Agilent Technologies

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Fixed WiMax Design Library

Acknowledgments

About Fixed WiMAX Design Library

The Agilent EEsof Fixed WiMAX wireless design library (WDL) is for the WiMAX OFDM (802.16-2004) market. This wireless design library follows IEEE Std 802.16-2004 and IEEE P802.16-2004/Cor1/D5. The design library focuses on WirelessMAN-OFDM PHY (section 8.3) in IEEE Std 802.16-2004 and is intended to be a baseline system for designers to get an idea of what a 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.

WiMAX Systems

While wireless connectivity options have expanded rapidly in recent years, wireless network access is available now only in limited physical areas. Internet and internet users need broadband access that extends over longer distances to more locations. The industry solution is the Worldwide Interoperability for Microwave Access (WiMAX) standard, developed to create certified standards-based products from a wide range of vendors.

WiMAX, a data-on-the-go alternative to cable and DSL, is a standards-based broadband wireless access technology for enabling the last-mile delivery of information. WiMAX will provide fixed, nomadic, portable and, eventually, mobile wireless broadband connectivity without the need for direct line-of-sight connection between a base station and a subscriber station. In a typical cell radius deployment of 3 to 10 Km, WiMAX-certified systems can be expected to support capacity of up to 40 Mbps per channel, for fixed and portable access applications. This is enough bandwidth to simultaneously support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity. Mobile network deployments are expected to provide up to 15 Mbps of capacity within a typical cell-radius deployment of up to 3 Km. It is expected that WiMAX technology will be incorporated in notebook computers and PDAs starting as early as the end of 2006, enabling urban areas and cities to become MetroZones for portable outdoor broadband wireless access. WiMAX technology has the potential to enable service carriers to converge the all-IP-based network for triple-play services such as data, voice, and video.

The IEEE 802.16 standard originally specified an operating frequency band from 10 to 66 GHz. The 802.16-2004 supports fixed broadband wireless access for both licensed and unlicensed spectra in the 2-to-11-GHz range. However, the 802.16e amendment is under development to address mobile broadband wireless access.

In addition to supporting the 2-to-11-GHz frequency range, the 802.16-2004 standard supports three physical layers (PHYs). The mandatory PHY mode is 256-point FFT Orthogonal Frequency Division Multiplexing (OFDM). The other two PHY modes are Single Carrier (SC) and 2048 Orthogonal Frequency Division Multiple Access (OFDMA) modes. The corresponding European standardize ETSI HiperMAN standard defines a single PHY mode identical to the 256 OFDM mode in the 802.16-2004 standard.

Because the goal of WiMAX is to promote the interoperability of equipment based on either the 802.16-2004 or HiperMAN standards, the forum has chosen to support the 256 OFDM mode exclusively. To ensure worldwide interoperability, the WiMAX Forum will only certify equipment supporting that particular PHY mode.

WiFi 802.11a and 802.11g also use OFDM and have established an excellent performance record for robust wireless networking. However, WiFi uses 64 OFDM. The number before OFDM refers to the number of carriers that can be used in the overall modulation scheme. The much greater number of carriers for WiMAX helps achieve greater range because a receiver using 256 OFDM can tolerate delay spreads up to 10 times greater than systems using 64 OFDM. Also, 256 OFDM provides good non-line-of-sight capability.

This Fixed WiMAX just supports WirelessMAN-OFDM PHY (256-point FFT OFDM) in IEEE Std 802.16-2004.

Major specifications for the WirelessMAN-OFDM PHY physical layer are listed in the following table.

Specification	**Settings**
Information data rate	up to 75 Mbps at 20 MHz bandwidth
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Error correcting code	Reed Solomon Coder and Convolutional Coder
Coding rate	1/2, 2/3, 3/4
N_{FFT}	256
Number of data subcarriers	192
Number of pilot subcarriers	8
Number of total subcarriers used	200
Number of lower frequency guard subcarriers	28
Number of higher frequency guard subcarriers	27
n :Sampling factor	For channel bandwidths that are a multiple of 1.75 MHz, then n = 8/7
G: Ratio of CP time to "useful" time	1/4, 1/8, 1/16, 1/32
BW: Nominal channel bandwidth	From 1.5 MHz to 28 MHz
F_s	$floor((n \cdot BW)/8000) \times 8000$
Δf	F_s/N_{FFT}
Tb: Useful symbol time	$1/(\Delta f)$
Tg: CP time	$G \cdot T_b$
Ts: OFDM symbol time	$T_b + T_g$

Component Libraries

The Fixed WiMAX wireless design library is organized by library according to the types of behavioral models and subnetworks.

Channel Components

The channel model provides fixed WiMAX channel model (SUI channel model).

- WMAN_FWA_Channel: FWA Channel model

Channel Coding Components

The channel coding models provide channel coding and scrambling in the transmitter end, and channel decoding in the receiving end.

