PUCCH is equal to the number of REs allocated for PUCCH transmission in each frame.
    - the number of tokens consumed at port RS_PUCCH is equal to the number of REs allocated for PUCCH DMRS transmission in each frame.
    - the number of tokens consumed at port Sym_PUSCH is equal to the number of REs allocated for PUSCH transmission in each frame.
    - the number of tokens consumed at port RS_PUSCH is equal to the number of REs allocated for PUSCH DMRS transmission in each frame.
    - the number of tokens consumed at port SRS is equal to the number of REs allocated for SRS transmission in each frame.

- *NumberREsPerFrame* tokens are produced at port Output, Out and ChannelType, respectively, where *NumberREsPerFrame* is the total number of REs in each frame. *NumberREsPerFrame* = *NumOfTotalRBs* * 12 (subcarriers per RB) * *NumberOfSymbolsPerFrame*.
- the number of tokens produced at port RBOut is equal to the number of REs allocated for PUSCH and PUCCH transmission.
- For the default parameter configurations, the number of tokens read from Sym_PUSCH is 36000; the number of tokens read from RS_PUSCH is 6000; *NumberREsPerFrame* = 72000; the number of tokens output at RBOut is 36000.

3. The transmitted signal in each slot is described by a resource grid of $N_{RB}^{UL}N_{sc}^{RB}$ subcarriers and N_{symb}^{UL} SC-FDMA symbols. The **Uplink Resource Grid** is illustrated below:



4. The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by higher layers and is illustrated in the **Resource block parameters** table below:

Configuration	N_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

5. The RBs allocated for PUSCH are decided by the parameters "RB_AllocType" and "RB_Alloc", for more information, please refer to *Resource Block Allocation* (3gpplte).
6. The demodulation reference signal for PUSCH is mapped to resource elements (k,l) , with l = 3 for normal cyclic prefix and l = 2 for extended cyclic prefix, in the subframe shall be in increasing order of first k, then the slot number.
7. If PUCCH_PUSCH is PUCCH or both, PUCCH would be transmitted. The physical resources used for PUCCH depends on two parameters, PUCCH_NRB2 ($N_{RB}^{(2)}$) and $N_{CS}^{(1)}$. $N_{CS}^{(1)}$ is always set to '0' in current EESof implementation which means no mixed resource block for of formats 1/1a/1b and 2/2a/2b is present.
8. The subframes in which PUCCH are transmitted is determined by PUCCH_SF_Alloc, which is an *Array Parameter* (3gpplte). The **Demodulation reference signal location for different PUCCH formats** is illustrated in the table below:

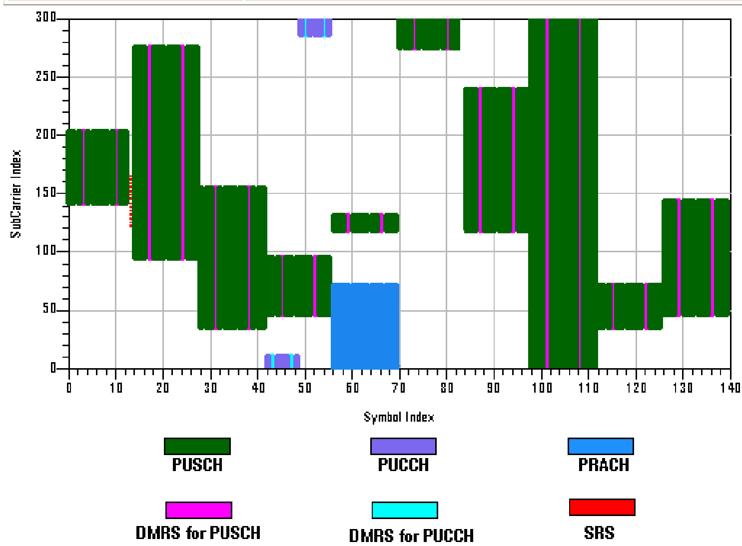
PUCCH format	Set of Values for *l* Normal cyclic prefix	Set of Values for *l* Extended cyclic prefix
1, 1a, 1b	2, 3, 4	2, 3
2	1, 5	3
2a, 2b	1, 5	N/A

9. If SRS transmission is enabled (SRS_Enable = YES), SRS would be transmitted on the time and frequency resources determined by SRS_BandwidthConfig,

SRS_SF_Config, SRS_MaxUpPts, SRS_Bandwidth, SRS_HoppingBandwidth, SRS_FreqPosition, SRS_ConfigIndex and SRS_TransmissionComb.

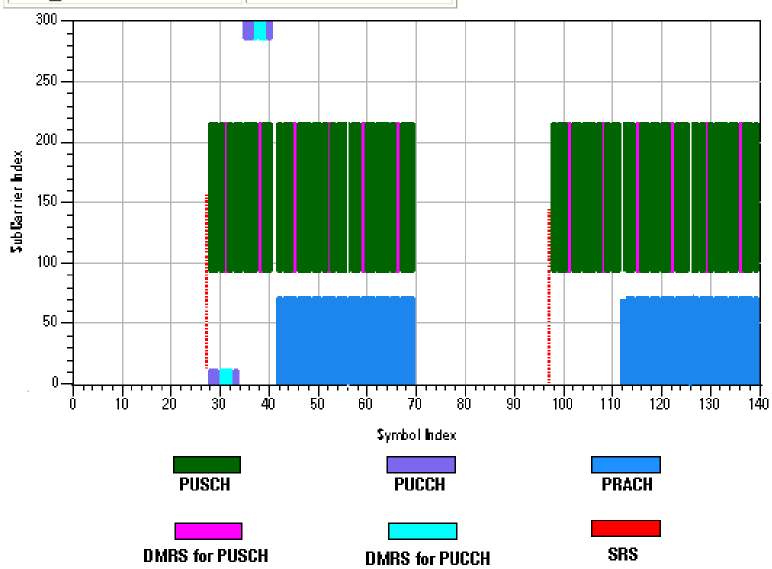
10. If PRACH transmission is enabled (PRACH_Enable = YES), the time and frequency resources for PRACH transmission determined by PRACH_Config, PRACH_ResourceIndex and PRACH_RBOffset are reserved. Allocating those RBs for other physical channels and signals are not allowed.
11. The module will output error message if there is any RB allocation conflict among PUSCH, PUCCH and PRACH.
12. The following two figures illustrate the resource allocation for UL physical channels and physical signals in FDD and TDD respectively.
    - **An example of 2-D RB allocation in FDD (5MHz) is shown in the table and figure below:**

Parameters	**Value**
FrameMode	FDD
Bandwidth	5 MHz
PUCCH_PUSCH	both
RB_AllocType	StartRB + NumRBs
RB_Alloc	{12,5},{8,15},{3,10},{4,4},{10,1},{23,2},{10,10},{0,25},{3,3},{4,8}
PUCCH_Format	Format 2a
PUCCH_Delta_shift	1
PUCCH_SF_Alloc	3
PUCCH_NRB2	0
PUCCH_n1	0
PUCCH_n2	0
PRACH_Enable	YES
PRACH_Config	1
PRACH_Mapping	4
SRS_Enable	YES
SRS_BandwidthConfig	7
SRS_SF_Config	3
SRS_Bandwidth	0
SRS_HoppingBandwidth	3
SRS_FreqPosition	0
SRS_ConfigIndex	0
SRS_TransmissionComb	0



- **Another example of 2-D RB Allocation in TDD (5MHz) is shown in the table and figure below:**

Parameters	Value
FrameMode	TDD
TDD_Config	Config 0
SpecialSF_Config	Config 4
CyclicPrefix	Normal
DL_CyclicPrefix	Normal
Bandwidth	5 MHz
PUCCH_PUSCH	both
RB_AllocType	StartRB + NumRBs
RB_Alloc	{8,10}
PUCCH_Format	Format Shortened 1a
PUCCH_Delta_shift	1
PUCCH_SF_Alloc	2
PUCCH_NRB2	0
PUCCH_n1	0
PUCCH_n2	0
PRACH_Enable	YES
PRACH_Config	29
PRACH_ResourceIndex	{0, 1}
SRS_Enable	YES
SRS_BandwidthConfig	6
SRS_SF_Config	4
SRS_MaxUpPts	YES
SRS_Bandwidth	0
SRS_HoppingBandwidth	3
SRS_FreqPosition	0
SRS_ConfigIndex	0
SRS_TransmissionComb	0



13. The meaning of the output at port Channel_Type is as follows:

output integer	Meaning
0	nothing
1	PUCCH
2	DMRS for PUCCH
3	PUSCH
4	DMRS for PUSCH
5	SRS
6	PRACH

14. DL_CyclicPrefix is used to determine the length of UpPTS in TDD mode in company with SpecialSF_Config and CyclicPrefix.
15. FrameNum indicates the system frame number of the first transmitted frame. FrameIncreased controls whether the FrameNum is increased during simulation. These two parameters affects the PRACH and SRS transmission which may vary from

frames.

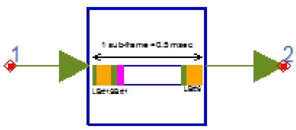
16. It should be noted that the parameter DFTSwap_Enable should be set to **NO** according to the LTE specifications.
17. See *LTE_UL_DemuxSCFDMASym* (3gpplte).

- For more information on the System Parameters details please refer to *UL System Parameters* (3gpplte).
- For more information on the PUSCH Parameters details please refer to *UL PUSCH Parameters* (3gpplte).
- For more information on the PUCCH Parameters details please refer to *UL PUCCH Parameters* (3gpplte).
- For more information on the PRACH Parameters details please refer to *UL PRACH Parameters* (3gpplte).
- For more information on the SRS Parameters details please refer to *UL SRS Parameters* (3gpplte).
- For more information on the Power Parameters details please refer to *UL Power Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_MuxSlot (Uplink Slot Multiplexer)



Description: Uplink slot multiplexer
Library: LTE, Multiplex

Parameters

Name	Description	Default	Type
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES	enum

Pin Inputs

Pin	Name	Description	Signal Type
1	SCFDMASig	input SC-FDMA symbol	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	FrameData	uplink slot signal	complex

Notes/Equations

1. This model is used to multiplex reference signals (RS symbol) and data SC-FDMA symbols into uplink slots by inserting cyclic prefix. Half carrier shift can also be performed in this model if enabled.
2. Each firing,
   - *NumberSymsPerSlot* * *FFTSize* tokens are consumed at SCFDMASig, where *NumberSymsPerSlot* is the number of SC-FDMA symbols in each slot, *FFTSize* is the FFT length.
   - *NumberSamplesPerSlot* tokens are produced at FrameData, where $NumberSamplesPerSlot = SamplingFreq * 2^{OversamplingOption} * 0.0005$. *SamplingFreq* is sampling frequency, which is denoted as F_s and determined by

     Bandwidth as follows:

Bandwidth	F_s
1.4 MHz	1.92 MHz
3.0 MHz	3.84 MHz
5.0 MHz	7.68 MHz
10.0 MHz	15.36 MHz
15.0 MHz	23.04 MHz
20.0 MHz	30.72MHz

   - For the default parameter configurations, *NumberSymsPerSlot* = 7, *FFTSize* = 1024, hence, each firing, 7168 tokens are consumed at SCFDMASig, 7680 tokens are produced at FrameData.
3. The transmitted signal in each slot is described by a resource grid of $N_{RB}^{UL} N_{sc}^{RB}$ subcarriers and N_{symb}^{UL} SC-FDMA symbols. The quantity N_{RB}^{UL} depends on the uplink transmission bandwidth configured in the cell and shall fulfil
   $N_{RB}^{min,UL} \le N_{RB}^{UL} \le N_{RB}^{max,UL}$
   Where $N_{RB}^{min,UL} = 6$ and $N_{RB}^{max,UL} = 110$ is the smallest and largest uplink bandwidth, respectively.

RB

4. The set of allowed values for N_{UL} is given by the **Transmission bandwidth configuration N_{RB} in E-UTRA channel bandwidths** table shown below:

Channel Bandwidth BW~Channel~[MHz]	**1.4**	**3**	**5**	**10**	**15**	**20**
Transmission bandwidth configuration N_{RB}	6	15	25	50	75	100

5. The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by higher layers and is given by the **Resource block parameters** table shown below:

Configuration	N_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

6. The following two tables specifies the cyclic prefix length $N_{CP,l}$ and FFT size for normal cyclic prefix and extended cyclic prefix respectively.

SC-FDMA parameters for normal CP

Channel Bandwidth (MHz)	**FFT Size**	**Cyclic prefix length for symbols 0 in FFT samples**	**Cyclic prefix length for symbols 1-6 in FFT samples**
1.4	128	10	9
3	256	20	18
5	512	40	36
10	1024	80	72
15	1536	120	108
20	2048	160	144

SC-FDMA parameters for extended CP

Channel Bandwidth (MHz)	**FFT Size**	**Cyclic prefix length in FFT samples**
1.4	128	32
3	256	64
5	512	128
10	1024	256
15	1536	384
20	2048	512

7. The half carrier shift is referred to the item 1/2 in the following equation for SC-FDMA baseband signal generation. The time-continuous signal $s_l(t)$ in SC-FDMA symbol l in an uplink slot is defined by

$$s_l(t) = \sum_{k=-\lfloor N_{RB}^{UL} N_{sc}^{RB}/2 \rfloor}^{\lceil N_{RB}^{UL} N_{sc}^{RB}/2 \rceil - 1} a_{k^{(-)},l} \cdot e^{j2\pi(k+1/2)\Delta f(t - N_{CP,l} T_s)}$$

for $0 \le t \le (N_{CP,l} - N) \times T_s$ where $k^{(-)} = k + \lfloor N_{RB}^{UL} N_{sc}^{RB}/2 \rfloor$, $N = 2048$, $\Delta f = 15$kHz and $a_{k,l}$ is the content of resource element (k, l).

8. The SC-FDMA symbols in a slot shall be transmitted in increasing order of l, starting with $l = 0$, where SC-FDMA symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1}(N_{CP,l'} + N)T_s$ within the slot.
9. It should be noted that the parameter HalfCarrierShift_Enable should be set to **YES** according to the LTE specifications.
10. See *LTE_UL_DemuxSlot* (3gpplte).

For more information on the parameters, please refer to *UL System Parameters* (3gpplte).

References

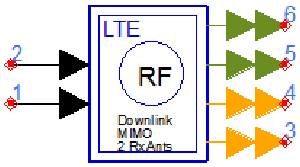
1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

3GPP LTE Receiver Components

These components are available for the LTE FDD downlink and uplink receiver:

Contents

LTE_DL_MIMO_2Ant_Rcv_RF (MIMO RF Downlink 2-Antenna Receiver)



Description: Downlink RF MIMO receiver with 2 rx antennas
Library: LTE, Receiver

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE downlink signals	Category		string	
RIn	source resistance	50 Ohm	Ohm	int	(0,∞)
RTemp	temperature	-273.15	Celsius	real	[-273.15,∞]
RefFreq	internal reference frequency	2500 MHz	Hz	real	(0,∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞,∞)
GainImbalance	Gain imbalance in dB Q channel relative to I channel at 2 receiver antennas	{0.0, 0.0}		real array	(-∞,∞)
PhaseImbalance	Phase imbalance in dB Q channel relative to I channel at 2 receiver antennas	{0.0, 0.0}		real array	(-∞,∞)
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx2		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO		enum	
MIMO_Parameters	MIMO-related parameters for all six Ues	Category		string	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CDD_Mode	CDD Mode for each UE, 1 for	{0, 0, 0, 0, 0, 0}		int	[0,1]

	Zero-Delay, 0 for Large-Delay			array	
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,2]
UEs_NumOfLayers	number of layers for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS index, Transport block size, Code rate	Transport block size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	0		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng 1/6, Ng 1/2,	Ng 1/6		enum	

	Ng 1, Ng 2				
PowerParameters	power-related parameters	Category		string	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
RxAlgorithmParameters	parameters for LTE downlink receiver algorithm	Category		string	
PreDownsampling	pre-downsampling to 1X symbol rate ?: NO, YES	NO		enum	
SyncMode	synchronization for every port or one synchronization for all ports: SyncPerPort, AverageSync	AverageSync		enum	
SearchType	start a new timing and frequence synchronization search for every frame or not: Search every frame, Search+Track	Search+Track		enum	
SearchRange	timing and frequence synchronization searching range for the first frame	3 msec	sec	real	[0,5.0ms]
TrackRange	timing and frequence synchronization tracking range for the frames except the first frame, valid when SearchType is set to Search+Track	0.1 msec	sec	real	[0,5.0ms]
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz		enum	
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE_2D	Linear		enum	
MMSE_RBWinLen	number of RBs for each MMSE-2D interpolation	3		int	
SNR	SNR in dB. (used by 2D-MMSE channel estimator in PDSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by 2D-MMSE channel estimator in PDSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by 2D-MMSE channel estimator in PDSCH)	100 Hz	Hz	real	[0,∞)
Sym_StartPos	start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP	{-3,-3}		int array	
DemapperType	symbol demodulation type: Hard, Soft	Soft		enum	
DemapperMaxLevel	the maximum level for soft demapping output when	1.0		real	(0,∞)

	DemapperType is Soft or CSI				
TC_Iteration	Turbo decoder iteration number	4		int	[1,20]

Pin Inputs

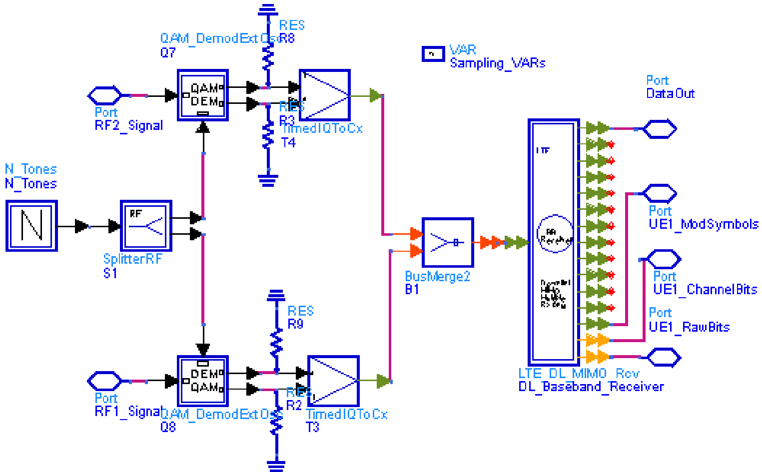
Pin	Name	Description	Signal Type
1	RF1_Signal	input of RF signal on Antenna 1	timed
2	RF2_Signal	input of RF signal on Antenna 2	timed

Pin Outputs

Pin	Name	Description	Signal Type
3	UE1_RawBits	UE1 raw bits	multiple int
4	UE1_ChannelBits	UE 1 channel bits after demodulation	multiple int
5	UE1_ModSymbols	UE 1 modulation symbols	multiple complex
6	DataOut	output frequency data with factor removing	multiple complex

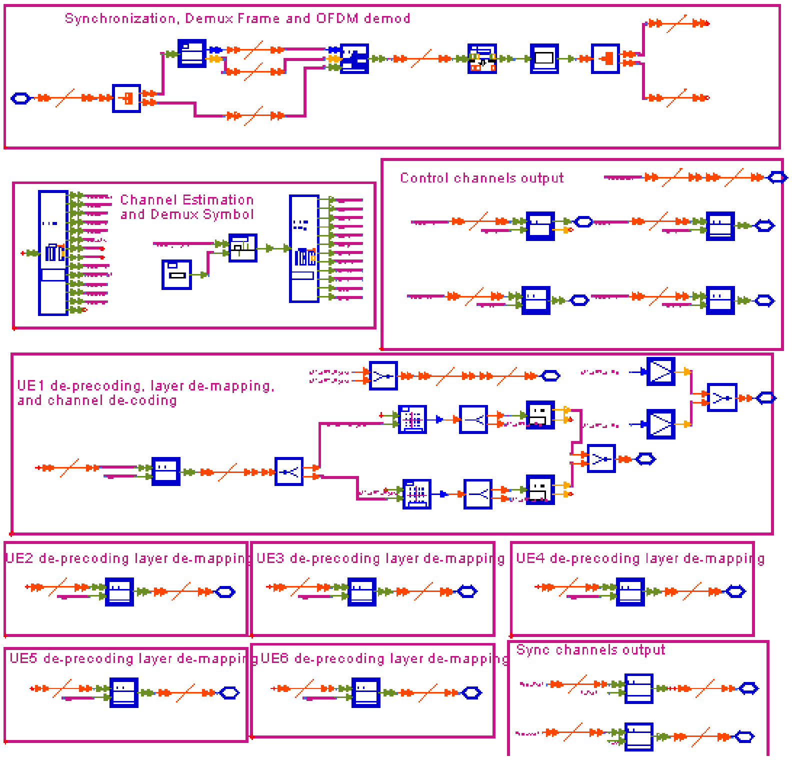
Notes/Equations

1. This subnetwork completes the 3GPP LTE downlink FDD RF receiver (up to six users) for two receiver antenna. The subnetwork includes LTE_DL_MIMO_Rcv with NumRxAnts = Rx2, which is the baseband 3GPP LTE coded downlink MIMO receiver, and the QAM_Demod. The schematic for this subnetwork is shown in the following figure.



LTE_DL_Receiver_RF Schematic

2. The baseband coded downlink MIMO receiver schematic is shown in the following figure. The detailed information for LTE_DL_MIMO_Rcv is in *LTE Downlink Baseband MIMO Receiver* (3gpplte).



LTE_DL_Receiver Schematic

RF Parameter Details:

- Rin is the RF input source resistance.
- RTemp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- RefFreq is the internal reference frequency.
- Sensitivity is the voltage output sensitivity, Vout/Vin.
- GainImbalance is the gain imbalance in dB Q channel relative to I channel for two receiver antennas.
- PhaseImbalance is the phase imbalance in dB Q channel relative to I channel for two receiver antennas.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).
- Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Ra), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Ra-10log10(P)), where P is the number of antenna ports.

- For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

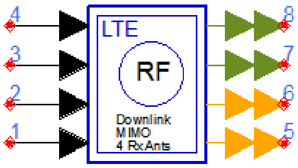
Rx Algorithm Parameters Details:

- Refer to *DL Rx Algorithm Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_MIMO_4Ant_Rcv_RF (MIMO RF Downlink 4-Antenna Receiver)



Description: Downlink RF MIMO receiver with 4 rx antennas
Library: LTE, Receiver

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE downlink signals	Category		string	
RIn	source resistance	50 Ohm	Ohm	int	(0,∞)
RTemp	temperature	-273.15	Celsius	real	[-273.15,∞]
RefFreq	internal reference frequency	2500 MHz	Hz	real	(0,∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞,∞)
GainImbalance	Gain imbalance in dB Q channel relative to I channel at 4 transmit antennas	{0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PhaseImbalance	Phase imbalance in dB Q channel relative to I channel at 4 transmit antennas	{0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx4		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO		enum	
MIMO_Parameters	MIMO-related parameters for all six Ues	Category		string	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]

UEs_CDD_Mode	CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,2]
UEs_NumOfLayers	number of layers for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS index, Transport block size, Code rate	Transport block size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	0		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start	{0, 0}		int array	

	RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]				
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}		int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}		int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng 1/6, Ng 1/2, Ng 1, Ng 2	Ng 1/6		enum	
PowerParameters	power-related parameters	Category		string	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
RxAlgorithmParameters	parameters for LTE downlink receiver algorithm	Category		string	
PreDownsampling	pre-downsampling to 1X symbol rate ?: NO, YES	NO		enum	
SyncMode	synchronization for every port or one synchronization for all ports: SyncPerPort, AverageSync	AverageSync		enum	
SearchType	start a new timing and frequence synchronization search for every frame or not: Search every frame, Search+Track	Search+Track		enum	
SearchRange	timing and frequence synchronization searching range for the first frame	3 msec	sec	real	[0,5.0ms]

TrackRange	timing and frequence synchronization tracking range for the frames except the first frame, valid when SearchType is set to Search+Track	0.1 msec	sec	real	[0,5.0ms]
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz		enum	
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE_2D	Linear		enum	
MMSE_RBWinLen	number of RBs for each MMSE-2D interpolation	3		int	
SNR	SNR in dB. (used by 2D-MMSE channel estimator in PDSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by 2D-MMSE channel estimator in PDSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by 2D-MMSE channel estimator in PDSCH)	100 Hz	Hz	real	[0,∞)
Sym_StartPos	start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP	{-3,-3}		int array	
DemapperType	symbol demodulation type: Hard, Soft	Soft		enum	
DemapperMaxLevel	the maximum level for soft demapping output when DemapperType is Soft or CSI	1.0		real	(0,∞)
TC_Iteration	Turbo decoder iteration number	4		int	[1,20]

Pin Inputs

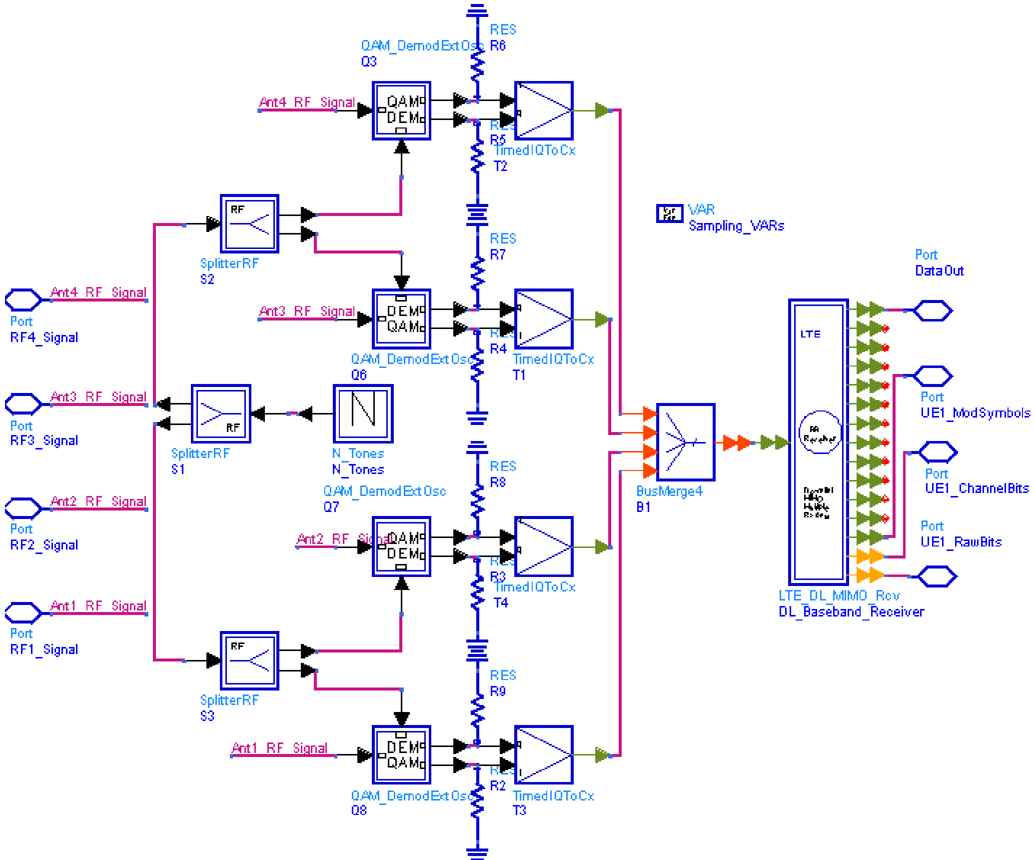
Pin	Name	Description	Signal Type
1	RF1_Signal	input of RF signal on Antenna 1	timed
2	RF2_Signal	input of RF signal on Antenna 2	timed
3	RF3_Signal	input of RF signal on Antenna 3	timed
4	RF4_Signal	input of RF signal on Antenna 4	timed

Pin Outputs

Pin	Name	Description	Signal Type
5	UE1_RawBits	UE1 raw bits	multiple int
6	UE1_ChannelBits	UE 1 channel bits after demodulation	multiple int
7	UE1_ModSymbols	UE 1 modulation symbols	multiple complex
8	DataOut	output frequency data with factor removing	multiple complex

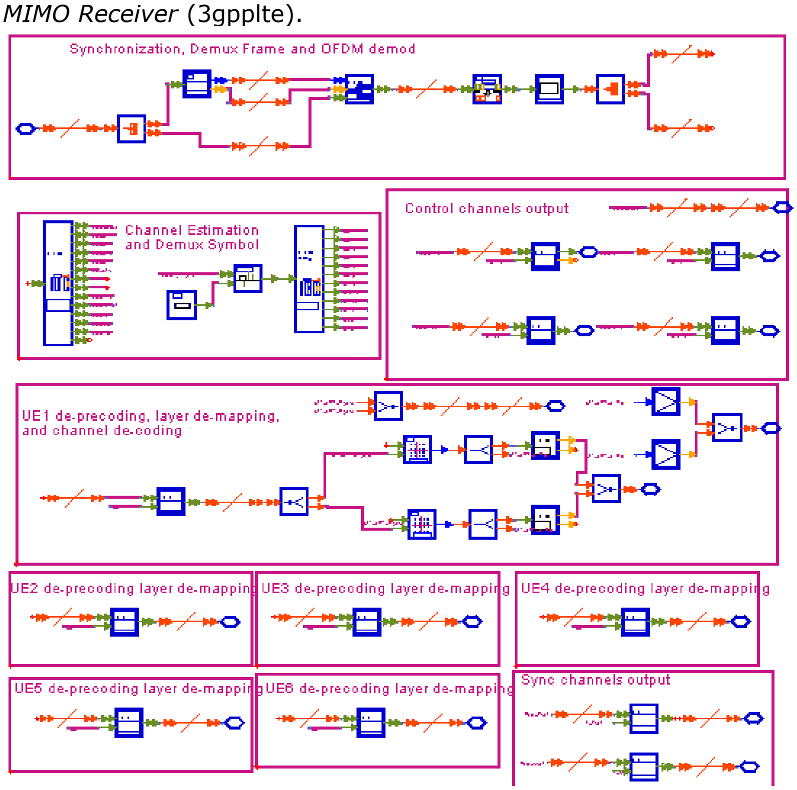
Notes/Equations

1. This subnetwork completes the 3GPP LTE downlink FDD RF receiver (up to six users) for four receiver antenna. The subnetwork includes LTE_DL_MIMO_Rcv with NumRxAnts = Rx4, which is the baseband 3GPP LTE coded downlink MIMO receiver, and the QAM_Demod. The schematic for this subnetwork is shown in the following figure.



LTE_DL_Receiver_RF Schematic

2. The baseband coded downlink MIMO receiver schematic is shown in the following figure. The detailed information for LTE_DL_MIMO_Rcv is in *LTE Downlink Baseband MIMO Receiver* (3gpplte).



LTE_DL_Receiver Schematic

RF Parameter Details:

- Rin is the RF input source resistance.
- RTemp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- RefFreq is the internal reference frequency.
- Sensitivity is the voltage output sensitivity, Vout/Vin.
- GainImbalance is the gain imbalance in dB Q channel relative to I channel for four receiver antennas.
- PhaseImbalance is the phase imbalance in dB Q channel relative to I channel for four receiver antennas.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).
- Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Ra), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Ra-10log10(P)), where P is the number of antenna ports.
- For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

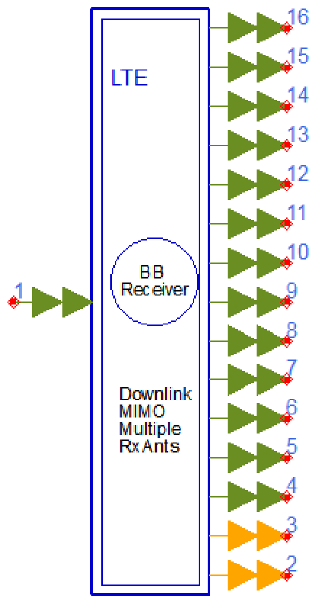
Rx Algorithm Parameters Details:

- Refer to *DL Rx Algorithm Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_MIMO_Rcv(Downlink Baseband MIMO Receiver)



Description: Downlink baseband MIMO receiver
Library: LTE, Receiver

Parameters

Name	Description	Default	Unit	Type	Range
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1		enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO,	NO		enum	

	YES				
MIMO_Parameters	MIMO-related parameters for all six Ues	Category		string	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CDD_Mode	CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,2]
UEs_NumOfLayers	number of layers for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS_index, Transport_block_size, Code_rate	Transport_block_size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	1		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PHICH_Duration	type of PHICH duration:	Normal_Duration		enum	

	Normal_Duration, Extended_Duration				
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6		enum	
PowerParameters	power-related parameters	Category		string	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
RxAlgorithmParameters	parameters for LTE downlink receiver algorithm	Category		string	
PreDownsampling	pre-downsampling to 1X symbol rate ?: NO, YES	NO		enum	
SyncMode	synchronization for every port or one synchronization for all ports: SyncPerPort, AverageSync	AverageSync		enum	
SearchType	start a new timing and frequence synchronization search for every frame or not: Search every frame, Search+Track	Search+Track		enum	
SearchRange	timing and frequence synchronization searching range for the first frame	3 msec	sec	real	[0,5.0ms]
TrackRange	timing and frequence synchronization tracking range for the frames except the first frame, valid when SearchType is set to Search+Track	0.1 msec	sec	real	[0,5.0ms]
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz		enum	
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE_2D, For EVM	Linear		enum	
MMSE_RBWinLen	number of RBs for each MMSE-2D interpolation	3		int	
SNR	SNR in dB. (used by 2D-MMSE channel estimator in PDSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by 2D-MMSE channel estimator in PDSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by 2D-MMSE channel estimator in PDSCH)	100 Hz	Hz	real	[0,∞)
Sym_StartPos	start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP	{-3,-3}		int array	
DemapperType	symbol demodulation type: Hard,	Soft		enum	

	Soft, CSI				
DemapperMaxLevel	the maximum level for soft demapping output when DemapperType is Soft or CSI	1.0		real	(0,∞)
TC_Iteration	Turbo decoder iteration number	4		int	[1,20]

Pin Inputs

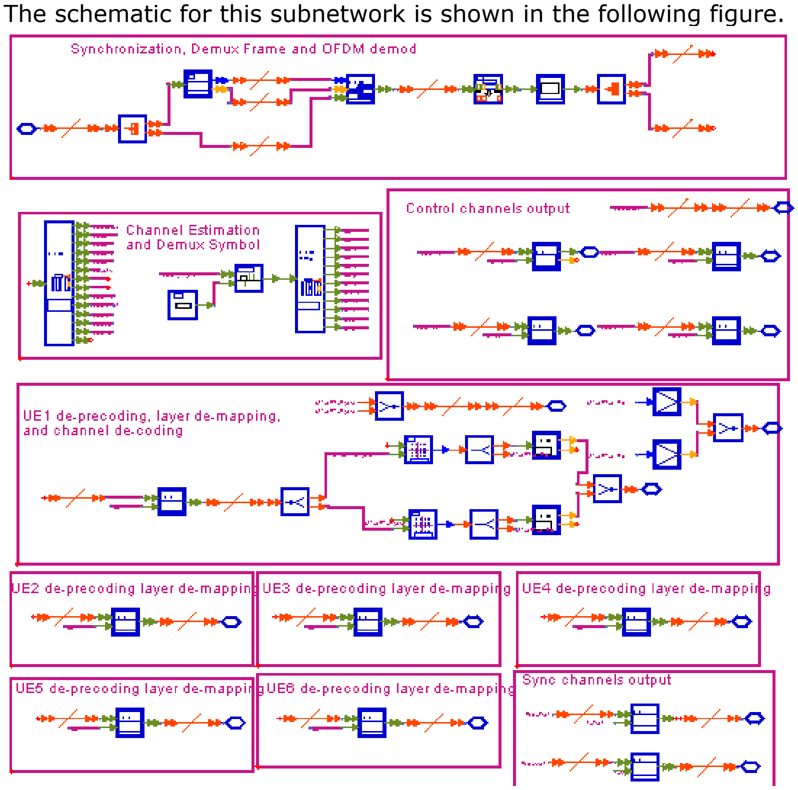
Pin	Name	Description	Signal Type
1	Ants_TD	multiple antennas input of frame signal in time domain	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	UE1_RawBits	UE1 raw bits	multiple int
3	UE1_ChannelBits	UE 1 channel bits after demodulation	multiple int
4	UE1_ModSymbols	UE 1 modulation symbols	multiple complex
5	UE2_ModSymbols	UE 2 modulation symbols	multiple complex
6	UE3_ModSymbols	UE 3 modulation symbols	multiple complex
7	UE4_ModSymbols	UE 4 modulation symbols	multiple complex
8	UE5_ModSymbols	UE 5 modulation symbols	multiple complex
9	UE6_ModSymbols	UE 6 modulation symbols	multiple complex
10	PDCCH_ModSymbols	PDCCH modulation symbols	multiple complex
11	PHICH_ModSymbols	PHICH modulation symbols	multiple complex
12	PCFICH_ModSymbols	PCFICH modulation symbols	multiple complex
13	PBCH_ModSymbols	PBCH modulation symbols	multiple complex
14	SSS_ModSymbols	SSS modulation symbols	multiple complex
15	PSS_ModSymbols	PSS modulation symbols	multiple complex
16	DataOut	output with factor removing	multiple complex

Notes/Equations

1. This subnetwork completes 3GPP LTE downlink FDD/TDD baseband receiver with multiple receiver antennas.
   The schematic for this subnetwork is shown in the following figure.



LTE_DL_ MIMO_Rcv Schematic

2. The number of input receiver antennas supported in this receiver includes 2 and 4, which should be consistent with the NumRxAnts parameter. The number of transmit

antenna ports is defined in the NumTxAnts parameter. All the configurations of NumTxAnts and NumRxAnts are supported in this source, including 1x2, 1x4, 2x2, 2x4, 4x2, and 4x4. For 1x2 and 1x4 which are the cases of receiver diversity, MRC (maximal ratio combining) method is employed.

3. LTE_DL_TimeFreqSync component is for timing and frequency synchronization by using P-SCH time domain signal and outputs synchronization index and estimated small frequency offset. The integer frequency offset is further estimated in the frequency domain S-SCH. Both synchronization index and estimated frequency offset are input to LTE_DL_DemuxFrame.
   First, LTE_DL_DemuxFrame compensates frequency offset by using the estimated frequency offset. Then, it outputs the real radio frame by using synchronization index after removing the IdleInterval. This model causes one frame radio delay.
   One radio frame (10 ms) includes 20 slots. LTE_DL_DemuxSlot is used to demultiplex one slot into seven or six OFDM symbols by removing cyclic prefix. The position to select OFDM useful symbols is determined by Sym_StartPos. There are 7 OFDM symbols for Normal Cyclic Prefix and 6 OFDM symbols for Extended Cyclic Prefix.
   Then, LTE_OFDM_Demodulator transfers input time domain signals into frequency domain signal by FFT procedure. The demodulated signals are generated by removing NULL subcarriers and exchanging plus frequency subcarriers and minus frequency subcarriers.
   The demodulated signals are input to LTE_DL_ChEstimator to get channel impulse response (CIR) for each active subcarrier. LTE_DL_ChEstimator has three estimation modes: linear, MMSE_2D and For_EVM. The obtained CIR of each active subcarrier is sent to LTE_DL_MIMO_DemuxCIR to get corresponding CIRs for P-SCH, S-SCH, BCH, PCFICH, PDCCH and six UEs (PDSCHs) respectively. Meanwhile, LTE_DL_DemuxOFDMSym demultiplexes the un-equalized OFDM symbols (in one radio frame) into P-SCH, S-SCH, BCH, PCFICH, PDCCH and six UEs (PDSCHs) un-equalized symbols and output all these signals. Then these un-equalized symbols, along with corresponding CIRs, are equalized, de-precoded and layer de-mapped into modulation symbols in corresponding Layer Demapper and Deprecoder components.
4. Note that for all UEs (PDSCHs), the number of code words output from Layer Demapper and Deprecoder are fixed to 2 regardless of the actual number of code words defined in the UEs_NumOfCWs parameter. When the actual number of code word is 1, the second code word output from Layer Demapper and Deprecoder is invalid.
5. For UE 1 (PDSCH 1), the modulation symbols in each code word are demapped in LTE_Demapper with two methods: Hard and Soft, results in received channel bits which are output at port UE1_ChannelBits. The demapped bits are delivered to LTE_DL_ChannelDecoder in which the de-scrambler, rate de-matching, Turbo decoder, code block de-segmentation and CRC decoder are performed. At last the received transport block bits are output at port UE1_RawBits.
6. For UE 2 to UE 6 (PDSCH 2 to PDSCH 6), only complex-valued modulation symbols from LTE_DL_DemuxOFDMSym are output.
7. The outputs at ports with the postfix ModSymbols are the complex-valued modulation symbols for corresponding channels.
8. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of demapper. These outputs are the received bits for uncoded BER and PER measurement.
9. The outputs at port UE1_RawBits are the decoded transport block bits for UE 1 (PDSCH 1). These outputs are the received bits for coded BER and PER measurement.
10. The outputs at port DataOut are the frequency subcarrier data without power scaling.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).

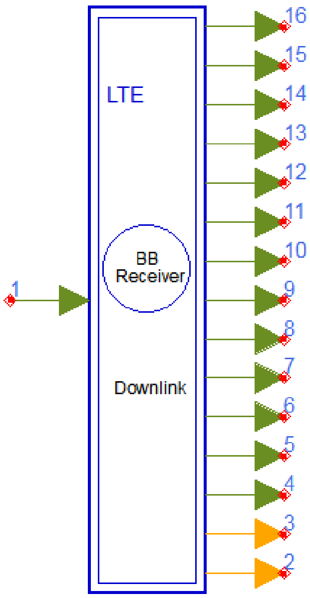
Rx Algorithm Parameters

- PreDownsampling: Is the pre-downsampling to 1X symbol rate or not? If PreDownsampling=YES, LTE_DL_DemuxFrame outputs the radio frame with oversampling ratio 1 and the FFT size in LTE_DL_OFDM_Demodulator is just the basic size defined in the specification. This setting can save some resources and speed up the simulation. If PreDownsampling=NO, LTE_DL_DemuxFrame outputs the radio frame with oversampling ratio and the FFT size in LTE_DL_OFDM_Demodulator is the basic size (defined in the specification) multiply oversampling ratio (defined in the top level model).
- SyncMode: timing and frequency synchronization mode. When SyncMode = AverageSync, the timing indices and frequency offsets on all the receiver antennas are combined with MRC method to generate a composite timing index and frequency offset which are then sent to LTE_DL_DemuxFrame. This mode is useful when P-SCH and S-SCH are only received on one of the receiver antennas. When SyncMode = SyncPerPort, the timing indices and frequency offset for each receiver antenna are sent to LTE_DL_DemuxFrame independently. This mode (SyncMode = SyncPerPort) may have better performance if P-SCH and S-SCH are received on all the receiver antennas.
- SearchType: the search type for the timing synchronization. When SearchType = Search every frame, the complete search is performed for each frame, whose search range is defined in SearchRange; When SearchType = Search+Track, the first frame performs the complete search whose search range is defined in SearchRange, the rest frames perform the tracking search whose search range is defined in TrackRange.
- SearchRange: search range for all frames when SearchType = Search every frame, and for the first frame when SearchType = Search+Track.
- TrackRange: tracking range for the rest frames when SearchType = Search+Track.
- FreqSync: frequency synchronization range, chosen from non, <100Hz, <15kHz, <35kHz.
- ChEstimatorMode: channel estimation modes, chosen from Linear, MMSE_2D, For EVM. When For EVM is selected, the estimation process defined in E.6 of [2] is employed.
- MMSE_RBWinLen: the number of RBs included to perform MMSE 2D estimation, valid when ChEstimatorMode = MMSE_2D.
- SNR: the signal noise ratio at each receiver antenna in dB for PDSCHs. This parameter is useful for the channel estimator.
- Tmax: the maximum echo delay in multi-path channel. This parameter is useful for the channel estimator.
- Fmax: the maximum Doppler frequency. This parameter is useful for the channel estimator.
- Sym_StartPos: start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP. The first value is for Long CP and the second is for Short CP. For more information, refer to *DL Demux Slot* (3gpplte).
- DemapperType: the type of Demapper, chosen from Hard, Soft and CSI. CSI (Channel State Information) is a channel estimate profile. Generally, the decoder with CSI has best performance while the decoder with Hard has worst performance.
- DemapperMaxLevel: the level of the output soft bits after Demapper which are restricted in the range [-DemapperMaxLevel, DemapperMaxLevel], valid when DemapperType is soft and CSI.
- TC_Iteration: the number of iterations for Turbo decoder.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_Receiver (Downlink Baseband Receiver)



Description: Downlink baseband receiver
Library: LTE, Receiver

Parameters

Name	Description	Default	Unit	Type	Range
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS_index, Transport_block_size, Code_rate	Transport_block_size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	

UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	1		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6		enum	
PowerParameters	power-related parameters	Category		string	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1,	p_B_p_A_1		enum	

	P_B_2, P_B_3				
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
RxAlgorithmParameters	parameters for LTE downlink receiver algorithm	Category		string	
PreDownsampling	pre-downsampling to 1X symbol rate ?: NO, YES	NO		enum	
SearchType	start a new timing and frequence synchronization search for every frame or not: Search every frame, Search+Track	Search+Track		enum	
SearchRange	timing and frequence synchronization searching range for the first frame	3 msec	sec	real	[0,5.0ms]
TrackRange	timing and frequence synchronization tracking range for the frames except the first frame, valid when SearchType is set to Search+Track	0.1 msec	sec	real	[0,5.0ms]
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz		enum	
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE_2D, For EVM	Linear		enum	
MMSE_RBWinLen	number of RBs for each MMSE-2D interpolation	3		int	
SNR	SNR in dB. (used by 2D-MMSE channel estimator in PDSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by 2D-MMSE channel estimator in PDSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by 2D-MMSE channel estimator in PDSCH)	100 Hz	Hz	real	[0,∞)
Sym_StartPos	start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP	{-3,-3}		int array	
DemapperType	symbol demodulation type: Hard, Soft, CSI	Soft		enum	
DemapperMaxLevel	the maximum level for soft demapping output when DemapperType is Soft or CSI	1.0		real	(0,∞)
TC_Iteration	Turbo decoder iteration number	4		int	[1,20]

Pin Inputs

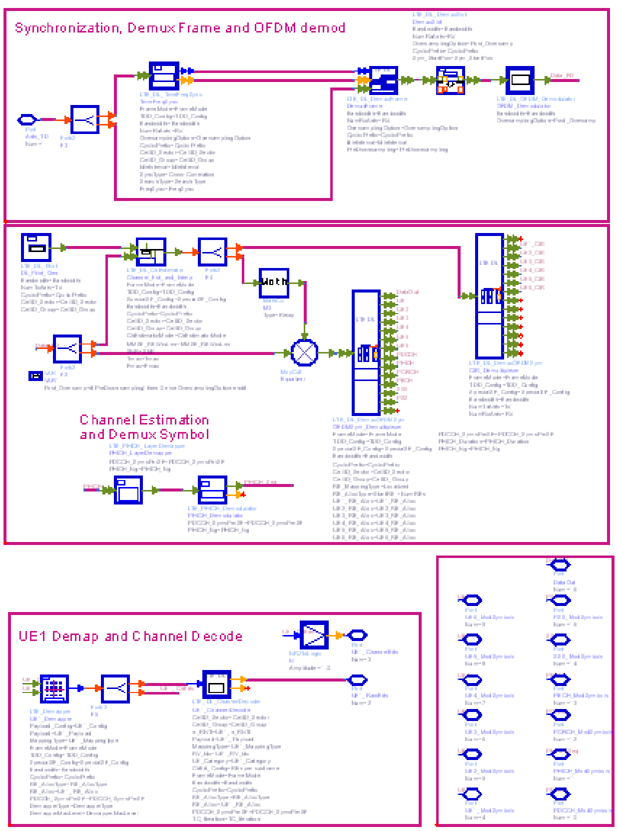
Pin	Name	Description	Signal Type
1	input	input downlink signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	UE1_RawBits	UE1 raw bits	int
3	UE1_ChannelBits	UE 1 channel bits after demodulation	int
4	UE1_ModSymbols	UE 1 modulation symbols	complex
5	UE2_ModSymbols	UE 2 modulation symbols	complex
6	UE3_ModSymbols	UE 3 modulation symbols	complex
7	UE4_ModSymbols	UE 4 modulation symbols	complex
8	UE5_ModSymbols	UE 5 modulation symbols	complex
9	UE6_ModSymbols	UE 6 modulation symbols	complex
10	PDCCH_ModSymbols	PDCCH modulation symbols	complex
11	PHICH_ModSymbols	PHICH modulation symbols	complex
12	PCFICH_ModSymbols	PCFICH modulation symbols	complex
13	PBCH_ModSymbols	PBCH modulation symbols	complex
14	SSS_ModSymbols	SSS modulation symbols	complex
15	PSS_ModSymbols	PSS modulation symbols	complex
16	DataOut	output with factor removing	complex

Notes/Equations

1. This subnetwork completes 3GPP LTE downlink FDD/TDD baseband receiver. The schematic for this subnetwork is shown in the following figure.



LTE_DL_Receiver Schematic

2. The number of input receiver antennas in this receiver is fixed to 1.
3. LTE_DL_TimeFreqSync component is for timing and frequency synchronization by using P-SCH time domain signal and outputs synchronization index and estimated small frequency offset. The integer frequency offset is further estimated in the frequency domain S-SCH. Both synchronization index and estimated frequency offset are input to LTE_DL_DemuxFrame.
First, LTE_DL_DemuxFrame compensates frequency offset by using the estimated frequency offset. Then, it outputs the real radio frame by using synchronization index after removing the IdleInterval. This model causes one frame radio delay.
One radio frame (10 ms) includes 20 slots. LTE_DL_DemuxSlot is used to demultiplex one slot into seven or six OFDM symbols by removing cyclic prefix. The position to select OFDM useful symbols is determined by Sym_StartPos. There are 7 OFDM

symbols for Normal Cyclic Prefix and 6 OFDM symbols for Extended Cyclic Prefix. Then, LTE_OFDM_Demodulator transfers input time domain signals into frequency domain signal by FFT procedure. The demodulated signals are generated by removing NULL subcarriers and exchanging plus frequency subcarriers and minus frequency subcarriers.
The demodulated signals are input to LTE_DL_ChEstimator to get channel impulse response (CIR) for each active subcarrier. LTE_DL_ChEstimator has three estimation modes: linear, MMSE_2D and For_EVM. After obtaining the CIR of each active subcarrier in each OFDM symbols, the frequency domain equalizer (one tap) or channel compensator can be used. The demodulated OFDM symbol can be achieved by this frequency domain equalizer.
LTE_DL_DemuxOFDMSym demultiplexes the demodulated OFDM symbols (in one radio frame) into P-SCH, S-SCH, BCH, PCFICH, PDCCH and six UEs (PDSCHs) modulation symbols and output all these signals.

4. For UE 1 (PDSCH 1), the modulation symbols are demapped in LTE_Demapper with three methods: Hard, Soft and CSI, results in received channel bits which are output at port UE1_ChannelBits. The demapped bits are delivered to LTE_DL_ChannelDecoder in which the de-scrambler, rate de-matching, Turbo decoder, code block de-segmentation and CRC decoder are performed. At last the received transport block bits are output at port UE1_RawBits.
5. For UE 2 to UE 6 (PDSCH 2 to PDSCH 6), only complex-valued modulation symbols from LTE_DL_DemuxOFDMSym are output.
6. The outputs at ports with the postfix ModSymbols are the complex-valued modulation symbols for corresponding channels.
7. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of demapper. These outputs are the received bits for uncoded BER and PER measurement.
8. The outputs at port UE1_RawBits are the decoded transport block bits for UE 1 (PDSCH 1). These outputs are the received bits for coded BER and PER measurement.
9. The outputs at port DataOut are the frequency subcarrier data without power scaling.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).

Rx Algorithm Parameters Details:

- PreDownsampling: Is the pre-downsampling to 1X symbol rate or not? If PreDownsampling=YES, LTE_DL_DemuxFrame outputs the radio frame with oversampling ratio 1 and the FFT size in LTE_DL_OFDM_Demodulator is just the basic size defined in the specification. This setting can save some resources and speed up the simulation. If PreDownsampling=NO, LTE_DL_DemuxFrame outputs the radio frame with oversampling ratio and the FFT size in LTE_DL_OFDM_Demodulator is the basic size (defined in the specification) multiply oversampling ratio (defined in the top level model).
- SearchType: the search type for the timing synchronization. When SearchType = Search every frame, the complete search is performed for each frame, whose search range is defined in SearchRange; When SearchType = Search+Track, the first frame performs the complete search whose search range is defined in SearchRange, the rest frames perform the tracking search whose search range is defined in TrackRange.

- SearchRange: search range for all frames when SearchType = Search every frame, and for the first frame when SearchType = Search+Track.
- TrackRange: tracking range for the rest frames when SearchType = Search+Track.
- FreqSync: frequency synchronization range, chosen from non, <100Hz, <15kHz, <35kHz.
- ChEstimatorMode: channel estimation modes, chosen from Linear, MMSE_2D, For EVM. When For EVM is selected, the estimation process defined in E.6 of [2] is employed.
- MMSE_RBWinLen: the number of RBs included to perform MMSE 2D estimation, valid when ChEstimatorMode = MMSE_2D.
- SNR: the signal noise ratio at each receiver antenna in dB for PDSCHs. This parameter is useful for the channel estimator.
- Tmax: the maximum echo delay in multi-path channel. This parameter is useful for the channel estimator.
- Fmax: the maximum Doppler frequency. This parameter is useful for the channel estimator.

> 1. Generally speaking, **MMSE_2D** channel estimator provides better BER/FER performance than **Linear** channel estimator, but it is more complicated at the same time. It requires more memory and costs more simulation time. If you just want to get a quick result but don't care much about the performance, **Linear** channel estimator would be a good choice.
> 2. If **ChEstimatorMode** is selected as **MMSE_2D**, **SNR** should be set as the signal to noise ratio in dB, **Tmax** should be set as the maximum delay of the channel, and **Fmax** should be set as the maximum doppler frequency. For example,
>   - In EPA5 channel, **SNR** should equal the actual SNR, **Tmax** should equal 0.41μs, and **Fmax** should equal 5Hz.
>   - In AWGN channel, **SNR** should equal the actual SNR, **Tmax** and **Fmax** should be set to small values, e.g. $1e^{-8}$s and 0.01Hz respectively.
>   - In connected solution, **SNR** can be set as a relatively large value e.g. 20dB, while **Tmax** and **Fmax** should be set to small values.
> 3. **MMSE_RBWinLen** indicates the number of RBs for each **MMSE_2D** interpolation. Obviously, it is only active when **ChEstimatorMode** is selected as **MMSE_2D**. This parameter impacts the complexity of the channel estimator. Larger **MMSE_RBWinLen** increases the computation complexity but not always leads to better performance. It depends on the channel characteristic. The default value 3 or 5 would work efficiently at most of the time.

- Sym_StartPos: start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP. The first value is for Long CP and the second is for Short CP. For more information, refer to *DL Demux Slot* (3gpplte).
- DemapperType: the type of Demapper, chosen from Hard, Soft and CSI. CSI (Channel State Information) is a channel estimate profile. Generally, the decoder with CSI has best performance while the decoder with Hard has worst performance.
- DemapperMaxLevel: the level of the output soft bits after Demapper which are restricted in the range [-DemapperMaxLevel, DemapperMaxLevel], valid when DemapperType is soft and CSI.

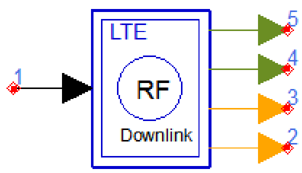
> Usually, **DemapperMaxLevel** is set to 100.0 for QPSK and 1.0 for 16QAM and 64QAM.

- TC_Iteration: the number of iterations for Turbo decoder.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_Receiver_RF (Downlink Receiver with RF De-modulator)



Description: Downlink receiver with RF de-modulator
Library: LTE, Receiver

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE downlink signals	Category		string	
RIn	source resistance	50 Ohm	Ohm	int	(0,∞)
RTemp	temperature	- 273.15	Celsius	real	[-273.15,∞]
RefFreq	internal reference frequency	2500 MHz	Hz	real	(0,∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞,∞)
Phase	Reference phase in degrees	0.0	deg	real	(-∞,∞)
GainImbalance	gain imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
PhaseImbalance	phase imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS index, Transport block size, Code rate	Transport block size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	

UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	0		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}		int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space	{4}		int array	[4, 8]

	for every subframe. The allowable levels are 4 and 8.				
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng 1/6, Ng 1/2, Ng 1, Ng 2	Ng 1/6		enum	
PowerParameters	power-related parameters	Category		string	
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
RxAlgorithmParameters	parameters for LTE downlink receiver algorithm	Category		string	
PreDownsampling	pre-downsampling to 1X symbol rate ?: NO, YES	NO		enum	
SearchType	start a new timing and frequence synchronization search for every frame or not: Search every frame, Search+Track	Search+Track		enum	
SearchRange	timing and frequence synchronization searching range for the first frame	3 msec	sec	real	[0,5.0ms]
TrackRange	timing and frequence synchronization tracking range for the frames except the first frame, valid when SearchType is set to Search+Track	0.1 msec	sec	real	[0,5.0ms]
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz		enum	
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE_2D	Linear		enum	
MMSE_RBWinLen	number of RBs for each MMSE-2D interpolation	3		int	
SNR	SNR in dB. (used by 2D-MMSE channel estimator in PDSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by 2D-MMSE channel estimator in PDSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler	100 Hz	Hz	real	[0,∞)

	frequency. (used by 2D-MMSE channel estimator in PDSCH)				
Sym_StartPos	start position (without oversampling) to get the OFDM symbol for FFT operation for long CP and short CP symbols respectively, compared to the start position of the OFDM body after CP	{-3,-3}		int array	
DemapperType	symbol demodulation type: Hard, Soft, CSI	Soft		enum	
DemapperMaxLevel	the maximum level for soft demapping output when DemapperType is Soft or CSI	1.0		real	(0,∞)
TC_Iteration	Turbo decoder iteration number	4		int	[1,20]

Pin Inputs

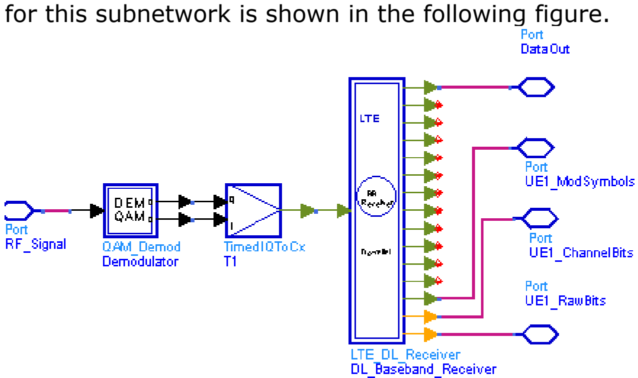
Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	UE1_RawBits	UE1 raw bits	int
3	UE1_ChannelBits	UE 1 channel bits after demodulation	int
4	UE1_ModSymbols	UE 1 modulation symbols	complex
5	DataOut	output frequency data with factor removing	complex

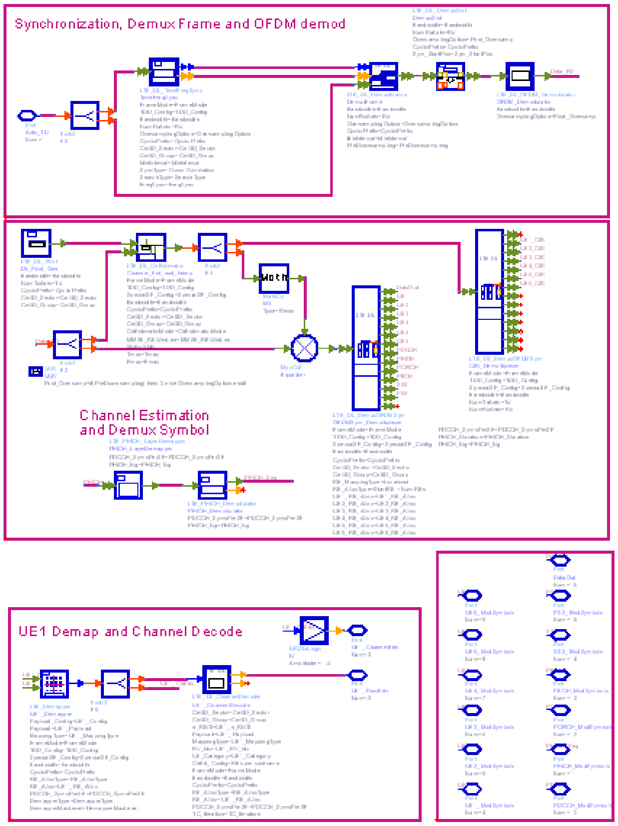
Notes/Equations

1. This subnetwork completes the 3GPP LTE downlink FDD RF receiver (up to six users) for single receiver antenna. The subnetwork includes LTE_DL_Receiver, which is the baseband 3GPP LTE coded downlink receiver, and the QAM_Demod. The schematic for this subnetwork is shown in the following figure.



LTE_DL_Receiver_RF Schematic

2. The baseband coded downlink receiver schematic is shown in the following figure. The detailed information for LTE_DL_Receiver is in *LTE Downlink Baseband Receiver* (3gpplte).



LTE_DL_Receiver Schematic

RF Parameter Details:

- Rin is the RF input source resistance.
- RTemp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- RefFreq is the internal reference frequency.
- Sensitivity is the voltage output sensitivity, Vout/Vin.
- Phase is the reference phase in degrees.
- GainImbalance is the gain imbalance in dB Q channel relative to I channel.
- PhaseImbalance is the phase imbalance in dB Q channel relative to I channel.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).

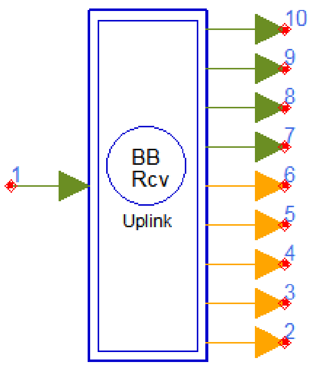
Rx Algorithm Parameters Details:

- Refer to *DL Rx Algorithm Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_Receiver (Uplink Baseband Receiver)



Description: Uplink baseband receiver
Library: LTE, Receiver

Parameters

Name	Description	Default	Unit	Type	Range
SystemParameters	system parameters for LTE uplink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0, 2]
CellID_Group	the index of cell identity group	0		int	[0, 167]
n_RNTI	radio network temporary identifier	0		int	[0, 65535]
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0, 1.0e-3]
FrameNum	frame number	0		int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO		enum	
DL_CyclicPrefix	type of cyclic prefix in downlink: DL_Normal, DL_Extended	DL_Normal		enum	
PUSCH_Parameters	PUSCH parameters for LTE uplink signals	Category		string	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
Payload_Config	the configuration mode of input data of PUSCH.: MCS_index, Transport_block_size, Code_rate	Transport_block_size		enum	

Payload	the input payload for PUSCH, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES		enum	
MappingType	the modulation orders for the PUSCH in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
RV_Idx	Redundancy Version Index	0		int	[0, 3]
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	NO		enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO		enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame		enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0		int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1		int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz		enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}		int array	
GroupHop_Enable	whether enable group hopping for DMRS on PUCCH and PUSCH or not: NO, YES	NO		enum	
SeqHop_Enable	whether enable sequence hopping for DMRS on PUSCH or not: NO, YES	NO		enum	
PUSCH_Delta_ss	used in determining the sequence-shift pattern for PUSCH	0		int	[0, 29]
PUSCH_n_DMRS1	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUSCH_n_DMRS2	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUCCH_Parameters	PUCCH parameters for LTE uplink signals	Category		string	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1		enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2		int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1		int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11		int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11		int	[0, 12*PUCCH_NB2-1]
PRACH_Parameters	PRACH parameters for LTE	Category		string	

	uplink signals				
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO		enum	
PRACH_Config	PRACH configuration index	0		int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{0}		int array	[0, 9]
PRACH_PrmbleIndex	preamble indexes, used to select preamble sequences from 64 preambles available in this cell	{0}		int array	[0, 63]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0		int	[0, 94]
PRACH_LogicalIndex	logical index of root ZC sequence	0		int	[0, 837]
PRACH_Ncs	cyclic shifts of ZC sequence	0		int	[0, 15]
PRACH_HS_flag	high speed flag: NO, YES	NO		enum	
SRS_Parameters	SRS parameters for LTE uplink signals	Category		string	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO		enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7		int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0		int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO		enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0		int	[0, 3]
SRS_HoppingBandwidth	the SRS hopping bandwidth	3		int	[0, 3]
SRS_FreqPosition	the SRS frequency domain position	0		int	[0, 23]
SRS_ConfigIndex	the UE-specific SRS configuration	0		int	[0, 1023]
SRS_TransmissionComb	transmission comb	0		int	[0, 1]
SRS_CyclicShift	used in computing the cyclic shift of SRS	0		int	[0, 7]
PowerParameters	power-related parameters	Category		string	
PUSCH_PwrOffset	the power offset in dB for PUSCH	0		real	(-∞, +∞)
PUSCH_RS_PwrOffset	the power offset in dB for PUSCH RS	0		real	(-∞, +∞)
PUCCH_PwrOffset	the power offset in dB for PUCCH	0		real	(-∞, +∞)
PUCCH_RS_PwrOffset	the power offset in dB for PUCCH RS	0		real	(-∞, +∞)
PRACH_PwrOffset	the power offset in dB for PRACH	0		real	(-∞, +∞)
SRS_PwrOffset	the power offset in dB for SRS	0		real	(-∞, +∞)
ControlInfoParameters	control information parameters for LTE uplink signals	Category		string	
RI_NumInfoBits	RI information bits size	{0}		int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}		int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}		int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}		int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0}		int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0}		int array	[0,14]

RxAlgorithmParameters	parameters for LTE uplink receiver algorithm	Category		string	
IQ_Offset_Correct	whether or not to correct IQ offset: NO, YES	YES		enum	
PreDownsampling	pre-downsampling to 1X symbol rate: NO, YES	NO		enum	
Sym_StartPos	the start position of the negative offset value to the CP length(without oversampling) to get the OFDM symbol for FFT operation	{-3,-3}		int array	
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE	Linear		enum	
SNR	SNR in dB. (used by MMSE channel estimator in PUSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by MMSE channel estimator in PUSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by MMSE channel estimator in PUSCH)	100 Hz	Hz	real	[0,∞)
DemapperType	symbol demodulation type: Hard, Soft	Soft		enum	
DemapperMaxLevel	the maximum level for soft demapping output when DemapperType is Soft or CSI	1.0		real	(0,∞)
TC_Iteration	Turbo decoder iteration number	4		int	[1,20]

Pin Inputs

Pin	Name	Description	Signal Type
1	Frame	input uplink signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	UE_RawBits	output of UE data after channel decoder	int
3	PUSCH_ChannelBits	output of PUSCH data before channel decoder	int
4	RI_Out	rank indication out	int
5	HARQACK_Out	HARQ and ACK out	int
6	CQI_Out	channel quality information out	int
7	PUSCH_ModSymbols	output of PUSCH modulation symbols in time domain	complex
8	PUSCH_FD	output of PUSCH data in frequency domain	complex
9	PUCCH_Sym	output of PUCCH signal in frequency domain	complex
10	FRM_FD	output of frame signal in frequency domain	complex

Parameters Details

Rx Algorithm Parameters Details:

- IQ_Offset_Correct : whether enable IQ offset correction or not. The IQ offset correction is done by LTE_IQ_Offset.
- PreDownsampling: whether enable pre-downsampling to 1× symbol rate in LTE_UL_DemuxFrame or not. If "NO", the downsampling is performed by LTE_SCFDMA_Demodulator.

> When PreDownsampling = YES, the downsampling operation is performed inside this receiver. Note that there is no internal anti-aliasing filter provided by the receiver. Users need to add external anti-aliasing filter to make sure no aliasing occurs when downsampling.

- Sym_StartPos: start position (without oversampling) to get the SC-FDMA symbol for FFT operation. Here the "start position" is compared to the first sample of the SC-FDMA symbol body excluding the cyclic prefix. Hence the value is negative indicating the start position locates in the CP duration. It consists of two elements which are for the first SC-FDMA symbol and the others respectively. For more information, refer to *LTE_UL_DemuxSlot* (3gpplte).
- ChEstimatorMode: interpolation algorithm used in channel estimator, the type is enum. It can be selected as Linear and MMSE. For more information, please refer to *LTE_UL_ChEstimator* (3gpplte).

- SNR: the signal noise ratio (in dB) of PUSCH at the receiver. It is used by MMSE interpolator for PUSCH channel estimation.
- Tmax: the maximum delay of multi-path channel, used by MMSE interpolator for PUSCH channel estimation. It is of time unit. It can be set to a small value e.g. 1e-8 s in AWGN channel.
- Fmax: the maximum doppler frequency, used by MMSE interpolator for PUSCH channel estimation. It is of frequency unit. It can be set to a small value e.g. 0.01 Hz in AWGN channel.

> 1. Generally speaking, **MMSE** channel estimator provides better BER/FER performance than **Linear** channel estimator, but it is more complicated at the same time. It requires more memory and costs more simulation time. If you just want to get a quick result but don't care much about the performance, **Linear** channel estimator would be a good choice.
> 2. If **ChEstimatorMode** is selected as **MMSE**, **SNR** should be set as the signal to noise ratio in dB, **Tmax** should be set as the maximum delay of the channel, and **Fmax** should be set as the maximum doppler frequency. For example,
>   - In EPA5 channel, **SNR** should equal the actual SNR, **Tmax** should equal 0.41μs, and **Fmax** should equal 5Hz.
>   - In AWGN channel, **SNR** should equal the actual SNR, **Tmax** and **Fmax** should be set to small values, e.g. $1e^{-8}$s and 0.01Hz respectively.
>   - In connected solution, **SNR** can be set as a relatively large value e.g. 20dB, while **Tmax** and **Fmax** should be set to small values.

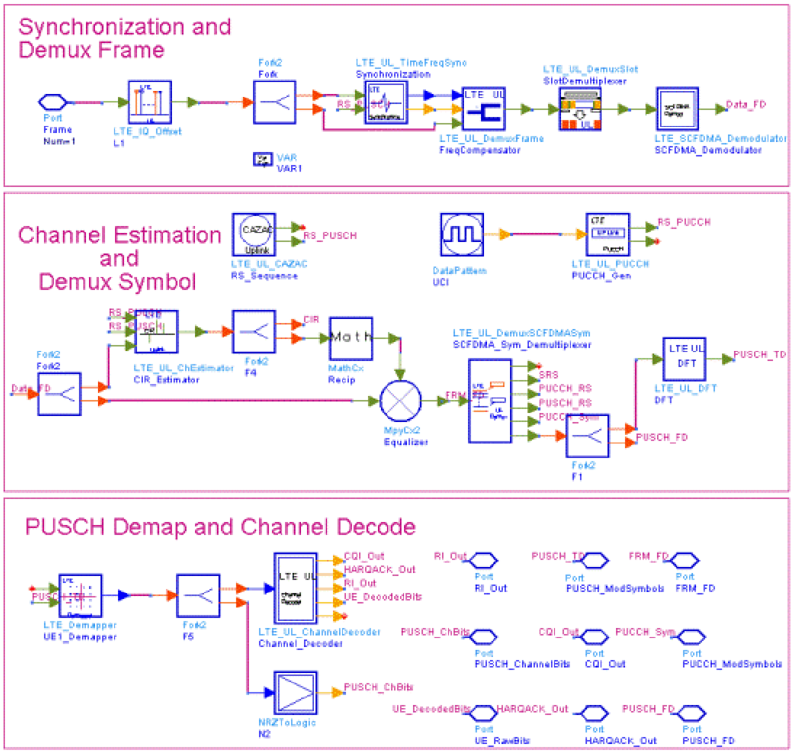
- DemapperType: the type of Demapper. It can be selected as Hard and Soft.
- DemapperMaxLevel: the level of the output soft bits from Demapper are restricted in the range [-DemapperMaxLevel, DemapperMaxLevel]. It is ignored when DemapperType = hard.

> Usually, **DemapperMaxLevel** is set to 100.0 for QPSK and 1.0 for 16QAM and 64QAM.

- TC_Iteration: the number of iterations for Turbo decoding.

Notes/Equations

1. This subnetwork constructs 3GPP LTE uplink baseband receiver for both frame structure type 1 and frame structure type 2.
2. Each firing,
    - the number of tokens consumed at port Frame is equal to the number of samples in each frame;
    - the number of tokens produced at port RawBits is equal to the sum of the transport block size of all subframes;
    - the number of tokens produced at port PUSCH_ChannelBits is equal to the number of PUSCH channel bits in each frame. For more information, refer to *Channel Bits Calculation* (3gpplte);
    - the number of tokens produced at port RI_Out is equal to the number of RI coded bits in each frame;
    - the number of tokens produced at port HARQACK_Out is equal to the number of HARQ-ACK coded bits in each frame;
    - the number of tokens produced at port CQI_Out is equal to the number of CQI coded bits in each frame;
    - the number of tokens produced at port PUSCH_ModSymbols is equal to the number of allocated REs for PUSCH (excluding PUSCH DMRS) in each frame;
    - the number of tokens produced at port PUSCH_FD is equal to the number of allocated REs for PUSCH (excluding PUSCH DMRS) in each frame;
    - the number of tokens produced at port PUCCH_Sym is equal to the number of allocated REs for PUCCH (excluding PUCCH DMRS) in each frame;
    - the number of tokens produced at port FRM_FD is equal to the total number of REs in each frame;
    - One frame delay is introduced in each output port
    - For the default parameters configurations, the number of samples in each frame is 153600, the transport block size in each subframe is 25550, the number of channel bits in each subframe is 72000, the number of allocated REs for PUSCH in each subframe is 36000, the number of total REs in each subframe is 42000. Uplink control information in the form of RI, HARQ-ACK and CQI are not transmitted. PUCCH is not transmitted.
3. The **LTE_UL_Receiver** schematic is shown below:



4. First of all, *LTE_IQ_Offset* (3gpplte) performs the DC calibration and corrects the IQ offset of the received signal as long as it is enabled (IQ_Offset_Correct = YES). Timing and frequency synchronization are performed in LTE_UL_TimeFreqSync utilizing the reference signals and cyclic prefix of SC-FDMA symbols.
5. Both timing synchronization index and estimated frequency offset from *LTE_UL_TimeFreqSync* (3gpplte) are passed into LTE_UL_DemuxFrame, as well as the received signal after IQ offset correcting.
6. Then, *LTE_UL_DemuxFrame* (3gpplte) compensated the frequency offset and outputs the real radio frame making use of the timing synchronization index. It should be noted that this model causes one radio frame delay.
7. One radio frame (10 ms) consists of 20 slots. *LTE_UL_DemuxSlot* (3gpplte) demultiplexes each slot into seven and six SC-FDMA symbols for normal cyclic prefix and extended cyclic prefix respectively, where the start of each symbol is calculated from Sym_StartPos.
8. Next, *LTE_SCFDMA_Demodulator* (3gpplte) transforms the time domain signals into frequency domain signal by calling FFT procedure (LTE_FFT). The frequency domain signals are regenerated by removing NULL subcarriers and swapping positive frequency subcarriers and negative frequency subcarriers in LTE_SCFDMA_Demodulator.
9. The demodulated signals and the local reference signals are input to *LTE_UL_ChEstimator* (3gpplte) to get channel impulse response (CIR) for each subcarrier occupied by PUSCH and PUCCH. LTE_UL_ChEstimator works on a slot basis. LTE_UL_ChEstimator uses the reference signal to get the real CIRs for those allocated resource blocks.
10. After getting CIR of each active subcarrier in each SC-FDMA symbol, the frequency domain equalizer (one tap) or channel compensator can be used.
11. *LTE_UL_DemuxSCFDMASym* (3gpplte) demultiplexes SC-FDMA symbols into PUSCH, DMRS for PUSCH, PUCCH, DMRS for PUCCH and SRS as they were organized in the transmitter side.
12. The frequency domain signals of PUSCH are converted into time domain after IDFT by *LTE_UL_DFT* (3gpplte). Then, the time domain symbols are demapped according to the MappingType and decoded by *LTE_UL_ChannelDecoder* (3gpplte) in which descrambling, deinterleaving and demultiplexing of data and control information, rate dematching , turbo decoding, code block de-segmentation and CRC decoding are performed .
13. The outputs from each output port of this subnetwork are described in the following table.

Ports name	Outputs description
TBS	transport block size in each firing
HARQ_Bits	HARQ ACK/NACK in each firing
FRM_FD	Frequency domain data without oversampling
PUCCH_ModeSymbols	Complex-valued modulation symbols of PUCCH
PUSCH_FD	Frequency domain PUSCH data without oversampling
PUSCH_ModeSymbols	Complex-valued modulation symbols of PUSCH
CQI_Out	CQI bits from deinterleaver, CQI bits are not decoded in current implementation.
HARQACK_Out	HARQ-ACK bits from deinterleaver, HARQ-ACK bits are not decoded in current implementation.
RI_Out	rank indication bits from deinterleaver, RI bits are not decoded in current implementation.
PUSCH_ChannelBits	outputs of LTE_Demapper. These channel bits are for uncoded BER and PER measurement. For more information, refer to *Channel Bits Calculation* (3gpplte).
UE_RawBits	decoded bits of PUSCH. These outputs are for coded BER and PER measurement.

14. See *LTE_UL_Src* (3gpplte).

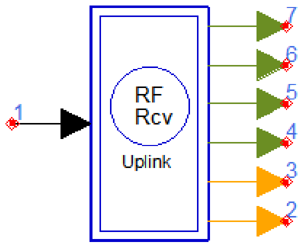
It should be noted that the demodulation and decoding of PUCCH, detection of SRS, detection of PRACH and decoding of uplink control information on PUSCH are not supported in current implementation.

- For more information on the System Parameters details please refer to *UL System Parameters* (3gpplte).
- For more information on the PUSCH Parameters details please refer to *UL PUSCH Parameters* (3gpplte).
- For more information on the PUCCH Parameters details please refer to *UL PUCCH Parameters* (3gpplte).
- For more information on the PRACH Parameters details please refer to *UL PRACH Parameters* (3gpplte).
- For more information on the SRS Parameters details please refer to *UL SRS Parameters* (3gpplte).
- For more information on the Power Parameters details please refer to *UL Power Parameters* (3gpplte).
- For more information on the Control Parameters details please refer to *UL Control Information Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.101 v8.6.0 "User Equipment (UE) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_UL_Receiver_RF (Uplink Receiver with RF De-modulator)



Description: Uplink receiver with RF de-modulator
Library: LTE, Receiver

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE uplink signals	Category		string	
RIn	source resistance	50 Ohm	Ohm	int	(0,∞)
RTemp	temperature	- 273.15	Celsius	real	[- 273.15,∞]
RefFreq	internal reference frequency	2500 MHz	Hz	real	(0,∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞,∞)
Phase	Reference phase in degrees	0.0	deg	real	(-∞,∞)
GainImbalance	gain imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
PhaseImbalance	phase imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
SystemParameters	system parameters for LTE uplink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
n_RNTI	radio network temporary identifier	0		int	[0,65535]
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
FrameNum	frame number	0		int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO		enum	
DL_CyclicPrefix	type of cyclic prefix in downlink: DL_Normal,	DL_Normal		enum	

	DL_Extended				
PUSCH_Parameters	PUSCH parameters for LTE uplink signals	Category		string	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
Payload_Config	the configuration mode of input data of PUSCH.: MCS index, Transport block size, Code rate	Transport block size		enum	
Payload	the input payload for PUSCH, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
Enable64QAM	whether 64QAM is allowed in LTE uplink: NO, YES	YES		enum	
MappingType	the modulation orders for the PUSCH in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
RV_Idx	Redundancy Version Index	0		int	[0, 3]
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	YES		enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO		enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame		enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0		int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1		int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz		enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[[SF0 start RB, SF0 number of RBs], ..., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
GroupHop_Enable	whether enable group hopping for DMRS on PUCCH and PUSCH or not: NO, YES	NO		enum	
SeqHop_Enable	whether enable sequence hopping for DMRS on PUSCH or not: NO, YES	NO		enum	
PUSCH_Delta_ss	used in determining the sequence-shift pattern for PUSCH	0		int	[0,29]
PUSCH_n_DMRS1	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUSCH_n_DMRS2	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUCCH_Parameters	PUCCH parameters for LTE uplink signals	Category		string	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1		enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2		int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format	1		int	[0, 99]

	2/2a/2b				
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11		int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11		int	[0, 12*PUCCH_NB2-1]
PRACH_Parameters	PRACH parameters for LTE uplink signals	Category		string	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO		enum	
PRACH_Config	PRACH configuration index	0		int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}		int array	[0, 9]
PRACH_PrmbleIndex	preamble indexes, used to select preamble sequences from 64 preambles available in this cell	{0}		int array	[0, 63]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0		int	[0, 94]
PRACH_LogicalIndex	logical index of root ZC sequence	0		int	[0, 837]
PRACH_Ncs	cyclic shifts of ZC sequence	0		int	[0, 15]
PRACH_HS_flag	high speed flag: NO, YES	NO		enum	
SRS_Parameters	SRS parameters for LTE uplink signals	Category		string	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO		enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7		int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0		int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO		enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0		int	[0, 3]
SRS_HoppingBandwidth	the SRS hopping bandwidth	3		int	[0, 3]
SRS_FreqPosition	the SRS frequency domain position	0		int	[0, 23]
SRS_ConfigIndex	the UE-specific SRS configuration	0		int	[0, 1023]
SRS_TransmissionComb	transmission comb	0		int	[0, 1]
SRS_CyclicShift	used in computing the cyclic shift of SRS	0		int	[0, 7]
PowerParameters	power-related parameters	Category		string	
PUSCH_PwrOffset	the power offset in dB for PUSCH	0		real	(-∞, +∞)
PUSCH_RS_PwrOffset	the power offset in dB for PUSCH RS	0		real	(-∞, +∞)
PUCCH_PwrOffset	the power offset in dB for PUCCH	0		real	(-∞, +∞)
PUCCH_RS_PwrOffset	the power offset in dB for PUCCH RS	0		real	(-∞, +∞)
PRACH_PwrOffset	the power offset in dB for PRACH	0		real	(-∞, +∞)
SRS_PwrOffset	the power offset in dB for SRS	0		real	(-∞, +∞)
ControlInfoParameters	control information parameters for LTE uplink signals	Category		string	
RI_NumInfoBits	RI information bits size	{0}		int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}		int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}		int array	[0,∞)

CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}		int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0}		int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0}		int array	[0,14]
RxAlgorithmParameters	parameters for LTE uplink receiver algorithm	Category		string	
IQ_Offset_Correct	whether or not to correct IQ offset: NO, YES	YES		enum	
PreDownsampling	pre-downsampling to 1X symbol rate: NO, YES	NO		enum	
Sym_StartPos	the start position of the negative offset value to the CP length(without oversampling) to get the OFDM symbol for FFT operation	{-3,-3}		int array	
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE	Linear		enum	
SNR	SNR in dB. (used by MMSE channel estimator in PUSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by MMSE channel estimator in PUSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by MMSE channel estimator in PUSCH)	100 Hz	Hz	real	[0,∞)
DemapperType	symbol demodulation type: Hard, Soft	Soft		enum	
DemapperMaxLevel	the maximum level for soft demapping output when DemapperType is Soft or CSI	1.0		real	(0,∞)
TC_Iteration	Turbo decoder iteration number	4		int	[1,20]

Pin Inputs

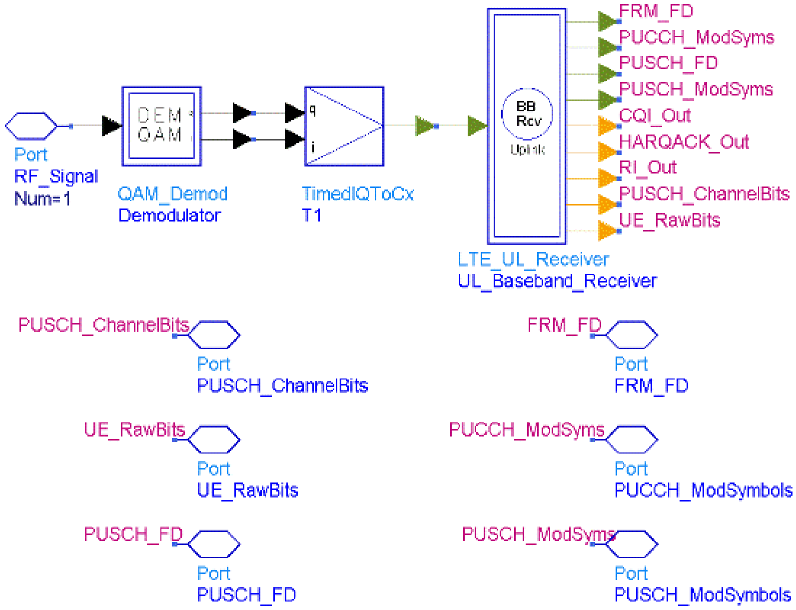
Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	UE_RawBits	output of UE data after channel decoding	int
3	PUSCH_ChannelBits	output of PUSCH data before channel decoding	int
4	PUSCH_ModSymbols	output of PUSCH modulation symbols	complex
5	PUSCH_FD	output of PUSCH in frequency domain	complex
6	PUCCH_ModSymbols	output of PUCCH modulation symbols	complex
7	FRM_FD	output of frame signal in frequency domain	complex

Notes/Equations

1. This subnetwork constructs 3GPP LTE uplink RF receiver for both frame structure 1 and frame structure 2. It consists of the 3GPP LTE uplink baseband receiver (LTE_UL_Receiver) and the QAM_Demod. The schematic for this subnetwork is shown in the following figure.



LTE_UL_Receiver_RF Schematic

2. For more information on the LTE uplink baseband receiver, please refer to *LTE_UL_Receiver* (3gpplte).

Parameter Details

RF parameters Details:

- Rin: the RF input source resistance
- RTemp: the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k · (RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- RefFreq: the internal reference frequency.
- Sensitivity: the voltage output sensitivity, Vout/Vin.
- Phase: the reference phase in degrees.
- GainImbalance: the gain imbalance in dB, Q channel relative to I channel.
- PhaseImbalance is the phase imbalance in dB, Q channel relative to I channel. For more information about Sensitivity, Phase, GainImbalance and PhaseImbalance, please refer to *QAM_Demod* (timed).

System Parameters Details:

- Please refer to *UL System Parameters* (3gpplte).

PUSCH Parameters Details:

- Please refer to *UL PUSCH Parameters* (3gpplte).

PUCCH Parameters Details:

- Please refer to *UL PUCCH Parameters* (3gpplte).

PRACH Parameters Details:

- Please refer to *UL PRACH Parameters* (3gpplte).

SRS Parameters Details:

- Please refer to *UL SRS Parameters* (3gpplte).

Power Parameters Details:

- Please refer to *UL Power Parameters* (3gpplte).

Control Information Parameters Details:

- Please refer to *UL Control Information Parameters* (3gpplte).

Rx Algorithm Parameters Details:

- Please refer to *UL Rx Algorithm Parameters* (3gpplte).

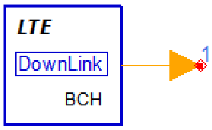
References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.101 v8.6.0 "User Equipment (UE) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

3GPP LTE Signaling Components

Contents

LTE_BCH_Gen



Description: generator for 24 BCH information bits
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
FrameNum	frame number	0	int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO	enum	
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration	enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	BCH	BCH bits	int

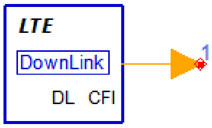
Notes/Equations

1. This model is to generate 24 information bits transmitted on PBCH.
2. The 24 bits are the MasterInformationBlock as defined in [1]. The formats are:
   - **Bit#0~2**: SystemBandwidth ENUMERATED {n6, n15, n25, n50, n75, n100}
   - **Bit#3**: phich-Duration ENUMERATED {normal, extended},
   - **Bit#4~5**: phich-Resource ENUMERATED {oneSixth, half, one, two}
   - **Bit#6~13**: systemFrameNumber: the 8 most significant bits of the SFN
   - **Bit#14~23**: spare
3. Each firing, Bit#0 is output first, and then Bit#1, Bit#2, ..., at last Bit#23.
4. When the FrameIncreased parameter is set to YES, the system frame number increases per each frame, and the index in the first frame is *FrameNum*. When the FrameIncreased parameter is set to NO, all the system frame number is fixed to *FrameNum*.

References

1. 3GPP TS 36.311 v8.5.0, "Radio Resource Control (RRC); Protocol specification", Mar 2009.

LTE_DL_CFI (Control Format Indicator)



Description: Downlink Control Format Indicator
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]

Pin Outputs

Pin	Name	Description	Signal Type
1	CFI	downlink pilot symbol	int

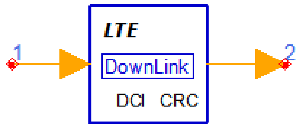
Notes/Equations

1. This model is used to generate the coded control format indicator bits as defined in 5.3.4 of 36.212.
2. Each firing, 32*N_PCFICHs tokens are generated, where N_PCFICHs is the number of PCFICHs of one frame. Each subframe has a PCFICH if the active PDCCH symbols exist in this subframe. So the N_PCFICH is same as the number of subframes that has active PDCCH symbols which is decided by the parameters FrameMode, TDD_Config and PDCCH_SymsPerSF.
3. The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The CFI takes values CFI = 1, 2 or 3.
   - For system bandwidths **N_RB>10**: the span of the DCI in units of OFDM symbols 1, 2 or 3 is given by the CFI. So the control format indicator takes values CFI=1, 2 or 3 (the number of OFDM symbols for PDCCH).
   - For system bandwidths **N_RB<10**: the span of the DCI in units of OFDM symbols 2, 3 or 4 is given by CFI+1. So the control format indicator takes values CFI=1, 2 or 3 (the number of OFDM symbols for PDCCH - 1).
4. The control format indicator is coded according to Table 5.3.4-1 of [2].
5. Parameter details:
   - For the system parameters FrameMode, TDD_Config and Bandwidth, refer to *DL System Parameters* (3gpplte).
   - For the parameter PDCCH_SymsPerSF, refer to *DL Control Channel Parameters* (3gpplte).
6. See *LTE_PCFICH_Scrambler* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_DL_DCI_CRC (Add CRC to Downlink Control Information)



Description: Downlink Control Information CRC Encoder
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}	int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}	int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}	int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}	int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}	int array	[0,2e16-1]
UE_TxAntSelection	UE transmit antenna selection is not configured or applicable or UE port0 or UE port1: Non_config, Port0, Port1	Non_config	enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

Notes/Equations

1. This model is used to add the Cyclic Redundancy Check bits for the DCIs transmitted in one frame.
2. Each firing, $\sum_{sf=0}^{N\_SF} \sum_{dci=0}^{N\_DCI\_SF} Len\_DCI(sf, dci)$ tokens are consumed at DataIn, and $\sum_{sf=0}^{N\_SF} \sum_{dci=0}^{N\_DCI\_SF} (Len\_DCI(sf, dci) + 16)$ tokens are generated at DataOut. The number of DCIs in one frame is decided by these system parameters and the length of each DCI Len_DCI(sf, dci) is decided by the DCI Formats.
3. The calculation of the CRC for each DCI is defined by 5.3.3.2 and 5.1.1 of [2].

1. Parameter Details:

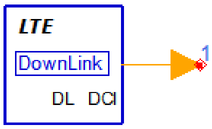
System Parameters	FrameMode TDD_Config Bandwidth NumTxAnts CyclicPrefix
PDCCH corresponding parameters	PDCCH_SymsPerSF PHICH_Ng PDCCH_UE_AggreLevel PDCCH_UE_DCI_Formats PDCCH_Common_AggreLevel PDCCH_Common_DCI_Formats
Scrambling corresponding parameters	UE_n_RNTI UE_TxAntSelection

- For the system parameters , refer to *DL System Parameters* (3gpplte).
- For control channel parameters, refer to *DL Control Channel Parameters* (3gpplte).
- UE_n_RNTI: radio network temporary identifier for UE. In the case where UE transmit antenna selection is not configured or applicable, after attachment, the CRC parity bits are scrambled with the corresponding RNTI x_rnti_0, x_rnti_1, ... x_rnti_15. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1, 10xN, where N is the maximun number of PDDCCHs across 10 subframes.
- UE_TxAntSelection: UE transmit antenna selection is not configured or applicable or UE port0 or UE port1. In the case where UE transmit antenna selection is configured and applicable, after attachment, the CRC parity bits of PDCCH with DCI format 0 are scrambled with the antenna selection mask x_AS_0, x_AS_1,..., x_AS_15 as indicated in Table 5.3.3.2-1 of [2] and the corresponding RNTI x_rnti_0, x_rnti_1, ... , x_rnti_15.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_DL_DCI_Gen (Downlink control information generator)



Description: Downlink Control Information Generator
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
SystemParameters	system parameters for LTE	Category	string	
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng 1/6, Ng 1/2, Ng 1, Ng 2	Ng 1/6	enum	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_SF_Config	the cell-specific SRS subframe configuration	0	int	[0, 14]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}	int array	[1,2,4,8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}	int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}	int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}	int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}	int array	[0,2e16-1]
DCI_Format0	parameters for DCI Format 0	Category	string	
PUSCH_RB_Hopping	whether uplink frequency-hopping is enabled for the mapping of VRBs to PRBs for PUSCH: NO, YES	NO	enum	
PUSCH_Hop_bit	used to fill the hopping bit or bits in PDCCH DCI Format 0	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
PUSCH_RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs	enum	
PUSCH_RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[[SF0 start RB, SF0 number of	{0, 25}	int array	

	RBs], ..., [SF9 start RB, SF9 number of RBs]]			
PUSCH_Config	the configuration mode of input data for PUSCH.: MCS index, Transport block size, Code rate	MCS index	enum	
PUSCH_Payload	the input payload for PUSCH, the meaning of the input is defined in PUSCH_Config	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	real array	
PUSCH_MappingType	the modulation orders for the PUSCH in each DCI. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
PUSCH_NewDataIndic	New data indicator for each DCI	{1,1,1,1,1,1,1,1,1,1}	int array	
PUSCH_TPC_cmd	TPC command for scheduled PUSCH for each DCI	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,3]
PUSCH_n_DMRS2	used in computing the cyclic shift for PUSCH DMRS for each DCI	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
UL_Idx_DAI	UL index which only applies to TDD operation	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,3]
PUSCH_CQI	CQI request	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
DCI_Format_1_1A	parameters for DCI Format 1 and 1A	Category	string	
PDSCH_RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized	enum	
PDSCH_ResAllocType	Resource allocation type	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,1]
PDSCH_RBG_Subset	RBG subset, active when PDSCH_ResAllocType is 1	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,3]
PDSCH_ResAllocShift	indicate a shift of the resource allocation span within a subset, active when PDSCH_ResAllocType is 1	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,1]
PDSCH_RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs	enum	
PDSCH_RB_Alloc	the RB allocation for the UE, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}	int array	
PDSCH_Config	the configuration mode of input data for PDSCH.: MCS index, Transport block size, Code rate	MCS index	enum	
PDSCH_Payload	the input payload for PDSCH, the meaning of the input is defined in PDSCH_Config	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	real array	
PDSCH_MappingType	the modulation orders for the PDSCH in each DCI. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
PDSCH_HARQ_ProcNum	HARQ process number for each DCI	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
PDSCH_NewDataIndic	New data indicator for each DCI	{1,1,1,1,1,1,1,1,1,1}	int array	
PDSCH_RV	Redundancy version for each DCI	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,3]
PUCCH_TPC_cmd	TPC command for scheduled PUCCH for each DCI	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,1]
DL_Idx	DL index which only applies to TDD operation	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,3]
DCI_Format1B	parameters for DCI Format 1B	Category	string	
PDSCH_PMI_Confirm	PMI confirmation for precoding	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0,1]
DCI_Format1D	parameters for DCI Format 1D	Category	string	
DL_PwrOffset	downlink power offset	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
DCI_Format_2_2A	parameters for DCI Format 2 and 2A	Category	string	
MIMO_Mode	MIMO mode: Spatial_Mux, Tx_Div	Spatial_Mux	enum	
CDD_Mode	cyclic delay diversity (CDD) mode, valid when MIMO_Mode is Spatial_Mux: Large-Delay, Zero-	Large-Delay	enum	

	Delay			
CdBlk_Index	codebook index for precoding, valid when MIMO_Mode is Spatial_Mux	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	[0, 15]
DL_TB2CW_Swap	Transport block to codeword swap	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}	int array	
PDSCH_UE_NumOfCWs	number of code words for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}	int array	[1,2]
PDSCH_UE_NumOfLayers	number of layers for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}	int array	[1,4]
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	DataOut	data out	int

Notes/Equations

1. This model is used to generate DCI information bits of one radio frame (10 subframe) following 5.3.3.1 of 36212-880, 9.1 of 36213-880 and 6.8 of 36211-890.
2. Each firing,
   the DCI information bits of one radio frame (10 subframe) are generated at DataOut port. The number of DCI bits in this subframe

   $$N_{DCIbits} = \sum_{l=0}^{l=NumOfActiveDCIs\_sf} N_{bits\_1dci}(sf, l)$$,

   where, *Nbits_1dci(sf, l)* is the number of bits of the l^{th} DCI in subframe *sf* defined in 5.3.3.1 of 36212-880 and *NumOfActiveDCI_sf* is the number of active DCIs of one subframe which is same as that of the active PDCCHs. They are decided by the PDCCH corresponding parameters and system parameters.

PDCCH corresponding parameters	PDCCH_SymsPerSF PDCCH_UE_AggreLevel PDCCH_UE_DCI_Formats PDCCH_Common_AggreLevel PDCCH_Common_DCI_Formats UE_n_RNTI
System Parameters	FrameMode TDD_Config

   These system parameters decided the active PDCCH symbols of each subframe. The PDCCH corresponding parameters decided the number of active DCIs and their format of each subframe.
   FrameMode and TDD_Config define the non-uplink subframes and they work with PDCCH_SymsPerSF define the active PDCCH symbols in each subframe. In these subframes having actual PDCCH, PDCCH_UE_AggreLevel, PDCCH_Common_AggreLevel indicate the PDCCH aggregation level and the number of PDCCH candidates. The allowable sizes of these 2 parameters are 1 or 10x1 (each element for one subframe). PDCCH_UE_DCI_Formats and PDCCH_Common_DCI_Formats indicate the active PDCCH (or PDCCHs) of the candidates as well as the corresponding DCI formats. Each active PDCCH contains one DCI. The allowable sizes of these 2 parameters are Mmax or 10xMmax (each Mmax elements for one subframe), where Mmax is 6 for UE-specific and 4 for Common. To support the E-UTRA Test Models defined in 36141-850, the allowable sizes of the parameter PDCCH_UE_DCI_Formats is extended to Mmax (all subframes have the same configuration), where Mmax_e can be 7, 8, 9 and 10. For each subframe, if the aggregation level is set to L, the number of PDCCH candidates is $M^{(L)}$, and so the first $M^{(L)}$ elements of the Mmax elements are active. -1 means no DCI (PDCCH) in correspoding candidate. Refer to Table 9.1.1-1 in 9.1.1 of 36213-880.
   For example,

PDCCH_UE_AggreLevel=2	PDCCH_UE_DCI_Formats=[2, -1, -1, 0, -1, -1]
PDCCH_Common_AggreLevel=8	PDCCH_Common_DCI_Formats=[-1, -1, -1, -1]
Actual DCIs	[DCI format 1A, DCI format 0] They are transmitted in UE-specific search space PDCCHs with Aggregation level 2. These 2 PDCCHs are candidate 0 and candidate 3 of the 6 candidates

   To support the E-UTRA Test Models defined in 36141-850, the allowable sizes of the parameter PDCCH_UE_DCI_Formats is extended to Mmax (all subframes have the same configuration), where Mmax can be 7, 8, 9 and 10.

- In our implementation, for the default parameters setting, *NumOfActiveDCI_sf* = 1, [DCI format 0], and *Nbits_1dci(sf,l)* = 25 for all the 10 subframes, and so $N_{DCIbits}$ = 250. This model has a parameter DisplayRates. If DisplayRates = YES, the rates for DataOut port as well as the detail information for all 10 subframes are displayed in the Simulation Log when this model is running.

3. Parameter details:
   - System parameters:
     - FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2.
     - TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6.Hidden when FrameMode = FDD
     - SpecialSF_Config: special subframe configuration when FrameMode is TDD. PDSCHs can be allocated in DwPTS. Hidden when FrameMode = FDD.
     - Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
     - NumTxAnts: number of transmitter antennas, the type is enum and it can be selected as Tx1, Tx2 and Tx4.
     - CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
     - PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
     - SRS_Enable: whether enable sounding reference signal transmission or not. If SRS_Enable = No, following parameters from SRS_BW to SRS_SF_Config will be ignored.
     - SRS_SF_Config: SRS subframe configuration. Cell specific sounding reference signal subframes are the subframes satisfying $\lfloor n_s / 2 \rfloor \bmod T_{SFC} \in \Delta_{SFC}$. For TDD, sounding reference signal is transmitted only in configured UL subframes or UpPTS. The cell specific subframe configuration period T_{SFC} and the cell specific subframe offset Δ_{SFC} for the transmission of sounding reference signals are listed in Tables 5.5.3.3-1 and 5.5.3.3-2 of 36211-890, for FDD and TDD, respectively.
     - For the system parameters , refer to *DL System Parameters* (3gpplte).
   - PDCCH corresponding parameters:
     - PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe. And so those elements of control channel parameters assigned to this subframe are inactive. If the number of OFDM symbols of PDCCH for all subframes are set to 0, all other parameters are inactive.
     - PDCCH_UE_AggreLevel and PDCCH_Common_AggreLevel: indicate the aggregation level for the UE-specific search space and common search space respectively. They are *Array Parameter* (3gpplte). The allowable sizes of these 2 parameters are 1 or 10x1 (each element for one subframe). The elements can be set to 1, 2, 4 or 8 for PDCCH_UE_AggreLevel, and 4 or 8 for PDCCH_Common_AggreLevel.
     - PDCCH_UE_DCI_Formats and PDCCH_Common_DCI_Formats: indicate the active PDCCH of the candidates as well as the corresponding DCI formats they containing for UE-specific search space and common search space. Each active PDCCH contains one DCI. They are *Array Parameter* (3gpplte). The allowable sizes of these 2 parameters are Mmax or 10xMmax (each Mmax elements for one subframe), where Mmax is 6 for UE-specific and 4 for Common. For each subframe, if the aggregation level is set to L, the number of PDCCH candidates is $M^{(L)}$, and so the first $M^{(L)}$ elements of the Mmax elements are active. To support the E-UTRA Test Models defined in 36141-850, the allowable sizes of the parameter PDCCH_UE_DCI_Formats is extended to Mmax (all subframes have the same configuration), where Mmax_e can be 7, 8, 9 and 10.
       For example, PDCCH_UE_AggreLevel = 4, the number of PDCCH candidates $^{(L)}$

is M = 2, so, the first 2 elements of are active. -1 means no DCI (PDCCH) in corresponding candidate. Refer to Table 9.1.1-1 in 9.1.1 of 36213. The DCIs of one subframe are compose of PDCCH_UE_DCI_Formats and PDCCH_Common_DCI_Formats
The mapping of the integer value of these 2 parameters to the actual DCI forma as follows:

Integer value	**DCI Formats**	
0	Format 0	support
1	Format 1	support
2	Format 1A	support
3	Format 1B	supported when NTx is set to 2 or 4
4	Format 1C	not support
5	Format 1D	supported when NTx is set to 2 or 4
6	Format 2	supported when NTx is set to 2 or 4
7	Format 2A	supported when NTx is set to 2 or 4
-1	No DCI is transmitted on this PDCCH candidate	

- UE_n_RNTI: this parameter is used as the variable n_{RNTI} (defined in 9.1.1 of 36213) for all UE-specific PDCCH candidates.

- DCI Format bits mapping corresponding parameters:

DCI Format 0	PUSCH_RB_Hopping PUSCH_Hop_bit PUSCH_RB_AllocType PUSCH_RB_Alloc PUSCH_Config PUSCH_Payload PUSCH_MappingType PUSCH_NewDataIndic PUSCH_TPC_cmd PUSCH_n_DMRS2 PUSCH_CQI
DCI Format 1	PDSCH_ResAllocType PDSCH_RB_AllocType PDSCH_RB_Alloc PDSCH_Config PDSCH_Payload PDSCH_MappingType PDSCH_HARQ_ProcNum PDSCH_NewDataIndic PDSCH_RV PUCCH_TPC_cmd
DCI Format 1A	PDSCH_RB_MappingType PDSCH_RB_AllocType PDSCH_RB_Alloc PDSCH_Config PDSCH_Payload PDSCH_MappingType PDSCH_HARQ_ProcNum PDSCH_NewDataIndic PDSCH_RV PDSCH_TPC_cmd
DCI Format 1B	PDSCH_RB_MappingType PDSCH_RB_AllocType PDSCH_RB_Alloc PDSCH_Config PDSCH_Payload PDSCH_MappingType PDSCH_HARQ_ProcNum PDSCH_NewDataIndic PDSCH_RV PUCCH_TPC_cmd PDSCH_PMI_Confirm
DCI Format 1D	PDSCH_RB_MappingType PDSCH_RB_AllocType PDSCH_RB_Alloc PDSCH_Config PDSCH_Payload PDSCH_MappingType

	PDSCH_HARQ_ProcNum PDSCH_NewDataIndic PDSCH_RV PUCCH_TPC_cmd PDSCH_PwrOffset
DCI Format 2	PDSCH_ResAllocType PDSCH_RB_AllocType PDSCH_RB_Alloc PDSCH_Config PDSCH_Payload PDSCH_MappingType PDSCH_HARQ_ProcNum PDSCH_NewDataIndic PDSCH_RV PUCCH_TPC_cmd MIMO_Mode CDD_Mode CdBlk_Index DL_TB2CW_Swap PDSCH_UE_NumOfCWs PDSCH_UE_NumOfLayers
DCI Format 2A	PDSCH_ResAllocType PDSCH_RB_AllocType PDSCH_RB_Alloc PDSCH_Config PDSCH_Payload PDSCH_MappingType PDSCH_HARQ_ProcNum PDSCH_NewDataIndic PDSCH_RV PUCCH_TPC_cmd MIMO_Mode CDD_Mode CdBlk_Index DL_TB2CW_Swap PDSCH_UE_NumOfCWs PDSCH_UE_NumOfLayers

PUSCH_RB_AllocType and PUSCH_RB_Alloc are same as the parameters RB_AllocType and RB_Alloc of LTE_UL_Src. For more information, refer to *Resource Block Allocation* (3gpplte).
PDSCH_RB_AllocType and PDSCH_RB_Alloc are same as the parameters RB_AllocType and RB_Alloc of LTE_DL_Src. For more information, refer to *Resource Block Allocation* (3gpplte).
There are certain restrictions of RB allocation for differently resource allocation types as the standard prescribed. But in our implementation, we do not add this restriction very well. For resource allocation type 0, ceil(N_RB_DL/P) bits provide the resource allocation as defined in 7.1.6.1 of 36.213. P is the resource block group (RBGs) size. In our implementation, if one of the P resource blocks is allocated, the bits indicating this RBGs is set to 1 and the last RBG contains N_RB_DL-P* floor(N_RB_DL/P) RB (RBs) if N_DL_RB mod P >0. The RB allocation is decided by PDSCH_RB_AllocType and PDSCH_RB_Alloc. For resource allocation type 1, as defined in section 7.1.6.2 of 36.213, ceil(log2(P)) bits of this field which used as a header specific to this resource allocation type to indicate the selected resource blocks subset, are set by the parameter PDSCH_RBG_Subset. 1 bit indicating a shift of the resource allocation span is set by the parameter PDSCH_ResAllocShift. And (ceil(N_RB_DL/P) - ceil(log2(P)) - 1) bits indicating the resource allocation are decided by PDSCH_RB_AllocType and PDSCH_RB_Alloc. P is the resource block group (RBGs) size. In our implementation, the bit is set to 1 if the PRB it indicting is allocated to the PDSCH. For resource allocation type 2, only localized VRB is supported and this field containing ceil(log2(N_RB_DL*(N_RB_DL+1)/2)) bits is determined by PDSCH_RB_AllocType and PDSCH_RB_Alloc as defined in section 7.1.6.3 of 36.213.
If all DCIs transmitted in UE-specific and common search space PDCCH only have format 0, only the DCI Format 0 corresponding parameters are displayed and other DCI Formats corresponding parameters are hidden.
DCI format 0 is used for the scheduling of PUSCH. Its information bits are generated according to these parameters below DCI_Format0 as defined in 5.3.3.1.1 of 36.212.

- Flag for format0/format1A differentiation (1 bit) is set to 0.
- Hopping flag (1 bit) is set to 1 if parameter PUSCH_RB_Hopping = YES, otherwise 0.
- Resource block assignment and hopping resource allocation is set according

to PUSCH_RB_AllocType and PUSCH_RB_Alloc. For non-hopping PUSCH, ceil(log2(N_RB_UL*(N_RB_UL+1)/2)) bits are generated according to 8.1 of 36.213. For PUSCH hopping, N_UL_hop MSB bits are used to obtain the value of n~_PRB(i) as indicated in subclause 8.4 of 36.213, (ceil(log2(N_RB_UL*(N_RB_UL+1)/2)) - N_UL_hop) bits provide the resource allocation of the first slot in the UL subframe.

- Modulation and coding scheme and redundancy version (5 bits) are generated according to these 3 parameters PUSCH_Config, PUSCH_Payload and PUSCH_MappingType.
    - If PUSCH_Config is set to MCS index, the MCS index is given by PUSCH_Payload directly.
- If PUSCH_Config is set to Code rate, the transport block size (TBS) index is given by A.3.1 of 36.101 and the section 7.1.7 of 36.213. Then, the MCS index is given by 8.6.1 of 36.213.
    - If PUSCH_Config is set to transport block size, the algorithm for determining the payload size A of a given sub_frame i is as follows; find A that is as close to PUSCH_Payload(sf) as possible, that is, min|A-PUSCH_Payload(sf)| subject to A is a valid TB size assuming an allocation of NRB resource blocks.
    - If there is more than one A that minimizes the equation above, then the larger value is chosen per default. The TBS index is given by the section 7.1.7.2 of 36.213. Then, the MCS index is given by 8.6.1 of 36.213. These 5bits are generated as defined in section 8.1 of 36.213.
    - New data indicator - 1 bit
    - TPC command for scheduled PUSCH - 2 bits as defined in section 5.1.1.1 of 36.213
    - Cyclic shift for DM RS - 3 bits as defined in section 5.5.2.1.1 of 36.211
    - UL index - 2 bits as defined in sections 5.1.1.1 and 8 of 36.213 (this field only applies to TDD operation with uplink -downlink configuration 0 and is not present in FDD)
- Downlink Assignment Index (DAI) -2 bits as defined in section 7.3 of 36.213 (this field only applies for TDD operation with uplink-downlink configurations 1-6 and is not present in FDD)
    - CQI request - 1 bit as defined in section 7.2.1 of 36.213
- If the number of information bits in format 0 is less than that of format 1A (including any padding bits appended to format 1A), zeros shall be appended to format 0 until the payload size equals that of format 1A.

DCI Format 1	PUSCH_RB_Hopping PUSCH_Hop_bit PUSCH_RB_AllocType PUSCH_RB_Alloc PUSCH_Config PUSCH_Payload PUSCH_MappingType PUSCH_NewDataIndic PUSCH_TPC_cmd PUSCH_n_DMRS2 PUSCH_CQI

If all DCIs transmitted in UE-specific and common search space PDCCH only have format 0, only the DCI Format 0 corresponding parameters are displayed and other DCI Formats corresponding parameters are hidden.
DCI format 0 is used for the scheduling of PUSCH. Its information bits are generated according to these parameters below DCI_Format0 as defined in 5.3.3.1.1 of 36.212.

- Flag for format0/format1A differentiation (1 bit) is set to 0.
- Hopping flag (1 bit) is set to 1 if parameter PUSCH_RB_Hopping = YES, otherwise 0.
- Resource block assignment and hopping resource allocation is set according to PUSCH_RB_AllocType and PUSCH_RB_Alloc. For non-hopping PUSCH, ceil(log2(N_RB_UL*(N_RB_UL+1)/2)) bits are generated according to 8.1 of 36.213. For PUSCH hopping, N_UL_hop MSB bits are used to obtain the value of n~_PRB(i) as indicated in subclause 8.4 of 36.213, (ceil(log2(N_RB_UL*(N_RB_UL+1)/2)) - N_UL_hop) bits provide the resource allocation of the first slot in the UL subframe.

- Modulation and coding scheme and redundancy version (5 bits) are generated according to these 3 parameters PUSCH_Config, PUSCH_Payload and PUSCH_MappingType.
    - If PUSCH_Config is set to MCS index, the MCS index is given by PUSCH_Payload directly.

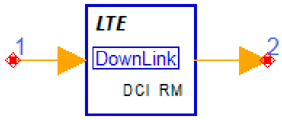
- If PUSCH_Config is set to Code rate, the transport block size (TBS) index is given by A.3.1 of 36.101 and the section 7.1.7 of 36.213. Then, the MCS index is given by 8.6.1 of 36.213.
    - If PUSCH_Config is set to transport block size, the algorithm for determining the payload size A of a given sub_frame i is as follows; find A that is as close to PUSCH_Payload(sf) as possible, that is, min|A-PUSCH_Payload(sf)| subject to A is a valid TB size assuming an allocation of NRB resource blocks.
    - If there is more than one A that minimizes the equation above, then the larger value is chosen per default. The TBS index is given by the section 7.1.7.2 of 36.213. Then, the MCS index is given by 8.6.1 of 36.213. These 5bits are generated as defined in section 8.1 of 36.213.
    - New data indicator - 1 bit
    - TPC command for scheduled PUSCH - 2 bits as defined in section 5.1.1.1 of 36.213
    - Cyclic shift for DM RS - 3 bits as defined in section 5.5.2.1.1 of 36.211
    - UL index - 2 bits as defined in sections 5.1.1.1 and 8 of 36.213 (this field only applies to TDD operation with uplink -downlink configuration 0 and is not present in FDD)
- Downlink Assignment Index (DAI) -2 bits as defined in section 7.3 of 36.213 (this field only applies for TDD operation with uplink-downlink configurations 1-6 and is not present in FDD)
    - CQI request - 1 bit as defined in section 7.2.1 of 36.213
- If the number of information bits in format 0 is less than that of format 1A (including any padding bits appended to format 1A), zeros shall be appended to format 0 until the payload size equals that of format 1A.

4. See *LTE_DL_DCI_CRC* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
3. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.

LTE_DL_DCI_RateMatch (DCI Rate Match)



LTE_DL_DCI_RateMatch

Description: Downlink Control Information Rate Matcher
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}	int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}	int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}	int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}	int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}	int array	[0,2e16-1]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output data	int

Notes/Equations

1. This model is used to implement rate match for LTE PDCCHs of one subframe as defined in 5.3.3.4 of 36.212.
2. Each firing, a radio frame (10 subframes) is processed.
    - the number of tokens consumed at DataIn is the convolutional coded DCI bits of this radio frame (10 subframes). For each subframe, the coded bits number is $3\times\sum_{dci=0}^{N\_DCI\_SF}(Len\_DCI(sf,dci)+16)$.
    - the number of tokens generated at DataOut is the number of rate matched DCI bits of this radio frame (10 subframes). For each subframe, the rate matched bits number is $\sum_{pdcch=0}^{N\_PDCCH\_SF} N\_PDCCHBits(sf,pdcch)$.
    - *N_PDCCHBits(sf, pdcch)* is the number of bits of active *PDCCH(sf, pdcch)* which

is decided by the given PDCCH format. The PDCCH supports 4 formats as listed in Table 6.8.1-1 of 36.211. In our implementation, the PDCCH format is defined by parameters PDCCH_UE_AggreLevel and PDCCH_Common_AggreLevel. Aggregation level = 1, 2, 4, 8 correspond to the PDCCH format = 0, 1, 2, 3.

3. The DCI rate match is implemented according to 5.1.4.2 of 36.212.
4. Parameter details:

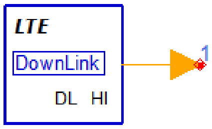
System Parameters	FrameMode TDD_Config Bandwidth NumTxAnts CyclicPrefix
PDCCH corresponding parameters	PHICH_Ng PDCCH_SymsPerSF PDCCH_UE_AggreLevel PDCCH_UE_DCI_Formats PDCCH_Common_AggreLevel PDCCH_Common_DCI_Formats UE_n_RNTI

For the system parameters, refer to *DL System Parameters* (3gpplte).
For PDCCH corresponding parameters, refer to *DL Control Channel Parameters* (3gpplte).
See *LTE_DL_DCI_CRC* (3gpplte) and *LTE_PDCCH_Mux* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_DL_HI (Hybrid-ARQ ACK and NAC bits)



Description: HARQ ACK/NACK generator in one radio frame
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
HI	physical hybrid-ARQ ACK/NAK indicators	{1,-1, -1, -1, -1, -1, -1, -1}	int array	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	HI_Bits	HI bits	int

Notes/Equations

1. This model is used to generate the HARQ ACK/NACK code bits of one radio frame (10 subframes).
2. Each firing, 1 radio frame is processed(10 subframes).
   - The number of tokens generated at DataOut is the number of HI bits of these 10 subframes:
     3(NumPHICHs*N_PHICH_Group(0))+...+3*(NumPHICHs*N_PHICH_Group(9))*, where *NumPHICHs*=8 for normal cyclic prefix and *NumPHICHs*=4 for extended cyclic prefix is the number of PHICHs of one PHICH group; *N_PHICH_Group(sf)* is the number of PHICH groups in this subframe as defined in Section 6.9 of 36.211. For the tokens at DataOut, the first 3 elements are the encoded HI bits (as 5.3.5.1 of 36.212 [2]) for the first orthogonal sequence index in the first PHICH group, and the second 3 elements are for the second orthogonal sequence index in the first PHICH group, and so on (in increasing order of first the orthogonal sequence index , then the PHICH group index).
3. These system parameters below are used to decide the *N_PHICH_Group(sf)* of each subframe.

System and Control Channel Parameters	FrameMode TDD_Config Bandwidth CyclicPrefix PDCCH_SymsPerSF PHICH_Ng
HI bits corresponding parameters	HI

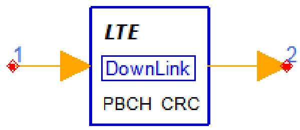
- For the system parameters, refer to *DL System Parameters* (3gpplte) and *DL Control Channel Parameters* (3gpplte).
- HI is used to set the indicators bits for HARQ acknowledgement. This is an *Array Parameter* (3gpplte).
  If the number of OFDM symbols of PDCCH for all subframes are set to 0, all other parameters are inactive. If the indicators bit for HARQ acknowledgement of one PHICH is set to 1, the coded HI bits are 1, 1 and 1. If it is set to 0, the coded HI bits are 0, 0 and 0. If it is set to -1, then output 0, 1 and 0.

When ETM_Support=YES for TDD mode, the factor m_i is set to 1 for all transmitted subframes as requried by TDD E-TM defined in 6.1.2.6 of 36.141 (V8.5.0). Otherwise, the factor m_i shall be set as per 6.9 of 36.211.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_PBCH_CRC (Add CRC to PBCH)



Description: PBCH CRC Encoder
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
BCH_BlockSize	transport block size for BCH	24	int	[1,∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	data in	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	data out	int

Notes/Equations

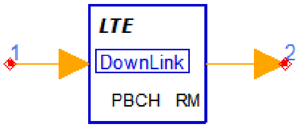
1. This model is used to add Cyclic Redundancy Check to the broadcast channel bits.
2. Each firing,
   A tokens are consumed and $A+L$ tokens are generated. Where A is the size of the transport block every transmission time interval (TTI) of 40ms and L is the number of parity bits and L=16.
3. The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block a_0, a_1, a_2,..., a_{A-1}, and the parity bits by p_0, p_1, p_2, ..., p_{L-1}.
4. The parity bits are computed and attached to the BCH transport block according to Section 5.1.1 of 36.212 setting L to 16 bits.
5. After the attachment, the CRC bits are scrambled according to the eNode-B transmit antenna configuration with the sequence x_ant_0, x_ant_1, ... , x_ant_{15} as indicated in Table 5.3.1.1-1 of Section 5.3.1.1 of 36.212 to form the sequence of bits where
   $c_k = a_k$, for $k=0, 1, 2, \ldots, A-1$
   $c_k = (\_p_{k-A} + x\_ant_{k-A})$ mod 2, for $k=A, A+1, \ldots, A+15$.
6. Parameter details:

- NumTxAnts: number of transmitter antennas, the type is enum and it can be selected as Tx1, Tx2 and Tx4. This parameter used to select the CRC mask for PBCH.
- BCH_BlockSize: transport block size for BCH.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_PBCH_RateMatch (Downlink SCH Rate Matching)



Description: PBCH Rate Matcher
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
BCH_BlockSize	Transport block size for BCH	24	int	[1,∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	Data In	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	Data Out	int

Notes/Equations

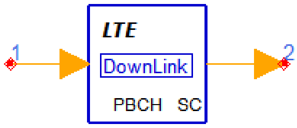
1. This model is used to provide the rate matching for the coded information bits.
2. Each firing:
   3(A+16)* tokens are consumed and 1920 tokens for normal cyclic prefix and 1728 tokens for extended cyclic prefix are generated, where A is the size of the transport block every transmission time interval (TTI) of 40ms and 1920 or 1728 is the number of bits transmitted on the physical broadcast channel of 4 radio frames.
3. A tail biting convolutionally coded block is delivered to the rate matching block. This block of coded bits is denoted by *d_i_0, d_i_1, d_i_2, ..., d_i_D-1*, with *i=0, 1, 2*, and where *i* is the coded stream index and *D* is the number of bits in each coded stream. This coded block is rate matched according to subclause 5.1.4.2. of 36.212.
4. After rate matching the bits are denoted by *e_0, e_1, ... , e_E-1*, where *E* is the number of rate matched bits, equals 1920 for normal cyclic prefix and 1728 for extended cyclic prefix.
5. Parameters Details

- CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the last six OFDM symbols have the same shorter cyclic prefix and the first OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
- BCH_BlockSize: transport block size for BCH information bits.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_PBCH_Scrambler (LTE PBCH Scrambler)



Description: PBCH Scrambler
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	scrambler input	int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	scrambler output	int

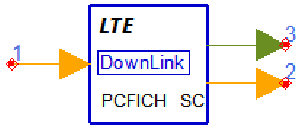
Notes/Equations

1. This model is used to scramble the block of bits after rate match.
2. Each firing, 1920 tokens for normal cyclic prefix and 1728 tokens for extended cyclic prefix are consumed and generated.
3. The block of bits *b_0, b_1, ..., b_Mbit-1*, where *Mbit* is the number of bits transmitted on the physical broadcast channel, equals 1920 for normal cyclic prefix and 1728 for extended cyclic prefix, shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits *b_s_0, b_s_1, ..., b_s_Mbit-1*, according to *b_s_i = (b_i + c_i) mod 2*, where the scrambling sequence *c_i* is given by Section 7.2 of 36.211.
4. The scrambling sequence shall be initialized with *c_init = N_ID_cell* in each radio frame fulfilling *n_f mod 4 = 0*.
5. Parameters Details:
   - CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the last six OFDM symbols have the same shorter cyclic prefix and the first OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
   - CellID_Sector and CellID_Group are used to initialize the scrambling sequence. CellID_Sector is the index of cell identity within the physical-layer cell-identity group. CellID_Group is the index of cell identity group, its value range is [0,167].
6. See *LTE_PBCH_RateMatch* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_PCFICH_Scrambler (LTE PCFICH Scrambler)



Description: PCFICH Scrambler
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	Input PCFICH bits for scrambling	int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	Output PCFICH scrambled bits	int
3	ModSym	Output PCFICH modulation symbols (QPSK)	complex

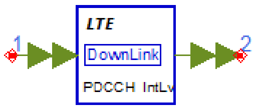
Notes/Equations

1. This model is used as the CFI coded bits scrambler as defined in 6.7.1 of 36.211.
2. Each firing, 32*N_PCFICHs tokens are consumed and generated, where N_PCFICHs is the number of PCFICHs of one frame. Each subframe has a PCFICH if the active PDCCH symbols exist in this subframe. So the N_PCFICH is same as the number of subframes that has active PDCCH symbols which is decided by the parameters FrameMode, TDD_Config and PDCCH_SymsPerSF.
3. The block of bits b(0), ... , b(31) transmitted in one subframe shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits _b_s(0), ... , b_s(31)_ according to b_s(idx) = (b(idx) + c(idx)) mod 2 where the scrambling sequence c(idx) is given by Section 7.2 of 36.211. The scrambling sequence generator shall be initialized with c_init = (floor(n_s/2)+1)*(2*N_ID_cell + 1) * 2^9 +N_ID_cell at the start of each subframe.
   The block of scrambled bits _b_s(0), ... , b_s(31)_ shall be modulated with QPSK modulation schemes as described in Section 7.1, resulting in a block of complex-valued modulation symbols d(0), ... , d(15). The modulated symbols are output at port ModSym.
4. Parameters Details:
   - For the system parameters , refer to *DL System Parameters* (3gpplte).
   - For the control channel parameters details, refer to *DL Control Channel Parameters* (3gpplte).
5. See *LTE_DL_CFI* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_PDCCH_Interleaver (PDCCH Interleaver)



LTE_PDCCH_Interleaver

Description: PDCCH Interleaver
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input data after layer mapping and precoding	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output data after interleaver	multiple complex

Notes/Equations

1. This model is used to perform the interleaver for PDCCH subframe by subframe, as described in Section 6.8.5 of [1].
2. The input and output ports are all multiple ports. The bus width connected to them should be equal to the NumTxAnts parameter.
3. Each firing, for each antenna port,
   - the number of tokens consumed and generated at each input port and output port are same: *PDCCH_NumModSymbols(0) + ... + PDCCH_NumModSymbols(9)* , where *PDCCH_NumModSymbols* is the number of modulation symbols for PDCCH in one subframe.
   - According to [1], PDCCH_NumModSymbols is calculated as follows:
     - If FrameMode = TDD, and the subframe is allocated to uplink transmission, PDCCH_NumModSymbols is 0 regardless of the setting for this subframe in PDCCH_SymsPerSF parameter.
     - Otherwise, get the total number (N1) of subcarriers (resource elements) in the *PDCCH_SymsPerSF* OFDM symbols for PDCCH, and the number of subcarriers (resource elements) allocated to RS (N2) according to 6.10 of [1], PCFICH (N3) according to 6.7 of [1] and PHICH (N4) according to 6.9 of [1] respectively. PDCCH_NumModSymbols is equal to (N1-N2-N3-N4).
4. The interleaver is defined by operations on quadruplets of complex-valued symbols. The block of input quadruplets, shall be permuted according to the sub-block interleaver in Section 5.1.4.2.1 of [2] with the following exceptions:
   - the input and output to the interleaver is defined by symbol quadruplets instead of bits
   - interleaving is performed on symbol quadruplets instead of bits by substituting the terms "bit", "bits" and "bit sequence" in Section 5.1.4.2.1 of [2] by "symbol quadruplet", "symbol quadruplets" and "symbol-quadruplet sequence", respectively

- <NULL> elements at the output of the interleaver in [2] shall be removed. Note that the removal of <NULL> elements does not affect any <NIL> elements inserted in Section 6.8.2.

5. Parameter details:

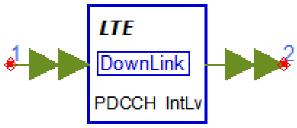
System Parameters	FrameMode TDD_Config Bandwidth NumTxAnts CyclicPrefix CellID_Sector CellID_Group
PDCCH corresponding parameters	PDCCH_SymsPerSF PHICH_Ng

   For the system parameters, refer to *DL System Parameters* (3gpplte).
   For PDCCH corresponding parameters, refer to *DL Control Channel Parameters* (3gpplte).
6. See *LTE_PDCCH_Scrambler* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_PDCCH_Mux (PDCCH Multiplexing)



Description: PDCCH Multiplexer
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}	int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0,-1,-1,-1,-1,-1}	int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}	int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1,-1,-1,-1}	int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1,1,1,1,1,1,1,1,1,1}	int array	[0,2e16-1]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output data	int

Notes/Equations

1. This model is used to implement PDCCH multiplexing as defined in section 9.1.1 of 36.213.
2. Each firing, one radio frame (10 subframes) is processed.
   - the number of tokens consumed at DataIn is the number of rate matched DCI bits of these 10 subframes. For each subframe is $\sum_{pdcch=0}^{N\_PDCCH\_SF} N\_PDCCHBits(sf, pdcch)$. Where *N_PDCCHBits(sf, pdcch)* is the

number of bits of active *PDCCH(sf, pdcch)* which is decided by the given PDCCH format. The PDCCH supports 4 formats as listed in Table 6.8.1-1 of 36.211. In our implementation, the PDCCH format is defined by parameters PDCCH_UE_AggreLevel and PDCCH_Common_AggreLevel. Aggregation level = 1, 2, 4, 8 correspond to the PDCCH format = 0, 1, 2, 3.

- the number of tokens generated at DataOut is *8*N_REG(0) + ... + 8*N_REG(9)*. Where *N_REG(sf)* is the available resource element groups which is allocated by PDCCH_SymsPerSF and not assigned to PCFICH or PHICH.

3. The PDCCH is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is *N_REG*. The control region consists of a set of CCEs, numbered from 0 to *N_CCE(k)-1*, according to Section 6.8.2 in 36.211, where *N_CCE(k)* is the total number of CCEs in the control region of subframe *k*. The CCEs corresponding to PDCCH candidate m of the search space *S_k_(L)* are given by
   L{(Y(k)+m)mod(floor(N_CCE(k) / L)}+i*,
   Where *Y(k)* is defined below, *i = 0, ..., L-1* and *m = 0, ..., M_(L)-1. M_(L)* is the number of PDCCH candidates to monitor in the given search space.
   The aggregation levels defining the search spaces are listed in Table 9.1.1-1 of 36.213. The DCI formats that the UE shall monitor depend on the configured transmission mode as defined in Section 7.1.
   For the common search spaces, *Y(k)* is set to 0 for the two aggregation levels *L = 4* and *L = 8*.
   For the UE-specific search space *S_k_(L)* at aggregation level , the variable *Y(k)* is defined by
   *Y(k) = (A*Y(k-1)) mod D*
   Where *Y(-1) = n_RNTI(>0) , A = 39827, D = 65537* and *k* is the subframe number within a radio frame.The RNTI value used for set by parameter UE_n_RNTI.
4. If necessary, <NIL> elements shall be inserted in the block of bits prior to scrambling to ensure that the PDCCHs starts at the CCE positions as described in 36.213 and to ensure that the length $M_{\text{tot}} = 8N_{REG} \geq \sum_{i=0}^{n\_PDCCH-1} M_{\text{bit}}^{(i)}$ of the scrambled block of bits matches the amount of resource-element groups not assigned to PCFICH or PHICH and that the PDCCH consisting of consecutive CCEs only start on a CCE fulfilling *i mod n=0*, where *i* is the CCE number.
5. In our implementation, the <NIL> elements inserted are set to 2.
6. Parameter details:

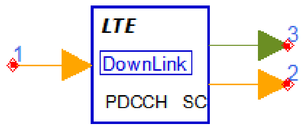
System Parameters	FrameMode TDD_Config Bandwidth NumTxAnts CyclicPrefix
PDCCH corresponding parameters	PDCCH_SymsPerSF PHICH_Ng PDCCH_UE_AggreLevel PDCCH_UE_DCI_Formats PDCCH_Common_AggreLevel PDCCH_Common_DCI_Formats UE_n_RNTI

   For the system parameters, refer to *DL System Parameters* (3gpplte).
   For PDCCH corresponding parameters, refer to *DL Control Channel Parameters* (3gpplte).
7. See *LTE_DL_DCI_RateMatch* (3gpplte) and *LTE_PDCCH_Scrambler* (3gpplte)..

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
3. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.

LTE_PDCCH_Scrambler (PDCCH Scrambler)



Description: PDCCH Scrambler
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}	int array	[0,4]
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6	enum	
ETM_Support	ETM support or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output data	int
3	ModSym	Output PDCCH modulation symbols (QPSK)	complex

Notes/Equations

1. This model is used to implement PDCCH scrambling as defined in section 6.8.2 of 36.211.
2. Each firing, one radio frame (10 Subframes) is processed.
   - The number of tokens consumed and generated at DataIn and DataOut is $8*(N\_REG(0)+ N\_REG(1) + \ldots + N\_REG(9))$.
   - The number of tokens generated at port ModSym is $4*(N\_REG(0)+ N\_REG(1) + \ldots + N\_REG(9))$.
     Where $N\_REG(sf)$ is the available resource element groups which is allocated by PDCCH_SymsPerSF and not assigned to PCFICH or PHICH.
3. For each subframe, the block of bits $b\_0(0), \ldots , b\_0(M\_0-1), b\_1(0), \ldots , b\_1(M\_1-1), \ldots , b\_nPDCCH(0), \ldots , b\_nPDCCH(M\_nPDCCH-1)$, are srambled with a cell-specific sequence prior to modulation, and result in $bs\_0(0), \ldots , bs\_0(M\_0-1), bs\_1(0), \ldots , bs\_1(M\_1-1), \ldots , bs\_nPDCCH(0), \ldots , bs\_nPDCCH(M\_nPDCCH-1)$ according to $bs(idx) = (b(idx) + c(idx)) \bmod 2$. The scrambling sequence $c(idx)$ is given by section 7.2 of 36.211. Where n is the number of PDCCHs transmitted in this subframe.
   The scrambling sequence generator shall be initialized with $c\_init=floor(n\_s/2)*2^9+N\_ID\_cell$ at the start of each subframe.
   The block of scrambled bits are modulated with QPSK modulation schemes as described in Section 7.1 of 36.211, resulting in a block of complex-valued modulation symbols $d(0), \ldots ,d(M\_symb-1)$.
   The scrambled bits and the inserted <NIL> bits are output at port DataOut. In our implementation, the inserted <NIL> bits, which is set to 2 in the model LTE_PDCCH_Mux, are output as 2.
   The complex-valued modulation symbols are output at port ModSym. In our implementation, the inserted <NIL> bits, which is set to 2 in the model

LTE_PDCCH_Mux, are mapping to 0.0+0.0*j with each 2 <NIL> bits and output at this port.

4. Parameter details:

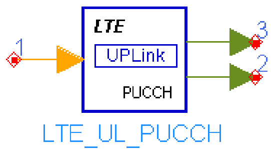
System Parameters	FrameMode TDD_Config Bandwidth NumTxAnts CyclicPrefix CellID_Sector CellID_Group
PDCCH corresponding parameters	PDCCH_SymsPerSF PHICH_Ng

   For the system parameters, refer to *DL System Parameters* (3gpplte).
   For PDCCH corresponding parameters, refer to *DL Control Channel Parameters* (3gpplte).
5. See *LTE_PDCCH_Mux* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

LTE_UL_PUCCH (Uplink PUCCH and PUCCH RS generation within one radio frame)



Description: PUCCH Generator
Library: LTE, Signaling

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0, 2]
CellID_Group	the index of cell identity group	0	int	[0, 167]
n_RNTI	radio network temporary identifier	0	int	[0, 65535]
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUCCH	enum	
GroupHop_Enable	whether enable group hopping for DMRS on PUCCH and PUSCH or not: NO, YES	NO	enum	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1	enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2	int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}	int array	[0, 9]
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1	int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11	int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11	int	[0, 12*PUCCH_NB2-1]

Pin Inputs

Pin	Name	Description	Signal Type
1	Input	PUCCH Infomation	int

Pin Outputs

Pin	Name	Description	Signal Type
2	PUCCH_Sym	PUCCH Symbols	complex
3	PUCCH_RS	PUCCH RS	complex
4	PUCCH_ScrambledBits	scrambled bits of PUCCH format 2/2a/2b	int
5	PUCCH_ModSyms	modulatd symbols of PUCCH	complex

Notes/Equations

1. This model is used to generate PUCCH (Physical Uplink Control Channel, carries uplink control information) and its demodulation reference signal for each subframe.
2. Each firing,
   - the number of tokens consumed at port Input is equal to the number of control bits transmitted on PUCCH in each frame, which is determined by PUCCH_Format and PUCCH_SF_Alloc.
   - the number of tokens produced at port PUCCH_Sym is equal to the number of REs allocated for PUCCH transmission (excluding DMRS for PUCCH) in each frame.

- the number of tokens produced at port PUCCH_RS is equal to the number of REs allocated for PUCCH DMRS transmission in each frame.
- the number of tokens produced at port PUCCH_ScrambledBits is 20 * *NumPUCCHSubFrame* if PUCCH format 2/2a/2b is transmitted in this frame. For other PUCCH formats, the output is a null token.
- the number of tokens produced at port PUCCH_ModSyms is the number of modulation symbols (before block-wise spreading) of PUCCH in each subframe. The modulation schemes corresponding to each PUCCH format are listed in the following figure.
- For the default parameter configurations, PUCCH is transmitted on subframe 2, the number of tokens produced at PUCCH_Sym is 96, the number of tokens produced at PUCCH_RS is 72, 1 token is produced at PUCCH_ ModSyms.

3. The PUCCH supports multiple formats shown in the **Supported PUCCH formats** table below:

PUCCH format	**Modulation scheme**	**Number of bits per subframe, M_{bits}**
1	N/A	N/A
1a	BPSK	1
1b	QPSK	2
shorten 1	N/A	N/A
shorten 1a	BPSK	1
shorten 1b	QPSK	2
2	QPSK	20
2a	QPSK + BPSK	21
2b	QPSK + BPSK	22

4. Formats 2a and 2b are supported for normal cyclic prefix only. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field.
5. It should be noted that the mix format is not supported in current implementation. No mixed resource block is present, i.e. $N^{(1)}_{cs}$ is always set to 0.
6. It should be noted that the channel coding for uplink control information on PUCCH is not provided in current implementation. The demodulation and decoding of PUCCH is also not supported in current implementation.

- For more information on the System Parameters details please refer to *UL System Parameters* (3gpplte).
- For more information on the PUCCH Parameters details please refer to *UL PUCCH Parameters* (3gpplte).

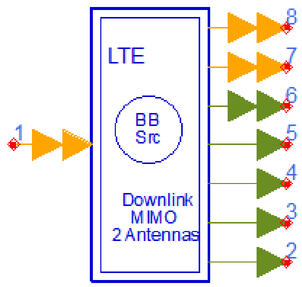
References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.

3GPP LTE Source Components

Contents

LTE_DL_MIMO_2Ant_Src(Downlink baseband 2 antennas MIMO source)



Description: Downlink baseband 2 antennas MIMO signal source
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO		enum	
MIMO_Parameters	MIMO-related parameters for all six Ues	Category		string	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CDD_Mode	CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,2]
UEs_NumOfLayers	number of layers for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS_index, Transport_block_size, Code_rate	Transport_block_size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	

	not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)				
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	1		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}		int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}		int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6		enum	
BCH_BlockSize	transport block size for BCH	24		int	[1,∞)
HI	physical hybrid-ARQ ACK/NAK indicators	{1, -1, -1, -1, -1, -1, -1, -1}		int array	
PowerParameters	power-related parameters	Category		string	
RS_EPRE	transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of	-25		real	(-∞,∞)

	dBm/15kHz				
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing		enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised_cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6		int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19		int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO		enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal_Lowpass	RRC		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22		real	[0,1.0]
DisplayMsg	control LTE system information displayed in Simulation Log window: None, Simple, Full	Simple		enum	

Pin Inputs

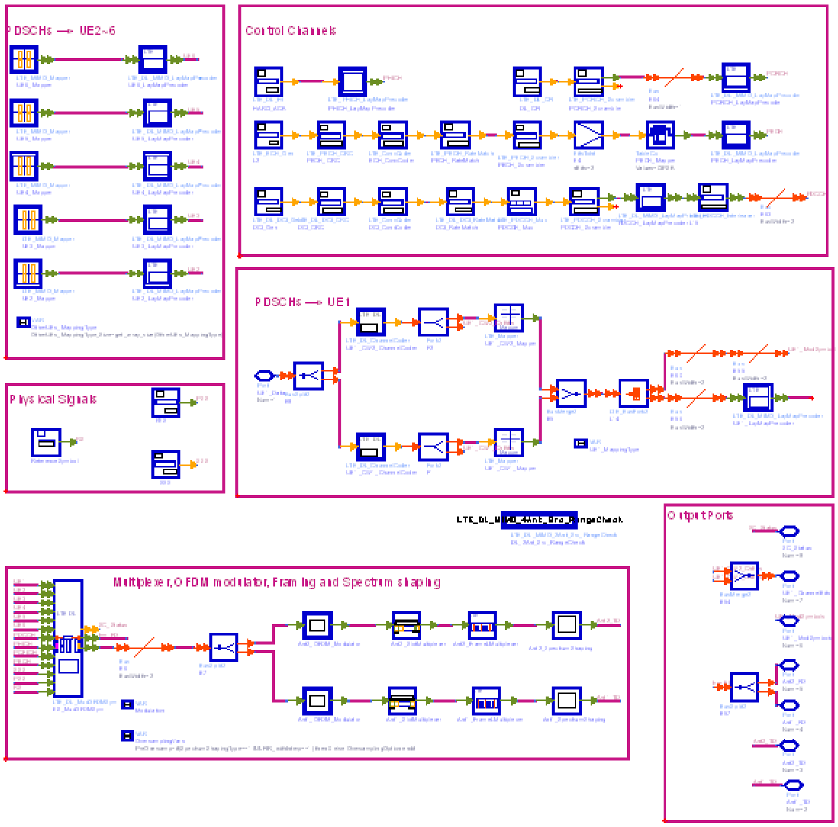
Pin	Name	Description	Signal Type
1	UE1_Data	UE 1 raw data	multiple int

Pin Outputs

Pin	Name	Description	Signal Type
2	Ant1_TD	Antenna 1 output of one frame signal in time domain	complex
3	Ant2_TD	Antenna 2 output of one frame signal in time domain	complex
4	Ant1_FD	Antenna 1 output of one frame in frequency domain	complex
5	Ant2_FD	Antenna 2 output of one frame in frequency domain	complex
6	UE1_ModSymbols	UE 1 modulation symbols	multiple complex
7	UE1_ChannelBits	UE 1 channel bits	multiple int
8	SC_Status	downlink subcarrier (resource element) status in one frame	multiple int

Notes/Equations

This subnetwork generates 3GPP FDD LTE (FS1) and TDD LTE (FS2) coded downlink baseband signal (up to six users (PDSCHs)) with two transmit antenna ports. The schematic for this subnetwork is shown in the following figure.



LTE_DL_MIMO_2Ant_Src Schematic

1. In this source, only the first UE (PDSCH 1) is encoded, and other UEs (UE 2 to UE 6) are uncoded
    - For UE 1 (PDSCH 1), two transport block data input from port UE1_Data are sent to two LTE_DL_ChannelCoder components respectively, in which the CRC encoder, code block segmentation, Turbo coder, rate matching and scrambler are performed. In this source, two code words are input regardless of the actual number of code words defined in the UEs_NumOfCWs[1] parameter for UE 1. When UEs_NumOfCWs[1] is 1, the channel coder (and LTE_Mapper) for the second code word is ignored. Then the output channel bits are modulated in LTE_Mapper component, resulting in complex-valued modulation symbols. The modulation symbols from at most two code words are mapped to layers and precoded in LTE_DL_MIMO_LayMapPrecoder component. The precoded symbols, along with other UEs precoded symbols, are sent to LTE_DL_MuxOFDMSym component for mapping to resource elements.
    - For UE 2 to UE 6 (PDSCH 2 to PDSCH 6), complex-valued modulation symbols are generated in LTE_DL_Mapper for the two code words with the source bits of PN 9, which are then sent to LTE_DL_MIMO_LayMapPrecoder component for lay mapping and precoding. The modulation schemes (QPSK, 16QAM or 64QAM) are

determined OtherUEs_MappingType parameter.

2. LTE_PSCH component generates P-SS according to Section 6.11.1 [1], which is the Zadoff-Chu root sequence. P-SS occupies central 72 subcarriers. For FDD LTE (frame structure type 1), P-SS should be mapped to the last OFDM symbol in slots 0 and 10. For TDD LTE (frame structure type 2), P-SS should be mapped to the third OFDM symbol in subframe 1 and 6. SS_PerTxAnt parameter determines whether the P-SS is transmitted on the first antenna port or on all the transmit antenna ports.
3. LTE_SSCH component generates S-SS according to Section 6.11.2 [1], which is the length-31 binary sequence. The S-SS occupies central 72 subcarriers. In a subframe for frame structure type 1 and in half-frame for frame structure type 2, the same antenna port as for the P-SS shall be used for the S-SS. For TDD LTE (frame structure type 1), S-SS should be mapped to the last second OFDM symbol in slots 0 and 10. For TDD LTE (frame structure type 2), S-SS should be mapped to the last OFDM symbol in slot 1 and 11. S_PerTxAnt parameter determines whether the S-SS is transmitted on the first antenna port or on all the transmit antenna ports.
4. The information bits for PBCH are generated in LTE_BCH_Gen according to the system parameters. Then these bits are sent to the CRC encoder, convolutional encoder, rate matching, and scrambler, QPSK modulation, layer mapping and precoding for transmit diversity. Then the precoded symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
   The information bits for PCFICH are generated in LTE_DL_CFI according to the PDCCH_SymsPerSF parameter. Then these bits are sent to LTE_PCFICH_Scrambler component for scrambling, and then mapped to QPSK modulation, and for layer mapping and precoding for transmit diversity. The precoded symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
5. The information bits for PDCCH are generated in LTE_DL_DCI_Gen component according to DCI configurations, which are delivered to the CRC encoder, turbo encoder, rate matching, scrambler, QPSK modulation, PDCCH interleaver, and layer mapping and precoding for transmit diversity. Then the precoded symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
6. The information bits for PHICH are read from the HI parameter in LTE_DL_HI component, which are sent to LTE_PHICH_Modulator and LTE_PHICH_LayerMapper for BPSK modulation, orthogonal spreading and resource group alignment. The outputs are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
7. PBCH, PHICH, PCFICH and PDCCH shall be transmitted on the both two antenna ports.
8. LTE_DL_MuxOFDMSym component is used to multiplex UEs (PDSCHs) data mapping signals, P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH and reference signals (pilots) into OFDM symbols following the downlink frame structure in frequency domain. UEs data mapping signals are mapped to resource elements according to Section 6.3.5 [1]. PBCH QPSK signals, PCFICH QPSK signals, PDCCH QPSK siganls, PHICH are mapped to resource elements according to Section 6.6.4 [1], 6.7.4 [1], 6.8.5 [1], 6.9.3 [1], respectively. The cell-specific reference signals are generated according to Section 6.10.1 [1] in LTE_DL_Pilots component and are mapped to resource elements according to Section 6.10.1.2 [1].
   The outputs at LTE_DL_MuxOFDMSym component are split into two frequency domain signals for two antenna ports. Each of them are transferred into time-domain signals by LTE_DL_OFDM_Modulator which implements OFDM modulation following 3GPP LTE downlink OFDM parameters. LTE_DL_MuxSlot is used to multiplex seven/six OFDM symbols by inserting cyclic prefix into one slot. LTE_DL_MuxFrame multiplexes 20 slots into one radio frame (10 ms) and inserts idle (time duration is IdleInterval) between two consecutive radio frames. LTE_SpecShaping is for spectrum shaping function for downlink source by using FIR filter or symbol windowing function.

Parameters for Downlink Transmission Scheme

Transmission BW		1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration		1 msecµ					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 x 3.84 MHz)	3.84 MHz	7.68 MHz (2 x 3.84 MHz)	15.36 MHz (4 x 3.84 MHz)	23.04 MHz (6 x 3.84 MHz)	30.72 MHz (8 x 3.84 MHz)
FFT size		128	256	512	1024	1536	2048
Number of Resource Blocks †		6	15	25	50	75	100
Number of occupied sub-carriers †		73	181	301	601	901	1201
Number of OFDM symbols per sub-frame (Normal/Extended CP)		7/6					
CP length (µ/samples)	Normal †	(4.69/9) x 6, (5.21/10) x 1	(4.69/18) x 6, (5.21/20) x 1	(4.69/36) x 6, (5.21/40) x 1	(4.69/72) x 6, (5.21/80) x 1	(4.69/108) x 6, (5.21/120) x 1	(4.69/144) x 6, (5.21/160) x 1
	Extended	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)

† See 3GPP TR 36.804 v0.5.0 \(2007-05). † Inlcudes DC sub-carrier which contains no data † In one slot, the first OFDM symbol has long CP length and other 6 OFDM symbols have short CP length when Normal CP.

9. The outputs at port Ant1_TD and Ant2_TD are the samples with oversampling in time domain for each antenna port.
10. The outputs at port Ant1_FD and Ant2_FD are the frequency domain data without oversampling for each antenna port.
11. The outputs at port UE1_ModSymbols are the complex-valued modulation symbols for UE 1 (PDSCH 1).
12. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of scrambler. These outputs are the reference bits for uncoded BER and PER measurement.
13. The outputs at port UE1_RawBits are the transport block bits for UE 1 (PDSCH 1). These outputs are the reference bits for coded BER and PER measurement.
14. The output at port SC_Status is the status for each subcarrier (resource element). The first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol. When the last subcarrier (resource element) in the first OFDM symbol is output, then next the first subcarrier (resource element) in the second OFDM symbol is output, and so on. The 8 LSB bits of each status value represent the channel type allocated on each subcarrier (resource element). The meaning of the 8 LSB bits is shown as follows:

Value	ChanneType
0	EMPTY
1	RS
2	PSS
3	SSS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
8	PDSCH 1 (UE 1)
9	PDSCH 2 (UE 2)
10	PDSCH 3 (UE 3)
11	PDSCH 4 (UE 4)
12	PDSCH 5 (UE 5)
13	PDSCH 6 (UE 6)

    The 24 MSB bits of each status value represent the index for the data allocated on each subcarrier (resource element). For each channel indicated in the table above, the data indexing is performed subframe by subframe independently. For example, for PDSCH 1 (UE 1), the first modulation symbol within each subframe is indexed as 0; the second modulation symbol is indexed as 1, and so on. When there is no data allocated on the subcarrier, the 24 MSB bits of each status is set to 0xFFFFFF.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

MIMO Parameters Details:

- UEs_MIMO_Mode: MIMO Mode for each UE, 1 for TD (transmit diversity), 0 for SM (spatial multiplexing). The type of intarray and its size should be 6 corresponding to six UEs in this source. The value range of each element should be {0,1}.
- UEs_CDD_Mode: CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay. The type of intarray and its size should be 6 corresponding to six UEs in this source. The value range of each element should be {0,1}.
- UEs_CdBlk_Index: precoding codebook index for each UE. The type of intarray and its size should be 6 corresponding to six UEs in this source. The value range of each element should be [0,15].
- UEs_NumCWs: Number of code words for each UE. The type of intarray and its size should be 6 corresponding to six UEs in this source. The value range of each element should be {1,2}.
- UEs_NumOfLayers: Number of layers for each UE. The type of intarray and its size should be 6 corresponding to six UEs in this source. The value range of each element should be {1,2,3,4}. The elements of UE_CDD_Mode, UE_CdBk_Index and UE_NumOfLayers just will be active only when the corresponding element is 0 (spatial multiplexing) in UE_MIMO_Mode parameter.

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).
- Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Ra), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Ra-10log10(P)), where P is the number of antenna ports.
- For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

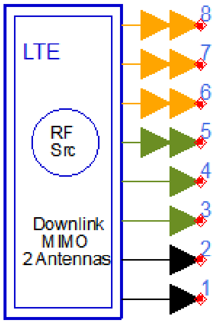
Spectrum Shaping Parameters Details:

- Refer to *DL Spectrum Shaping Parameters* (3gpplte).
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = None, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_MIMO_2Ant_Src_RF (Downlink RF 2 antennas MIMO signal source)



Description: Downlink RF 2 antennas MIMO signal source
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE downlink signals	Category		string	
ROut	Source resistance	DefaultROut	Ohm	int	(0,∞)
RTemp	TEMPERATURE	DefaultRTemp	Celsius	real	[-273.15,∞]
FCarrier	Carrier frequency	2500 MHz	Hz	real	(0,∞)
GainImbalance	Gain imbalance in dB Q channel relative to I channel at 2 transmit antennas	{0.0, 0.0}		real array	(-∞,∞)
PhaseImbalance	Phase imbalance in dB Q channel relative to I channel at 2 transmit antennas	{0.0, 0.0}		real array	(-∞,∞)
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO		enum	
MIMO_Parameters	MIMO-related parameters for all six Ues	Category		string	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CDD_Mode	CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,2]

UEs_NumOfLayers	number of layers for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_CW1_DataPattern	the data transmitted in the transport block of UE1 Code word 1: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	
UE1_CW2_DataPattern	the data transmitted in the transport block of UE1 Code word 2: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	
UE1_Config	the configuration mode of input data for UE 1.: MCS index, Transport block size, Code rate	Transport block size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	0		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}		int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	

PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}		int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng 1/6, Ng 1/2, Ng 1, Ng 2	Ng 1/6		enum	
BCH_BlockSize	transport block size for BCH	624		int	[1,∞)
HI	physical hybrid-ARQ ACK/NAK indicators	{1, -1, -1, -1, -1, -1, -1, -1}		int array	
PowerParameters	power-related parameters	Category		string	
RS_EPRE	transmit energy per resource element (RE) for cell specific RS for each antenna port, in unit of dBm/15kHz	-25		real	(-∞,∞)
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing		enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6		int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19		int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO		enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal Lowpass	RRC		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when	.22		real	[0,1.0]

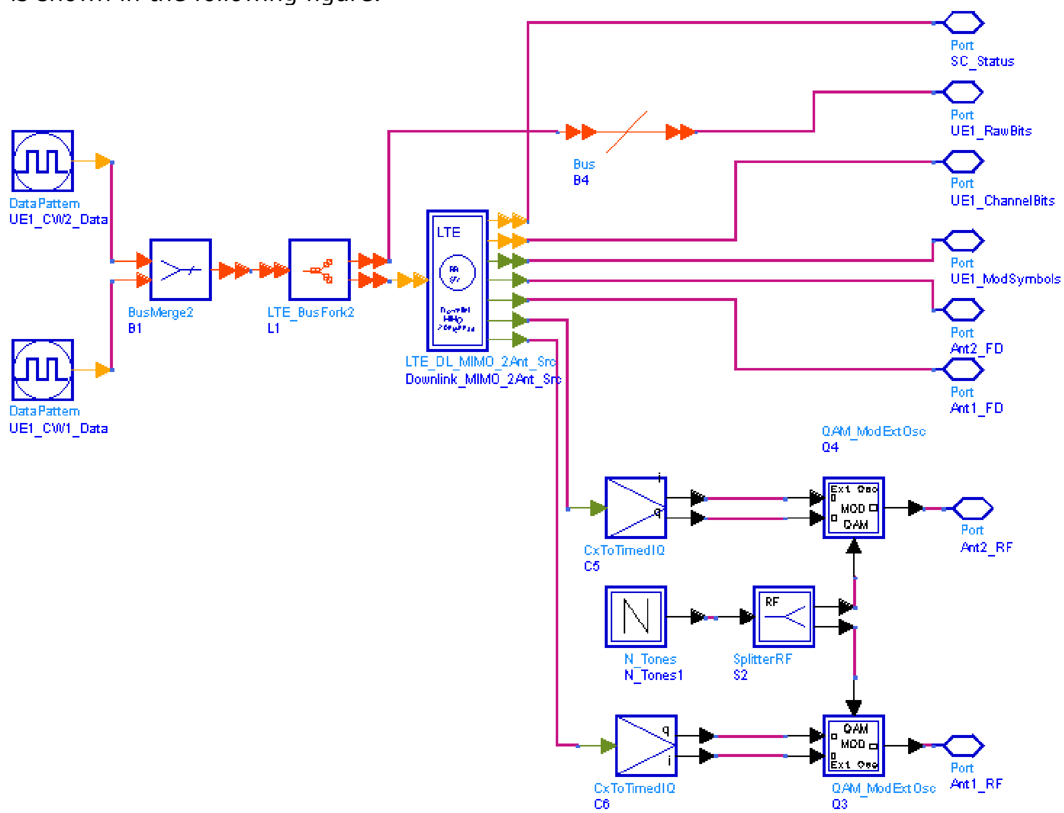
	SpectrumShapingType=FIRFilter				
DisplayMsg	the messages displayed in Status/Summary window: None, Simple, Full	Simple		enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	Ant1_RF	Antenna 1 RF signal	timed
2	Ant2_RF	Antenna 2 RF signal	timed
3	Ant1_FD	Antenna 1 output of one frame in frequency domain	complex
4	Ant2_FD	Antenna 2 output of one frame in frequency domain	complex
5	UE1_ModSymbols	UE 1 modulation symbols	multiple complex
6	UE1_ChannelBits	UE 1 channel bits	multiple int
7	UE1_RawBits	UE 1 raw bits from MAC layer	multiple int
8	SC_Status	downlink subcarrier (resource element) status in one frame	multiple int

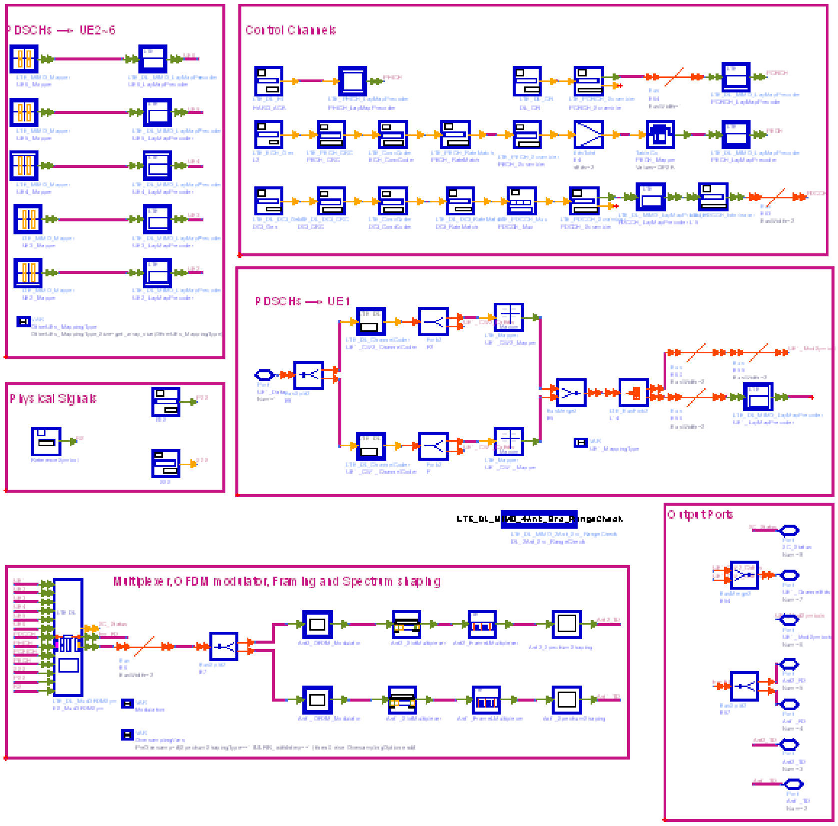
Notes/Equations

1. This subnetwork generates 3GPP LTE FDD-LTE (FS1) and TDD-LTE (FS2) coded downlink MIMO 2 antennas RF signal (up to six users). The subnetwork includes LTE_DL_MIMO_2Ant_Src, which generates baseband 3GPP FDD and TDD LTE uncoded downlink source, and the RF_Modulator. The schematic for this subnetwork is shown in the following figure.



LTE_DL_MIMO_2Ant_Src_RF Schematic

2. LTE_DL_MIMO_2Ant_Src generates 3GPP FDD LTE (FS1) and TDD LTE (FS2) coded downlink 2 antennas MIMO baseband signal (up to six users). The schematic for this subnetwork is shown in the following figure. The detailed information for LTE_DL_MIMO_2Ant_Src is in *Downlink MIMO 2Ant Baseband Source* (3gpplte).



LTE_DL_MIMO_2Ant_Src_RF_figure2 Schematic

3. The outputs at port Ant1_RF and Ant2_RF are the RF signals in time domain for each antenna port.
4. The outputs at port Ant1_FD and Ant2_FD are the frequency domain data without oversampling for each antenna port.
5. The outputs at port UE1_ModSymbols are the complex-valued modulation symbols for UE 1 (PDSCH 1).
6. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of scrambler. These outputs are the reference bits for uncoded BER and PER measurement.
7. The outputs at port UE1_RawBits are the transport block bits for UE 1 (PDSCH 1). These outputs are the reference bits for coded BER and PER measurement.
8. The output at port SC_Status is the status for each subcarrier (resource element). The first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol. When the last subcarrier (resource element) in the first OFDM symbol is output, then next the first subcarrier (resource element) in the second OFDM symbol is output, and so on. The 8 LSB bits of each status value represent the channel type allocated on each subcarrier (resource element). The meaning of the 8 LSB bits is shown as follows:

Value	ChanneType
0	EMPTY
1	RS
2	PSS
3	SSS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
8	PDSCH 1 (UE 1)
9	PDSCH 2 (UE 2)
10	PDSCH 3 (UE 3)
11	PDSCH 4 (UE 4)
12	PDSCH 5 (UE 5)
13	PDSCH 6 (UE 6)

The 24 MSB bits of each status value represent the index for the data allocated on each subcarrier (resource element). For each channel indicated in the table above, the data indexing is performed subframe by subframe independently. For example, for PDSCH 1 (UE 1), the first modulation symbol within each subframe is indexed as 0; the second modulation symbol is indexed as 1, and so on. When there is no data allocated on the subcarrier, the 24 MSB bits of each status is set to 0xFFFFFF.

RF Parameter Details:

- ROut is the RF output source resistance.
- RTemp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- FCarrier is the RF output signal frequency.
- MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage. Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set this parameter to YES.
- GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
  The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
  $$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\Phi\pi}{180}\right)\right)$$
  where A is a scaling factor based on the Power and ROut parameters specified by the user, VI(t) is the in-phase RF envelope, VQ(t) is the quadrature phase RF envelope, g is the gain imbalance:
  $$g = 10^{\frac{GainImbalance}{20}}$$
  and, ϕ (in degrees) is the phase imbalance.
  Next, the signal VRF(t) is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by *sqrt(2 __ ROut __ Power)* .

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

MIMO Parameters Details:

- Refer to *DL MIMO Parameters* (3gpplte).

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).
- Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Ra), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Ra-10log10(P)), where P is the number of antenna ports.
- For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

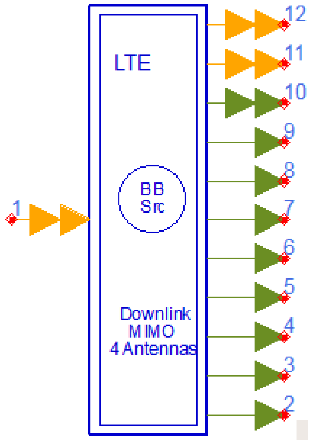
Spectrum Shaping Parameters Details:

- Refer to *DL Spectrum Shaping Parameters* (3gpplte).
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = None, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_MIMO_4Ant_Src (Downlink baseband 4 antennas MIMO signal source)



Description: Downlink baseband 4 antennas MIMO signal source
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO		enum	
MIMO_Parameters	MIMO-related parameters for all six Ues	Category		string	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CDD_Mode	CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,2]
UEs_NumOfLayers	number of layers for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS_index, Transport_block_size, Code_rate	Transport_block_size		enum	

UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	1		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}		int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}		int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6		enum	
BCH_BlockSize	transport block size for BCH	24		int	[1,∞)
HI	physical hybrid-ARQ ACK/NAK indicators	{1, -1, -1, -1, -1, -1,		int	

		-1, -1}		array	
PowerParameters	power-related parameters	Category		string	
RS_EPRE	transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz	-25		real	(-∞,∞)
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing		enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised_cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6		int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19		int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO		enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal_Lowpass	RRC		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22		real	[0,1.0]
DisplayMsg	control LTE system information displayed in Simulation Log window: None, Simple, Full	Simple		enum	

Pin Inputs

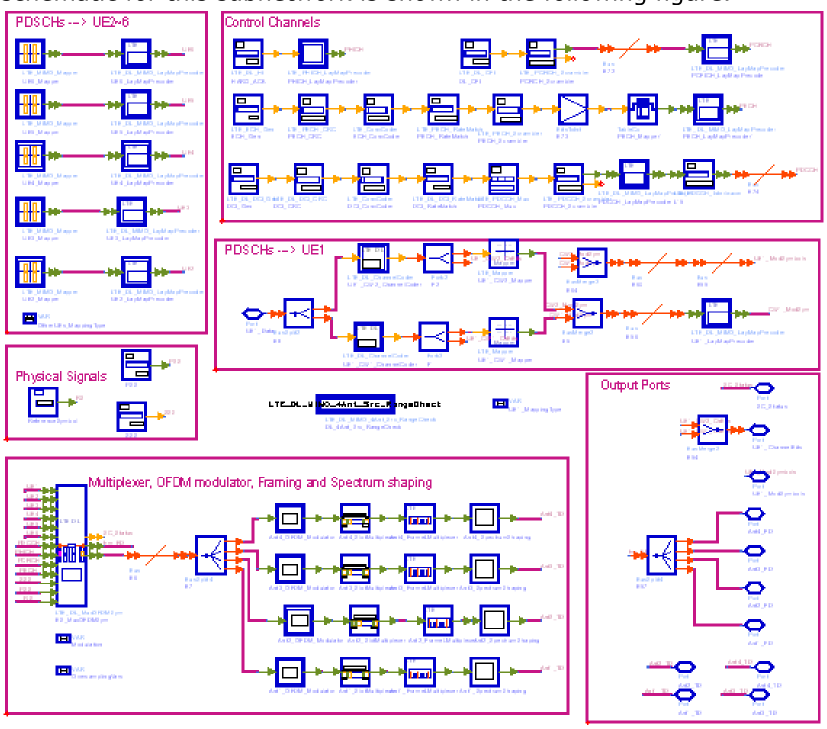
Pin	Name	Description	Signal Type
1	UE1_Data	UE 1 raw data	multiple int

Pin Outputs

Pin	Name	Description	Signal Type
2	Ant1_TD	Antenna 1 output of one frame signal in time domain	complex
3	Ant2_TD	Antenna 2 output of one frame signal in time domain	complex
4	Ant3_TD	Antenna 3 output of one frame signal in time domain	complex
5	Ant4_TD	Antenna 4 output of one frame signal in time domain	complex
6	Ant1_FD	Antenna 1 output of one frame in frequency domain	complex
7	Ant2_FD	Antenna 2 output of one frame in frequency domain	complex
8	Ant3_FD	Antenna 3 output of one frame in frequency domain	complex
9	Ant4_FD	Antenna 4 output of one frame in frequency domain	complex
10	UE1_ModSymbols	UE 1 modulation symbols	multiple complex
11	UE1_ChannelBits	UE 1 channel bits	multiple int
12	SC_Status	downlink subcarrier (resource element) status in one frame	multiple int

Notes/Equations

This subnetwork generates 3GPP FDD LTE (FS1) and TDD LTE (FS2) coded downlink baseband signal (up to six users (PDSCHs)) with four transmit antenna ports. The schematic for this subnetwork is shown in the following figure.



LTE_DL_MIMO_4Ant_Src Schematic

1. In this source, only the first UE (PDSCH 1) is encoded, and other UEs (UE 2 to UE 6) are uncoded
   - For UE 1 (PDSCH 1), two transport block data input from port UE1_Data are sent to two LTE_DL_ChannelCoder components respectively, in which the CRC encoder, code block segmentation, Turbo coder, rate matching and scrambler are performed. In this source, two code words are input regardless of the actual number of code words defined in the UEs_NumOfCWs[1] parameter for UE 1. When UEs_NumOfCWs[1] is 1, the channel coder (and LTE_Mapper) for the second code word is ignored. Then the output channel bits are modulated in LTE_Mapper component, resulting in complex-valued modulation symbols. The modulation symbols from at most two code words are mapped to layers and precoded in LTE_DL_MIMO_LayMapPrecoder component. The precoded symbols, along with other UEs precoded symbols, are sent to LTE_DL_MuxOFDMSym component for mapping to resource elements.
   - For UE 2 to UE 6 (PDSCH 2 to PDSCH 6), complex-valued modulation symbols are generated in LTE_DL_Mapper for the two code words with the source bits of PN 9, which are then sent to LTE_DL_MIMO_LayMapPrecoder component for lay

mapping and precoding. The modulation schemes (QPSK, 16QAM or 64QAM) are determined OtherUEs_MappingType parameter.

2. LTE_PSCH component generates P-SS according to Section 6.11.1 [1], which is the Zadoff-Chu root sequence. P-SS occupies central 72 subcarriers. For FDD LTE (frame structure type 1), P-SS should be mapped to the last OFDM symbol in slots 0 and 10. For TDD LTE (frame structure type 2), P-SS should be mapped to the third OFDM symbol in subframe 1 and 6. SS_PerTxAnt parameter determines whether the P-SS is transmitted on the first antenna port or on all the transmit antenna ports.
3. LTE_SSCH component generates S-SS according to Section 6.11.2 [1], which is the length-31 binary sequence. The S-SS occupies central 72 subcarriers. In a subframe for frame structure type 1 and in half-frame for frame structure type 2, the same antenna port as for the P-SS shall be used for the S-SS. For TDD LTE (frame structure type 1), S-SS should be mapped to the last second OFDM symbol in slots 0 and 10. For TDD LTE (frame structure type 2), S-SS should be mapped to the last OFDM symbol in slot 1 and 11. S_PerTxAnt parameter determines whether the S-SS is transmitted on the first antenna port or on all the transmit antenna ports.
4. The information bits for PBCH are generated in LTE_BCH_Gen which are passed to the CRC encoder, convolutional encoder, rate matching, and scrambler, QPSK modulation, layer mapping and precoding for transmit diversity. Then the precoded symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
The information bits for PCFICH are generated in LTE_DL_CFI according to the PDCCH_SymsPerSF parameter. Then these bits are sent to LTE_PCFICH_Scrambler component for scrambling, and then mapped to QPSK modulation, and for layer mapping and precoding for transmit diversity. The precoded symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
The information bits for PDCCH are generated in LTE_DL_DCI_Gen component according to DCI configurations, which are delivered to the CRC encoder, turbo encoder, rate matching, scrambler, QPSK modulation, PDCCH interleaver, and layer mapping and precoding for transmit diversity. Then the precoded symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
The information bits for PHICH are read from the HI parameter in LTE_DL_HI component, which are sent to LTE_PHICH_Modulator and LTE_PHICH_LayerMapper for BPSK modulation, orthogonal spreading and resource group alignment. The outputs are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
5. PBCH, PHICH, PCFICH and PDCCH shall be transmitted on the both four antenna ports.
6. LTE_DL_MuxOFDMSym component is used to multiplex UEs (PDSCHs) data mapping signals, P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH and reference signals (pilots) into OFDM symbols following the downlink frame structure in frequency domain. UEs data mapping signals are mapped to resource elements according to Section 6.3.5 [1]. PBCH QPSK signals, PCFICH QPSK signals, PDCCH QPSK siganls, PHICH are mapped to resource elements according to Section 6.6.4 [1], 6.7.4 [1], 6.8.5 [1], 6.9.3 [1], respectively. The cell-specific reference signals are generated according to Section 6.10.1 [1] in LTE_DL_Pilots component and are mapped to resource elements according to Section 6.10.1.2 [1].
7. The outputs at LTE_DL_MuxOFDMSym component are split into two frequency domain signals for two antenna ports. Each of them are transferred into time-domain signals by LTE_DL_OFDM_Modulator which implements OFDM modulation following 3GPP LTE downlink OFDM parameters. LTE_DL_MuxSlot is used to multiplex seven/six OFDM symbols by inserting cyclic prefix into one slot. LTE_DL_MuxFrame multiplexes 20 slots into one radio frame (10 ms) and inserts idle (time duration is IdleInterval) between two consecutive radio frames. LTE_SpecShaping is for spectrum shaping function for downlink source by using FIR filter or symbol windowing function.

Parameters for Downlink Transmission Scheme

Transmission BW		1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration		1 msecμ					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 x 3.84 MHz)	3.84 MHz	7.68 MHz (2 x 3.84 MHz)	15.36 MHz (4 x 3.84 MHz)	23.04 MHz (6 x 3.84 MHz)	30.72 MHz (8 x 3.84 MHz)
FFT size		128	256	512	1024	1536	2048
Number of Resource Blocks †		6	15	25	50	75	100
Number of occupied sub-carriers †		73	181	301	601	901	1201
Number of OFDM symbols per sub-frame (Normal/Extended CP)		7/6					
CP length (μ/samples)	Normal †	(4.69/9) x 6, (5.21/10) x 1	(4.69/18) x 6, (5.21/20) x 1	(4.69/36) x 6, (5.21/40) x 1	(4.69/72) x 6, (5.21/80) x 1	(4.69/108) x 6, (5.21/120) x 1	(4.69/144) x 6, (5.21/160) x 1
	Extended	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)
† See 3GPP TR 36.804 v0.5.0 \(2007-05). † Inlcudes DC sub-carrier which contains no data † In one slot, the first OFDM symbol has long CP length and other 6 OFDM symbols have short CP length when Normal CP.							

8. The outputs at port Ant1_TD, Ant2_TD, Ant2_TD and Ant4_TD are the samples with oversampling in time domain for each antenna port.
9. The outputs at port Ant1_FD, Ant2_FD, Ant3_FD and Ant4_FD are the frequency domain data without oversampling for each antenna port.
10. The outputs at port UE1_ModSymbols are the complex-valued modulation symbols for UE 1 (PDSCH 1).
11. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of scrambler. These outputs are the reference bits for uncoded BER and PER measurement.
    The outputs at port UE1_RawBits are the transport block bits for UE 1 (PDSCH 1). These outputs are the reference bits for coded BER and PER measurement.
12. The output at port SC_Status is the status for each subcarrier (resource element). The first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol. When the last subcarrier (resource element) in the first OFDM symbol is output, then next the first subcarrier (resource element) in the second OFDM symbol is output, and so on. The 8 LSB bits of each status value represent the channel type allocated on each subcarrier (resource element). The meaning of the 8 LSB bits is shown as follows:

Value	ChanneType
0	EMPTY
1	RS
2	PSS
3	SSS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
8	PDSCH 1 (UE 1)
9	PDSCH 2 (UE 2)
10	PDSCH 3 (UE 3)
11	PDSCH 4 (UE 4)
12	PDSCH 5 (UE 5)
13	PDSCH 6 (UE 6)

    The 24 MSB bits of each status value represent the index for the data allocated on each subcarrier (resource element). For each channel indicated in the table above, the data indexing is performed subframe by subframe independently. For example, for PDSCH 1 (UE 1), the first modulation symbol within each subframe is indexed as 0; the second modulation symbol is indexed as 1, and so on. When there is no data allocated on the subcarrier, the 24 MSB bits of each status is set to 0xFFFFFF.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

MIMO Parameters Details:

- Refer to *DL MIMO Parameters* (3gpplte).

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).
- Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Ra), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Ra-10log10(P)), where P is the number of antenna ports.
- For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

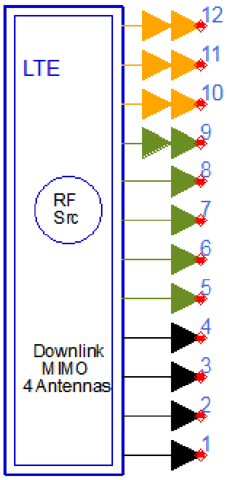
Spectrum Shaping Parameters Details:

- Refer to *DL Spectrum Shaping Parameters* (3gpplte).
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = None, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_MIMO_4Ant_Src_RF (Downlink RF 4 antennas MIMO signal source)



Description: Downlink RF 4 antennas MIMO signal source
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE downlink signals	Category		string	
ROut	Source resistance	DefaultROut	Ohm	int	(0,∞)
RTemp	TEMPERATURE	DefaultRTemp	Celsius	real	[-273.15,∞]
FCarrier	Carrier frequency	2500 MHz	Hz	real	(0,∞)
GainImbalance	Gain imbalance in dB Q channel relative to I channel at 4 transmit antennas	{0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PhaseImbalance	Phase imbalance in dB Q channel relative to I channel at 4 transmit antennas	{0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SS_PerTxAnt	whether synchronization signals (P-SS and S-SS) are transmitted on each transmit antenna: NO, YES	NO		enum	
MIMO_Parameters	MIMO-related parameters for all six Ues	Category		string	
UEs_MIMO_Mode	MIMO Mode for each UE, 1 for TD, 0 for SM	{0, 0, 0, 0, 0, 0}		int array	[0,1]

UEs_CDD_Mode	CDD Mode for each UE, 1 for Zero-Delay, 0 for Large-Delay	{0, 0, 0, 0, 0, 0}		int array	[0,1]
UEs_CdBlk_Index	codebook index for precoding for each UE	{0, 0, 0, 0, 0, 0}		int array	[0,15]
UEs_NumOfCWs	number of code words for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,2]
UEs_NumOfLayers	number of layers for each UE	{2, 2, 2, 2, 2, 2}		int array	[1,4]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_CW1_DataPattern	the data transmitted in the transport block of UE1 Code word 1: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	
UE1_CW2_DataPattern	the data transmitted in the transport block of UE1 Code word 2: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	
UE1_Config	the configuration mode of input data for UE 1.: MCS index, Transport block size, Code rate	Transport block size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	0		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every	{1}		int array	[1, 8]

	subframe. The allowable levels are 1, 2, 4 and 8.				
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}		int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng 1/6, Ng 1/2, Ng 1, Ng 2	Ng 1/6		enum	
BCH_BlockSize	transport block size for BCH	624		int	[1,∞)
HI	physical hybrid-ARQ ACK/NAK indicators	{1, -1, -1, -1, -1, -1, -1, -1}		int array	
PowerParameters	power-related parameters	Category		string	
RS_EPRE	transmit energy per resource element (RE) for cell specific RS for each antenna port, in unit of dBm/15kHz	-25		real	(-∞,∞)
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing		enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6		int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19		int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter:	NO		enum	

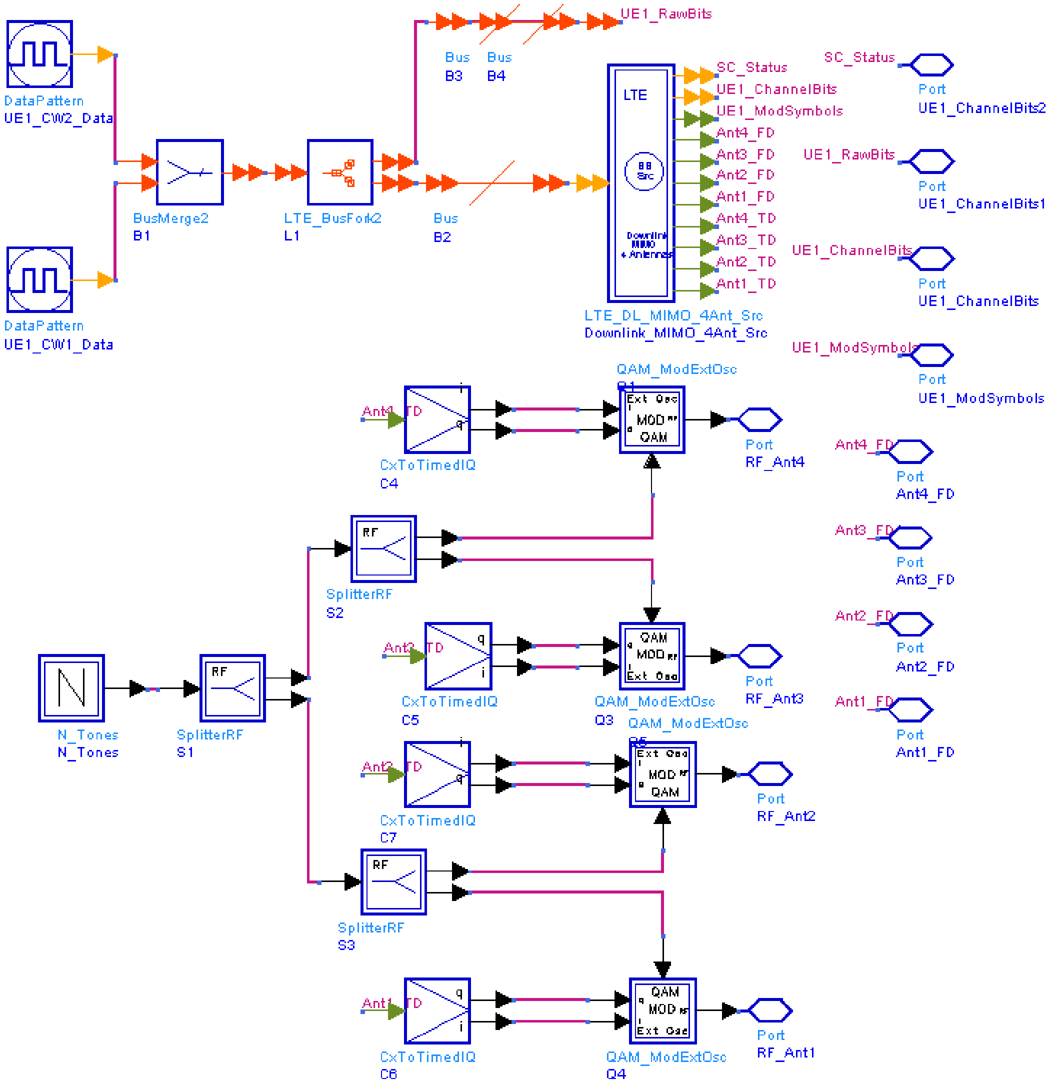
	NO, YES				
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal Lowpass	RRC		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22		real	[0,1.0]
DisplayMsg	the messages displayed in Status/Summary window: None, Simple, Full	Simple		enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	Ant1_RF	Antenna 1 RF signal	timed
2	Ant2_RF	Antenna 2 RF signal	timed
3	Ant3_RF	Antenna 3 RF signal	timed
4	Ant4_RF	Antenna 4 RF signal	timed
5	Ant1_FD	Antenna 1 output of one frame in frequency domain	complex
6	Ant2_FD	Antenna 2 output of one frame in frequency domain	complex
7	Ant3_FD	Antenna 3 output of one frame in frequency domain	complex
8	Ant4_FD	Antenna 4 output of one frame in frequency domain	complex
9	UE1_ModSymbols	UE 1 modulation symbols	multiple complex
10	UE1_ChannelBits	UE 1 channel bits	multiple int
11	UE1_RawBits	UE 1 raw bits from MAC layer	multiple int
12	SC_Status	downlink subcarrier (resource element) status in one frame	multiple int

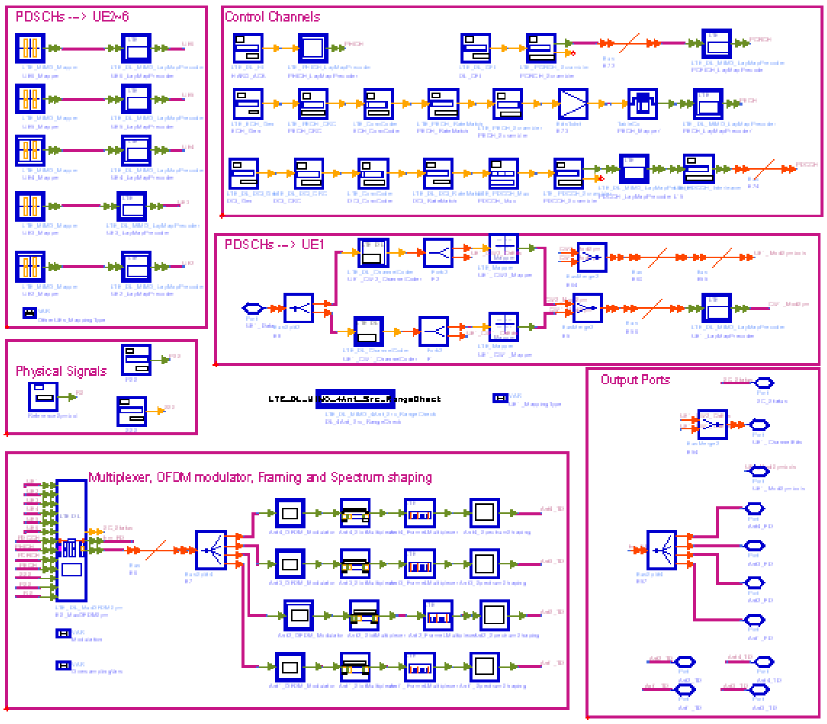
Notes/Equations

1. This subnetwork generates 3GPP LTE FDD-LTE (FS1) and TDD-LTE (FS2) coded downlink MIMO 4 antennas RF signal (up to six users). The subnetwork includes LTE_DL_MIMO_4Ant_Src, which generates baseband 3GPP FDD and TDD LTE coded downlink source, and the RF_Modulator. The schematic for this subnetwork is shown in the following figure.



LTE_DL_MIMO_4Ant_Src_RF Schematic

2. LTE_DL_MIMO_4Ant_Src generates 3GPP FDD LTE (FS1) and TDD LTE (FS2) coded downlink 4 antennas MIMO baseband signal (up to six users). The schematic for this subnetwork is shown in the following figure. The detailed information for LTE_DL_MIMO_4Ant_Src is in *Downlink MIMO 4Ant Baseband Source* (3gpplte).



LTE_DL_MIMO_42Ant_Src_Schematic

3. The outputs at port Ant1_RF, Ant2_RF, Ant3_RF and Ant4_RF are the RF signals in time domain for each antenna port.
4. The outputs at port Ant1_FD, Ant2_FD, Ant3_FD and Ant4_FD are the frequency domain data without oversampling for each antenna port.
5. The outputs at port UE1_ModSymbols are the complex-valued modulation symbols for UE 1 (PDSCH 1).
6. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of scrambler. These outputs are the reference bits for uncoded BER and PER measurement.
7. The outputs at port UE1_RawBits are the transport block bits for UE 1 (PDSCH 1). These outputs are the reference bits for coded BER and PER measurement.
8. The output at port SC_Status is the status for each subcarrier (resource element). The first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol. When the last subcarrier (resource element) in the first OFDM symbol is output, then next the first subcarrier (resource element) in the second OFDM symbol is output, and so on. The 8 LSB bits of each status value represent the channel type allocated on each subcarrier (resource element). The meaning of the 8 LSB bits is shown as follows:

Value	ChanneType
0	EMPTY
1	RS
2	PSS
3	SSS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
8	PDSCH 1 (UE 1)
9	PDSCH 2 (UE 2)
10	PDSCH 3 (UE 3)
11	PDSCH 4 (UE 4)
12	PDSCH 5 (UE 5)
13	PDSCH 6 (UE 6)

The 24 MSB bits of each status value represent the index for the data allocated on

each subcarrier (resource element). For each channel indicated in the table above, the data indexing is performed subframe by subframe independently. For example, for PDSCH 1 (UE 1), the first modulation symbol within each subframe is indexed as 0; the second modulation symbol is indexed as 1, and so on. When there is no data allocated on the subcarrier, the 24 MSB bits of each status is set to 0xFFFFFF.

RF Parameter Details:

- ROut is the RF output source resistance.
- RTemp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- FCarrier is the RF output signal frequency.
- MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage. Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set this parameter to YES.
- GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
  The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
  $$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\Phi\pi}{180}\right)\right)$$
  where A is a scaling factor based on the Power and ROut parameters specified by the user, VI(t) is the in-phase RF envelope, VQ(t) is the quadrature phase RF envelope, g is the gain imbalance:
  $$g = 10^{\frac{GainImbalance}{20}}$$
  and, ϕ (in degrees) is the phase imbalance.
  Next, the signal VRF(t) is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by *sqrt(2* ROut* Power).
  System Parameters Details:
- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).
- SS_PerTxAnt: whether the P-SS/S-SS are transmitted on the first antenna port or on all the transmit antenna ports.

MIMO Parameters Details:

- Refer to *DL MIMO Parameters* (3gpplte).

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).
- Note that for PSS_Ra, when SS_PerTxAnt = NO, the PSS EPRE on the first antenna port is (RS_EPRE+PSS_Ra), when the PSS EPRE on rest ports are 0. When SS_PerTxAnt = YES, the PSS EPRE on the each antenna port is (RS_EPRE+PSS_Ra-10log10(P)), where P is the number of antenna ports.
- For SSS_Ra, the SSS EPRE allocation for multiple antenna ports is the same as PSS EPRE above.

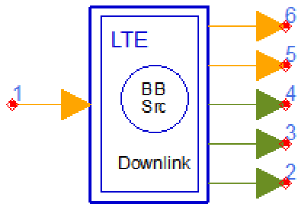
Spectrum Shaping Parameters Details:

- Refer to *DL Spectrum Shaping Parameters* (3gpplte).
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = None, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_Src (Downlink Baseband Signal Source)



Description: 3GPP LTE downlink signal source
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized, Distributed	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_Config	the configuration mode of input data for UE 1.: MCS_index, Transport_block_size, Code_rate	Transport_block_size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	1		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	

OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}		int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}		int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	
PHICH_Ng	PHICH Ng value: Ng_1_6, Ng_1_2, Ng_1, Ng_2	Ng_1_6		enum	
BCH_BlockSize	transport block size for BCH	24		int	[1,∞)
HI	physical hybrid-ARQ ACK/NAK indicators	{1, -1, -1, -1, -1, -1, -1, -1}		int array	
PowerParameters	power-related parameters	Category		string	
RS_EPRE	transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz	-25		real	(-∞,∞)
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	

UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing		enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised_cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6		int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19		int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO		enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal_Lowpass	RRC		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22		real	[0,1.0]
DisplayMsg	control LTE system information displayed in Simulation Log window: None, Simple, Full	Simple		enum	

Pin Inputs

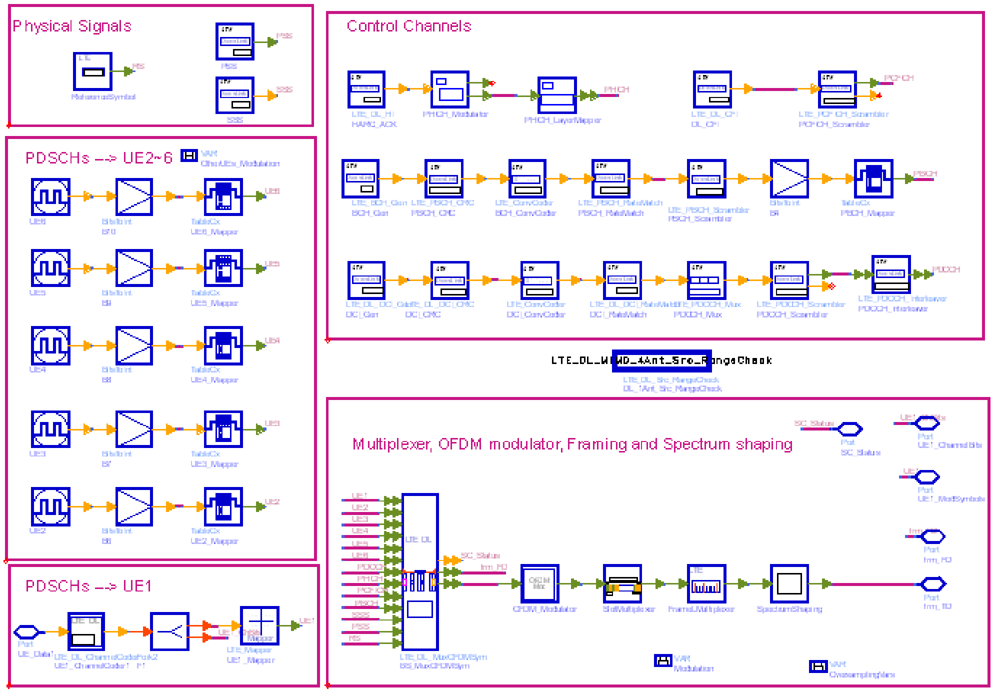
Pin	Name	Description	Signal Type
1	UE1_Data	UE 1 raw data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	frm_TD	output of one frame signal in time domain	complex
3	frm_FD	output of one frame in frequency domain	complex
4	UE1_ModSymbols	UE 1 modulation symbols	complex
5	UE1_ChannelBits	UE 1 channel bits before modulation	int
6	SC_Status	downlink subcarrier (resource element) status in one frame	int

Notes/Equations

1. This subnetwork generates 3GPP FDD LTE (FS1) and TDD LTE (FS2) coded downlink baseband signal (up to six users (PDSCHs)). The schematic for this subnetwork is shown in the following figure.



LTE_DL_Src Schematic

2. In this source, only the first UE (PDSCH 1) is encoded, and other UEs (UE 2 to UE 6) are uncoded.
    - For UE 1 (PDSCH 1), the transport block data input from port UE1_Data are sent to LTE_DL_ChannelCoder component, in which the CRC encoder, code block segmentation, Turbo coder, rate matching and scrambler are performed. Then the output channel bits are modulated in LTE_Mapper component, resulting in complex-valued modulation symbols which, along with other UEs modulation symbols, are sent to LTE_DL_MuxOFDMSym component for mapping to resource elements.
    - For UE 2 to UE 6 (PDSCH 2 to PDSCH 6), PN15 bits are directly sent to the symbol modulation to generate complex-valued modulation symbols according to the OtherUEs_MappingType parameter.
3. LTE_PSCH component generates P-SS according to Section 6.11.1 [1], which is the Zadoff-Chu root sequence. P-SS occupies central 72 subcarriers. For FDD LTE (frame structure type 1), P-SS should be mapped to the last OFDM symbol in slots 0 and 10. For TDD LTE (frame structure type 2), P-SS should be mapped to the third OFDM symbol in subfrme 1 and 6.
4. LTE_SSCH component generates S-SS according to Section 6.11.2 [1], which is the length-31 binary sequence. The S-SS occupies central 72 subcarriers. In a subframe for frame structure type 1 and in half-frame for frame structure type 2, the same antenna port as for the P-SS shall be used for the S-SS. For TDD LTE (frame structure type 1), S-SS should be mapped to the last second OFDM symbol in slots 0 and 10. For TDD LTE (frame structure type 2), S-SS should be mapped to the last OFDM symbol in slot 1 and 11.
5. The information bits for PBCH are generated in LTE_BCH_Gen which are passed to the CRC encoder, convolutional encoder, rate matching, and scrambler and QPSK modulation. Then the QPSK symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
6. The information bits for PCFICH are generated in LTE_DL_CFI according to the PDCCH_SymsPerSF parameter. Then these bits are sent to LTE_PCFICH_Scrambler component for scrambling, and then mapped to QPSK modulation. The QPSK symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
7. The information bits for PDCCH are generated in LTE_DL_DCI_Gen component according to DCI configurations, which are delivered to the CRC encoder, turbo encoder, rate matching, scrambler, QPSK modulation and PDCCH interleaver. Then the QPSK symbols are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.
8. The information bits for PHICH are read from the HI parameter in LTE_DL_HI component, which are sent to LTE_PHICH_Modulator and LTE_PHICH_LayerMapper

for BPSK modulation, orthogonal spreading and resource group alignment. The outputs are mapped to corresponding resource elements in LTE_DL_MuxOFDMSym component.

9. LTE_DL_MuxOFDMSym component is used to multiplex UEs (PDSCHs) data mapping signals, P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH and reference signals (pilots) into OFDM symbols following the downlink frame structure in frequency domain. UEs data mapping signals are mapped to resource elements according to Section 6.3.5 [1]. PBCH QPSK signals, PCFICH QPSK signals, PDCCH QPSK siganls, PHICH are mapped to resource elements according to Section 6.6.4 [1], 6.7.4 [1], 6.8.5 [1], 6.9.3 [1], respectively. The cell-specific reference signals are generated according to Section 6.10.1 [1] in LTE_DL_Pilots component and are mapped to resource elements according to Section 6.10.1.2 [1].
10. The frequency domain signals are transferred into time-domain signals by LTE_DL_OFDM_Modulator which implements OFDM modulation following 3GPP LTE downlink OFDM parameters. LTE_DL_MuxSlot is used to multiplex seven/six OFDM symbols by inserting cyclic prefix into one slot. LTE_DL_MuxFrame multiplexes 20 slots into one radio frame (10 ms) and inserts idle (time duration is IdleInterval) between two consecutive radio frames. LTE_SpecShaping is for spectrum shaping function for downlink source by using FIR filter or symbol windowing function.

Parameters for Downlink Transmission Scheme

<table>
<tr><td colspan="2">Transmission BW</td><td>1.4 MHz</td><td>3 MHz</td><td>5 MHz</td><td>10 MHz</td><td>15 MHz</td><td>20 MHz</td></tr>
<tr><td colspan="2">Sub-frame duration</td><td colspan="6">1 msecµ</td></tr>
<tr><td colspan="2">Sub-carrier spacing</td><td colspan="6">15 kHz</td></tr>
<tr><td colspan="2">Sampling frequency</td><td>1.92 MHz (1/2 x 3.84 MHz)</td><td>3.84 MHz</td><td>7.68 MHz (2 x 3.84 MHz)</td><td>15.36 MHz (4 x 3.84 MHz)</td><td>23.04 MHz (6 x 3.84 MHz)</td><td>30.72 MHz (8 x 3.84 MHz)</td></tr>
<tr><td colspan="2">FFT size</td><td>128</td><td>256</td><td>512</td><td>1024</td><td>1536</td><td>2048</td></tr>
<tr><td colspan="2">Number of Resource Blocks †</td><td>6</td><td>15</td><td>25</td><td>50</td><td>75</td><td>100</td></tr>
<tr><td colspan="2">Number of occupied sub-carriers †</td><td>73</td><td>181</td><td>301</td><td>601</td><td>901</td><td>1201</td></tr>
<tr><td colspan="2">Number of OFDM symbols per sub-frame (Normal/Extended CP)</td><td colspan="6">7/6</td></tr>
<tr><td rowspan="2">CP length (µ/samples)</td><td>Normal †</td><td>(4.69/9) x 6, (5.21/10) x 1</td><td>(4.69/18) x 6, (5.21/20) x 1</td><td>(4.69/36) x 6, (5.21/40) x 1</td><td>(4.69/72) x 6, (5.21/80) x 1</td><td>(4.69/108) x 6, (5.21/120) x 1</td><td>(4.69/144) x 6, (5.21/160) x 1</td></tr>
<tr><td>Extended</td><td>(16.67/32)</td><td>(16.67/64)</td><td>(16.67/128)</td><td>(16.67/256)</td><td>(16.67/384)</td><td>(16.67/512)</td></tr>
<tr><td colspan="8">† See 3GPP TR 36.804 v0.5.0 \(2007-05). † Inlcudes DC sub-carrier which contains no data † In one slot, the first OFDM symbol has long CP length and other 6 OFDM symbols have short CP length when Normal CP.</td></tr>
</table>

11. The outputs at port frm_TD are the samples with oversampling in time domain.
12. The outputs at port frm_FD are the frequency domain data without oversampling.
13. The outputs at port UE1_ModSymbols are the complex-valued modulation symbols for UE 1 (PDSCH 1).
14. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of scrambler. These outputs are the reference bits for uncoded BER and PER measurement. For more information, refer to *Channel Bits Calculation* (3gpplte).
15. The outputs at port UE1_RawBits are the transport block bits for UE 1 (PDSCH 1). These outputs are the reference bits for coded BER and PER measurement.
16. The output at port SC_Status is the status for each subcarrier (resource element). The first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol. When the last subcarrier (resource element) in the first OFDM symbol is output, then next the first subcarrier (resource element) in the second OFDM symbol is output, and so on. The 8 LSB bits of each status value represent the channel type allocated on each subcarrier (resource element). The meaning of the 8 LSB bits is shown as follows:

Value	ChannelType
0	EMPTY
1	RS
2	PSS
3	SSS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
8	PDSCH 1 (UE 1)
9	PDSCH 2 (UE 2)
10	PDSCH 3 (UE 3)
11	PDSCH 4 (UE 4)
12	PDSCH 5 (UE 5)
13	PDSCH 6 (UE 6)

The 24 MSB bits of each status value represent the index for the data allocated on each subcarrier (resource element). For each channel indicated in the table above, the data indexing is performed subframe by subframe independently. For example, for PDSCH 1 (UE 1), the first modulation symbol within each subframe is indexed as 0; the second modulation symbol is indexed as 1, and so on. When there is no data allocated on the subcarrier, the 24 MSB bits of each status is set to 0xFFFFFF.

System Parameters Details:

- FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD. FDD supports frame structure typ1 and TDD supports frame structure type 2.
- TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6. Tale 4.2.2 in [1] defines these 7 configurations.
- SpecialSF_Config: special subframe configuration when FrameMode is TDD. PDSCHs can be allocated in DwPTS.
- Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
- OversamplingOption: Over-sampling ratio option. Oversampling ratio 1, ratio 2, ratio 4 and ratio 8 are supported in this downlink source.
- CyclicPrefix: type of cyclic prefix. It can be set to Normal and Extended. Please note the first six OFDM symbols have the same shorter cyclic prefix and the last OFDM symbol has the longer cyclic prefix in the Normal Cyclic Prefix mode.
- CellID_Sector: the index of cell identity within the physical-layer cell-identity group . It defines the PSCH sequence. The root indices of P-SCH are M=29, M=34, M=25. CellID_Sector=0 is M=29, 1 is 34 and 2 is 25.
- CellID_Group: index of cell identity group, its value range is [0,167].
- RB_MappingType: mapping type from virtual resource blocks to physical resource blocks as defined in 6.2.3 of [1] which could be localized or distributed type. In this release, only localized type is supported.
- IdleInterval: idle interval between two consecutive radio frame

UE1 Parameters Details:

- UE1_Config: specify the meaning of UE1_Payload for UE1 which could be MCS index, Transport block size or Code rate. For more information, refer to *Relation of Transport Block Sizes, Channel Bits and Code Rates* (3gpplte).
- UE1_Payload: the input payload for UE 1, the meaning of the input is defined in UE1_Config. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 2x1, 10x1, 10x2.
- UE1_MappingType: the modulation scheme for UE1. 0 means QPSK; 1 means 16QAM; 2 means 64QAM. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 2x1, 10x1, 10x2.
- UE1_RV_Idx: redundancy version index for UE 1 which is used in rate matching.
- UE1_n_RNTI: radio network temporary identifier for UE 1
- UE1_Category: defines UE downlink capability, which is used to get the total number of soft channel bits (Nsoft) for rate-matching in downlink, as defined in 5.1.4.1.2 of [1]. The relationship of UE1_Category and Nsoft is given in the following table according to 36.306.

UE1 Category	Total number of soft channel bits (Nsoft)
Category 1	250368
Category 2	1237248
Category 3	1237248
Category 4	1827072
Category 5	3667200

- RB_AllocType: RB allocation type which could StartRB + NumRBs, RB indices (1D), or RB indices (2D). For more information, refer to *Resource Block Allocation* (3gpplte).
- UE1_RB_Alloc: RB allocation for UE1. The type of RB allocation is defined in RB_AllocType. This is an *Array Parameter* (3gpplte). The allowable sizes are 2x1, 10x1 when RB_AllocType=StartRB + NumRBs.

OtherUEs Parameters Details:

- OtherUEs_MappingType: the modulation schemes for UE2 to UE6. 0 means QPSK; 1 means 16QAM; 2 means 64QAM. This is an *Array Parameter* (3gpplte). The allowable sizes are 5x1, 5x2.
- UE2_RB_Alloc: RB allocation for UE2. The type of RB allocation is defined in RB_AllocType. This is an *Array Parameter* (3gpplte). The allowable sizes are 2x1, 10x2 when RB_AllocType=StartRB + NumRBs.
- UE3_RB_Alloc: RB allocation for UE3. The type of RB allocation is defined in RB_AllocType. This is an *Array Parameter* (3gpplte). The allowable sizes are 2x1, 10x2 when RB_AllocType=StartRB + NumRBs.
- UE4_RB_Alloc: RB allocation for UE4. The type of RB allocation is defined in RB_AllocType. This is an *Array Parameter* (3gpplte). The allowable sizes are 2x1, 10x2 when RB_AllocType=StartRB + NumRBs.
- UE5_RB_Alloc: RB allocation for UE5. The type of RB allocation is defined in RB_AllocType. This is an *Array Parameter* (3gpplte). The allowable sizes are 2x1, 10x2 when RB_AllocType=StartRB + NumRBs.
- UE6_RB_Alloc: RB allocation for UE6. The type of RB allocation is defined in RB_AllocType. This is an *Array Parameter* (3gpplte). The allowable sizes are 2x1, 10x2 when RB_AllocType=StartRB + NumRBs.

Control Channel Parameters Details:

- PDCCH_SymsPerSF: number of OFDM symbols of PDCCH for each subframe. Its value can be set as 0, 1, 2, 3 and 4. Note that value 4 for small bandwidth is supported in this release. For more information, refer to Table 6.7-1 of 36211-860. This is an *Array Parameter* (3gpplte). The allowable sizes are 1x1, 10x1. If the number of PDCCH symbols of PDCCH for one subframe is set to 0, there is no PDCCH (no DCI), PHICH and PCFICH in this subframe. And so those elements of control channel parameters assigned to this subframe are inactive. If the number of OFDM symbols of PDCCH for all subframes are set to 0, all other parameters are inactive.
- PDCCH_UE_AggreLevel and PDCCH_Common_AggreLevel: indicate the aggregation level for the UE-specific search space and common search space respectively. They are *Array Parameter* (3gpplte). The allowable sizes of these 2 parameters are 1 or 10x1 (each element for one subframe). The elements can be set to 1, 2, 4 or 8 for PDCCH_UE_AggreLevel, and 4 or 8 for PDCCH_Common_AggreLevel.
- PDCCH_UE_DCI_Formats and PDCCH_Common_DCI_Formats: indicate the active PDCCH of the candidates as well as the corresponding DCI formats they containing for UE-specific search space and common search space. Each active PDCCH contains one DCI. They are *Array Parameter* (3gpplte). The allowable sizes of these 2 parameters are Mmax or 10xMmax (each Mmax elements for one subframe), where Mmax is 6 for UE-specific and 4 for Common. For each subframe, if the aggregation level is set to L, the number of PDCCH candidates is $M^{(L)}$, and so the first $M^{(L)}$ elements of the Mmax elements are active. To support the E-UTRA Test Models defined in 36141-850, the allowable sizes of the parameter PDCCH_UE_DCI_Formats is extended to Mmax (all subframes have the same configuration), where Mmax can be 7, 8, 9 and 10.

  For example, PDCCH_UE_AggreLevel = 4, the number of PDCCH candidates is $M^{(L)}$ = 2, so, the first 2 elements of are active. -1 means no DCI (PDCCH) in corresponding candidate. Refer to Table 9.1.1-1 in 9.1.1 of 36213-860. The DCIs of one subframe are composed of PDCCH_UE_DCI_Formats and PDCCH_Common_DCI_Formats.
  For example,

PDCCH_UE_AggreLevel=2	PDCCH_UE_DCI_Formats=[2, -1, -1, 0, -1, -1]
PDCCH_Common_AggreLevel=8	PDCCH_Common_DCI_Formats=[-1, -1, -1, -1]
Actual DCIs	[DCI format 1A, DCI format 0] They are transmitted in UE-specific search space PDCCHs with Aggregation level 2. These 2 PDCCHs are candidate 0 and candidate 3 of the 6 candidates

Note that in this source, for UE-Specific search space, the UE1_n_RNTI parameter is used for the variable n_{RNTI} (defined in 9.1.1 of [2])for all UE-specific PDCCH candidates.

- PHICH_Duration: type of PHICH duration which only affects subframes containing the maximum PDCCH Symbols case. The type is enum and it can be set to Normal Duration and Extended Duration.
- PHICH_Ng: number of PHICH group. The type is enum and it can be set to 1/6, 1/2, 1 and 2.
- BCH_BlockSize: transport block size for BCH.
- HI: HI (HARQ indicator) transmitted on PHICH for each subframe, selected from 0, 1 and -1, where -1 means no HI allocation. The allowable sizes are 1x1, 10x1, Nx1, 10xN, where N is number of PHICHs per PHICH group. N could be 8 in Normal cyclic prefix and be 4 in Extended cyclic prefix. See *Array Parameter* (3gpplte).

Power Parameters Details:

- RS_EPRE: transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz
- PCFICH_Rb: ratio of total PCFICH EPRE transmitted on all antenna ports to RS in dB in symbols with RS.
- PHICH_Ra: ratio of total PHICH EPRE transmitted on all antenna ports to RS in dB in symbols with RS. Note that the parameter defines the EPRE per each PHICH channel, and the EPRE per each PHCIH group is the sum of all PHICHs transmitted on the same PHICH group.
- PHICH_Rb: ratio of total PHICH EPRE transmitted on all antenna ports to RS in dB in symbols without RS. Note that the parameter defines the EPRE per each PHICH channel, and the EPRE per each PHCIH group is the sum of all PHICHs transmitted on the same PHICH group.
- PBCH_Ra: ratio of total PBCH EPRE transmitted on all antenna ports to RS in dB in symbols with RS
- PBCH_Rb: ratio of total PBCH EPRE transmitted on all antenna ports to RS in dB in symbols without RS
- PDCCH_Ra: ratio of total PDCCH EPRE transmitted on all antenna ports to RS in dB in symbols with RS
- PDCCH_Rb: ratio of total PDCCH EPRE transmitted on all antenna ports to RS in dB in symbols without RS
- PDSCH_PowerRatio: define the meaning of the UEs_Pa parameter below. When PDSCH_PowerRatio = 'p_B/p_A = 1', the value in UEs_Pa for each UE is the ratio (in dB) of PDSCH EPRE to cell-specific RS EPRE(denoted by ρ_A or ρ_B, morever ρ_A=ρ_B), as defined in Table 5.2-2 of [2]; Otherwise, PDSCH_PowerRatio is set to select P_B which is defined in Table 5.2-1 of [2]. In this setting, the value in UEs_Pa for each UE is P_A (in dB) which is a UE specific parameter provided by higher layers, as defined in 5.2 of [2]. Based on P_B and P_A, the final ρ_A and ρ_B can be calculated. In general, PDSCH_PowerRatio = "p_B/p_A = 1" does not follow the specification, but it is easy to set and easy to get the PDSCH EPRE to cell-specific RS EPRE.
- UEs_Pa: defines the power ratio (in dB) for each UE which could be ρ_A/ρ_B or P_A based on the setting of PDSCH_PowerRatio. This is an *Array Parameter* (3gpplte). The allowable size is 6x1.
- PSS_Ra: ratio of total PSS EPRE transmitted on all antenna ports to RS in dB in symbols without RS
- SSS_Ra: ratio of total SS EPRE transmitted on all antenna ports to RS in dB in symbols without RS

Spectrum Shaping Parameters Details:

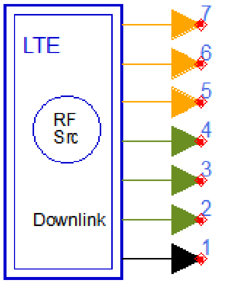
- SpectrumShapingType: Spectrum-shaping type. It can be set to TimeWindowing and FIRFilter. The symbol windowing function is for spectrum shaping if TimeWindowing is set. The FIR filter is used for spectrum shaping if FIRFilter is set.

- WindowType: Type of time transition windowing between two consecutive symbols, It is active only when SpectrumShapingType =TimeWindowing. Two kind of symbol windowing function(Tuckey window and Raised cosine window) are provided.
- CyclicInterval: The overlapped cyclic interval between two adjacent OFDM symbols in unit of chips (without oversampleing).
- CI_StartPos: the start position of cyclic interval (without oversampling), compared to the start position of CP. This value is negative which means ahead of CP. For more information, refer to[].
- FIR_Taps: Number of FIR filter taps. It is active only when SpectrumShapingType = FIRFilter.
- FIR_withInterp: Spectrum-shaping FIR filter is with interpolation operation or not? It is active only when SpectrumShapingType = FIRFilter. If YES, FIR filter completes interpolation function as well as filter function. If NO, FIR filter just completes filter function.
- FIR_FilterType: spectrum-shaping FIR filter type, valid when SpectrumShapingType = FIRFilter
- RRC_Alpha: roll-off factor for root raised-cosine filter.
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = Simple, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_Src_RF (Downlink Signal Source with RF Modulator)



Description: Downlink signal source with RF modulator
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE downlink signals	Category		string	
ROut	source resistance	50 Ohm	Ohm	int	(0,∞)
RTemp	temperature	- 273.15	Celsius	real	[-273.15,∞]
FCarrier	carrier frequency	2500 MHz	Hz	real	(0,∞)
MirrorSpectrum	indication of mirror spectrum about carrier: NO, YES	NO		enum	
GainImbalance	gain imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
PhaseImbalance	phase imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
I_OriginOffset	I origin offset in percent with repect to output rms voltage	0.0		real	(-∞,∞)
Q_OriginOffset	q origin offset in percent with repect to output rms voltage	0.0		real	(-∞,∞)
IQ_Rotation	IQ rotation in degrees	0.0		real	(-∞,∞)
SystemParameters	system parameters for LTE downlink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
RB_MappingType	the mapping type of VRBs to PRBs: Localized	Localized		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
UE1_Parameters	parameters for coded UE1	Category		string	
UE1_DataPattern	the data transmitted in UE1 transport block: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	

UE1_Config	the configuration mode of input data for UE 1.: MCS index, Transport block size, Code rate	Transport block size		enum	
UE1_Payload	the input payload for UE 1, the meaning of the input is defined in UE1_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
UE1_MappingType	the modulation orders for UE 1 in each subframe, valid when UE1_Payload is not set to MCS index. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
UE1_RV_Idx	Redundancy Version Index for UE 1	0		int	[0,3]
UE1_n_RNTI	Radio network temporary identifier for UE 1	0		int	[0,2e16-1]
UE1_Category	defines UE capability, used to get the total number of soft channel bits for rate-matching in downlink: Category1, Category2, Category3, Category4, Category5	Category1		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
UE1_RB_Alloc	the RB allocation for UE 1, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
OtherUEs_Parameters	parameters for other uncoded Ues	Category		string	
OtherUEs_MappingType	the modulation orders for other UEs except UE 1 in all subframes. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0}		int array	
UE2_RB_Alloc	the RB allocation for UE 2, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE3_RB_Alloc	the RB allocation for UE 3, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE4_RB_Alloc	the RB allocation for UE 4, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE5_RB_Alloc	the RB allocation for UE 5, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
UE6_RB_Alloc	the RB allocation for UE 6, in the formats of [start RB, number of RBs] or [[SF0 start RB, SF0 number of RBs], . . ., [SF9 start RB, SF9 number of RBs]]	{0, 0}		int array	
ControlChannelParameters	parameters for control channels	Category		string	
PDCCH_SymsPerSF	number of OFDM symbols of PDCCH for each subframe	{2, 2, 2, 2, 2, 2, 2, 2, 2, 2}		int array	[0,4]
PDCCH_UE_AggreLevel	the aggregation levels of UE-specific PDCCH search space for every subframe. The allowable levels are 1, 2, 4 and 8.	{1}		int array	[1, 8]
PDCCH_UE_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{0, -1, -1, -1, -1, -1}		int array	
PDCCH_Common_AggreLevel	the aggregation levels of Common PDCCH search space for every subframe. The allowable levels are 4 and 8.	{4}		int array	[4, 8]
PDCCH_Common_DCI_Formats	the DCI Formats of the PDCCH candidates for every subframe (-1 means no DCI in corresponding candidate).	{-1, -1, -1, -1}		int array	
UE_n_RNTI	Radio network temporary identifier for UE	{1, 1, 1, 1, 1, 1, 1, 1, 1, 1}		int array	[0,2e16-1]
PHICH_Duration	type of PHICH duration: Normal_Duration, Extended_Duration	Normal_Duration		enum	

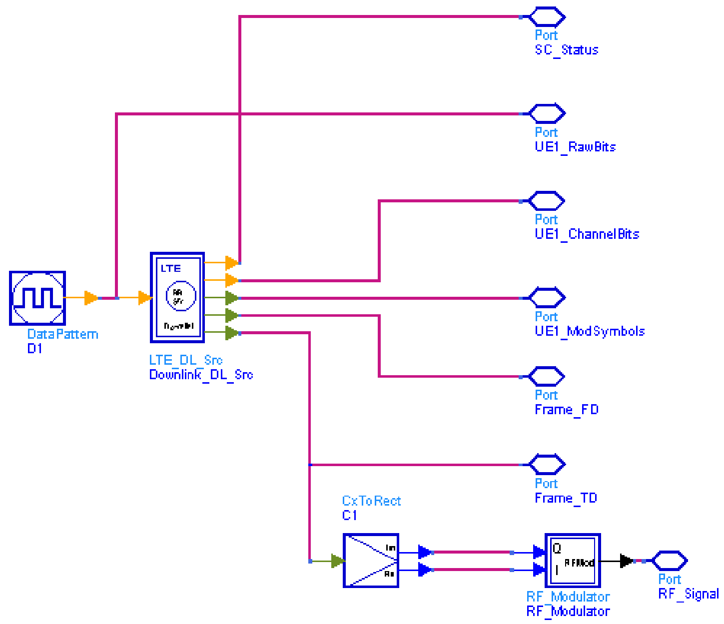
PHICH_Ng	PHICH Ng value: Ng 1/6, Ng 1/2, Ng 1, Ng 2	Ng 1/6		enum	
BCH_BlockSize	transport block size for BCH	24		int	[1,∞)
HI	physical hybrid-ARQ ACK/NAK indicators	{1, -1, -1, -1, -1, -1, -1, -1}		int array	
PowerParameters	power-related parameters	Category		string	
RS_EPRE	transmit energy per resource element (RE) for cell specific RS for each antenna port, in unit of dBm/15kHz	-25		real	(-∞,∞)
PCFICH_Rb	PCFICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Ra	PHICH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PHICH_Rb	PHICH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PBCH_Ra	PBCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PBCH_Rb	PBCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDCCH_Ra	PDCCH-to-RS EPRE ratio in dB in symbols with RS	0		real	(-∞,∞)
PDCCH_Rb	PDCCH-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
PDSCH_PowerRatio	PDSCH Cell Specific Ratio: p_B_p_A_1, P_B_0, P_B_1, P_B_2, P_B_3	p_B_p_A_1		enum	
UEs_Pa	PDSCH-to-RS EPRE ratio in dB in symbols without RS for each UE	{0.0, 0.0, 0.0, 0.0, 0.0, 0.0}		real array	(-∞,∞)
PSS_Ra	PSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SSS_Ra	SSS-to-RS EPRE ratio in dB in symbols without RS	0		real	(-∞,∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing		enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6		int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19		int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO		enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal Lowpass	RRC		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22		real	[0,1.0]
DisplayMsg	the messages displayed in Status/Summary window: None, Simple, Full	Simple		enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Signal	output of RF signal	timed
2	Frame_TD	output of one frame signal in time domain	complex
3	Frame_FD	output of one frame in frequency domain	complex
4	UE1_ModSymbols	UE 1 modulation symbols	complex
5	UE1_ChannelBits	UE 1 channel bits before modulation	int
6	UE1_RawBits	UE 1 raw bits from MAC layer	int
7	SC_Status	downlink subcarrier (resource element) status in one frame	int

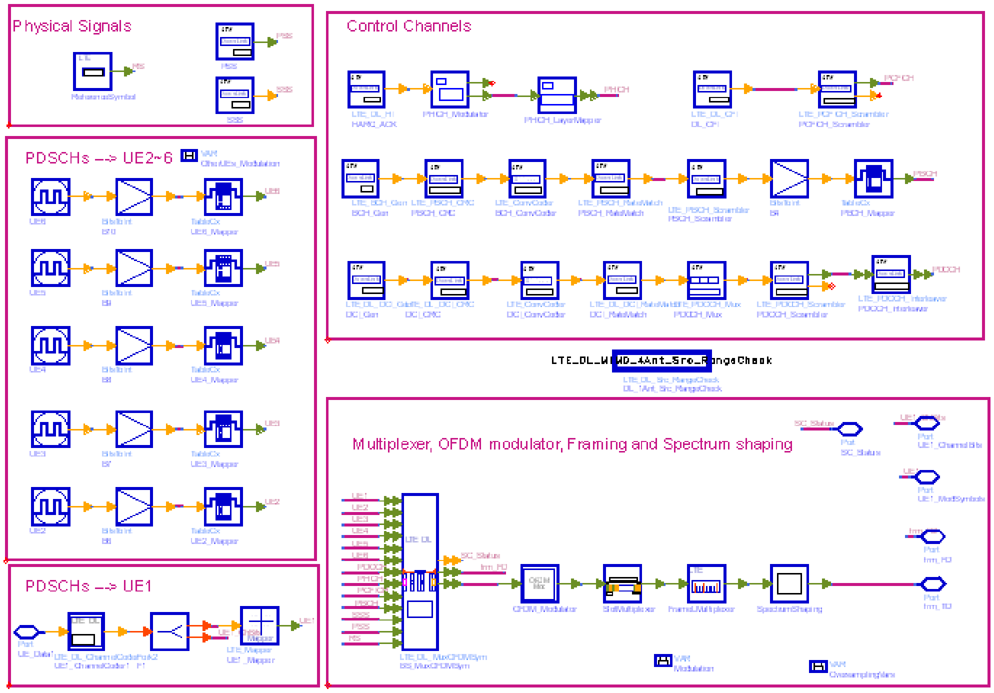
Notes/Equations

1. This subnetwork generates 3GPP FDD LTE (FS1) and TDD LTE (FS2) coded downlink RF signal (up to six users). The subnetwork includes LTE_DL_Src, which generates baseband 3GPP both FDD and TDD LTE coded downlink source, and the RF_Modulator. The schematic for this subnetwork is shown in the following figure.



LTE_DL_Src_RF Schematic

2. LTE_DL_Src generates 3GPP FDD LTE (FS1) and TDD LTE (FS2) coded downlink 1 antenna baseband signal (up to six users). The schematic for this subnetwork is shown in the following figure. The detailed information for LTE_DL_Src is in *Downlink Baseband Source* (3gpplte).



LTE_DL_Src Schematic

3. The outputs at port RF_Signal are the RF signals.
4. The outputs at port Frame_TD are the time domain baseband signals.
5. The outputs at port Frame_FD are the frequency domain data without oversampling.
6. The outputs at port UE1_ModSymbols are the complex-valued modulation symbols for UE 1 (PDSCH 1).
7. The outputs at port UE1_ChannelBits are the channel bits for UE 1 (PDSCH 1) which are the output of scrambler. These outputs are the reference bits for uncoded BER and PER measurement. For more information, refer to *Channel Bits Calculation* (3gpplte).
8. The outputs at port UE1_RawBits are the transport block bits for UE 1 (PDSCH 1). These outputs are the reference bits for coded BER and PER measurement.
9. The output at port SC_Status is the status for each subcarrier (resource element). The first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol. When the last subcarrier (resource element) in the first OFDM symbol is output, then next the first subcarrier (resource element) in the second OFDM symbol is output, and so on. The 8 LSB bits of each status value represent the channel type allocated on each subcarrier (resource element). The meaning of the 8 LSB bits is shown as follows:

Value	ChannelType
0	EMPTY
1	RS
2	PSS
3	SSS
4	PBCH
5	PCFICH
6	PHICH
7	PDCCH
8	PDSCH 1 (UE 1)
9	PDSCH 2 (UE 2)
10	PDSCH 3 (UE 3)
11	PDSCH 4 (UE 4)
12	PDSCH 5 (UE 5)
13	PDSCH 6 (UE 6)

The 24 MSB bits of each status value represent the index for the data allocated on each subcarrier (resource element). For each channel indicated in the table above, the data indexing is performed subframe by subframe independently. For example, for PDSCH 1 (UE 1), the first modulation symbol within each subframe is indexed as

0; the second modulation symbol is indexed as 1, and so on. When there is no data allocated on the subcarrier, the 24 MSB bits of each status is set to 0xFFFFFF.

RF Parameter Details:

- ROut is the RF output source resistance.
- RTemp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- FCarrier is the RF output signal frequency.
- Power is used to set the modulator output RF power. This is true for an ideal transmitted signal (no impairments added) or when small impairments are added. If large impairments are added to the signal (using GainImbalance, I_OriginOffset, and Q_OriginOffset parameters) the output RF power may be different from the value of the Power parameter.
- MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage. Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set this parameter to YES.
- GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
  The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
  $$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\Phi\pi}{180}\right)\right)$$
  where A is a scaling factor based on the Power and ROut parameters specified by the user, VI(t) is the in-phase RF envelope, VQ(t) is the quadrature phase RF envelope, g is the gain imbalance:
  $$g = 10^{\frac{GainImbalance}{20}}$$
  and, ϕ (in degrees) is the phase imbalance.
  Next, the signal VRF(t) is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage.

System Parameters Details:

- For the same parameters as LTE_DL_Src, refer to *DL System Parameters* (3gpplte).

UE1 Parameters Details:

- Refer to *DL UE1 Parameters* (3gpplte).

OtherUEs Parameters Details:

- Refer to *DL OtherUEs Parameters* (3gpplte).

Control Channel Parameters Details:

- Refer to *DL Control Channel Parameters* (3gpplte).

Power Parameters

- Refer to *DL Power Parameters* (3gpplte).

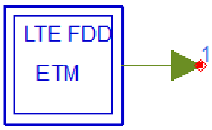
Spectrum Shaping Parameters Details:

- Refer to *DL Spectrum Shaping Parameters* (3gpplte).
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = None, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_DL_TestModel_FDD



Description: 3GPP LTE downlink ETM signal source
Library: LTE, Source

Parameters

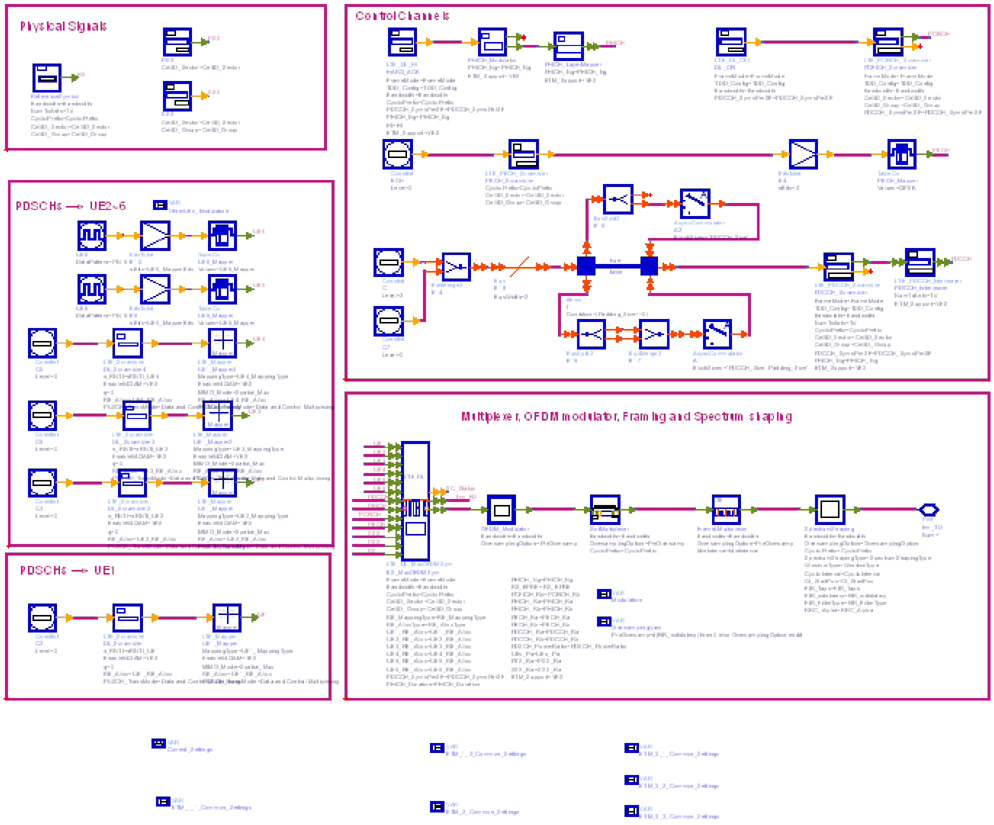
Name	Description	Default	Type	Range
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
TestModel	E-UTRA test model type: ETM11, ETM12, ETM2, ETM31, ETM32, ETM33	ETM11	enum	
RS_EPRE	transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz	-25	real	(-∞,∞)
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing	enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised_cosine	Tukey	enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6	int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3	int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19	int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO	enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal_Lowpass	RRC	enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22	real	[0,1.0]
DisplayMsg	control LTE system information displayed in Simulation Log window: None, Simple, Full	Simple	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	frm_TD	output of one frame signal in time domain	complex

Notes/Equations

1. This subnetwork generates 3GPP FDD LTE E-UTRA FDD Test Models according to clause 6.1.1 and 6.1.2 of 3GPP TS 36.141 V8.6.0. The schematic for this subnetwork is shown in the following figure.



LTE_DL_TestModel_FDD Schematic

2. All these E-UTRA Test Models defined in clause 6.1.1 of 3GPP TS 36.141 V8.6.0 are supported and the data content of physical channels and signals are filled according to clause 6.1.2 of 3GPP TS 36.141 V8.6.0. User can set parameters TestModel and Bandwidth to get specific test model.
3. Parameters details:
    - TestModel: used to set the test model type i.e. E-TM1.1, E-TM1.2, E-TM2, E-TM3.1, E-TM3.2 and E-TM3.3.
    - Bandwidth: bandwidth of LTE E-UTRA test model, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
    - OversamplingOption: Over-sampling ratio option. Oversampling ratio 1, ratio 2, ratio 4 and ratio 8 are supported in this downlink source.
    - RS_EPRE: transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz.

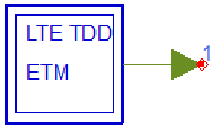
    Spectrum Shaping Parameters Details:
    - SpectrumShapingType: Spectrum-shaping type. It can be set to TimeWindowing and FIRFilter. The symbol windowing function is for spectrum shaping if TimeWindowing is set. The FIR filter is used for spectrum shaping if FIRFilter is set.
    - WindowType: Type of time transition windowing between two consecutive symbols, It is active only when SpectrumShapingType =TimeWindowing. Two kind of symbol windowing function(Tuckey window and Raised cosine window) are provided.
    - CyclicInterval: The overlapped cyclic interval between two adjacent OFDM symbols in unit of chips (without oversampleing).
    - CI_StartPos: the start position of cyclic interval (without oversampling), compared to the start position of CP. This value is negative which means ahead of CP. For more information, refer to[].
    - FIR_Taps: Number of FIR filter taps. It is active only when SpectrumShapingType = FIRFilter.
    - FIR_withInterp: Spectrum-shaping FIR filter is with interpolation operation or not? It is active only when SpectrumShapingType = FIRFilter. If YES, FIR filter completes interpolation function as well as filter function. If NO, FIR filter just completes filter function.
    - FIR_FilterType: spectrum-shaping FIR filter type, valid when SpectrumShapingType = FIRFilter

- RRC_Alpha: roll-off factor for root raised-cosine filter.
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = Simple, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.141 V8.6.0, “Base Station (BS) conformance testing”, March 2010.
2. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
3. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
4. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA)", V7.0.0, June 2006.

LTE_DL_TestModel_TDD



Description: 3GPP LTE downlink ETM signal source
Library: LTE, Source

Parameters

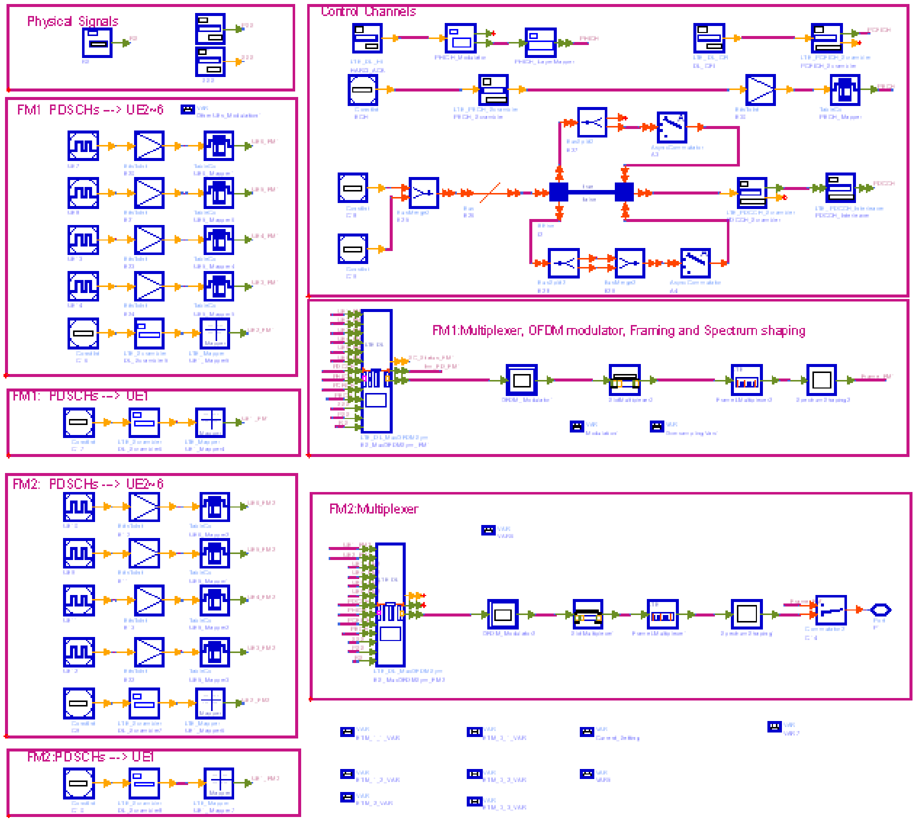
Name	Description	Default	Type	Range
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
TestModel	E-UTRA test model type: ETM11, ETM12, ETM2, ETM31, ETM32, ETM33	ETM11	enum	
RS_EPRE	transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz	-25	real	(-∞,∞)
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum	
SpectrumShapingType	spectrum shaping method: TimeWindowing, FIRFilter	TimeWindowing	enum	
WindowType	type of time transition windowing between two consecutive symbols, valid when SpectrumShapingType=TimeWindowing: Tukey, Raised_cosine	Tukey	enum	
CyclicInterval	the overlapped cyclic interval between two adjacent symbols in unit of chips (without oversampling), valid when SpectrumShapingType=TimeWindowing	6	int	[0,96]
CI_StartPos	the start position of cyclic interval (without oversampling), compared to the start position of CP (negative means ahead of CP)	-3	int	[-96,0]
FIR_Taps	number of FIR filter taps, valid when SpectrumShapingType=FIRFilter	19	int	[1,1024]
FIR_withInterp	whether spectrum-shaping FIR filter with interpolation operation or not, valid when SpectrumShapingType=FIRFilter: NO, YES	NO	enum	
FIR_FilterType	spectrum-shaping FIR filter type, valid when SpectrumShapingType=FIRFilter: RRC, Ideal_Lowpass	RRC	enum	
RRC_Alpha	roll-off factor for root raised-cosine filter, valid when SpectrumShapingType=FIRFilter	.22	real	[0,1.0]
DisplayMsg	control LTE system information displayed in Simulation Log window: None, Simple, Full	Simple	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	frm_TD	output of one frame signal in time domain	complex

Notes/Equations

1. This subnetwork generates 3GPP FDD LTE E-UTRA TDD Test Models according to clause 6.1.1 and 6.1.2 of 3GPP TS 36.141 V8.6.0. The schematic for this subnetwork is shown in the following figure.



LTE_DL_TestModel_TDD Schematic

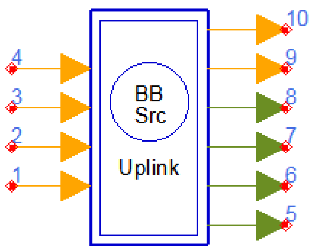
2. All these E-UTRA Test Models defined in clause 6.1.1 of 3GPP TS 36.141 V8.6.0 are supported and the data content of physical channels and signals are filled according to clause 6.1.2 of 3GPP TS 36.141 V8.6.0. User can set parameters TestModel and Bandwidth to get specific test model. For E-UTRA TDD, test models are derived based on the uplink/downlink configuration 3 and special subframe configuration 8 defined in TS36.211, i.e. as showing in the table 6.1.1-1 of 3GPP TS 36.141 V8.6.0. Number of frames for the test models is 2
3. Parameters details:
    - TestModel: used to set the test model type i.e. E-TM1.1, E-TM1.2, E-TM2, E-TM3.1, E-TM3.2 and E-TM3.3.
    - Bandwidth: bandwidth of LTE E-UTRA test model, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
    - OversamplingOption: Over-sampling ratio option. Oversampling ratio 1, ratio 2, ratio 4 and ratio 8 are supported in this downlink source.
    - RS_EPRE: transmit energy per resource element (RE) for transmitted cell specific RS for each antenna port, in unit of dBm/15kHz.
      Spectrum Shaping Parameters Details:
    - SpectrumShapingType: Spectrum-shaping type. It can be set to TimeWindowing and FIRFilter. The symbol windowing function is for spectrum shaping if TimeWindowing is set. The FIR filter is used for spectrum shaping if FIRFilter is set.
    - WindowType: Type of time transition windowing between two consecutive symbols, It is active only when SpectrumShapingType =TimeWindowing. Two kind of symbol windowing function(Tuckey window and Raised cosine window) are provided.
    - CyclicInterval: The overlapped cyclic interval between two adjacent OFDM symbols in unit of chips (without oversampleing).
    - CI_StartPos: the start position of cyclic interval (without oversampling), compared to the start position of CP. This value is negative which means ahead of CP. For more information, refer to[].
    - FIR_Taps: Number of FIR filter taps. It is active only when SpectrumShapingType = FIRFilter.
    - FIR_withInterp: Spectrum-shaping FIR filter is with interpolation operation or not? It is active only when SpectrumShapingType = FIRFilter. If YES, FIR filter completes interpolation function as well as filter function. If NO, FIR filter just

completes filter function.
- FIR_FilterType: spectrum-shaping FIR filter type, valid when SpectrumShapingType = FIRFilter
- RRC_Alpha: roll-off factor for root raised-cosine filter.
- DisplayMsg: control the messages displayed in Status/Summary window. When DisplayMsg = None, no message is shown; When DisplayMsg = Simple, the System Configurations and UE-specific Configurations are output; When DisplayMsg = Full, the System Configurations, UE-specific Configurations and Power are output.

References

1. 3GPP TS 36.141 V8.6.0, “Base Station (BS) conformance testing”, March 2010.
2. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
3. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
4. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA)", V7.0.0, June 2006.

LTE_UL_Src (Uplink Baseband Signal Source)



Description: Uplink baseband signal source
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
SystemParameters	system parameters for LTE uplink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0, 2]
CellID_Group	the index of cell identity group	0		int	[0, 167]
n_RNTI	radio network temporary identifier	0		int	[0, 65535]
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0, 1.0e-3]
FrameNum	frame number	0		int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO		enum	
DL_CyclicPrefix	type of cyclic prefix in downlink: DL_Normal, DL_Extended	DL_Normal		enum	
Printf_RB_SF_Alloc	print the RB_SF allocation to file: NO, YES	NO		enum	
PUSCH_Parameters	PUSCH parameters for LTE uplink signals	Category		string	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
Payload_Config	the configuration mode of input data of PUSCH.: MCS_index, Transport_block_size, Code_rate	Transport_block_size		enum	
Payload	the input payload for PUSCH, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	

Enable64QAM	indicates whether 64QAM is allowed in uplink: NO, YES	YES		enum	
MappingType	the modulation orders for the PUSCH in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
RV_Idx	Redundancy Version Index	0		int	[0, 3]
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	NO		enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO		enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame		enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0		int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1		int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz		enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}		int array	
GroupHop_Enable	whether enable group hopping for DMRS on PUCCH and PUSCH or not: NO, YES	NO		enum	
SeqHop_Enable	whether enable sequence hopping for DMRS on PUSCH or not: NO, YES	NO		enum	
PUSCH_Delta_ss	used in determining the sequence-shift pattern for PUSCH	0		int	[0, 29]
PUSCH_n_DMRS1	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUSCH_n_DMRS2	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUCCH_Parameters	PUCCH parameters for LTE uplink signals	Category		string	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1		enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2		int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1		int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11		int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11		int	[0, 12*PUCCH_NB2-1]
PRACH_Parameters	PRACH parameters for LTE uplink signals	Category		string	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO		enum	

PRACH_Config	PRACH configuration index	0		int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{0}		int array	[0, 9]
PRACH_PrmbleIndex	preamble indexes, used to select preamble sequences from 64 preambles available in this cell	{0}		int array	[0, 63]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0		int	[0, 94]
PRACH_LogicalIndex	logical index of root ZC sequence	0		int	[0, 837]
PRACH_Ncs	cyclic shifts of ZC sequence	0		int	[0, 15]
PRACH_HS_flag	high speed flag: NO, YES	NO		enum	
SRS_Parameters	SRS parameters for LTE uplink signals	Category		string	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO		enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7		int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0		int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO		enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0		int	[0, 3]
SRS_HoppingBandwidth	the SRS hopping bandwidth	3		int	[0, 3]
SRS_FreqPosition	the SRS frequency domain position	0		int	[0, 23]
SRS_ConfigIndex	the UE-specific SRS configuration	0		int	[0, 1023]
SRS_TransmissionComb	transmission comb	0		int	[0, 1]
SRS_CyclicShift	used in computing the cyclic shift of SRS	0		int	[0, 7]
PowerParameters	power-related parameters	Category		string	
PUSCH_PwrOffset	the power offset in dB for PUSCH	0		real	(-∞, +∞)
PUSCH_RS_PwrOffset	the power offset in dB for PUSCH RS	0		real	(-∞, +∞)
PUCCH_PwrOffset	the power offset in dB for PUCCH	0		real	(-∞, +∞)
PUCCH_RS_PwrOffset	the power offset in dB for PUCCH RS	0		real	(-∞, +∞)
PRACH_PwrOffset	the power offset in dB for PRACH	0		real	(-∞, +∞)
SRS_PwrOffset	the power offset in dB for SRS	0		real	(-∞, +∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum-shaping type: TimeWindowing, FIRFilter	FIRFilter		enum	
WindowType	type of time transition windowing between two consecutive symbols: Tukey, Raised_cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent SC-FDMA symbols in unit of chips (without oversampleing)	6		int	[0, 96]
CI_StartPos	the start position of cyclic interval(take the start position of CP as origin), indicates the number of samples(without oversampling) of ECP added before CP	-3		int	[-96, 0]
FIR_Taps	number of FIR filter taps	19		int	[1, 1000]
FIR_withInterp	spectrum-shaping FIR filter	NO		enum	

	with interpolation operation: NO, YES				
FIR_FilterType	spectrum-shaping FIR filter type: Square-Root Raised Cosine, Ideal Lowpass	Square-Root Raised Cosine		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter	0.22		real	[0, 1.0]
ControlInfoParameters	control information parameters for LTE uplink signals	Category		string	
RI_NumInfoBits	RI information bits size	{0}		int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}		int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}		int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}		int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0}		int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0}		int array	[0,14]
ACK_NACK_FeedbackMode	ACK/NACK feedback modes for TDD: ACK_NACK_multiplexing, ACK_NACK_bundling	ACK_NACK_multiplexing		enum	
Nbundled	Nbundled for TDD ACK/NACK bundling	{1}		int array	[1,20]

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	input of Data signal	int
2	RI_In	rank indication in	int
3	HARQACK_In	HARQ and ACK in	int
4	CQI_In	channel quality information in	int

Pin Outputs

Pin	Name	Description	Signal Type
5	Frame	output of frame signal	complex
6	FRM_FD	output of frame signal in frequency domain	complex
7	Data_FD	output of PUSCH signal in frequency domain	complex
8	PUSCH_ModSymbols	PUSCH modulation symbols	complex
9	PUSCH_ChannelBits	PUSCH channel bits before modulation	int
10	SC_Status	uplink subcarrier (resource element) status in one frame	int

Parameter Details

System Parameters Details:

- FrameMode: frame mode of LTE, the type is enum and it can be selected as FDD and TDD, supporting frame structure type 1 and frame structure type 2 respectively.
- TDD_Config: uplink-downlink configuration for TDD, the type is enum and it can be selected as Config 0, Config 1, Config 2, Config 3, Config 4, Config 5 and Config 6. These configurations are listed in Table 4.2-2 [1].
- SpecialSF_Config: special subframe configuration when FrameMode is TDD. The configurations of special subframe (lengths of DwPTS/GP/UpPTS) are listed in Table 4.2-1 [1].
- Bandwidth: bandwidth of LTE, the type is enum and it can be selected as BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz and BW 20 MHz.
- OversamplingOption: Over-sampling ratio option. Oversampling ratio 1, ratio 2, ratio 4 and ratio 8 are supported in this uplink source.
- CyclicPrefix: type of cyclic prefix. It can be selected as Normal and Extended, corresponding to seven and six SC-FDMA symbols per slot, respectively. It should be noted that, in case of the normal cyclic prefix, the cyclic-prefix length for the first SC-FDMA symbol of a slot is somewhat larger, compared to the remaining SC-FDMA symbols.
- CellID_Sector: the index of cell identity within the physical-layer cell-identity group, it should be in range [0,2].

- CellID_Group: the index of cell identity group, it should be in range [0,167].
- n_RNTI: radio network temporary identifier.
- HalfCarrierShift_Enable: whether enable half carrier shift or not, the type is query (bool). This parameter should be set to **YES** according to the LTE specifications.
- FrameNum: the system frame number of the first transmitted frame.
- FrameIncreased: controls whether the frame number increased or not during simulation. FrameNum and FrameIncreased would affect the frequency hopping of PUSCH in TDD mode as well as the transmission of PRACH and SRS which may vary from frames.
- DL_CyclicPrefix: cyclic prefix mode of downlink. It determines the length of UpPTS in TDD mode in company with CyclicPrefix and SpecialSF_Config. It mainly affects the transmission instances of SRS.
- Printf_RB_SF_Alloc: whether print the RB_SF allocation to file or not, the type is query (bool).

PUSCH Parameters Details:

- PUCCH_PUSCH: PUCCH and PUSCH selection. It can be selected as PUSCH, PUCCH and both, indicating the generated signal from this uplink source containing only PUSCH, only PUCCH and both PUSCH and PUCCH, respectively. It should be noted that when both PUSCH and PUCCH are transmitted, overlap in RB allocation for PUSCH and PUCCH is not allowed.
- Payload_Config: specify the meaning of Payload, it can be selected as MCS index, Transport block size or Code rate. For more information, refer to *Relation of Transport Block Sizes, Channel Bits and Code Rates* (3gpplte).
- Payload: the input payload for PUSCH, the meaning of the elements is defined by Payload_Config. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- MappingType: the modulation scheme for PUSCH, where 0 means QPSK; 1 means 16QAM; 2 means 64QAM. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1. Note that this parameter is invalid when Payload_Config = MCS index, in which the modulation scheme is determined by MCS index.
- RV_Idx: redundancy version index which is used in rate matching.* DFTSwap_Enable: whether enable DFT swap for PUSCH and PRACH or not. This parameter should be set to **NO** according to the LTE specifications.
- PUSCH_HoppingEnable: whether PUSCH frequency-hopping is enabled or not.
- PUSCH_HoppingMode: PUSCH frequency hopping mode, it can be selected as interSubFrame and intraAndInterSubFrame.
- PUSCH_HoppingOffset: the offset used for PUSCH frequency hopping.
- PUSCH_Hopping_Nsb: number of sub-bands for PUSCH frequency hopping.
- PUSCH_HoppingBits: information in hopping bits. It can be selected as 0 or 1 when Bandwidth < 10MHz, and can be selected as 00, 01, 10, or 11 when Bandwidth >= 10MHz. It determines the hopping type according to Table 8.4.2 [3].

System BW N_{RB}^{UL}	Number of Hopping bits	Information in hopping bits	$\tilde{n}_{PRB}(i)$
6 – 49	1	0	$\left(\left\lfloor N_{RB}^{PUSCH}/2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$,
		1	Type 2 PUSCH Hopping
50 – 110	2	00	$\left(\left\lfloor N_{RB}^{PUSCH}/4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		01	$\left(-\left\lfloor N_{RB}^{PUSCH}/4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		10	$\left(\left\lfloor N_{RB}^{PUSCH}/2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		11	Type 2 PUSCH Hopping

- PUSCH_TransMode: whether control and data are sent via PUSCH, it can be selected as Data and Control Multiplexing, Data Only and Control Only. If it is selected as Data and Control Multiplexing, control and data are sent via PUSCH based on subclause 5.2.2 [2]. Otherwise, only data or control is sent via PUSCH.

- RB_AllocType: RB allocation type, RB_AllocType = StartRB + NumRBs is recommended for uplink since the RB allocation for PUSCH is supposed to be contiguous. For more information, refer to *Resource Block Allocation* (3gpplte).
- RB_Alloc: RB allocation for PUSCH. The RB allocation type is defined in RB_AllocType. It is an *Array Parameter* (3gpplte). The supported sizes are 2 × 1, 10 × 1 when RB_AllocType = StartRB + NumRBs.
- GroupHop_Enable: Whether enable group hopping for PUSCH and PUCCH or not.
- SeqHop_Enable: Whether enable sequence hopping for PUSCH and PUCCH or not.

- PUSCH_Delta_ss: Δ_{ss} {0,1,...,29}, which is configured by higher layers. For PUSCH, the sequence-shift pattern $f_{ss}^{PUSCH}(n_s)$ is given by $f_{ss}^{PUSCH}(n_s) = (f_{ss}^{PUCCH}(n_s) + \Delta_{ss}$) mod 30.
- PUSCH_n_DMRS1: $n^{(1)}_{DMRS}$ is a broadcasted value. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- PUSCH_n_DMRS2: $n^{(2)}_{DMRS}$ is included in the uplink scheduling assignment, each element can be selected as 0,2,3,4,6,8,9 and 10. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.

PUCCH Parameters Details:

- PUCCH_Format: PUCCH format, it can be selected as Format 1, Format 1a, Format 1b, Shortened 1, Shortened 1a, Shortened 1b, Format 2, Format 2a and Format 2b. The modulation schemes for the different PUCCH formats are given by the following table.

PUCCH format	Modulation scheme	Number of bits per subframe, M_{bits}
1	N/A	N/A
1a	BPSK	1
1b	QPSK	2
2	QPSK	2
2a	QPSK + BPSK	21
2b	QPSK + BPSK	22

- PUCCH_NumCQIBits: number of CQI bits transmitted on PUCCH format 2/2a/2b.
- PUCCH_NumHARQACKBits: number of HARQ-ACK bits transmitted on PUCCH format 2 in extended CP mode.
- PUCCH_Delta_shift: Δ_{shift}^{PUCCH} {1,2,3}, it is set by higher layers.
- PUCCH_SF_Alloc: indicates which subframes contain PUCCH, it would be ignored when PUCCH_PUSCH = PUSCH. It is an an *Array Parameter* (3gpplte). The supported size is N × 1, where N is in range [1,10].
- PUCCH_NRB2: $N_{RB}^{(2)}$ denotes the bandwidth in terms of resource blocks that are reserved exclusively for PUCCH formats 2/2a/2b transmission in each slot.
- PUCCH_n1: $n_{PUCCH}^{(1)}$ represents the resources in terms of resources blocks used for transmission of PUCCH format 1/1a/1b.
- PUCCH_n2: $n_{PUCCH}^{(2)}$ represents the resources in terms of resources blocks used for transmission of PUCCH format 2/2a/2b.
  For more information on PUCCH and DMRS for PUCCH, please refer to *LTE_UL_PUCCH* (3gpplte).

PRACH Parameters Details:

- PRACH_Enable: whether enable PRACH or not. If PRACH_Enable = NO, following parameters from PRACH_Config to PRACH_RBOffset will be ignored.
- PRACH_Config: PRACH configuration. The preamble formats and the subframes in which the random access preamble transmission is allowed are determined by PRACH_Config as listed in Table 5.7.1-2 and Table 5.7.1-3 [1] for FDD and TDD, respectively.
- PRACH_ResourceIndex: if FrameMode = FDD, PRACH_ ResourceIndex indicates the subframes in which the random access preamble transmission starts. For example, in FDD, suppose PRACH_Config is set to 25, PRACH_ ResourceIndex can be set as a subset of {1, 4, 7}. Suppose PRACH_ ResourceIndex = {1, 4}, two PRACH preamble sequences of format 1 would start to transmitted in subframe 1 and 4 respectively, as each preamble sequence of format 1 would last two subframes, they would be transmitted in subframe 1-2 and 4- 5 respectively. If FrameMode = TDD, PRACH_ ResourceIndex indicates the index of preamble mapping pattern in time and frequency, where mapping pattern refers to a quadruple of the format (f_{RA}, t_{RA}^0, t_{RA}^1 , t_{RA}^2) indicates the location of a specific random resource. The valid mapping patterns for each PRACH configuration under different UL/DL configuration are listed in Table 5.7.1-4 [1]. For example, in TDD Config 0, suppose PRACH_Config is set to 12, the valid preamble mapping patterns are (0,0,0,2), (0,0,1,2), (0,0,0,1) and

(0,0,1,1) as listed in Table 5.7.1-4[1]. These four patterns were numbered 0, 1, 2 and 3 respectively from top to bottom. If PRACH_ ResourceIndex is set to {0, 1}, two PRACH preamble sequences would be transmitted and mapped onto the time and frequency resources defined by (0,0,0,2) and (0,0,1,2). It should be noted that PRACH_ ResourceIndex is an *Array Parameter* (3gpplte), in FDD, PRACH_ ResourceIndex should be set as a subset of the subframes in which the random access preamble transmission is allowed, while in TDD, PRACH_ ResourceIndex should be set as a subset of {0, . . ., Number of valid mapping patterns for the current PRACH configuration and TDD configuration}.

- PRACH_PrmbleIndex: PRACH preamble index. There are 64 preambles available in each cell. Transmitted preamble sequences are selected from the preamble sequence set using the preamble indexes. PRACH_PrmbleIndex is an *Array Parameter* (3gpplte). It must consist of one element or of the same size as PRACH_ ResourceIndex. If it has only one element, preamble sequences of the same index would be transmitted, while the number of PRACH transmission in one frame is determined by PRACH_ ResourceIndex; otherwise, different preamble sequences would be selected from the set according to the indexes. Each element of PRACH_PrmbleIndex should be in range [0, 63]. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index PRACH_LogicalIndex. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found.
- PRACH_RBOffset: PRACH frequency offset, expressed as a physical resource block number and fulfilling $0 \le n_{\mathrm{PRABOffset}}^{\mathrm{RA}} \le N_{\mathrm{RB}}^{\mathrm{UL}} - 6$.
- PRACH_LogicalIndex: logical index of root ZC sequence, the type is int and it must be in range of [0,837]. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5[1] for preamble format 0-3 and 4, respectively.
- PRACH_Ncs: index of cyclic shifts of ZC sequence, the type is int and it must be in range of [0,15]. The value of N_{CS} is listed in Table 5.7.2-2 [1].

N_{CS} configuration	**N_{CS} value Unrestricted set**	**N_{CS} value Unrestricted set**
0	0	15
1	13	18
2	15	22
3	18	26
4	22	32
5	26	38
6	32	46
7	38	55
8	46	68
9	59	82
10	76	100
11	93	128
12	119	158
13	167	202
14	279	237
15	419	

- PRACH_HS_flag: whether in high speed mode or not. If Yes, N_{CS} value would be selected from restricted set; otherwise, it would be selected from unrestricted set. The calculation of C_{v} would also be different.

  For more information on the generation of PRACH, please refer to *LTE_RACH* (3gpplte).

SRS Parameters Details:

- SRS_Enable: whether enable sounding reference signal transmission or not. If SRS_Enable = No, following parameters from SRS_BW to SRS_SF_Config will be ignored.
- SRS_BandwidthConfig: the cell-specific SRS bandwidth configuration (C_{SRS}).
- SRS_SF_Config: SRS subframe configuration. Cell specific sounding reference signal

subframes are the subframes satisfying $\lfloor n_s/2 \rfloor \bmod T_{SFC} \in \Delta_{SFC}$. For TDD, sounding reference signal is transmitted only in configured UL subframes or UpPTS. The cell specific subframe configuration period T_{SFC} and the cell specific subframe offset Δ_{SFC} for the transmission of sounding reference signals are listed in Tables 5.5.3.3-1 and 5.5.3.3-2 [1], for FDD and TDD, respectively.
- SRS_MaxUpPts: whether enable the reconfiguration of maximum m~SRS,0~ or not.
- SRS_Bandwidth: the UE-specific SRS bandwidth (B_{SRS})..
- SRS_HoppingBandwidth: the SRS hopping bandwidth (b_{hop}).
- SRS_FreqPosition: the SRS frequency domain position (n_{RRC}).
- SRS_ConfigIndex: the UE-specific SRS configuration (I_{SRS}).
- SRS_TransmissionComb: transmission comb (k_{TC}).
- SRS_CyclicShift: used in computing the cyclic shift of SRS, n_{SRS} = 0, 1, 2, 3, 4, 5, 6, 7.
  For more information on the generation of SRS, please refer to *LTE_UL_CAZAC* (3gpplte).

Power parameters Details:

- PUSCH_PwrOffset: the power offset in dB for PUSCH.
- PUSCH_RS_PwrOffset: the power offset in dB for DMRS for PUSCH.
- PUCCH_PwrOffset: the power offset in dB for PUCCH.
- PUCCH_RS_PwrOffset: the power offset in dB for DMRS for PUCCH.
- PRACH_PwrOffset: the power offset in dB for PRACH.
- SRS_PwrOffset: the power offset in dB for SRS.

Spectrum Shaping Parameters Details:

- SpectrumShapingType: Spectrum-shaping type. It can be selected as TimeWindowing and FIRFilter. Tukey window and Raised Cosine window are provided for TimeWindowing, while Square-Root Raised Cosine filter and ideal lowpass filter are provided for FIRFilter.
- WindowType: type of the windowing between two consecutive symbols. It can be selected as Tuckey window and Raised cosine window, and it is active only when SpectrumShapingType = TimeWindowing.
- CyclicInterval: the overlapped cyclic interval between two adjacent OFDM symbols in unit of samples (without oversampling), it is active only when SpectrumShapingType = TimeWindowing..
- CI_StartPos: the start position of cyclic interval (without oversampling), compared to the start position of CP. This value is negative which means ahead of CP. It is active only when SpectrumShapingType = TimeWindowing.
- FIR_Taps: number of taps of FIR filter. It is active only when SpectrumShapingType = FIRFilter.
- FIR_withInterp: whether perform interpolation in Spectrum-shaping FIR filter or not. It is active only when SpectrumShapingType = FIRFilter. If YES, FIR filter implements interpolation function as well as filter function. If NO, FIR filter implements filter function only.
- FIR_FilterType: type of spectrum-shaping FIR filter. It can be selected as Square-Root Raised Cosine, Ideal Lowpass and EquiRipple. It is active only when SpectrumShapingType = FIRFilter. When SpectrumShapingType = FIRFilter and FIR_FilterType = EquiRipple, the FIR_withInterp should be set to NO, FIR_Taps is ignored.
  The EquiRipple FIR taps are defined by the EquiRippleFIR_Taps variable in the 'Equations' page of this subnetwork. The detailed information for the EquiRipple FIR is shown below which is dependent on the OversamplingOption parameter. Users can modify the EquiRippleFIR_Taps variable to set the desired FIR taps.

OversamplingOption	Tap order	Pass band	Stop band
0 (1×)	24	0.66	0.94
1 (2×)	48	0.33	0.47
2 (4×)	96	0.165	0.235
3 (8×)	192	0.0825	0.1175

- RRC_Alpha: roll-off factor of root raised-cosine filter, it is active only when

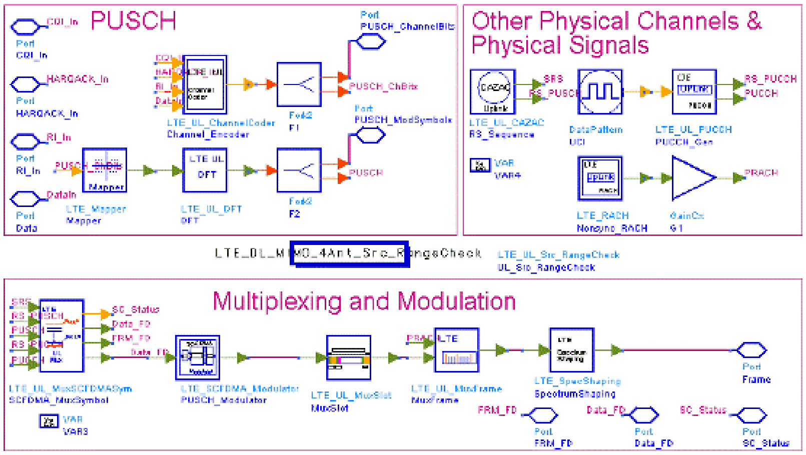
SpectrumShapingType = FIRFilter.
For more information on spectrum shaping, please refer to *LTE_SpecShaping* (3gpplte).

Control Information Parameters Details:

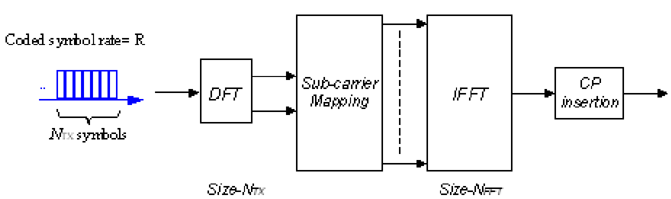
- RI_NumInfoBits: number of information bits of rank indication. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- RI_BetaOffsetIndex: index of RI beta offset. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- CQI_NumInfoBits: number of information bits of channel quality information. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- CQI_BetaOffsetIndex: index of CQI beta offset. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- HARQACK_NumInfoBits: number of information bits of HARQ-ACK. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- HARQACK_BetaOffsetIndex: index of HARQ-ACK beta offset. It is an *Array Parameter* (3gpplte). The supported sizes are 1 × 1 and 10 × 1.
- ACK_NACK_FeedbackMode: ACK/NACK feedback modes for TDD.
- Nbundled: Nbundled for TDD ACK/NACK bundling.
  For more information on channel coding of control information, please refer to *LTE_UL_ControlInfoEncoder* (3gpplte).

Notes/Equations

1. This subnetwork generates LTE uplink baseband signal for both frame structure type 1 and frame structure type 2. LTE uplink transmission is based on SC-FDMA.
2. Generally, one frame data are produced each firing.
   Each firing,
   - The number of tokens consumed at port DataIn is equal to the sum of transport block size for all subframes of one frame. When there is no transport block allocated, 1 token is consumed at this port. Refer to *Relation of Transport Block Sizes* (3gpplte) for how to calculate transport block size for each subframe.
   - The number of tokens consumed at port RI_In is equal to the number of RI information bits for each frame. When RI is not transmitted, 1 token is consumed at this port.
   - The number of tokens consumed at port HARQACK_In is equal to the number of HARQ-ACK information bits for each frame. When HARQ-ACK is not transmitted, 1 token is consumed at this port.
   - The number of tokens consumed at port CQI_In is equal to the number of CQI information bits for each frame. When CQI is not transmitted, 1 token is consumed at this port.
   - One frame samples with oversampling in time domain are produced at port Frame.
   - One frame frequency domain data without oversampling are produced at port FRM_FD.
   - The number of tokens produced at Data_FD is equal to the number of REs allocated for PUSCH and PUCCH transmission.
   - The number of tokens produced at PUSCH_ModSymbols is equal to the number of PUSCH modulation symbols in each frame.
   - The number of tokens produced at PUSCH_ChannelBits is equal to the sum of the number of PUSCH channel bits and number of RI and CQI coded bits in each frame. These outputs are the reference bits for uncoded BER and PER measurement. For more information on how to get the size of modulation symbols and channel bits, refer to *Channel Bits Calculation* (3gpplte).
   - The number of tokens produced at port SC_Status is equal to the total number of REs in each frame.
   - For the default parameters configurations, the number of tokens consumed at port DataIn is 25550 each firing. RI, HARQ-ACK, CQI are not transmitted via PUSCH. The number of tokens produced at port Frame is 153600 each firing. The number of tokens produced at port FRM_FD and SC_Status is 42000 each firing. The number of tokens produced at port Data_FD and PUSCH_ModSymbols are 36000 each firing. The number of tokens produced at port PUSCH_ChannelBits is 72000.
3. The **LTE_UL_Src** schematic is shown below:



4. In this subnetwork, data and control streams (in the form of CQI/PMI, HARQ-ACK and rank indication) are encoded and multiplexed through *LTE_UL_ChannelCoder* (3gpplte) in which the CRC attachment, code block segmentation, channel coding, rate matching, multiplexing of data and control information, channel interleaving and scrambling are performed. Then the block of scrambled bits are modulated as described in Section 7.1 [1], resulting in a block of complex-valued symbols (QPSK, 16QAM, 64QAM are allowed for PUSCH). A size-M DFT is applied to a block of M modulation symbols, where M is the number of subcarriers allocated for PUSCH in one SC-FDMA symbol and can be changed on a subframe basis. Demodulation reference signal for PUSCH and sounding reference signal are generated by *LTE_UL_CAZAC* (3gpplte), while demodulation reference signal for PUCCH and uplink control information carried by PUCCH are both output from *LTE_UL_PUCCH* (3gpplte). Reference signals, PUSCH and PUCCH are multiplexed and mapped onto the allocated time and frequency resources in *LTE_UL_MuxSCFDMASym* (3gpplte) considering power offset of each physical signal and channel. Then, the uplink SC-FDMA signal in time domain is generated from *LTE_SCFDMA_Modulator* (3gpplte) component in which IFFT is implemented. Cyclic prefix insertion and half carrier shift are implemented in *LTE_UL_MuxSlot* (3gpplte). Then the output is multiplexed with physical random access preamble sequences in *LTE_UL_MuxFrame* (3gpplte). PRACH is generated in *LTE_RACH* (3gpplte), if PRACH is not enabled, the output would be '0's. At last, *LTE_SpecShaping* (3gpplte) is employed to provide the spectrum shaping of the uplink source through FIR filtering or time windowing as configured.
5. The basic uplink transmission scheme is a single-carrier frequency division multiple access (**SC-FDMA** as shown below) with cyclic prefix to achieve uplink inter-user orthogonality and to enable straightforward application of low-complexity high-performance frequency-domain equalization at the receiver side. Frequency-domain generation of the signal, sometimes known as DFT-spread OFDM, is assumed and illustrated in the following figure. This allows for a relatively high degree of commonality with the downlink OFDM scheme and the same parameters; for example, clock frequency can be reused.



6. The basic parameters of the LTE uplink transmission scheme have been chosen to be aligned, as much as possible, with the corresponding parameters of the OFDM based LTE downlink. For uplink transmission scheme, the sub-carrier spacing is Δf = 15 kHz. Each radio frame is 10 ms long and consists of 20 slots of length T_{slot} = 0.5 ms.

   The basic transmission parameters are then specified in more detail in the Parameters for **Downlink Transmission Scheme** table below:

Spectrum Allocation (MHz)	Sampling frequency (MHz)	FFT Size	Number of Resource Blocks	Normal CP length (μ s/samples)	Extended CP length (μ s /samples)
20	30.72	2048	100	(4.69/144) x 6, (5.21/160) x 1	(16.67/512)
15	23.04	1536	75	(4.69/108) x 6, (5.21/120) x 1	(16.67/384)
10	15.36	1024	50	(4.69/72) x 6, (5.21/80) x 1	(16.67/256)
5	7.68	512	25	(4.69/36) x 6, (5.21/40) x 1	(16.67/128)
3	3.84	256	15	(4.69/18) x 6, (5.21/20) x 1	(16.67/64)
1.4	1.92	128	6	(4.69/9) x 6, (5.21/10) x 1	(16.67/32)

7. A physical resource block is defined as N_{symb}^{UL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{UL} and N_{sc}^{RB} are given by the **Resource block parameters** below:

Configuration	N_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

8. An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers. The following uplink physical channels are defined:
    - Physical Uplink Shared Channel, PUSCH
    - Physical Uplink Control Channel, PUCCH
    - Physical Random Access Channel, PRACH
9. An uplink physical signal is used by the physical layer but does not carry information originating from higher layers. Two types of uplink reference signals are supported:
    - Demodulation reference signal, associated with transmission of PUSCH and PUCCH
    - Sounding reference signal, not associated with transmission of PUSCH and PUCCH
      The same set of base sequence is used for demodulation and sounding reference signals.
10. The outputs from each output port of this subnetwork are described in the following table.

Ports name	Outputs description
FRM_TD	Samples with oversampling in time domain
FRM_FD	Frequency domain data without oversampling
Data_FD	Frequency domain PUSCH data without oversampling
PUSCH_ModeSymbols	Complex-valued modulation symbols for PUSCH
PUSCH_ChannelBits	Scrambled channel bits for PUSCH from LTE_UL_ChannelCoder. These outputs are the reference bits for uncoded BER and PER measurement. For more information, refer to *Channel Bits Calculation* (3gpplte).
PUSCH_RawBits	Transport block bits for PUSCH. These outputs are the reference bits for coded BER and PER measurement.
SC_Status	Status for each subcarrier (resource element). The order of the output is in increasing order of first the subcarrier index, then the symbol index, starting with the first subcarrier of the first symbol in each frame, i.e. the first value is the status for the first subcarrier (resource element) in the first OFDM symbol, and then the second is for the second subcarrier (resource element) in the first OFDM symbol, and so on. The meaning of the status value is shown in the SC_Status values table.

SC_Status values

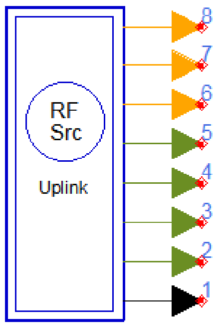
Value	ChannelType
0	EMPTY
1	PUCCH
2	DMRS for PUCCH
3	PUSCH
4	DMRS for PUSCH
5	SRS
6	PRACH

11. It should be noted that the channel coding for control information transmitted on PUCCH is not supported.
12. See *LTE_UL_Src_RF* (3gpplte) and *LTE_UL_Receiver* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.
3. 3GPP TS 36.101 v8.6.0 "User Equipment (UE) radio transmission and reception", September 2009.

LTE_UL_Src_RF (Uplink Signal Source with RF Modulator)



Description: Uplink signal source with RF modulator
Library: LTE, Source

Parameters

Name	Description	Default	Unit	Type	Range
RF_Parameters	RF parameters for LTE uplink signals	Category		string	
ROut	source resistance	50 Ohm	Ohm	int	(0,∞)
RTemp	temperature	- 273.15	Celsius	real	[- 273.15,∞]
FCarrier	carrier frequency	2500 MHz	Hz	real	(0,∞)
Power	power	0.01 W	W	real	(0,∞)
MirrorSpectrum	indication of mirror spectrum about carrier: NO, YES	NO		enum	
GainImbalance	gain imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
PhaseImbalance	phase imbalance in dB Q channel relative to I channel	0.0		real	(-∞,∞)
I_OriginOffset	I origin offset in percent with repect to output rms voltage	0.0		real	(-∞,∞)
Q_OriginOffset	Q origin offset in percent with repect to output rms voltage	0.0		real	(-∞,∞)
IQ_Rotation	IQ rotation in degrees	0.0		real	(-∞,∞)
SystemParameters	system parameters for LTE uplink signals	Category		string	
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6	Config 0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config 0, Config 1, Config 2, Config 3, Config 4, Config 5, Config 6, Config 7, Config 8	Config 4		enum	
Bandwidth	bandwidth: BW 1.4 MHz, BW 3 MHz, BW 5 MHz, BW 10 MHz, BW 15 MHz, BW 20 MHz	BW 5 MHz		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8	Ratio 2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
n_RNTI	radio network temporary identifier	0		int	[0,65535]
HalfCarrierShift_Enable	whether or not to enable 1/2	YES		enum	

	subcarrier shifting: NO, YES				
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
FrameNum	frame number	0		int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO		enum	
DL_CyclicPrefix	type of cyclic prefix in downlink: DL_Normal, DL_Extended	DL_Normal		enum	
Printf_RB_SF_Alloc	print the RB_SF allocation to file: NO, YES	NO		enum	
PUSCH_Parameters	PUSCH parameters for LTE uplink signals	Category		string	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
Payload_Config	the configuration mode of input data of PUSCH.: MCS index, Transport block size, Code rate	Transport block size		enum	
Payload	the input payload for PUSCH, the meaning of the input is defined in Payload_Config	{2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555, 2555}		real array	
Enable64QAM	whether 64QAM is allowed in LTE uplink: NO, YES	YES		enum	
MappingType	the modulation orders for the PUSCH in each subframe. (0:QPSK, 1:16QAM, 2:64QAM)	{0, 0, 0, 0, 0, 0, 0, 0, 0, 0}		int array	
RV_Idx	Redundancy Version Index	0		int	[0, 3]
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	YES		enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO		enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame		enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0		int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1		int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz		enum	
PUSCH_TransMode	whether control and data are sent via PUSCH: Data_and_Control_Multiplexing, Data_Only, Control_Only	Data_and_Control_Multiplexing		enum	
RB_AllocType	RB allocation type: StartRB + NumRBs, RB indices (1D), RB indices (2D)	StartRB + NumRBs		enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[[SF0 start RB, SF0 number of RBs], ..., [SF9 start RB, SF9 number of RBs]]	{0, 25}		int array	
GroupHop_Enable	whether enable group hopping for DMRS on PUCCH and PUSCH or not: NO, YES	NO		enum	
SeqHop_Enable	whether enable sequence hopping for DMRS on PUSCH or not: NO, YES	NO		enum	
PUSCH_Delta_ss	used in determining the sequence-shift pattern for PUSCH	0		int	[0,29]
PUSCH_n_DMRS1	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUSCH_n_DMRS2	used in computing the cyclic shift for PUSCH DMRS	{0}		int array	
PUCCH_Parameters	PUCCH parameters for LTE uplink signals	Category		string	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b,	Format_1		enum	

	Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b				
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2		int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1		int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11		int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11		int	[0, 12*PUCCH_NB2-1]
PRACH_Parameters	PRACH parameters for LTE uplink signals	Category		string	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO		enum	
PRACH_Config	PRACH configuration index	0		int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}		int array	[0, 9]
PRACH_PrmbleIndex	preamble indexes, used to select preamble sequences from 64 preambles available in this cell	{0}		int array	[0, 63]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0		int	[0, 94]
PRACH_LogicalIndex	logical index of root ZC sequence	0		int	[0, 837]
PRACH_Ncs	cyclic shifts of ZC sequence	0		int	[0, 15]
PRACH_HS_flag	high speed flag: NO, YES	NO		enum	
SRS_Parameters	SRS parameters for LTE uplink signals	Category		string	
SRS_Enable	sounding reference symbol is enable: NO, YES	NO		enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7		int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0		int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO		enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0		int	[0, 3]
SRS_HoppingBandwidth	the SRS hopping bandwidth	3		int	[0, 3]
SRS_FreqPosition	the SRS frequency domain position	0		int	[0, 23]
SRS_ConfigIndex	the UE-specific SRS configuration	0		int	[0, 1023]
SRS_TransmissionComb	transmission comb	0		int	[0, 1]
SRS_CyclicShift	used in computing the cyclic shift of SRS	0		int	[0, 7]
PowerParameters	power-related parameters	Category		string	
PUSCH_PwrOffset	the power offset in dB for PUSCH	0		real	(-∞, +∞)
PUSCH_RS_PwrOffset	the power offset in dB for PUSCH RS	0		real	(-∞, +∞)
PUCCH_PwrOffset	the power offset in dB for PUCCH	0		real	(-∞, +∞)
PUCCH_RS_PwrOffset	the power offset in dB for PUCCH RS	0		real	(-∞, +∞)
PRACH_PwrOffset	the power offset in dB for PRACH	0		real	(-∞, +∞)

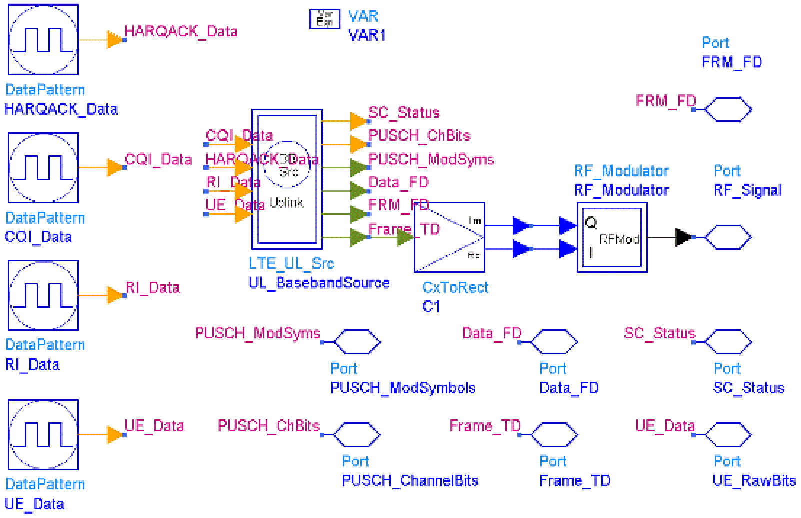
SRS_PwrOffset	the power offset in dB for SRS	0		real	(-∞, +∞)
SpectrumShapingParameters	parameters for transmit spectrum shaping	Category		string	
SpectrumShapingType	spectrum-shaping type: TimeWindowing, FIRFilter	FIRFilter		enum	
WindowType	type of time transition windowing between two consecutive symbols: Tukey, Raised cosine	Tukey		enum	
CyclicInterval	the overlapped cyclic interval between two adjacent SC-FDMA symbols in unit of chips (without oversampleing)	6		int	[0,96]
CI_StartPos	the start position of cyclic interval(take the start position of CP as origin), indicates the number of samples(without oversampling) of ECP added before CP	-3		int	[-96,0]
FIR_Taps	number of FIR filter taps	19		int	[1,1000]
FIR_withInterp	spectrum-shaping FIR filter with interpolation operation: NO, YES	NO		enum	
FIR_FilterType	spectrum-shaping FIR filter type: Square-Root Raised Cosine, Ideal Lowpass	Square-Root Raised Cosine		enum	
RRC_Alpha	roll-off factor for root raised-cosine filter	0.22		real	[0,1.0]
ControlInfoParameters	control information parameters for LTE uplink signals	Category		string	
RI_NumInfoBits	RI information bits size	{0}		int array	[0,∞)
RI_BetaOffsetIndex	RI offset values, used in calculating the number of coded RI symbols	{0}		int array	[0,12]
CQI_NumInfoBits	CQI information bits size	{0}		int array	[0,∞)
CQI_BetaOffsetIndex	CQI offset values, used in calculating the number of coded CQI symbols	{2}		int array	[2,15]
HARQACK_NumInfoBits	HARQ-ACK information bits size	{0}		int array	[0,∞)
HARQACK_BetaOffsetIndex	HARQ-ACK offset values, used in calculating the number of coded HARQ-ACK symbols	{0}		int array	[0,14]
ACK_NACK_FeedbackMode	ACK/NACK feedback modes for TDD: ACK_NACK_multiplexing, ACK_NACK_bundling	ACK_NACK_multiplexing		enum	
Nbundled	Nbundled for TDD ACK/NACK bundling	{1}		int array	[1,20]

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Signal	output of RF signal	timed
2	Frame_TD	output of frame signal in time domain	complex
3	FRM_FD	output of frame signal in frequency domain	complex
4	Data_FD	valid RB output without RS	complex
5	PUSCH_ModSymbols	output of PUSCH modulation symbols in frequency domain	complex
6	UE_RawBits	output of UE data before channel codiing	int
7	PUSCH_ChannelBits	output of PUSCH data after channel codiing	int
8	SC_Status	uplink subcarrier (resource element) status in one frame	int

Notes/Equations

1. This subnetwork generates LTE uplink RF signal for both frame structure 1 and frame structure 2. LTE uplink transmission is based on SC-FDMA (or DFT-S-OFDM). The subnetwork consists of LTE_UL_Src which generates the 3GPP LTE uplink baseband signal, the RF_Modulator and four DataPattern generating data and control information bits. The schematic for this subnetwork is shown in the following figure.



LTE_UL_Src_RF Schematic

2. For more information on the LTE uplink baseband signal generation, please refer to *LTE_UL_Src* (3gpplte).

Parameter Details

RF parameters Details:

- ROut is the RF output source resistance.
- RTemp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k · (RTemp+273.15)) Watts/Hz, where k is Boltzmann's constant.
- FCarrier is the RF output signal frequency.
- Power is used to set the modulator output RF power. This is true for an ideal transmitted signal (no impairments added) or when small impairments are added. If large impairments are added to the signal (using GainImbalance, I_OriginOffset, and Q_OriginOffset parameters) the output RF power may be different from the value of the Power parameter.
- MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage. Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set this parameter to YES.
- GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here. The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
  $V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\Phi\pi}{180}\right)\right)$ where A is a scaling factor based on the Power and ROut parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance $g = 10^{\frac{GainImbalance}{20}}$ and Φ (in degrees) is the phase imbalance. Next, the signal $V_{RF}(t)$ is rotated by *IQ_Rotation* degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by *sqrt(2 × ROut × Power)* .

System Parameters Details:

- Please refer to *UL System Parameters* (3gpplte).

PUSCH Parameters Details:

- Please refer to *UL PUSCH Parameters* (3gpplte).

PUCCH Parameters Details:

- Please refer to *UL PUCCH Parameters* (3gpplte).

PRACH Parameters Details:

- Please refer to *UL PRACH Parameters* (3gpplte).

SRS Parameters Details:

- Please refer to *UL SRS Parameters* (3gpplte).

Power Parameters Details:

- Please refer to *UL Power Parameters* (3gpplte).

Spectrum Shaping Parameters Details:

- Please refer to *UL Spectrum Shaping Parameters* (3gpplte).

Control Information Parameters Details:

- Please refer to *UL Control Information Parameters* (3gpplte).

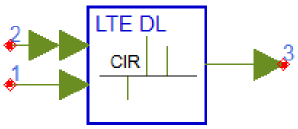
References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.
3. 3GPP TS 36.101 v8.6.0 "User Equipment (UE) radio transmission and reception", September 2009.

3GPP LTE Sync Equalization Components

Contents

LTE_DL_ChEstimator (Downlink Channel Estimator and Interpolator)



Description: Downlink channel estimator and interpolator for FDD and TDD
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1		enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE_2D, For EVM	Linear		enum	
MMSE_RBWinLen	number of RBs for each MMSE-2D interpolation	3		int	
SNR	SNR in dB. (used by 2D-MMSE channel estimator in PDSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by 2D-MMSE channel estimator in PDSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by 2D-MMSE channel estimator in PDSCH)	100 Hz	Hz	real	[0,∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Pilots	reference signals	complex
2	input	output signals from FFT	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	Coef	channel coefficient in active subcarriers	complex

Notes/Equations

1. This model is used to estimate 3GPP LTE downlink channel response (CR) with the pilot symbols assisted for both FDD and TDD schemes. The downlink reference signals (pilots) are based on [1].
2. Each firing,
    - If ChEstimatorMode is select as 0:Linear or 1:MMSE-2D,
        - the number of tokens consumed at port Pilots is equal to the number of RS REs for all antenna ports in each subframe, for more information, please refer to *LTE_DL_Pilot* (3gpplte).
        - *NumberREsPerSubframe* tokens are consumed at each port of the multiport input, *NumberREsPerSubframe* = *NumOfTotalRBs* * 12 (subcarriers per RB) * *NumberOfSymbolsPerSubframe*.
        - *NumberREsPerSubframe* * *NumberTxAnts* * *NumberRxAnts* tokens are

produced at port Coef, where *NumberTxAnts* and *NumberRxAnts* are the number of Tx and Rx antennas respectively.

- If ChEstimatorMode is select as 2:For EVM,
    - the number of tokens consumed at port Pilots is equal to the number of RS REs for all antenna ports in each frame.
    - *NumberREsPerFrame* tokens are consumed at each port of the multiport input, *NumberREsPerFrame = NumOfTotalRBs* * 12 (subcarriers per RB) * *NumberOfSymbolsPerFrame*.
    - *NumberREsPerFrame* * *NumberTxAnts* * *NumberRxAnts* tokens are produced at port Coef.
- For the default parameter configurations, the number of tokens consumed at Pilots is 2000; 72000 tokens are consumed at input; 72000 tokens are produced at Coef.

3. Linear interpolation and MMSE interpolation are supported in this channel estimator. Channel estimation is done on a subframe basis. In addition, channel estimation algorithm for EVM measurement defined in [2] is also provided.
4. The least-squares CR estimate at a pilot location (*i*) can be obtained as: $H_i = Y_i / X_i$, where Y_i is the received Pilot symbol and X_i is the transmitted Pilot symbol on the i^{th} subcarrier.
5. After getting the CRs at pilot locations, an interpolation algorithm is used to obtain all CR estimations.
    - If ChEstimatorMode is set to Linear, linear interpolation in frequency domain is performed to get CEs in all subcarriers in RS OFDM symbols, then do linear interpolation in time domain is performed to get CEs in all other OFDM symbols.
    - If ChEstimatorMode is set to MMSE_2D, two-dimensional MMSE interpolation is performed on a subframe basis in time domain and *MMSE_RBWinLen* RBs in frequency domain. For more information, please refer to [3].
    - If ChEstimatorMode is set to For EVM, time averaging at each RS subcarrier is performed; the time-averaging length is 10 subframes. This process creates an average amplitude and phase for each reference signal subcarrier (i.e. every third subcarrier with the exception of the reference subcarrier spacing across the DC subcarrier). Then, the moving average in the frequency domain of the time-averaged RS subcarriers is performed, i.e. every third subcarrier. The moving average window size is 19. For reference subcarriers at or near the edge of the channel the window size is reduced accordingly as depicted in the following figure. At last, linear interpolation is performed from the averaged results to compute channel estimation for each subcarrier.

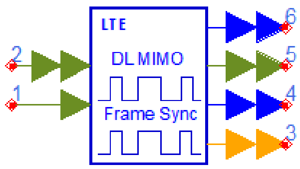
6. If ChEstimatorMode is MMSE_2D, SNR should be set as the signal to noise ratio in dB, Tmax should be set as the maximum delay spread of the channel, Fmax should be set as the maximum dopper frequency, while these parameters are ignored when ChEstimatorMode is Linear. In AWGN channel, Tmax and Fmax can be set as a small value, e.g. Tmax = 1e-8s, Fmax = 0.01Hz.
7. See *LTE_UL_ChEstimator* (3gpplte).

- For more information on system parameters, please refer to *DL System Parameters* (3gpplte)
- For more information on Rx Algorithm Parameters, please refer to *DL Rx Algorithm Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. P. Hoeher, S. Kaiser, and P. Robertson. "Two-Dimensional Pilot-Symbol-Aided Channel Estimation by Wiener Filtering". Proc. IEEE ICASSP '97, Munich, Germany, pp. 1845-1848, Apr. 1997.

LTE_DL_MIMO_FrameSync (Downlink Time and Frequency Synchronizer)



Description: Downlink time and frequency synchronizer in time domain
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
SyncType	synchronization type indicating using PSS cross-correlation between two received PSSs or auto-correlation between received PSS and local generated PSS: Cross-Correlation, Auto-Correlation	Cross-Correlation		enum	
SearchType	start a new timing and frequence synchronization search for every frame or not: Search every frame, Search+Track	Search+Track		enum	
SearchRange	timing and frequence synchronization searching range for the first frame	3 msec	sec	real	[0,5.0ms]
TrackRange	timing and frequence synchronization tracking range for the frames except the first frame, valid when SearchType is set to Search+Track	0.1 msec	sec	real	[0,5.0ms]
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	PSCH	the ideal PSCH	complex
2	input	received baseband signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	TimeDete	time offset detection	multiple int
4	FODete	frequency offset detection	multiple real
5	SSCH_Sym	SSCH OFDM symbol output	multiple complex
6	Corr_Max	the max corr value of PSCH	multiple real

Notes/Equations

This model is used to achieve downlink radio frame synchronization and estimate frequency offset less than 15 KHz for both FDD and TDD modes.

1. Firstly, the input signal is passed through a FIR filter to remove the signal out of P-

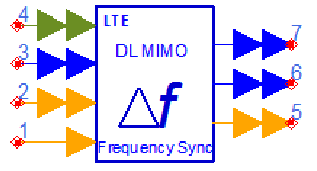
SCH bandwidth. Then, half radio frame (5 ms timing) is identified using the P-SCH. Using the P-SCH can only identify the 5 ms timing because there are 2 P-SCH symbols in one radio frame. The radio frame timing should be found by the S-SCH in cell search step 2 (in LTE_DL_MIMO_FreqSync component).

2. The timing synchronization supports two correlation methods defined in the SyncType parameter:
   - SyncType = Cross-Correlation
     In this mode, the timing synchronization is achieved by performing cross-correlation between two received P-SCH
   - SyncType = Auto-Correlation
     In this mode, the timing synchronization is achieved by performing auto-correlation between local P-SCH and received P-SCH.
3. The timing synchronization processes support two modes determined by the SearchType parameter
   - When SearchType = Search every frame
     In this mode, the timing synchronization is done radio frame by radio frame. The searching range is determined by SearchRange parameter, starting from the beginning of the input signal. To get timing synchronization successfully, make sure that at least one complete P-SCH exists in the range [0, SearchRange] of each radio frame.
   - When SearchType = Search+Track
     In this mode, the timing synchronization is divided into two steps: Initial searching and Tracking searching. The initial searching is performed on the first radio frame, the same as when SearchType = Search every frame. Then beginning with the second frame, tracking searching is employed. Tracking searching will search the range [Index- TrackRange/2, Index+TrackRange/2] to get the timing synchronization index, where Index is the timing synchronization index gotten in the previous radio frame. Usually, TrackRange is less than SearchRange for reducing computing complexity
4. The frequency offset less than one subcarrier spacing (15 KHz) is also estimated in this model by using the repetition characters of P-SCH and Cyclic Prefix (CP) in OFDM symbols. More specifically, the offset less than 100Hz is achieved by estimating the offset between two P-SCHs; the offset, greater than 100Hz but less than 15KHz is achieved by estimating the offset in CP of OFDM symbols. The estimation range is determined by the FreqSync parameter. When FreqSync = non, the output frequency offset is 0; when FreqSync = <100Hz, <15KHz, or <35KHz, the output frequency offset from this model will be less than 100Hz, 15KHz, 15KHz respectively.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_MIMO_FreqSync (Time and Frequency Estimation)



Description: Timing and freqency estimation in freqency domain
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Type
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1	enum
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum
Sync_Mode	synchronization for every port or one synchronization for all ports: SyncPerPort, AverageSync	SyncPerPort	enum
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz	enum

Pin Inputs

Pin	Name	Description	Signal Type
1	SSCH	SSCH signals generated by the receiver	int
2	TD_ByFrameSync	time offset detection by the FrameSync model	multiple int
3	FD_ByFrameSync	frequency offset detection by the FrameSync model	multiple real
4	input	SSCH signals from FFT	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
5	TimeDete	time offset detection	multiple int
6	FODete	frequency offset detection	multiple real
7	Corr_Max	the max corr value of SSCH	multiple real

Notes/Equations

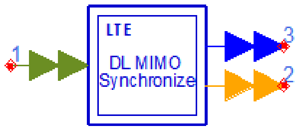
1. This model is used to achieve integer subcarrier-spacing (15KHz) frequency offsets for both FDD and TDD modes.
2. In this model, the auto-correlation between local S-SCH and received S-SCH is performed for each receiver antenna to get the integer subcarrier-spacing frequency offsets when FreqSync = <35KHz. Otherwise no integer subcarrier-spacing frequency offsets are estimated.
3. When SyncMode = AverageSync, the timing indices and frequency offsets on all the receiver antennas are combined with MRC method based on the receiver S-SCH to generate a composite timing index and frequency offset. This mode is useful when P-SCH and S-SCH are only received on one of the receiver antennas.
4. When SyncMode = SyncPerPort, the timing indices and frequency offset for each receiver antenna are sent out independently. This mode may have better performance if P-SCH and S-SCH are received on all the receiver antennas.
5. The inputs at port S-SCH is the local S-SCH signal for auto-correlation with received S-SCH.
   The inputs at port input are the received S-SCH signals for each receiver antenna.
   The inputs at port TD_ByFrameSync are the timing synchronization indices for each receiver antenna estimated in LTE_DL_MIMO_FrameSync.
   The inputs at port FD_ByFrameSync are the frequency offsets for each receiver antenna estimated in LTE_DL_MIMO_FrameSync.
   The outputs at port TimeDeta are the timing synchronization indices for each receiver antenna
   The outputs at port FODeta are the frequency offsets combining integer and

fractional offsets for each receiver antenna.
The outputs at port Corr_Max are the maximum auto-correlation values for each receiver antenna.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_DL_TimeFreqSync (Downlink Time and Frequency Synchronizer)



Description: Frequency and time synchronization for DL
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
NumRxAnts	number of Rx Antennas: Rx1, Rx2, Rx4	Rx1		enum	
OversamplingOption	Ratio 1, Ratio 2, Ratio 4, Ratio 8: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0,2]
CellID_Group	the index of cell identity group	0		int	[0,167]
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0,1.0e-3]
Sync_Mode	synchronization for every port or one synchronization for all ports: SyncPerPort, AverageSync	SyncPerPort		enum	
SyncType	synchronization type indicating using PSS cross-correlation between two received PSSs or auto-correlation between received PSS and local generated PSS: Cross-Correlation, Auto-Correlation	Cross-Correlation		enum	
SearchType	start a new timing and frequence synchronization search for every frame or not: Search every frame, Search+Track	Search+Track		enum	
SearchRange	timing and frequence synchronization searching range for the first frame	3 msec	sec	real	[0,5.0ms]
TrackRange	timing and frequence synchronization tracking range for the frames except the first frame, valid when SearchType is set to Search+Track	0.1 msec	sec	real	[0,5.0ms]
FreqSync	frequency estimation range select: non, <100Hz, <15kHz, <35kHz	<15kHz		enum	

Pin Inputs

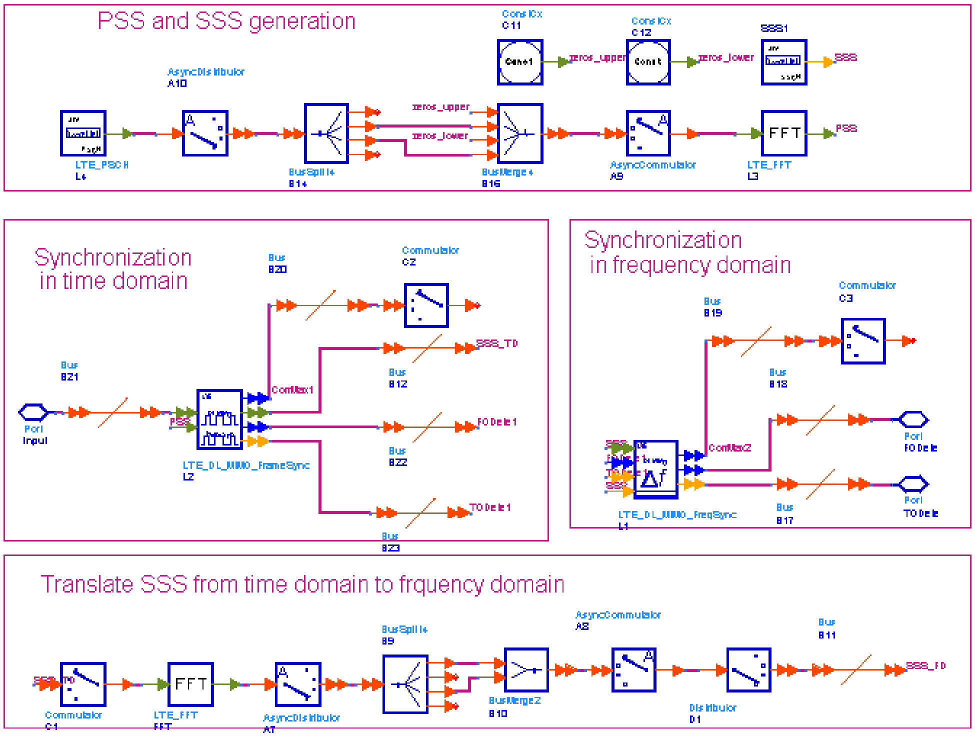
Pin	Name	Description	Signal Type
1	input	input downlink signal of one antenna port	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	TODete	output the time delay	multiple int
3	FODete	output the frequency offset	multiple real

Notes/Equations

1. This subnetwork is used to achieve downlink radio frame synchronization and estimate frequency offset for both FDD and TDD mode. The schematic for this subnetwork is shown in the following figure.

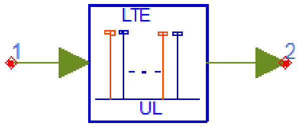


2. The input and output are multiple ports whose bus width should be consistent with the NumRxAnts parameter.
3. This subnetwork includes two models: *LTE_DL_MIMO_FrameSync* (3gpplte) for frame synchronization and estimation of frequency offset less than 15 KHz; *LTE_DL_MIMO_FreqSync* (3gpplte) for estimation of integer subcarrier-spacing (15KHz) frequency offset.
4. The process for timing and frequency synchronization is described as follows:
    - The input signal is sent to LTE_DL_MIMO_FrameSync, where the raw half-frame (5ms) synchronization and frequency offset less than 15 KHz are achieved. The outputs are the raw timing index, frequency offset and the time-domain S-SS waveform.
    - The S-SS waveform is transformed from time domain to frquency domain, which are then sent to LTE_DL_MIMO_FreqSync for estimation of integer subcarrier-spacing (15KHz) frequency offset, along with raw timing index and frequency offset less than 15 KHz. In LTE_DL_MIMO_FreqSync, the final frame (10ms) synchronization is also achieved by comparing the received two S-SSs with local S-SSs.
5. SyncMode: timing and frequency synchronization mode for multiple receiver antenna ports. When SyncMode = AverageSync, the timing indices and frequency offsets on all the receiver antennas are combined with MRC method to generate a composite timing index and frequency offset which are then sent to LTE_DL_DemuxFrame. This mode is useful when P-SCH and S-SCH are only received on one of the receiver antennas. When SyncMode = SyncPerPort, the timing indices and frequency offset for each receiver antenna are sent to LTE_DL_DemuxFrame independently. This mode (SyncMode = SyncPerPort) may have better performance if P-SCH and S-SCH are received on all the receiver antennas.
6. SyncType: when SyncType is Cross-Correlation, the timing synchronization is achieved by performing cross-correlation between two received P-SCH; when SyncType = Auto-Correlation, the timing synchronization is achieved by performing auto-correlation between local P-SCH and received P-SCH.
7. SearchType: the search type for the timing synchronization. When SearchType = Search every frame, the complete search is performed for each frame, whose search range is defined in SearchRange; When SearchType = Search+Track, the first frame performs the complete search whose search range is defined in SearchRange, the rest frames perform the tracking search whose search range is defined in TrackRange.
8. SearchRange: search range for all frames when SearchType = Search every frame, and for the first frame when SearchType = Search+Track.
9. TrackRange: tracking range for the rest frames when SearchType = Search+Track.
10. FreqSync: frequency synchronization range, chosen from non, <100Hz, <15kHz, <35kHz.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_IQ_Offset (Uplink IQ Offset Compensation)



Description: Uplink IQ offset compensation
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Unit	Type	Range
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0, 1.0e-3]
IQ_Offset_Correct	whether or not to correct IQ offset: NO, YES	YES		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	signal input	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	sigal output	complex

Notes/Equations

1. This model performs LTE Uplink DC calibration.
2. Each firing,
   - *NumberSamplesPerFrame* tokens are consumed at port DataIn;
   - *NumberSamplesPerFrame* tokens are produced at port DataOut;
   - where *NumberSamplesPerFrame* is the number of samples in each frame, $NumberSamplesPerFrame = SamplingFreq * 2^{OversamplingOption} * 0.01s$. *SamplingFreq* is sampling frequency, which is denoted as F_s and determined by Bandwidth as follows:

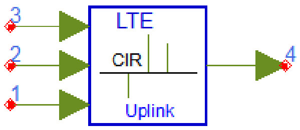
Bandwidth	F_s
1.4 MHz	1.92 MHz
3.0 MHz	3.84 MHz
5.0 MHz	7.68 MHz
10.0 MHz	15.36 MHz
15.0 MHz	23.04 MHz
20.0 MHz	30.72MHz

For more information on the parameters, please refer to *UL System Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.

LTE_UL_ChEstimator (Uplink Channel Estimator and Interpolator)



Description: Uplink Channel Estimator and Interpolator
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0, 2]
CellID_Group	the index of cell identity group	0		int	[0, 167]
FrameNum	frame number	0		int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO		enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO		enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame		enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0		int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1		int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}		int array	
PUCCH_Format	PUCCH format: Format_1, Format_1a, Format_1b, Shortened_1, Shortened_1a, Shortened_1b, Format_2, Format_2a, Format_2b	Format_1		enum	
PUCCH_Delta_shift	used to calculate PUCCH cyclic shift Alfa	2		int	[1, 3]
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]
PUCCH_NRB2	number of RBs used for transmisstion PUCCH format 2/2a/2b	1		int	[0, 99]
PUCCH_n1	resources used for transmisstion PUCCH format 1/1a/1b	11		int	[0, 12*100-1]
PUCCH_n2	resources used for transmission PUCCH format 2/2a/2b	11		int	[0, 12*PUCCH_NB2-1]
ChEstimatorMode	mode of interpolation algorithm in channel estimator: Linear, MMSE	Linear		enum	
SNR	SNR in dB. (used by MMSE channel estimator in PUSCH)	15		real	(-∞,∞)
Tmax	the maximum delay of multi-path channel. (used by MMSE channel estimator in PUSCH)	1.0 usec	sec	real	[0,∞)
Fmax	the maximum doppler frequency. (used by MMSE channel estimator in PUSCH)	100 Hz	Hz	real	[0,∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	output signals from FFT	complex
2	RS_PUSCH	PUSCH Reference signals	complex
3	RS_PUCCH	PUCCH Reference signals	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	Coef	channel coefficient in active subcarriers	complex

Notes/Equations

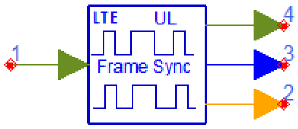
1. This model is used to estimate 3GPP LTE uplink channel response (CR) with the reference signals assisted for both FDD and TDD schemes. This model only estimates CRs in the time and frequency resources occupied by PUSCH and PUCCH. In the other locations, this model outputs '1's.
2. Each firing, this model estimates uplink channel response for one frame.
   - *NumberREsPerFrame* tokens are consumed at port input, *NumberREsPerFrame* = *NumOfTotalRBs* * 12 (subcarriers per RB) * *NumberOfSymbolsPerFrame*.
   - the number of tokens consumed at port RS_PUSCH is equal to the number of PUSCH DMRS REs in each frame.
   - the number of tokens consumed at port RS_PUCCH is equal to the number of PUCCH DMRS REs in each frame.
   - *NumberREsPerFrame* tokens are produced at port Coef.
   - For the default parameter configurations, 72000 tokens are consumed at input; 6000 tokens are consumed at RS_PUSCH; 72000 tokens are produced at Coef.
3. Linear interpolation and MMSE interpolation are supported in this channel estimator. Channel estimation is done on a slot basis.
4. For PUSCH channel estimation,
   1. At first, the least-squares CR estimate at a pilot location (i) is obtained as:
      $H_i = Y_i / X_i$
      where Y_i is the received Pilot symbol and X_i is the transmitted Pilot symbol on the i^{th} subcarrier.
   2. After getting the CRs at pilot locations,
      - If ChEstimatorMode is Linear, the CRs got at pilot locations are repeated to get all CR estimations, hence, the CRs at the same frequency location of all symbols in a slot is the same;
      - If ChEstimatorMode is MMSE, MMSE interpolation is performed on the subcarriers occupied by PUSCH DMRS, then the CRs at pilot locations are repeated in the whole slot. For more information on the algorithm, please refer to [2].
5. For PUCCH, only linear interpolation is provided. At first, the least-squares CRs in PUCCH pilots' locations are obtained, then linear interpolation is employed to get the CRs in all PUCCH symbol loations.
6. If ChEstimatorMode is MMSE, SNR should be set as the signal to noise ratio in dB, Tmax should be set as the maximum delay of the channel, while these parameters are ignored when ChEstimatorMode is Linear.
7. See *LTE_DL_ChEstimator* (3gpplte).

- For more information on system parameters, please refer to *UL System Parameters* (3gpplte).
- For more information on PUSCH Parameters, please refer to *UL PUSCH Parameters* (3gpplte).
- For more information on PUCCH Parameters, please refer to *UL PUCCH Parameters* (3gpplte).
- For more information on Rx Algorithm Parameters, please refer to *UL Rx Algorithm Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. P. Hoeher, S. Kaiser, and P. Robertson. "Two-Dimensional Pilot-Symbol-Aided Channel Estimation by Wiener Filtering". Proc. IEEE ICASSP '97, Munich, Germany, pp. 1845-1848, Apr. 1997.

LTE_UL_FrameSync (Uplink Frame Synchronizer)



Description: Uplink time and frequency synchronizer in time domain
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0, 1.0e-3]
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}		int array	
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	received data stream	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	TimeDete	time offset detection	int
3	FODete	frequency offset detection	real
4	PUSCHRS	PUSCH RS output	complex

Notes/Equations

1. This model is used to achieve uplink symbol timing synchronization and estimate frequency offset less than 15 KHz for both FDD and TDD modes.
2. Each firing,
   - NumberSamplesPerFrame tokens are consumed at the input port, where NumberSamplesPerFrame = $SamplingFreq * 2^{\text{OversamplingOption}} * 0.01s$, SamplingFreq is sampling frequency, which is denoted as F_s and determined by Bandwidth as follows:

Bandwidth	F_s	**DFTSize**
1.4 MHz	1.92 MHz	128
3.0 MHz	3.84 MHz	256
5.0 MHz	7.68 MHz	512
10.0 MHz	15.36 MHz	1024
15.0 MHz	23.04 MHz	1536
20.0 MHz	30.72MHz	2048

- 1 token is produced in the TimeDete port, which is the delay detected by this model.
- 1 token is produced in the FODete port, which is the frequency offset detected by this model.
- FFTSize tokens are produced in the PUSCHRS port, which is the PUSCH RS OFDM symbol. FFTSize = DFTSize * $2^{OversamplingOption}$. DFTSize is determined by the Bandwidth.
- 2*TotalSubcarriers tokens are produced in the SSCH_Sym port, which are the two S-SCH OFDM symbols after FFT.
- 21 tokens are produced in the Corr_Max port, which is the correlation values (auto-correlation or cross-correlation) around the max one.

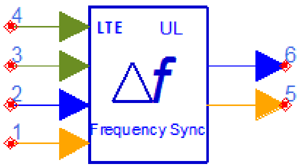
3. Timing synchronization and frequency estimation are done by the cyclic prefix(CP).
4. The outputs at ports TimedDete and FODeta are the timing index and frequency offset respectively.
5. The outputs at port PUSCHRs are the time-domain waveform of RS for PUSCH. Note that the RS waveform for PUSCH is only available when PUSCH exists (PUCCH_PUSCH = PUSCH or both), otherwise zeros are output.

- For more information on system parameters, please refer to *UL System Parameters* (3gpplte).
- For more information on PUSCH Parameters, please refer to *UL PUSCH Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.1.0, September 2006.

LTE_UL_FreqSync (Uplink Frequency Synchronizer)



Description: Timing and freqency estimation in freqency domain, using the PUSCH RS
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0, 2]
CellID_Group	the index of cell identity group	0	int	[0, 167]
FrameNum	frame number	0	int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO	enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame	enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0	int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1	int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}	int array	
IntFreqEstimation	estimation the large frequency offset (multiple of 15kHz) or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	TD_ByFrameSync	time offset detection by the FrameSync model	int
2	FD_ByFrameSync	frequency offset detection by the FrameSync model	real
3	input	SSCH signals from FFT	complex
4	PUSCHRS	PUSCH RS signals generated by the receiver	complex

Pin Outputs

Pin	Name	Description	Signal Type
5	TimeDete	time offset detection	int
6	FODete	frequency offset detection	real

Notes/Equations

1. This model is used to achieve integer subcarrier-spacing (15KHz) frequency offsets and adjust the time offset estimated by the model *LTE_UL_FrameSync* (3gpplte) for

both FDD and TDD modes, given the local and received frequency-domain RS for PUSCH.

2. Each firing,
   - TotalSubcarriers tokens are consumed in the input port, which is the PUSCH RS OFDM symbol after FFT. TotalSubcarriers = 12*NumOfRBs. The NumOfRBs is determined by the Bandwidth.

Bandwidth	NumOfRBs
1.4 MHz	6
3.0 MHz	15
5.0 MHz	25
10.0 MHz	50
15.0 MHz	75
20.0 MHz	100

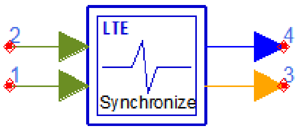
   - the number of tokens consumed at port PUSCHRS is equal to the number of DMRS symbols in each frame, which is determined by FrameMode, TDD_Config (in TDD mode), RBAlloc_Type and RB_Alloc.
   - 1 token is consumed in the TD_ByFrameSync port, which is the timing synchronization index LTE_UL_FrameSync.
   - 1 token is consumed in the FD_ByFrameSync port, which is the frequency offset in LTE_UL_FrameSync.
   - 1 token is produced in the TimeDete port, which is the final timing synchronization index.
   - 1 token is produced in the FODete port, which is the final frequency offset.
3. Note that this model is valid only when the parameter PUCCH_PUSCH = PUSCH or both.
4. The integer subcarrier-spacing (15KHz) frequency offset is estimated by performing cross-correlation between received RS for PUSCH and local RS for PUSCH. The timing index is adjusted according to the phase offset of received PUSCH RS symbols in frequency domain.

- For more information on system parameters, please refer to *UL System Parameters* (3gpplte).
- For more information on PUSCH Parameters, please refer to *UL PUSCH Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.1.0, September 2006.

LTE_UL_TimeFreqSync (Uplink Time and Frequency Synchronizer)



Description: Frequency and time synchronization for Uplink
Library: LTE, Sync Equalization

Parameters

Name	Description	Default	Unit	Type	Range
FrameMode	frame mode: FDD, TDD	FDD		enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0		enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz		enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2		enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal		enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0		int	[0, 2]
CellID_Group	the index of cell identity group	0		int	[0, 167]
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES		enum	
IdleInterval	idle interval between two consecutive radio frames	0	sec	real	[0, 1.0e-3]
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH		enum	
PUSCH_HoppingEnable	whether PUSCH frequency-hopping is enabled or not: NO, YES	NO		enum	
PUSCH_HoppingMode	PUSCH frequency hopping mode: interSubFrame, intraAndInterSubFrame	interSubFrame		enum	
PUSCH_HoppingOffset	the offset used for PUSCH frequency hopping	0		int	[0, 63]
PUSCH_Hopping_Nsb	number of sub-bands for PUSCH frequency hopping	1		int	[1, 4]
PUSCH_HoppingBits	information in hopping bits: zero_or_zz, one_or_zone, onezero, oneone	zero_or_zz		enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs		enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}		int array	
PUCCH_SF_Alloc	which sub frames contain the PUCCH, valid when PUCCH_PUSCH is other than PUSCH	{2}		int array	[0, 9]

Pin Inputs

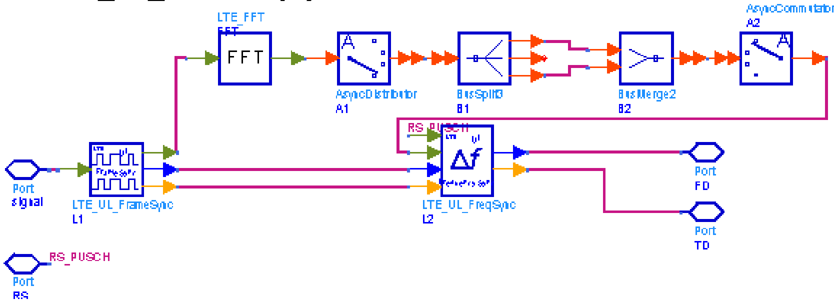
Pin	Name	Description	Signal Type
1	RS_PUSCH	PUSCH RS	complex
2	signal	input uplink signal	complex

Pin Outputs

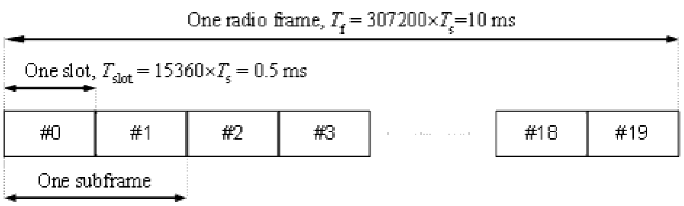
Pin	Name	Description	Signal Type
3	TD	output the time delay	int
4	FD	output the frequency offset	real

Notes/Equations

1. This subnetwork is used to achieve uplink symbol timing synchronization and estimate frequency offset.
2. The **LTE_UL_TimeFreqSync** schematic is shown below:



3. Timing synchronization and frequency estimation are done by the cyclic prefix(CP). LTE uplink transmissions are organized into radio frames. Each 10 ms radio frame consists of 20 slots of length 0.5 ms, numbered from 0 to 19. A sub-frame is defined as two consecutive slots (see the **Generic Frame Structure** below, and Reference 2).



4. In current implementation, because the reference signals (RS) among slots are different, it is difficult to do the timing and frequency estimation by the RS. We use the CP of each OFDM symbol, the timing synchronization is based on the repetition structure of CP within one OFDM symbol.
5. This subnetwork includes two models: *LTE_UL_FrameSync* (3gpplte) for OFDM symbol synchronization and estimation of frequency offset less than 15 KHz; *LTE_UL_FreqSync* (3gpplte) for estimation of integer subcarrier-spacing (15KHz) frequency offset.
6. The process for timing and frequency synchronization is described as follows:
   - The input signal is sent to LTE_UL_FrameSync, where the OFDM symbol synchronization and frequency offset less than 15 KHz are achieved by the cyclic prefix(CP). The outputs are the timing index, frequency offset and the time-domain waveform of RS for PUSCH. Note that the RS waveform for PUSCH is only available when PUSCH exists (PUCCH_PUSCH = PUSCH or both), otherwise zeros are output.
   - The RS waveform for PUSCH is transformed from time domain to frquency domain, which are then sent to LTE_UL_FreqSync for estimation of integer subcarrier-spacing (15KHz) frequency offset by performing cross-correlation between received RS for PUSCH and local RS for PUSCH, along with timing index and frequency offset less than 15 KHz.

> - For more information on system parameters, please refer to *UL System Parameters* (3gpplte).
> - For more information on PUSCH Parameters, please refer to *UL PUSCH Parameters* (3gpplte).

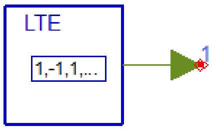
References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.1.0, September 2006.

3GPP LTE Sync Signal Components

Contents

LTE_DL_Pilot (Downlink Pilot Generator)



Description: Downlink pilot generator
Library: LTE, Sync Signal

Parameters

Name	Description	Default	Type	Range
Bandwidth	bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
NumTxAnts	number of Tx Antennas: Tx1, Tx2, Tx4	Tx1	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]

Pin Outputs

Pin	Name	Description	Signal Type
1	Pilots	downlink pilot symbol	complex

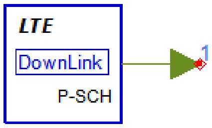
Notes/Equations

1. This model is used to generate 3GPP LTE downlink cell-specific Reference Signals (RS). The downlink reference signals (pilots) are based on Reference 2 and used for downlink demodulation.
2. The reference-signal sequence $r_{l,n_s}(m)$ is defined by
$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,2N_{RB}^{max,DL}-1$$
where n_s is the slot number within a radio frame and *l* is the OFDM symbol number within the slot.
3. Pseudo-random sequence generation
For the definition of pseudo-random sequence *c(i)*, please refer to the Downlink Scrambler model document. The pseudo-random sequence generator shall be initialised with $c_{init} = 2^{13}\cdot l' + 2^{9}\cdot \lfloor n_s/2 \rfloor + N_{ID}^{cell}$ at the start of each OFDM symbol where $l' = (n_s \bmod 2)\cdot N_{symb}^{DL} + l$ is the OFDM symbol number with a subframe.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_PSCH (P-SCH Generator)



Description: P-SCH generator
Library: LTE, Sync Signal

Parameters

Name	Description	Default	Type	Range
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	(0, 1, 2)

Pin Outputs

Pin	Name	Description	Signal Type
1	PSCH	P-SCH sequence	complex

Notes/Equations

1. This model is used to generate 3GPP LTE P-SCH signal in frequency domain.
2. The mapping of the sequence to resource elements depends on the frame structure. The antenna port used for transmission of the primary synchronization signal is not specified. For frame structure type 1, the primary synchronization signal is transmitted in the last OFDM symbols of slots 0 and 10 and the sequence d(n) shall be mapped to the resource elements according to

$$a_{k,l} = d(n), \quad k = n - 31 + \left\lfloor \frac{N_{RB}^{DL} N_{sc}^{RB}}{2} \right\rfloor, \quad l = N_{symb}^{DL} - 1, \quad n = 0,\ldots,61$$

   Resource elements (k,l) in slots 0 and 10 where

$$k = n - 31 + \left\lfloor \frac{N_{RB}^{DL} N_{sc}^{RB}}{2} \right\rfloor, \quad l = N_{symb}^{DL} - 1, \quad n = -5,-4,\ldots,-1,62,63,\ldots,66$$

   are reserved and not used for transmission of the primary synchronization signal. For frame structure type 2, the primary synchronization signal is transmitted in the third OFDM symbol in subframes 1 and 6.
3. P-SCH sequence is generated from a frequency-domain Zadoff-Chu sequence according to

$$d_u(n) = \begin{cases} e^{-j\frac{\pi u n(n+1)}{63}}, & n = 0,1,\ldots,30 \\ e^{-j\frac{\pi u (n+1)(n+2)}{63}}, & n = 31,32,\ldots,61 \end{cases}$$

   where the Zadoff-Chu root sequence index *u* is given by:

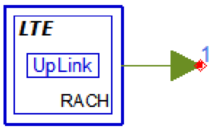
Physical-layer cell identity within the physical-layer cell-identity group	Root index u
0	25
1	29
2	34

4. The cell identity within the physical-layer cell-identity group is set by parameter CellID_Sector.

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
3. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.

LTE_RACH (Uplink Non-Synchronized Random Access Channel Generator)



Description: Uplink non-synchronized Random Access CHannel generator
Library: LTE, Sync Signal

Parameters

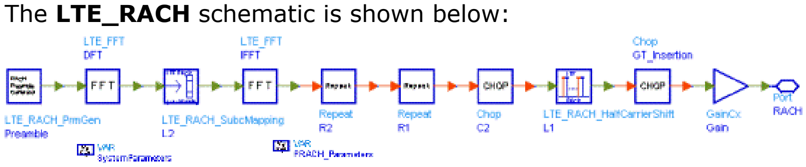
Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum	
FrameNum	frame number	0	int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO	enum	
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	NO	enum	
PRACH_Enable	whether or not to enable PRACH: NO, YES	YES	enum	
PRACH_Config	PRACH configuration index	0	int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}	int array	[0, 9]
PRACH_PrmbleIndex	preamble indexes, used to select preamble sequences from 64 preambles available in this cell	{0}	int array	[0, 63]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0	int	[0, 94]
PRACH_LogicalIndex	logical index of root ZC sequence	0	int	[0, 837]
PRACH_Ncs	cyclic shifts of ZC sequence	0	int	[0, 15]
PRACH_HS_flag	high speed flag: NO, YES	NO	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	RACH	output of non-synchronized RACH signal	complex

Notes/Equations

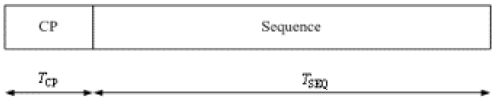
1. This subnetwork generates LTE PRACH signal.
2. The **LTE_RACH** schematic is shown below:



3. Each firing,
   - this subnetwork generates LTE PRACH signal for each frame. The number of tokens produced is the number of samples of all PRACH preambles, which is equal to *SamplingFreq* * $2^{\text{OversamplingOption}}$ * *PreambleLength* * *NumPreambles*.
   - If PRACH is not transmitted in this subframe, the output would be all '0's.
   - For the default parameter configurations, PRACH preamble format is format 0, the number of tokens produced each firing is 15360.
4. The main purpose of the random access procedure is to obtain uplink time synchronization and to obtain access to the network. The physical layer random access burst, illustrated in the following figure, consists of a cyclic prefix of length T_{CP}

, and a sequence part of length T_{SEQ}.

5. The parameter values are listed in the **Random access preamble format** below:



6. The parameter values are listed in the **Random access preamble parameters** table below and depend on the frame structure and the random access configuration.

Preamble format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_S$	$24576 \cdot T_S$
1	$21024 \cdot T_S$	$24576 \cdot T_S$
2	$6240 \cdot T_S$	$2 \cdot 24576 \cdot T_S$
3	$21024 \cdot T_S$	$2 \cdot 24576 \cdot T_S$
4	$448 \cdot T_S$	$4096 \cdot T_S$

7. The preamble formats and the subframes in which the random access preamble transmission is allowed for a given configuration in frame structure type 1 and frame structure type 2 are listed in Table 5.7.1-2 [1] and Table 5.7.1-3 [1] respectively. The mapping to physical resources for the different random access opportunities needed for a centern PRACH density value (D_{RA} are listed in Table 5.7.1-4 [1].
8. The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences.
9. The time-continuous random access signal s(t) is defined by

$$s(t) = \beta_{PRACH} \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi(k+\varphi+K(k_0+1/2))\Delta f_{RA}(t-T_{CP})}$$

, where $0 \le t < T_{SEQ} - T_{CP}$, β_{PRACH} is an amplitude scaling factor and $k_0 = n_{PRB}^{RA} N_{sc}^{RB} - N_{RB}^{UL} N_{sc}^{RB} / 2$. The factor $K = \Delta f / \Delta f_{RA}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission. The variable Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, are both given by Table 5.7.3-1 [1].
10. The **Random access baseband parameters** are listed in the table below:

Preamble format	Δf_{RA}	**φ**
0 - 3	1250Hz	7
4	7500Hz	2

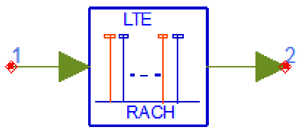
11. As can be seen from the schematic, LTE_RACH_PrmGen generates preamble sequence from Zadoff-Chu sequences with zero correlation zone. The preamble sequence is then FFT transformed and mapped onto the allocated frequency resources. DFT swap would be performed during subcarrier mapping if enabled.
12. After subcarrier mapping, IFFT is performed and CP is inserted. Half carrier shift is implemented as defined in 5.7.3[1], where "half carrier" refers to the item 1/2 in the equation. For preamble format is 1, 2 or 3, preamble is repeated. At last, normalization is employed.
13. It should be noted that the parameter DFTSwap_Enable should be set to **NO** according to the LTE specifications.
14. See *LTE_RACH_PrmGen* (3gpplte), *LTE_RACH_SubcMapping* (3gpplte), *LTE_RACH_HalfCarrierShift* (3gpplte) and *LTE_UL_MuxFrame* (3gpplte).

For more information, please refer to *UL System Parameters* (3gpplte) and *UL PRACH Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. D.C. Chu, "Polyphase Codes With Good Periodic Correlation Properties", IEEE Transaction on Information Theory, pp. 531-532, July 1972.

LTE_RACH_HalfCarrierShift (RACH Half Carrier Shift)



Description: PRACH Half carrier shift
Library: LTE, Sync Signal

Parameters

Name	Description	Default	Type	Range
HalfCarrierShift_Enable	whether or not to enable 1/2 subcarrier shifting: NO, YES	YES	enum	
FFTSize	fft size	6144	int	(0, ∞)
K	factor K accounts for the difference in subcarrier spacing	12	int	(0, ∞)
NumPrmble	number of preamble samples	6144	int	(0, ∞)
NumCP	number of cyclic prefix samples	792	int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	SeqIn	input sequence	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	SeqOut	output sequence	complex

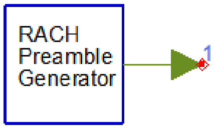
Notes/Equations

1. This model implements the half carrier shift for random access signal.
2. Each firing, *NumCP* + *NumPrmble* tokens are consumed at port SeqIn, and *NumCP* + *NumPrmble* tokens are produced at port SeqOut. For the default parameter configurations, 6936 tokens are consumed at port SeqIn and 6936 tokens are produced at port SeqOut.
3. Parameter Details
   - HalfCarrierShift_Enable: whether or not to enable 1/2 subcarrier shifting.
   - FFTSize: fft size
   - K: accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission.
   - NumPrmble: number of samples of the preamble sequence.
   - NumCP: number of samples of the cyclic prefix.
4. The time-continuous random access signal *s*(t) is defined by
   $$s(t) = \beta_{\text{PRACH}} \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi(k+\varphi+K(k_0+1/2))\Delta f_{RA}(t-T_{CP})}$$
   , where $0 \le t < T_{SEQ} - T_{CP}$, β_{PRACH} is an amplitude scaling factor and $k_0 = n_{PRB}^{RA} N_{sc}^{RB} - N_{RB}^{UL} N_{sc}^{RB} / 2$. The factor $K = \Delta f / \Delta f_{RA}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission.
5. The variable Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, are both given by Table 5.7.3-1 [1].
6. The item 1/2 in the above equation is not taken into consideration in those models ahead of LTE_RACH_HalfCarrierShift in the subnetwork LTE_RACH. In order to conform to the equation above, this model is employed to perform the half carrier shift.
7. See *LTE_RACH* (3gpplte), *LTE_RACH_PrmGen* (3gpplte) and *LTE_RACH_SubcMapping* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_RACH_PrmGen (RACH Preamble Sequence Generator)



Description: RACH preamble sequence generator
Library: LTE, Sync Signal

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO	enum	
PRACH_Config	PRACH configuration index	0	int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}	int array	[0, 9]
PRACH_PrmbleIndex	preamble indexes, used to select preamble sequences from 64 preambles available in this cell	{0}	int array	[0, 63]
PRACH_LogicalIndex	logical index of root ZC sequence	0	int	[0, 837]
PRACH_Ncs	cyclic shifts of ZC sequence	0	int	[0, 15]
PRACH_HS_flag	high speed flag: NO, YES	NO	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	ZC	ZC sequence	complex

Notes/Equations

1. This model generates the physical layer random access preamble sequence based on [1].
2. Each firing, this model generates RACH preambles for one frame. The length of each preamble sequence is determined by the preamble format configured by FrameMode and PRACH_Config, please refer to *Random access preamble parameters* (3gpplte). If PRACH is not transmitted, '0's are output. For the default parameter configurations, the preamble format is format 0, hence the length of the Zadoff-Chu sequence is 839.
3. The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use. The u^{th} root Zadoff-Chu sequence is defined by
   $x_u(n) = e^{-j\frac{\pi u n(n+1)}{N_{ZC}}}, \quad 0 \le n \le N_{ZC} - 1$, where the length N_{ZC} of the Zadoff-Chu sequence is given by Table 5.7.2-1 [1].
4. From the u^{th} root Zadoff-Chu sequence, random access preambles with zero correlation zones of length N_{CS} - 1 are defined by cyclic shifts C_v according to $x_{u,v}(n) = x_u(n + C_v) \bmod N_{ZC}$, where the cyclic shift is given by
   $$C_v = \begin{cases} vN_{CS} & v = 0,1,\ldots,\lfloor N_{ZC}/N_{CS} \rfloor - 1 \quad \text{for unrestrict ed sets} \\ d_{\text{start}}\lfloor v/n_{\text{shift}}^{\text{RA}} \rfloor + (v \bmod n_{\text{shift}}^{\text{RA}})N_{CS} & v = 0,1,\ldots,n_{\text{shift}}^{\text{RA}} n_{\text{group}}^{\text{RA}} + \bar{n}_{\text{shift}}^{\text{RA}} - 1 \quad \text{for restricted sets} \end{cases}$$
5. The variable d_u is the cyclic shift corresponding to a Doppler shift of magnitude 1 / T_{SEQ} and is given by

$$d_u = \begin{cases} u^{-1} \bmod N_{ZC} & 0 \le u^{-1} \bmod N_{ZC} < N_{ZC}/2 \\ N_{ZC} - u^{-1} \bmod N_{ZC} & \text{otherwise} \end{cases}$$

6. The parameters for restricted sets of cyclic shifts depend on d_u. For $N_{CS} \le d_u < N_{ZC}/3$, the parameters are given by

$$n_{shift}^{RA} = \lfloor d_u / N_{CS} \rfloor$$
$$d_{start} = 2d_u + n_{shift}^{RA} N_{CS}$$
$$n_{group}^{RA} = \lfloor N_{ZC} / d_{start} \rfloor$$
$$\bar{n}_{shift}^{RA} = \max\left(\left\lfloor (N_{ZC} - 2d_u - n_{group}^{RA} d_{start}) / N_{CS} \right\rfloor, 0\right)$$

7. For $N_{ZC}/3 \le d_u \le (N_{ZC} - N_{CS}) / 2$, the parameters are given by

$$n_{shift}^{RA} = \lfloor (N_{ZC} - 2d_u) / N_{CS} \rfloor$$
$$d_{start} = N_{ZC} - 2d_u + n_{shift}^{RA} N_{CS}$$
$$n_{group}^{RA} = \lfloor d_u / d_{start} \rfloor$$
$$\bar{n}_{shift}^{RA} = \min\left(\max\left(\left\lfloor (d_u - n_{group}^{RA} d_{start}) / N_{CS} \right\rfloor, 0\right), n_{shift}^{RA}\right)$$

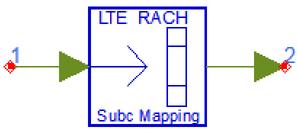
8. For all other values of d_u, there are no cyclic shifts in the restricted set.
9. For example, suppose the parameters are configured as follows:
   - FrameMode=FDD
   - PRACH_Enable=YES
   - PRACH_Config=9
   - PRACH_ResourceIndex={1,4}
   - PRACH_PrmbleIndex={9}
   - PRACH_LogicalIndex=25
   - PRACH_Ncs=1
   - PRACH_HS_flag=NO
   1. Since PRACH_Config is 9, the preamble format is 0 according to Table 5.7.1-2[1] and the length of the preamble sequence is 839 according to Table 5.7.2-1 [1].
   2. Two preamble sequences would be transmitted in subframe 1 and 4, each of the same indexes 9.
   3. The logical index PRACH_LogicalIndex is 25, hence the physical root sequence index u is 783 according to Table 5.7.2-4 [1].
   4. As PRACH_HS_flag is *NO* and PRACH_Ncs is 1, the cyclic shifts N_{CS} is 13 according to Table 5.7.2-2[1].
   5. The number of preambles can be generated from the 783th root Zadoff-Chu sequence is floor(N_{ZC} / N_{CS}) = 64. As the PRACH_PrmbleIndex is 9, then v = 9, and cyclic shift is given by $C_v = vN_{CS}$ = 9*13.
10. See *LTE_RACH* (3gpplte), *LTE_RACH_SubcMapping* (3gpplte) and *LTE_RACH_HalfCarrierShift* (3gpplte).

For more information, please refer to *UL System Parameters* (3gpplte) and *UL PRACH Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. D.C. Chu, "Polyphase Codes With Good Periodic Correlation Properties", IEEE Transaction on Information Theory, pp. 531-532, July 1972.

LTE_RACH_SubcMapping (RACH Subcarrier Mapping)



Description: RACH subcarrier mapping
Library: LTE, Sync Signal

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
OversamplingOption	oversampling ratio option: Ratio_1, Ratio_2, Ratio_4, Ratio_8	Ratio_2	enum	
FrameNum	frame number	0	int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO	enum	
DFTSwap_Enable	PUSCH DFT swap is enable: NO, YES	NO	enum	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO	enum	
PRACH_Config	PRACH configuration index	0	int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}	int array	[0, 9]
PRACH_RBOffset	PRACH frequency offset, the first RB available for PRACH	0	int	[0, 94]

Pin Inputs

Pin	Name	Description	Signal Type
1	ZC	ZC sequence	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	MappingOut	sequence after subcarrier mapping	complex

Notes/Equations

1. This model implements the sub-carrier mapping for random access preamble sequence after DFT. The random access preamble sequence is mapped on to the allocated frequency resources.
2. Each firing,
   - the number of tokens consumed at port ZC is equal to the length of the Zadoff-Chu sequence in each frame. The preamble length is equal to 839 for preamble format 0 ~ 3 and 139 for preamble 4.
   - *DFTSize* * *NumPreamble* tokens are produced at port MappingOut, where *DFTSize* = *BaseDFTSize* * *OversamplingRate* = *SamplingFreq* / Δf_{RA} * $2^{OversamplingOption}$. *SamplingFreq* is denoted as F_s and determined by Bandwidth as follows:

Bandwidth	F_s
1.4 MHz	1.92 MHz
3.0 MHz	3.84 MHz
5.0 MHz	7.68 MHz
10.0 MHz	15.36 MHz
15.0 MHz	23.04 MHz
20.0 MHz	30.72MHz

   - For the default parameter configurations, *DFTSize* = 12288.
3. For frame structure type 1 with preamble format 0-3, there is at most one random

access resource per subframe. The first physical resource block n_{PRB}^{RA} allocated to the PRACH opportunity considered for preamble format 0, 1, 2 and 3 is defined as $n_{PRB}^{RA} = n_{PRBoffset}^{RA}$, where the parameter *prach-FrequencyOffset* $n_{PRBoffset}^{RA}$ is expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{PRABOffset}^{RA} \le N_{RB}^{UL} - 6$.

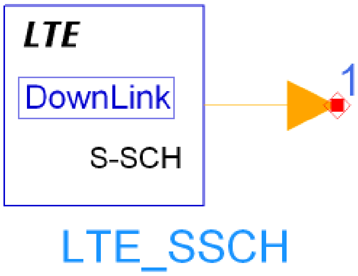
4. For frame structure type 2 with preamble format 0-4, there might be multiple random access resources in an UL subframe (or UpPTS for preamble format 4) depending on the UL/DL configuration [see table 4.2-2 [1]]. Table 5.7.1-3[1] lists PRACH configurations allowed for frame structure type 2 where the configuration index corresponds to a certain combination of preamble format, PRACH density value, D_{RA}, and version index, r_{RA}.
5. The random access opportunities for each PRACH configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value D_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to
$$n_{PRB}^{RA} = \begin{cases} n_{PRBoffset}^{RA} + 6\left\lfloor \frac{f_{RA}}{2} \right\rfloor, & \text{if } f_{RA} \bmod 2 = 0 \\ N_{RB}^{UL} - 6 - n_{PRBoffset}^{RA} - 6\left\lfloor \frac{f_{RA}}{2} \right\rfloor, & \text{otherwise} \end{cases}$$
, where N_{RB}^{UL} is the number of uplink resource blocks, n_{PRB}^{RA} is the first physical resource block allocated to the PRACH opportunity considered and where the parameter prach-FrequencyOffset $n_{PRBoffset}^{RA}$ is the first physical resource block available for PRACH expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{PRABOffset}^{RA} \le N_{RB}^{UL} - 6$..
6. For preamble format 4, the frequency multiplexing shall be done according to
$$n_{PRB}^{RA} = \begin{cases} 6 f_{RA}, & \text{if } \left((n_f \bmod 2) \times (2 - N_{SP}) + t_{RA}^{1}\right) \bmod 2 = 0 \\ N_{RB}^{UL} - 6(f_{RA} + 1), & \text{otherwise} \end{cases}$$
, where n_f is the system frame number and where N_F is the number of DL to UL switch points within the radio frame.
7. Each random access preamble occupies a bandwidth corresponding to 6 consecutive resource blocks for both frame structures.
8. It should be noted that the parameter DFTSwap_Enable should be set to **NO** according to the LTE specifications.
9. See *LTE_RACH* (3gpplte), *LTE_RACH_PrmGen* (3gpplte) and *LTE_RACH_HalfCarrierShift* (3gpplte).

For more information, please refer to *UL System Parameters* (3gpplte) and *UL PRACH Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_SSCH (S-SCH Generator)



Description: LTE downlink SSCH(M) Sequence generator
Library: LTE, Sync Signal

Parameters

Name	Description	Default	Type	Range
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0,2]
CellID_Group	the index of cell identity group	0	int	[0,167]

Pin Outputs

Pin	Name	Description	Signal Type
1	Out	Output	real

Notes/Equations

1. This model is used to generate 3GPP LTE S-SCH signal in frequency domain.
2. Sequence generation The sequence *d*(0), ..., *d*(61) used for the second synchronization signal is an interleaved concatenation of two length-31 binary sequences. The concatenated sequence is scrambled with a scrambling sequence given by the primary synchronization signal.
   The combination of two length-31 sequences defining the secondary synchronization signal differs between subframe 0 and subframe 5 according to

$$d(2n) = \begin{cases} s_0^{(m_0)}(n)c_0(n) & \text{in subframe } 0 \\ s_1^{(m_1)}(n)c_0(n) & \text{in subframe } 5 \end{cases}$$

$$d(2n+1) = \begin{cases} s_1^{(m_1)}(n)c_1(n)z_1^{(m_0)}(n) & \text{in subframe } 0 \\ s_0^{(m_0)}(n)c_1(n)z_1^{(m_1)}(n) & \text{in subframe } 5 \end{cases}$$

   where $0 \le n \le 30$. The indices and m_0, m_1 are derived from the physical-layer cell-identity group $N_{ID}^{(1)}$ according to

$$m_0 = m' \bmod 31$$

$$m_1 = \left(m_0 + \lfloor m'/31 \rfloor + 1\right) \bmod 31$$

$$m' = N_{\mathrm{ID}}^{(1)} + q(q+1)/2, \quad q = \left\lfloor \frac{N_{\mathrm{ID}}^{(1)} + q'(q'+1)/2}{30} \right\rfloor, \quad q' = \left\lfloor N_{\mathrm{ID}}^{(1)}/30 \right\rfloor$$

   where the output of the above expression is listed in the following table.

Mapping between physical-layer cell-identity group $N_{ID}^{(1)}$ and the indices m_0 and m_1.

$N_{ID}^{(1)}$	m_0	m_1	$N_{ID}^{(1)}$	m_0	m_1	$N_{ID}^{(1)}$	m_0	m_1	$N_{ID}^{(1)}$	m_0	m_1	$N_{ID}^{(1)}$	m_0	m_1
0	0	1	34	4	6	68	9	12	102	15	19	136	22	27
1	1	2	35	5	7	69	10	13	103	16	20	137	23	28
2	2	3	36	6	8	70	11	14	104	17	21	138	24	29
3	3	4	37	7	9	71	12	15	105	18	22	139	25	30
4	4	5	38	8	10	72	13	16	106	19	23	140	0	6
5	5	6	39	9	11	73	14	17	107	20	24	141	1	7
6	6	7	40	10	12	74	15	18	108	21	25	142	2	8
7	7	8	41	11	13	75	16	19	109	22	26	143	3	9
8	8	9	42	12	14	76	17	20	110	23	27	144	4	10
9	9	10	43	13	15	77	18	21	111	24	28	145	5	11
10	10	11	44	14	16	78	19	22	112	25	29	146	6	12
11	11	12	45	15	17	79	20	23	113	26	30	147	7	13
12	12	13	46	16	18	80	21	24	114	0	5	148	8	14
13	13	14	47	17	19	81	22	25	115	1	6	149	9	15
14	14	15	48	18	20	82	23	26	116	2	7	150	10	16
15	15	16	49	19	21	83	24	27	117	3	8	151	11	17
16	16	17	50	20	22	84	25	28	118	4	9	152	12	18
17	17	18	51	21	23	85	26	29	119	5	10	153	13	19
18	18	19	52	22	24	86	27	30	120	6	11	154	14	20
19	19	20	53	23	25	87	0	4	121	7	12	155	15	21
20	20	21	54	24	26	88	1	5	122	8	13	156	16	22
21	21	22	55	25	27	89	2	6	123	9	14	157	17	23
22	22	23	56	26	28	90	3	7	124	10	15	158	18	24
23	23	24	57	27	29	91	4	8	125	11	16	159	19	25
24	24	25	58	28	30	92	5	9	126	12	17	160	20	26
25	25	26	59	0	3	93	6	10	127	13	18	161	21	27
26	26	27	60	1	4	94	7	11	128	14	19	162	22	28
27	27	28	61	2	5	95	8	12	129	15	20	163	23	29
28	28	29	62	3	6	96	9	13	130	16	21	164	24	30
29	29	30	63	4	7	97	10	14	131	17	22	165	0	7
30	0	2	64	5	8	98	11	15	132	18	23	166	1	8
31	1	3	65	6	9	99	12	16	133	19	24	167	2	9
32	2	4	66	7	10	100	13	17	134	20	25			
33	3	5	67	8	11	101	14	18	135	21	26			

The two sequences $s_0^{(m_0)}(n)$ and $s_1^{(m_1)}(n)$ are defined as two different cyclic shifts of the m-sequence $\tilde{s}(n)$ according to

$$s_0^{(m_0)}(n) = \tilde{s}\left((n+m_0) \bmod 31\right)$$

$$s_1^{(m_1)}(n) = \tilde{s}\left((n+m_1) \bmod 31\right)$$

Where $\tilde{s}(i) = 1-2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = \left(x(\bar{i}+2)+x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 1$, $x(1) = 0$, $x(2) = 0$, $x(3) = 0$, $x(4) = 1$.

The two scrambling sequences $c_0(n)$ and $c_1(n)$ depend on the primary synchronization signal and are defined by two different cyclic shifts of the m-sequence $\tilde{c}(n)$ according to

$$c_0(n) = \tilde{c}((n+N_{ID}^{(2)}) \bmod 31)$$

$$c_1(n) = \tilde{c}((n+N_{ID}^{(2)}+3) \bmod 31)$$

where $N_{ID}^{(2)}$ is the physical-layer identity within the physical-layer cell identity group $N_{ID}^{(1)}$ and $\tilde{c}(i) = 1-2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = \left(x(\bar{i}+3)+x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 1$, $x(1) = 0$, $x(2) = 0$, $x(3) = 0$, $x(4) = 1$.

The scrambling sequence $z_1^{(m_0)}(n)$ and $z_1^{(m_1)}(n)$ are defined by a cyclic shift of the m-sequence $\tilde{z}(n)$ according to

$$z_1^{(m_0)}(n) = \tilde{z}((n+(m_0 \bmod 8)) \bmod 31)$$

$$z_1^{(m_1)}(n) = \tilde{z}((n+(m_1 \bmod 8)) \bmod 31)$$

where m_0 and m_1 are obtained from the table above and $\tilde{z}(i) = 1-2x(i)$, $0 \le i \le 30$, is defined by

$x(\bar{i}+5) = (x(\bar{i}+4) + x(\bar{i}+2) + x(\bar{i}+1) + x(\bar{i})) \bmod 2, \qquad 0 \le \bar{i} \le 25$

with initial conditions $x(0) = 1$, $x(1) = 0$, $x(2) = 0$, $x(3) = 0$, $x(4) = 1$.

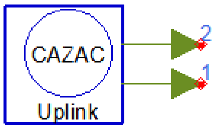
Parameter Details

- CellID_Sector: the index of cell identity within the physical-layer cell-identity group
- CellID_Group: index of cell identity group, its value range is [0,167].

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.

LTE_UL_CAZAC (Uplink CAZAC Sequence Generator)



Description: Uplink CAZAC sequence generator
Library: LTE, Sync Signal

Parameters

Name	Description	Default	Type	Range
FrameMode	frame mode: FDD, TDD	FDD	enum	
TDD_Config	downlink and uplink allocations for TDD: Config_0, Config_1, Config_2, Config_3, Config_4, Config_5, Config_6	Config_0	enum	
SpecialSF_Config	special subframe configuration for TDD: Config0, Config1, Config2, Config3, Config4, Config5, Config6, Config7, Config8	Config4	enum	
Bandwidth	Bandwidth: BW_1_4_MHz, BW_3_MHz, BW_5_MHz, BW_10_MHz, BW_15_MHz, BW_20_MHz	BW_5_MHz	enum	
CyclicPrefix	type of cyclic prefix: Normal, Extended	Normal	enum	
CellID_Sector	the index of cell identity within the physical-layer cell-identity group	0	int	[0, 2]
CellID_Group	the index of cell identity group	0	int	[0, 167]
FrameNum	frame number	0	int	[0, ∞)
FrameIncreased	frame number increasing or not: NO, YES	NO	enum	
DL_CyclicPrefix	type of cyclic prefix in downlink: DL_Normal, DL_Extended	DL_Normal	enum	
PUCCH_PUSCH	PUCCH and PUSCH selection: PUSCH, PUCCH, both	PUSCH	enum	
RB_AllocType	RB allocation type: StartRB_NumRBs, RB_indices_1D, RB_indices_2D	StartRB_NumRBs	enum	
RB_Alloc	the RB allocation for PUSCH, in the fomats of [start RB, number of RBs] or[SF0 start RB, SF0 number of RBs; ...; SF9 start RB, SF9 number of RBs]	{0, 25}	int array	
GroupHop_Enable	whether enable group hopping for DMRS on PUCCH and PUSCH or not: NO, YES	NO	enum	
SeqHop_Enable	whether enable sequence hopping for DMRS on PUSCH or not: NO, YES	NO	enum	
PUSCH_Delta_ss	used in determining the sequence-shift pattern for PUSCH	0	int	[0, 29]
PUSCH_n_DMRS1	used in computing the cyclic shift for PUSCH DMRS	{0}	int array	
PUSCH_n_DMRS2	used in computing the cyclic shift for PUSCH DMRS	{0}	int array	
PRACH_Enable	whether or not to enable PRACH: NO, YES	NO	enum	
PRACH_Config	PRACH configuration index	0	int	[0, 63]
PRACH_ResourceIndex	the PRACH Resource Index. In FDD, it indicates the subframe number where the preamble starts; in TDD, it indicates the preamble mapping in time and frequency	{1}	int array	[0, 9]
SRS_Enable	sounding reference symbol is enable: NO, YES	NO	enum	
SRS_BandwidthConfig	the cell-specific SRS bandwidth configuration	7	int	[0, 7]
SRS_SF_Config	the cell-specific SRS subframe configuration	0	int	[0, 14]
SRS_MaxUpPts	whether enable the reconfiguration of maximum m_SRS_0 or not: NO, YES	NO	enum	
SRS_Bandwidth	the UE-specific SRS bandwidth	0	int	[0, 3]
SRS_ConfigIndex	the UE-specific SRS configuration	0	int	[0, 1023]
SRS_CyclicShift	used in computing the cyclic shift of SRS	0	int	[0, 7]

Pin Outputs

Pin	Name	Description	Signal Type
1	RS_PUSCH	reference signal for PUSCH	complex
2	RS_S	sounding reference signal	complex

Notes/Equations

1. This model is used to generate demodulation reference signal associated with transmission of PUSCH and sounding reference signal.
2. Each firing, this model generates DMRS for PUSCH and SRS of one frame.
    - the number of tokens produced at port RS_PUSCH is equal to the number of DMRS symbols in each frame, which is determined by FrameMode, TDD_Config (in TDD mode), RBAlloc_Type and RB_Alloc, for more details, please refer to *Resource Block Allocation* (3gpplte). If PUSCH is not transmitted, 1 null token would be output.
    - the number of tokens produced at port RS_S is equal to the number of SRS symbols in each frame, which is determined by FrameMode, TDD_Config, SpecialSF_Config, Bandwidth, CyclicPrefix, DL_CyclicPrefix, SRS_Enable, SRS_BandwidthConfig, SRS_SF_Config, SRS_MaxUpPts (in TDD mode), SRS_Bandwidth, SRS_ConfigIndex, PRACH_Enable, PRACH_Config and PRACH_ResourceIndex. For more details, please refer to [1] and [2]. If SRS is not transmitted in this subframe, 1 null token would be output.
    - For the default parameter configurations, the number of DMRS symbols in each frame is 6000; SRS is not transmitted.
3. PUSCH_n_DMRS1 and PUSCH_n_DMRS2 are array parameters with each element indicating the $n_{DMRS}^{(1)}$ and $n_{DMRS}^{(2)}$ values in the corresponding subframe.
4. PRACH_Enable, PRACH_Config and PRACH_ResourceIndex are used in the reconfiguration of $m_{SRS,0}$ in SRS generation in TDD mode. $m_{SRS,0}$ shall be reconfigured to $m_{SRS,0}^{max} = \max_{cC}\{m_{SRS,0}^{c}\} \leq (N_{RB}^{UL} - 6\ N_{RA})$ if this reconfiguration is enabled by the cell specific parameter SRS_MaxUpPts, otherwise if the reconfiguration is disabled $m_{SRS,0}^{max} = m_{SRS,0}$, where *c* is a SRS BW configuration and C_{SRS} is the set of SRS BW configurations from the Tables 5.5.3.2-1 to 5.5.3.2-4 [1] for each uplink bandwidth N_{RB}^{UL}, N_{RA} is the number of format 4 PRACH in the addressed UpPTS and derived from Table 5.7.1-4 [1]. N_{RA} is calculated from the PRACH parameters PRACH_Config and PRACH_ResourceIndex when PRACH_Enable is *YES*, otherwise N_{RA} equals 0.

> - For more information on system parameters, please refer to *UL System Parameters* (3gpplte).
> - For more information on PUSCH Parameters, please refer to *UL PUSCH Parameters* (3gpplte).
> - For more information on SRS Parameters, please refer to *UL SRS Parameters* (3gpplte).

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.

3GPP LTE Wireless Design Library

The Agilent EEsof EDA 3GPP LTE Wireless Design Library is provided for the 3GPP long term evolution (LTE) market. This design library follows the 3GPP TS 36.211 V8.9.0(December 2009), 3GPP TS 36.212 v8.8.0 (December 2009) and 3GPP TS 36.213 v8.8.0 (December 2009). The 3GPP LTE Design Library is intended to be a baseline system for designers to develop an idea of what nominal or ideal system performance would be. Evaluations can be made regarding degraded system performance due to system impairments that may include non-ideal component performance.

3GPP LTE System

In 3GPP LTE system, downlink and uplink transmissions are organized into radio frames with 10 ms duration. Two radio frame structures are supported:

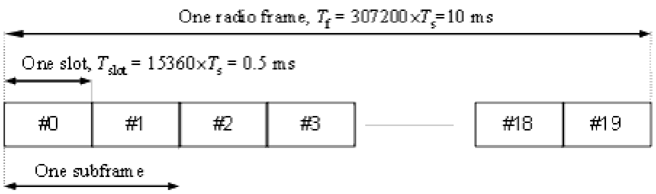
- Type 1, applicable to FDD LTE,
- Type 2, applicable to TDD LTE.

Frame Structure Type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \times T_s = 10ms$ long and consists of 20 slots of length $T_{slot} = 15360 \times T_s = 0.5ms$, numbered from 0 to 19 (see the following figure). A subframe is defined as two consecutive slots where subframe i consists of slots 2i and 2i_1.

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

Figure: Frame structure type 1



Frame Structure Type 2

Frame structure type 2 is applicable to TDD. Each radio frame of length $T_f = 307200 \times T_s = 10ms$ consists of two half-frames of length $T_f = 153600 \cdot T_s = 5\,\text{ms}$ each. Each half-frame consists of eight slots of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$ and three special fields, DwPTS, GP, and UpPTS. The length of DwPTS and UpPTS is given by Table 1 subject to the total length of DwPTS, GP and UpPTS being equal to $30720 \cdot T_s = 1\,\text{ms}$. Subframe 1 in all configurations and subframe 6 in configurations 0, 1, 2 and 6 in Table 2 consists of DwPTS, GP and UpPTS. All other subframes are defined as two slots where subframe i consists of slots 2i and 2i_1.

Subframes 0 and 5 and DwPTS are always reserved for downlink transmission.

The supported uplink-downlink allocations are listed in Table 2 where, for each subframe in a radio frame, "D" denotes the subframe is reserved for downlink transmissions, "U" denotes the subframe is reserved for uplink transmissions and "S" denotes a special subframe with the three fields DwPTS, GP and UpPTS. Both 5 ms and 10 ms switch-point periodicity is supported.

In case of 5 ms switch-point periodicity, UpPTS and subframes 2 and 7 are reserved for uplink transmission.
In case of 10 ms switch-point periodicity, DwPTS exist in both half-frames while GP and UpPTS only exist in the first half-frame and DwPTS in the second half-frame has a length equal to $30720 \cdot T_s = 1\,\text{ms}$. UpPTS and subframe 2 are reserved for uplink transmission and subframes 7 to 9 are reserved for downlink transmission.

Figure: Frame structure type 2

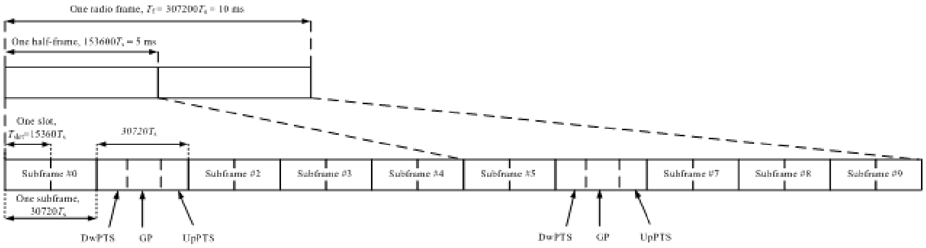


Table 1: Lengths of DwPTS/GP/UpPTS

Configuration	Normal cyclic prefix			Extended cyclic prefix		
	DwPTS	GP	UpPTS	DwPTS	GP	UpPTS
0	$6592 \cdot T_s$	$21936 \cdot T_s$	$2192 \cdot T_s$	$7680 \cdot T_s$	$20480 \cdot T_s$	$2560 \cdot T_s$
1	$19760 \cdot T_s$	$8768 \cdot T_s$		$20480 \cdot T_s$	$7680 \cdot T_s$	
2	$21952 \cdot T_s$	$6576 \cdot T_s$		$23040 \cdot T_s$	$5120 \cdot T_s$	
3	$24144 \cdot T_s$	$4384 \cdot T_s$		$25600 \cdot T_s$	$2560 \cdot T_s$	
4	$26336 \cdot T_s$	$2192 \cdot T_s$		$7680 \cdot T_s$	$17920 \cdot T_s$	$5120 \cdot T_s$
5	$6592 \cdot T_s$	$19744 \cdot T_s$	$4384 \cdot T_s$	$20480 \cdot T_s$	$5120 \cdot T_s$	
6	$19760 \cdot T_s$	$6576 \cdot T_s$		$23040 \cdot T_s$	$2560 \cdot T_s$	
7	$21952 \cdot T_s$	$4384 \cdot T_s$		-	-	-
8	$24144 \cdot T_s$	$2192 \cdot T_s$		-	-	-

Table 2: Uplink-downlink allocations

Configuration	Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	10 ms	D	S	U	U	U	D	S	U	U	D

OFDMA

The downlink transmission scheme (OFDMA) is based on conventional OFDM using a cyclic prefix, with a sub-carrier spacing $\Delta f = 15$ kHz and a cyclic-prefix (CP) duration $T_{CP} \approx 4.7/16.7$ μ (Normal/Extended CP). Assuming that a 10 ms radio frame is divided into 20 equally sized slots, this parameter set implies a slot duration T_{slot} = 0.5 μ . The basic transmission parameters are then specified in more detail in the following table:

Parameters for Downlink Transmission Scheme

Transmission BW		1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration		1.0 ms					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 x 3.84 MHz)	3.84 MHz	7.68 MHz (2 x 3.84 MHz)	15.36 MHz (4 x 3.84 MHz)	23.04 MHz (6 x 3.84 MHz)	30.72 MHz (8 x 3.84 MHz)
FFT size		128	256	512	1024	1536	2048
Number of Resource Blocks		6	15	25	50	75	100
Number of occupied sub-carriers		73	181	301	601	901	1201
Number of OFDM symbols per sub-frame (Normal/Extended CP)		7/6					
CP length (μ/samples)	Normal †	(4.69/9) x 6, (5.21/10) x 1	(4.69/18) x 6, (5.21/20) x 1	(4.69/36) x 6, (5.21/40) x 1	(4.69/72) x 6, (5.21/80) x 1	(4.69/108) x 6, (5.21/120) x 1	(4.69/144) x 6, (5.21/160) x 1
	Extended	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)
† In one slot, the first OFDM symbol has longer CP length and other 6 OFDM symbols have shorter CP length when Normal CP.							

Physical channels

A downlink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 36.212 and 36.211. The following downlink physical channels are defined:

- Physical Downlink Shared Channel, PDSCH
- Physical Broadcast Channel, PBCH
- Physical Multicast Channel, PMCH
- Physical Control Format Indicator Channel, PCFICH
- Physical Downlink Control Channel, PDCCH
- Physical Hybrid ARQ Indicator Channel, PHICH

Physical signals

A downlink signal corresponds to a set of resource elements used by the physical layer but does not carry information originating from higher layers. The following downlink physical signals are defined:

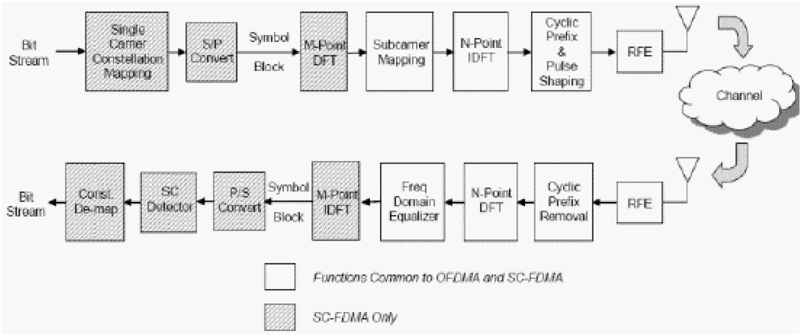
- Reference signal
- Synchronization signal

SC-FDMA

LTE uplink requirements differ from downlink requirements in several ways. Not surprisingly, power consumption is a key consideration for UE terminals. The high PAPR and related loss of efficiency associated with OFDM signaling are major concerns. As a result, an alternative to OFDM was sought for use in the LTE uplink.

Single Carrier - Frequency Domain Multiple Access (SC-FDMA) is well suited to the LTE uplink requirements. The basic transmitter and receiver architecture is very similar (nearly identical) to OFDMA, and it offers the same degree of multipath protection. Importantly, because the underlying waveform is essentially single-carrier, the PAPR is lower.

Structure for OFDMA/SC-FDMA



Physical channels

An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 36.212 and 36.211. The following uplink physical channels are defined:

- Physical Uplink Shared Channel, PUSCH
- Physical Uplink Control Channel, PUCCH
- Physical Random Access Channel, PRACH

Physical signals

An uplink physical signal is used by the physical layer but does not carry information originating from higher layers. The following uplink physical signals are defined:

- Reference signal
- Sounding reference signal

3GPP LTE Library

EEsof ADS 3GPP LTE library can support both FDD-LTE and TDD-LTE. It includes 113 components and 20 test benches.

Component Libraries

This 3GPP LTE Wireless Design Library is organized by the types of behavioral models and subnetworks.

Channel Coding Components:
The channel coding components are for both downlink and uplink channel codec as mentioned below:

- LTE_CRCDecoder: LTE CRC Decoder
- LTE_CRCEncoder: LTE CRC Encoder
- LTE_CodeBlkDeseg: LTE code block de-segmentation
- LTE_CodeBlkSeg: LTE code block segmentation
- LTE_ConvCoder: LTE Convolutional Coder
- LTE_DL_ChannelCoder: LTE Downlink Channel Coder
- LTE_DL_ChannelDecoder: LTE Downlink Channel Decoder
- LTE_DeScrambler: LTE downlink and uplink de-scrambler
- LTE_RateDematch: LTE downlink and uplink rate dematching
- LTE_RateMatch: LTE downlink and uplink SCH rate matching
- LTE_Scrambler: LTE downlink and uplink scrambler
- LTE_TurboCoder: LTE turbo encoder
- LTE_TurboDecoder: LTE turbo decoder
- LTE_UL_ChannelCoder: LTE Uplink Channel Coder
- LTE_UL_ChannelDecoder: LTE Uplink Channel Decoder
- LTE_UL_ChInterleaver: LTE Uplink Channel Interleaver
- LTE_UL_ChDeinterleaver: LTE Uplink Channel De-Interleaver
- LTE_UL_ControlInfoEncoder: LTE Uplink Control Information Coder

Channel Model Components:
The ITU physical channel model, LTE channel model and MIMO channel model are provided. The models are listed below:

- LTE_Channel_ITU: ITU Downlink EVM Channel Model
- LTE_Channel: LTE Channel Model
- LTE_MIMO_Channel: LTE MIMO Channel Model

MIMO Precoder Components:
MIMO precoding/de-precoding, layer mapper/demapper models for downlink transmit diversity and spatial multiplexing are provided. The models are listed below:

- LTE_DL_MIMO_Deprecoder: Downlink MIMO De-precoder
- LTE_DL_MIMO_LayDemapDeprecoder: Downlink MIMO Layer Demapper and De-precoder
- LTE_DL_MIMO_LayMapPrecoder: Downlink MIMO Layer mapper and Precoder
- LTE_DL_MIMO_LayerDemapper: Downlink MIMO Layer Demapper
- LTE_DL_MIMO_LayerMapper: Downlink MIMO Layer Mapper
- LTE_DL_MIMO_Precoder: Downlink MIMO Precoder
- LTE_PHICH_Deprecoder: Downlink MIMO De-precoder
- LTE_PHICH_LayDemapDeprecoder: PHICH MIMO Layer Demapper and De-precoder
- LTE_PHICH_LayMapPrecoder: PHICH MIMO Layer mapper and Precoder
- LTE_PHICH_LayerDemapper: PHICH MIMO Layer Demapper
- LTE_PHICH_LayerMapper: PHICH MIMO Layer Mapper
- LTE_PHICH_Precoder: PHICH MIMO Precoder

Measurement Components:
The measurement models provide basic measurements for both FDD/TDD downlink and uplink, such as EVM and CCDF. The models are listed below:

- LTE_BER_FER: LTE Bit Error Rate and Frame Error Rate measurement
- LTE_DL_EVM: Downlink EVM Measurement with RF De-modulator
- LTE_RF_CCDF: CCDF Measurement
- LTE_RF_CM: Cubic Metric (CM) Measurement

- LTE_UL_EVM: Uplink EVM (RCE) Measurement

Modulation Components:
The modulation models provide mapping/demapping, OFDM modulation/demodulation, SCFDMA modulation/demodulation both downlink and uplink. The models are listed below:

- LTE_Demapper: QPSK, 16-QAM and 64-QAM De-mapper
- LTE_DL_OFDM_Demodulator: Downlink OFDM De-modulator
- LTE_DL_OFDM_Modulator: Downlink OFDM Modulator
- LTE_FFT: Complex Fast Fourier Transform
- LTE_Mapper: QPSK, 16-QAM and 64-QAM Mapper
- LTE_MIMO_Mapper: MIMO Mapper
- LTE_PHICH_Demodulator: PHICH De-modulator
- LTE_PHICH_Modulator: PHICH Modulator
- LTE_SCFDMA_Demodulator: SCFDMA De-modulator
- LTE_SCFDMA_Modulator: SCFDMA Modulator
- LTE_SpecShaping: Spectrum Shaping
- LTE_SS_MIMO_Demod: MIMO Demodulation for Synchronization Signals (PSCH and SSCH)
- LTE_UL_DFT: Uplink Complex Discrete Fourier Transform

Multiplex Components:
The multiplex models provide OFDM/SCFDMA symbol multiplexing/de-multiplexing, DL/UL framing/de-framing for DL/UL transceiver. The models are listed below:

- LTE_BusFork2: Copy particles from an input bus to each output bus
- LTE_DL_DemuxFrame: Downlink Radio Frame De-multiplexer with Frequency Offset Compensator
- LTE_DL_DemuxOFDMSym: Downlink OFDM Symbol De-multiplexer in one Radio Frame
- LTE_DL_DemuxSlot: Downlink Slot De-multiplexer
- LTE_DL_MIMO_DemuxCIR: Downlink Channel Impulse Response de-multiplexer in one Radio Frame
- LTE_DL_MuxFrame: Downlink Radio Frame Multiplexer
- LTE_DL_MuxOFDMSym: Downlink OFDM Symbol Multiplexer in one Radio Frame
- LTE_DL_MuxSlot: Downlink Slot Multiplexer
- LTE_UL_DemuxFrame: Uplink Radio Frame De-multiplexer with Frequency Offset Compensator
- LTE_UL_DemuxSCFDMASym: Uplink SC-FDMA Symbol De-multiplexer in one Radio Frame
- LTE_UL_DemuxSlot: Uplink Slot De-multiplexer
- LTE_UL_MuxFrame: Uplink Radio Frame Multiplexer
- LTE_UL_MuxSCFDMASym: Uplink SC-FDMA symbol multiplexer
- LTE_UL_MuxSlot: Uplink Slot Multiplexer

Receiver Components:
The receiver models are for both downlink and uplink receivers.

- LTE_DL_MIMO_2Ant_Rcv_RF: Downlink RF MIMO Receivers with 2 Rx Antennas
- LTE_DL_MIMO_4Ant_Rcv_RF: Downlink RF MIMO Receivers with 4 Rx Antennas
- LTE_DL_MIMO_Rcv: Downlink Baseband MIMO Receiver
- LTE_DL_Receiver: Downlink Baseband Receiver
- LTE_DL_Receiver_RF: Downlink Receiver with RF De-modulator
- LTE_UL_Receiver: Uplink Baseband Receiver
- LTE_UL_Receiver_RF: Uplink Receiver with RF De-modulator

Signaling Components:
The Signaling models are provided for downlink and uplink control channels.

- LTE_BCH_Gen: PBCH Information Bits Generator
- LTE_DL_CFI: Downlink Control Format Indicator
- LTE_DL_DCI_CRC: Downlink Control Information CRC Encoder
- LTE_DL_DCI_Gen: Downlink Control Information Generator
- LTE_DL_DCI_RateMatch: Downlink Control Information Rate Matcher
- LTE_DL_HI: HARQ ACK/NACK generator in one radio frame
- LTE_PBCH_CRC: PBCH CRC Encoder
- LTE_PBCH_RateMatch: PBCH Rate Matcher
- LTE_PBCH_Scrambler: PBCH Scrambler
- LTE_PCFICH_Scrambler: PCFICH Scrambler

- LTE_PDCCH_Interleaver: PDCCH Interleaver
- LTE_PDCCH_Mux: PDCCH Multiplexer
- LTE_PDCCH_Scrambler: PDCCH Scrambler
- LTE_UL_PUCCH: PUCCH Generator

Source Components:
These models are provided downlink and uplink sources.

- LTE_DL_MIMO_2Ant_Src: Downlink baseband 2 antennas MIMO signal source
- LTE_DL_MIMO_2Ant_Src_RF: Downlink RF 2 antennas MIMO signal source
- LTE_DL_MIMO_4Ant_Src: Downlink baseband 4 antennas MIMO signal source
- LTE_DL_MIMO_4Ant_Src_RF: Downlink RF 4 antennas MIMO signal source
- LTE_DL_Src: Downlink Baseband Signal Source
- LTE_DL_Src_RF: Downlink Signal Source with RF Modulator
- LTE_UL_Src: Uplink Baseband Signal Source
- LTE_UL_Src_RF: Uplink Signal Source with RF Modulator
- LTE_DL_TestModel_FDD: E-URTA Test Model for FDD
- LTE_DL_TestModel_TDD: E-URTA Test Model for TDD

Sync Equalization Components:
Sync Equalization models provide timing/frequency synchronization, channel estimation and etc for downlink and uplink receiver.

- LTE_DL_ChEstimator: Downlink Channel Estimator and InterpolatorLTE_DL_TimeFreqSync
- LTE_DL_MIMO_FrameSync: Downlink Timing and Frequency Synchronizer in Time Domain
- LTE_DL_MIMO_FreqSync: Downlink Timing and Frequency Synchronizer in Frequency Domain
- LTE_DL_TimeFreqSync: Downlink Timing and Frequency Synchronizer
- LTE_IQ_Offset: Uplink IQ Offset Compensator
- LTE_UL_ChEstimator: Uplink Channel Estimator and Interpolator
- LTE_UL_FrameSync: Uplink Timing and Frequency Synchronizer in Time Domain
- LTE_UL_FreqSync: Uplink Timing and Frequency Synchronizer in Frequency Domain
- LTE_UL_TimeFreqSync: Uplink Timing and Frequency Synchronizer

Sync Signal Components:
These models are provided for timing/frequency synchronization and channel estimation for both downlink and uplink.

- LTE_DL_Pilot: Downlink Pilot Generator
- LTE_PSCH: P-SCH Generator
- LTE_RACH: Uplink Non-synchronized Random Access Channel Generator
- LTE_RACH_HalfCarrierShift: PRACH Half carrier shift
- LTE_RACH_PrmGen: RACH Preamble Generator
- LTE_RACH_SubcMapping: RACH Subcarrier Mapper
- LTE_SSCH: Secondary Synchronization Channel Generator.
- LTE_UL_CAZAC: Uplink CAZAC Sequence Generator

Design Examples

This 3GPP LTE Wireless Design Library includes several design examples for LTE downlink/uplink transmitter measurement, downlink/uplink coded BER on fading channel, TDD LTE transmitter and receiver measurement. Eight workspaces (LTE_DL_TestModel_FDD_wrk, LTE_DL_TestModel_TDD_wrk, LTE_FDD_DL_Tx_wrk, LTE_FDD_DL_Rx_wrk, LTE_FDD_UL_Tx_wrk, LTE_FDD_UL_Rx_wrk, LTE_TDD_Tx_wrk and LTE_TDD_Rx_wrk) are provided in this 3GPP LTE design library.

LTE_DL_TestModel_FDD_wrk:
The LTE_DL_TestModel_FDD_wrk workspace provides E-UTRA Test Models for the 3GPP FDD LTE downlink system following 3GPP TS 36.141 V8.5.0(2009-12). The E-TM1.1, E-TM1.2, E-TM2, E-TM3.1, E-TM3.2 and E-TM3.3 are supported. The bandwidth 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz are all supported. The example links the test model with Agilent VSA89601 software.

- LTE_DL_TestModel_FDD_Tx: FDD Downlink test model connected with 89600 VSA software

LTE_DL_TestModel_TDD_wrk:
The LTE_DL_TestModel_TDD_wrk workspace provides E-UTRA Test Models for the 3GPP TDD LTE downlink system following 3GPP TS 36.141 V8.2.0(2009-03). The E-TM1.1, E-TM1.2, E-TM2, E-TM3.1, E-TM3.2 and E-TM3.3 are supported. The bandwidth 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz are all supported. The example links the test model with Agilent VSA89601 software.

- LTE_DL_TestModel_TDD_Tx: TDD Downlink test model connected with 89600 VSA software

LTE_FDD_DL_Rx_wrk:
This workspace provides receiver measurement examples for the 3GPP FDD LTE downlink system. Test benches for SISO, SIMO and MIMO BER/BLER on fading channel are provided.

- LTE_DL_Fading_BER: FDD Downlink BER and BLER on Fading channel
- LTE_DL_MIMO_2x2_Fading_BER: FDD Downlink MIMO 2x2 BER and BLER on Fading channel
- LTE_DL_SIMO_1x2_Fading_BER: FDD Downlink SIMO 1x2 BER and BLER on Fading channel

LTE_FDD_DL_Tx_wrk:
This workspace provides tyransmitter design examples for the 3GPP FDD LTE downlink system. The EVM, spectrum, link with Agilent VSA89601 software and etc are provided.

- LTE_DL_VSA: FDD Downlink transmitter connected with 89600 VSA software
- LTE_DL_TxSpectrum: FDD Downlink transmitter spectrum and CCDF measurements
- LTE_DL_TxEVM: FDD Downlink transmitter EVM measurement
- LTE_DL_MIMO_2x2_TxEVM: FDD Downlink 2x2 MIMO transmitter EVM measurement
- LTE_DL_MIMO_2Ant_VSA: FDD Downlink 2Ant transmitter connected with 89600 VSA software

LTE_FDD_UL_Rx_wrk:
This workspace provides receiver measurement examples for the 3GPP FDD LTE uplink system. Test benches on AWGN and fading channel are provided.

- LTE_UL_AWGN_BER: Uplink FDD coded BER and PER Measurement on AWGN Channel
- LTE_UL_Fading_BER: Uplink FDD coded BER and PER Measurement on fading Channel

LTE_FDD_UL_Tx_wrk:
This workspace provides transmitter design examples for the 3GPP FDD LTE uplink system. The transmitter measurements include constellation, spectrum, and CCDF as well as other measurements.

- LTE_UL_TxEVM: FDD Uplink Tx EVM, constellation measurements
- LTE_UL_TxSpectrum: Uplink Tx spectrum, CCDF and in-band emission measurements
- LTE_UL_VSA: Uplink transmitters connected with 89600 VSA software

LTE_TDD_Rx_wrk:
This workspace provides downlink and uplink receiver design examples for the 3GPP TDD System. The receiver measurements include TDD uplink BER/BLER on AWGN, TDD Downlink SISO, SIMO and MIMO BER/BLER on AWGN and fading channel.

- LTE_TDD_DL_AWGN_BER: TDD DL AWGN BER/BLER measurements
- LTE_TDD_UL_AWGN_BER: TDD UL AWGN BER/BLER measurements
- LTE_TDD_DL_1x2_Fading_BER: TDD DL SIMO 1x2 BER and BLER on Fading Channel
- LTE_TDD_DL_4x2_Fading_BER: TDD DL MIMO 4x2 BER and BLER on Fading Channel

LTE_TDD_Tx_wrk:
This workspace provides transmitter design examples for the 3GPP TDD LTE system. The transmitter measurements include constellation, spectrum, and CCDF as well as other measurements.

- LTE_TDD_DL_TxEVM: TDD Downlink transmitter EVM measurement
- LTE_TDD_UL_TxEVM: TDD Uplink transmitter EVM measurement
- LTE_TDD_DL_4Ant_TxSpectrum: TDD DL 4 antennas transmitter spectrum and CCDF measurements

Array Parameter Overview

The array parameters in ADS LTE WL are quite flexible which support multiple array sizes. These parameters can be roughly divided into two categories: subframe-related and UE-related.

The following table lists all array parameters in DL.

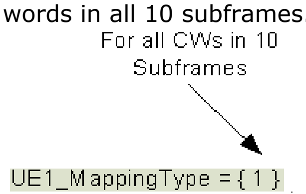
Parameter	Parameter type	Allowable input sizes
UEs_MIMO_Mode	UEs-related	6x1
UEs_CDD_Mode	UEs-related	6x1
UEs_CdBlk_Index	UEs-related	6x1
UEs_NumOfCWs	UEs-related	6x1
UEs_NumOfLayers	UEs-related	6x1
OtherUEs_MappingType	UEs-related	5x1, 5x2
UEs_Pa	UEs-related	6x1
UE1_Payload	Subframes-related	1x1, 2x1, 10x1, 10x2
UE1_MappingType	Subframes-related	1x1, 2x1, 10x1, 10x2
UE1_RB_Alloc	subframes-related	2x1, 10x2 when RB_AllocType=StartRB + NumRBs
PDCCH_SymsPerSF	subframes-related	1x1, 10x1
PDCCH_UE_AggreLevel	subframes-related	1x1, 10x1
PDCCH_Common_AggreLevel	subframes-related	1x1, 10x1
PDCCH_UE_DCI_Formats	subframes and DCIs-related	Nx1, 10xN, where N is max number of UE-Specific PDCCHs in one subframe and 10 the the number of subframe in one radio frame
PDCCH_Common_DCI_Formats	subframes and DCIs-related	4x1, 10x4, where 4 is max number of Common PDCCHs in one subframe and 10 the the number of subframe in one radio frame
UE_n_RNTI	subframes and DCIs-related	1, 10x1, 10xN, where N is max number of PDCCHs in one subframe and 10 the the number of subframe in one radio frame
HI	subframes-related	1x1, 10x1, Nx1, 10xN, where N is number of PHICHs per PHICH group
UE2_RB_Alloc	subframes-related	2x1, 10x2 when RB_AllocType=StartRB + NumRBs
UE3_RB_Alloc	subframes-related	2x1, 10x2 when RB_AllocType=StartRB + NumRBs
UE4_RB_Alloc	subframes-related	2x1, 10x2 when RB_AllocType=StartRB + NumRBs
UE5_RB_Alloc	subframes-related	2x1, 10x2 when RB_AllocType=StartRB + NumRBs
UE6_RB_Alloc	subframes-related	2x1, 10x2 when RB_AllocType=StartRB + NumRBs

The following table lists all array parameters in UL.

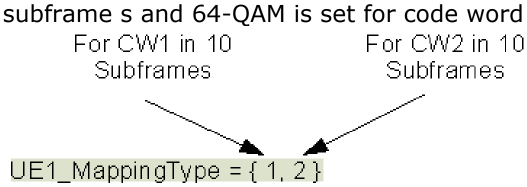
Parameter	Parameter type	Allowable input sizes
Payload	subframes-related	1 × 1, 10 × 1
NumChBits	subframes-related	1 × 1, 10 × 1
MappingType	subframes-related	1 × 1, 10 × 1
RB_Alloc	subframes-related	1 × 1, 10 × 1 when RB_AllocType=StartRB + NumRBs
PUSCH_n_DMRS2	subframes-related	1 × 1, 10 × 1
PUCCH_SF_Alloc	subframes-related	N × 1, where N is the number of subframes in which PUCCH is transmitted
PRACH_Mapping	subframes-related	N × 1, where N is the number of PRACH opportunities in one frame
PRACH_PrmbleIndex	subframes-related	N × 1, where N is the number of PRACH opportunities in one frame
RI_NumInfoBits	subframes-related	1 × 1, 10 × 1
RI_NumCodedSyms	subframes-related	1 × 1, 10 × 1
CQI_NumInfoBits	subframes-related	1 × 1, 10 × 1
CQI_NumCodedSyms	subframes-related	1 × 1, 10 × 1
HARQACK_NumInfoBits	subframes-related	1 × 1, 10 × 1
HARQACK_NumCodedSyms	subframes-related	1 × 1, 10 × 1
Sym_StartPos	-	2 × 1

For subframe-related parameters, the allowable array sizes are 1x1, 2x1, 10x1, 10x2 and 10xN, where N is the number of independent items in each subframe. The corresponding values in the 10 subframes (one radio frame) for each code word can be gotten regardless of the actual size of the array parameters.
In the following, the parameter UE1_MappingType, which defines the modulation (0 means QPSK, 1 means 16-QAM and 2 means 64-QAM) for PDSCH 1 (UE1), is taken as an example to illustrate the meanings for different array sizes.

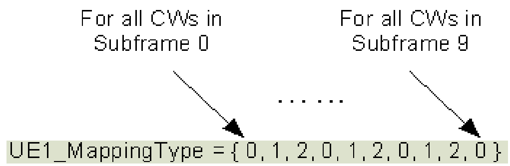
- Array size is 1x1
  When the array size is 1x1, the modulation orders for all code words in all 10 subframes are the same. The number of code words can be up to 2 in DL and be fixed to 1 in UL. In the example shown in the figure below, 16-QAM is set for all code words in all 10 subframes.



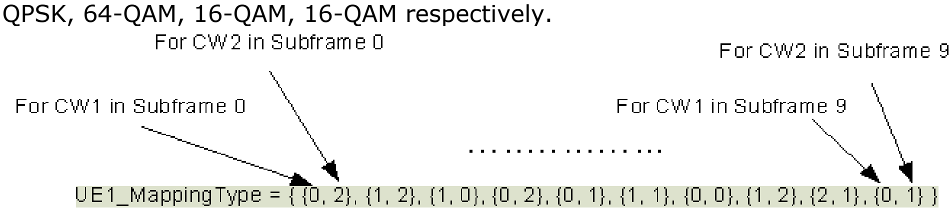
- Array size is 2x1
  Array size 2x1 is only applicable to the case that two code words are set in DL. The first value is for code word 1 in all 10 subframes, and the second is for code word 2. In the example shown in the figure below, 16-QAM is set for code word 1 in all 10 subframe s and 64-QAM is set for code word 2.



- Array size is 10x1
  When the array size is 10x1, the modulation orders for each subframe are different, while the modulation orders for the two code words in DL remain the same. In the example shown in the figure below, the modulation orders for code words in 10 subframe s are QPSK, 16-QAM, 64-QAM, QPSK, 16-QAM, 64-QAM, QPSK, 16-QAM, 64-QAM, QPSK respectively.



- Array size is 10x2
  Array size 2x1 is only applicable to the case that two code words are set in DL, in which the modulation order for each code word in each subframe is defined independently. In the example shown in the figure below, the modulation orders for code word 1 in 10 subframe s are QPSK, 16-QAM, 16-QAM, QPSK, QPSK, 16-QAM, QPSK, 16-QAM, 64-QAM, QPSK respectively, and the modulation orders for code word 2 in 10 subframes are 64-QAM, 64-QAM, QPSK, 64-QAM, 16-QAM, 16-QAM, QPSK, 64-QAM, 16-QAM, 16-QAM respectively.



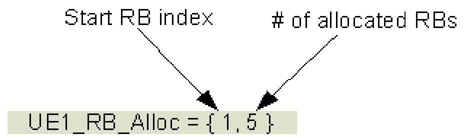
- Array size is Nx1
  Array size 10xN is only applicable to the following parameters: PDCCH_UE_DCI_Formats, PDCCH_Common_DCI_Formats and HI. Where N=6, 7, 8, 9, 10, represents the maximum number of UE-Specific PDCCH candidates; N=4, represents the maximum number of Common PDCCH candidates. And for HI where N represents the maximum number of PHICHs per PHICH group (8 for Normal CP and 4 for extended CP). In this method, the setting for each one of N is defined independently, while each one of N in all 10 subframes remains the same. Set the corresponding value to -1 if users want to disable the transmission of PHICHs.
- Array size is 10xN
  Array size 10xN is only applicable to the following parameters: PDCCH_UE_DCI_Formats, PDCCH_Common_DCI_Formats and HI. Where N=6, represents the maximum number of UE-Specific PDCCH candidates; N=4, represents the maximum number of Common PDCCH candidates; and N, represents the number of PHICHs per PHICH group in 10 subframes respectively. In this methods, the setting for each one of N in each subframe is defined independently. Set the corresponding value to -1 if users want to disable the transmission of UE-Specific and Common PDCCHs, DCIs or PHICHs.
  PDCCH_UE_DCI_Formats and PDCCH_Common_DCI_Formats, for each subframe, if the aggregation level is set to L, the number of PDCCH candidates is M_L, and so the first M_L elements of the Mmax elements are active. -1 means no DCI (PDCCH) in correspoding candidate. Refer to Table 9.1.1-1 in 9.1.1 of 36213-880.
  Note that, for TDD (frame structure type2), the values in the subframes allocated to UL for all subframe-related parameters are ignored and discarded in ADS LTE WL.

For UE-related parameters, the allowable array sizes are Nx1 and Nx2, where N is the number of UEs, 2 is for the case of two code words.

Resource Block (RB) Allocation

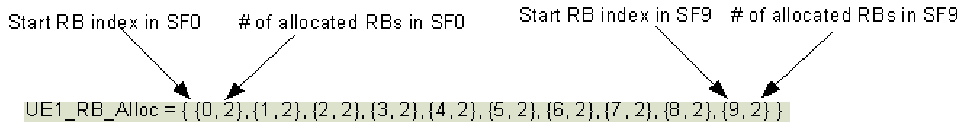
In ADS LTE WL, three methods are defined for setting resource block allocation in both DL and UL. The parameter RB_AllocType specifies the allocation method. The parameters UEx_RB_Alloc (x is 1~6) in DL specify the RB allocation for UE1 to UE6; the parameter RB_Alloc in UL specifies the RB allocation for PUSCH.

- RB_AllocType = StartRB + NumRBs
  In this method, the parameters UEx_RB_Alloc (x is 1~6) in DL and RB_Alloc in UL are subframe-related with allowable sizes of 2x1 and 10x2.
  - When the size is 2x1, the RB allocation in all 10 subframes is the same. The first value represents the start RB index allocated to the UE in all 10 subframes; the second represents the number of allocated RBs in all 10 subframes. An example is shown in the following figure:



In this example, the allocated RB indices in all 10 subframes are 1, 2, 3, 4, 5.

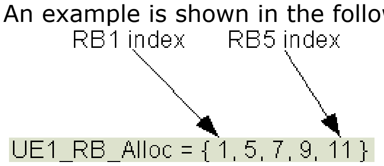
- When the size is 10x2, the RB allocation in each subframes are set independently. An example is shown in the following figure:



In this example, the allocated RB indices in the 10 subframes are:

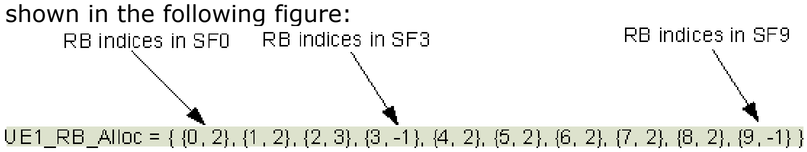
Subframe Index	Allcoated RB Indices
Subframe 0	0, 1
Subframe 1	1, 2
Subframe 2	2, 3
Subframe 3	3, 4
Subframe 4	4, 5
Subframe 5	5, 6
Subframe 6	6, 7
Subframe 7	7, 8
Subframe 8	8, 9
Subframe 9	9, 10

- RB_AllocType = RB indices (1D)
  In this method, the values in the parameters UEx_RB_Alloc (x is 1~6) in DL and RB_Alloc in UL represent allocated RB indices in all 10 subframes. The RB allocation in all 10 subframes is the same.
  An example is shown in the following figure:



In this example, the allocated RB indices in all 10 subframes are 1, 5, 7, 9, 11.

- RB_AllocType = RB indices (2D)
  In this method, the values in the parameters UEx_RB_Alloc (x is 1~6) in DL and RB_Alloc in UL represent allocated RB indices in all 10 subframes. An example is shown in the following figure:



Note that the size of RB indices in each subframe should be the same. If the actual size in each subframe varies across the 10 subframes, set the allocated size to the maximum size in the 10 subframes and set the rest indices to -1 in the subframes whose size is less than the maximum size.
In this example, the allocated RB indices in the 10 subframes are:

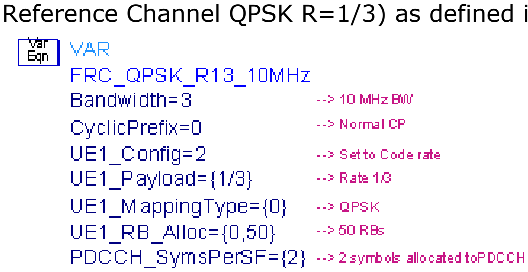
Subframe Index	Allcoated RB Indices
Subframe 0	0, 2
Subframe 1	1, 2
Subframe 2	2, 3
Subframe 3	3
Subframe 4	4, 2
Subframe 5	5, 2
Subframe 6	6, 2
Subframe 7	7, 2
Subframe 8	8, 2
Subframe 9	9

Relation of Transport Block Sizes, Channel Bits and Code Rates

For a given subframe, the input to the CRC encoder is the transport block given by the size $N_{TransBlock}$. The output from the encoding process is the channel bits given by the size N_{bits}(see Channel Bits Calculation), which will be sent to Symbol Modulation transmitted in the given subframe.
The code rate (R) for the given subframe is
$R = N_{TransBlock} / N_{bits}$

In ADS LTE WL, three methods are defined for PDSCH 1 (UE 1) to get the transport block sizes, channel bits and code rates with the parameters UE1_Config and UE1_Payload, as follows:

- UE1_Config = MCS index
  In this method, the settings in UE1_Payload are interpreted as MCS indices throughout a frame which is used to get transport block size and modulation order (Q_m) for UE1 according to Table 7.1.7.1-1 of 36.101 for DL and Table 8.6.1-1 of 36.101 for UL. For this method, the UE1_MappingType is useless since the modulation order (Q_m) is set by MCS index. The number of available channel bits varies across the 10 sub-frames is calculated based on the radio block allocation NRB and modulation order (Q_m) (gotten from MCS index). The number of available channel bits varies due to PBCH and PSS/SSS overhead. The actual code rates across the 10 sub-frames are given in ADS Status/Summary window with the following equation:
  Coderate = $N_{TransBlock} / N_{bits}$
  Note that, if users want to disable the transmission in some of the 10 subframes, set UE1_Payload to -1 in corresponding subframes.
- UE1_Config = Transport block size
  In this method, the settings in UE1_Payload are interpreted as the transport block size throughout a frame. The number of available channel bits varies across the 10 sub-frames is calculated based on the radio block allocation NRB and modulation order (Q_m) (gotten from UE1_MappingType). The number of available channel bits varies due to PBCH and PSS/SSS overhead. The actual code rates across the 10 sub-frames are given in ADS Status/Summary window with the following equation:
  Coderate = $N_{TransBlock} / N_{bits}$
  Note that, if users want to disable the transmission in some of the 10 subframes, set UE1_Payload to 0 in corresponding subframes.
- UE1_Config = Code rate
  In this methods, the settings in UE1_Payload are interpreted as the target code rate throughout a frame. This methods is useful when users try to get Reference measurement channels as defined in Annex A of 36.101.
  Given a desired coding rate R, modulation order (Q_m) (gotten from UE1_MappingType) and radio block allocation NRB, the algorithm for determining the payload size follows A.3.1 of 36.101.
  The following shows an example for how to set Reference channel [R.2 FDD] (Fixed Reference Channel QPSK R=1/3) as defined in Table A.3.3.1-1 of 36.101.



  Note that, if users cannot be able to disable the transmission in some of the 10 subframes even when UE1_Payload in corresponding subframes is set to 0. In this case, the minimum transport block size listed in Table 7.1.7.1-1 of 36.101 for DL and Table 8.6.1-1 of 36.101 for UL is used.

PUSCH in UL has the same relation of transport block sizes, channel bits and code rates as PDSCHs in DL, as described above, with the exception that the corresponding parameters are Payload_Config and Payload, instead of UE1_Config and UE1_Payload.

The actual transport block sizes, channel bits and code rates across the 10 sub-frames are given in ADS Status/Summary window when DisplayMsg is set to Simple or Full in DL.

Channel Bits Calculation

Given allocated resource blocks (RBs) for PDSCH in DL and PUSCH in UL, the number of available resource elements (REs) N_{REs} varies across the 10 subframes due to the overhead of control channels and reference signals.
For DL, the overhead includes:

- PBSCH
- PSS/SSS
- PDCCH (defined by the parameter PDCCH_SymsPerSF)
- Cell-specific reference signal pattern (determined by the parameter NumTxAnts)

Overall, the following parameters determine the number of available resource elements (REs) across the 10 subframes for PDSCH:

- RB_AllocType, UEx_RB_Alloc (x=1~6): determine allocated resource blocks across the 10 subframes. For more information, see Resource Block Allocation.
- CyclicPrefix: determine the number of symbols per slot
- PDCCH_SymsPerSF: determine the number of symbols allocated to PDCCH
- NumTxAnts: determine cell-specific reference signal pattern

For UL, the overhead includes:

- Demodulation reference signal for PUSCH
- Sounding reference signal (determined by the parameters SRS_Enable and SRS_SFindex).
- When one subframe has sounding reference signal determined by the parameters SRS_Enable and SRS_SFindex, the last symbol of this subframe is reserved for the transmission of sounding reference signal.

Overall, the following parameters determine the number of available resource elements (REs) across the 10 subframes for PUSCH:

- RB_AllocType, RB_Alloc: determine allocated resource blocks across the 10 subframes. For more information, see Resource Block Allocation.
- CyclicPrefix: determine the number of symbols per slot
- SRS_Enable and SRS_SFindex: determine the existence of sounding reference signal

The number of available channel bits N_{bits} alse varies across the sub-frames given by

$N_{bits} = N_{REs} * Q_m$, where Q_m is 2 for QPSK, 4 for 16-QAM and 6 for 64-QAM

The actual available resource elements (REs) and channel bits across the 10 sub-frames are given in ADS Status/Summary window.

Glossary of Terms

CCDF	complementary cumulative distribution function
CM	cubic metric
CP	cyclic prefix
DL	downlink
EVM	Error vector magnitude
IFFT	inverse fast fourier transform
LTE	Long Term Evolution
OFDM	orthogonal frequency division multiplexing
PBCH	physical broadcast channel
PDCCH	physical downlink control channel
PHY	physical layer
P-SCH	primary synchanization channel
QPSK	quadrature phase shift keying
RF	radio frequency
RX	receive or receiver
RB	resource block
S-SCH	secondary synchanization channel
TX	transmit or transmitter
UL	uplink

References

1. 3GPP TS 36.211 v8.9.0, "Physical Channels and Modulation", December 2009.
2. 3GPP TS 36.212 v8.8.0, "Multiplexing and Channel Coding", December 2009.
3. 3GPP TS 36.213 v8.8.0, "Physical Layer Procedures", September 2009.
4. 3GPP TS 36.101 v8.6.0 "User Equipment (UE) radio transmission and reception", September 2009.
5. 3GPP TS 36.104 v8.7.0 "Base Station (BS) radio transmission and reception", September 2009.
6. TR 25.814 "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA),", V7.0.0, June 2006.