- WMAN_CRC_Coder: CRC generator
- WMAN_Puncturer: puncturer or de-puncturer
- WMAN_RSDecoder: Reed Solomon decoder
- WMAN_Scramber: Scrambler
- WMAN_FEC: Forward error correction encoder
- WMAN_FEC_Decoder: Forward error correction decoder

Measurement Component

The measurement models provide basic measurements.

- WMAN_DL_Constellation_RF: Downlink constellation measurement
- WMAN_DL_RF_CCDF_FD: Downlink CCDF measurement with frame duration
- WMAN_DL_SpecFlat: Downlink spectral flatness measurement
- WMAN_RF_CCDF: CCDF measurement
- WMAN_UL_Constellation_RF: Uplink constellation measurement
- WMAN_UL_RF_CCDF_FD: Uplink CCDF measurement with frame duration
- WMAN_UL_SpecFlat: Uplink spectral flatness measurement
- WMAN_EVM: EVM measurement (in Sink location)

Multiplex Components

The multiplex models provide framing and de-framing in WMAN transceivers.

- WMAN_BurstWoFEC: Other bursts generator without FEC
- WMAN_DL_DemuxBurst: Downlink bursts demultiplexer
- WMAN_DL_DemuxBurst_FD: Downlink bursts demultiplexer with frame duration
- WMAN_DL_MuxBurst: Downlink bursts multiplexer
- WMAN_DL_MuxBurst_FD: Downlink bursts multiplexer with frame duration
- WMAN_DL_MuxFrame: Downlink frame demultiplexer
- WMAN_DemuxOFDMSym: OFDM symbol demultiplexer

- WMAN_UL_DemuxBurst: Uplink bursts demultiplexer
- WMAN_UL_MuxBurst: Uplink bursts multiplexer
- WMAN_UL_MuxFrame: Uplink frame demultiplexer
- WMAN_UL_MuxOFDMSym: Uplink OFDM symbol multiplexer

Receiver Components

The receiver models provide channel estimator, frame synchronization and frequency synchronization, top level baseband receivers and top level RF receivers.

- WMAN_DL_ChEstimator: Downlink channel estimator
- WMAN_DL_DemuxFrame: Downlink frame de-multiplexer with frequency offset compensation, cyclic prefix removed
- WMAN_DL_DemuxFrame_FD: Downlink frame de-multiplexer with frame duration
- WMAN_DL_FrameSync: Downlink frame synchronizer
- WMAN_DL_FreqSync: Downlink frequency synchronizer
- WMAN_DL_PhaseTracker: Downlink phase tracker
- WMAN_Demapper: Soft demapper
- WMAN_UL_ChEstimator: Uplink channel estimator
- WMAN_UL_DemuxFrame: Uplink frame de-multiplexer with frequency offset compensation, cyclic prefix removed
- WMAN_UL_DemuxFrame_FD: Uplink frame de-multiplexer with frame duration
- WMAN_UL_FrameSync: Uplink frame synchronizer
- WMAN_UL_FreqSync: Uplink frequency synchronizer
- WMAN_UL_PhaseTracker: Uplink phase tracker
- WMAN_DL_Receiver: Downlink baseband receiver
- WMAN_DL_Receiver_RF: Downlink RF receiver
- WMAN_DL_Rx_FD: Downlink baseband receiver with frame duration
- WMAN_DL_Rx_FD_RF: Downlink RF receiver with frame duration
- WMAN_UL_Receiver: Uplink baseband receiver
- WMAN_UL_Receiver_RF: Uplink RF receiver
- WMAN_UL_Rx_FD: Downlink baseband receiver with frame duration
- WMAN_UL_Rx_FD_RF: Downlink RF receiver with frame duration

Signal Source Components

The signal source models provide models to generate downlink and uplink signal sources.

- WMAN_DCD: DCD generator
- WMAN_DLFP: Downlink frame prefix generator
- WMAN_DL_MAP: Downlink map generator
- WMAN_DL_Pilot: Downlink pilot generator
- WMAN_MACHeader: MAC header generator
- WMAN_Preamble: Preamble generator
- WMAN_UCD: UCD generator
- WMAN_UL_MAP: Uplink map generator
- WMAN_UL_Pilot: Uplink pilot generator
- WMAN_BrdcstMessage: Downlink broadcast message generator
- WMAN_DL_SignalSrc: Downlink baseband signal source
- WMAN_DL_SignalSrc_RF: Downlink RF signal source
- WMAN_DL_Src_FD: Downlink baseband signal source with frame duration
- WMAN_DL_Src_FD_RF: Downlink RF signal source with frame duration
- WMAN_DataPattern: Data pattern

- WMAN_MACPDU: MAC PDU generator
- WMAN_UL_SignalSrc: Uplink baseband signal source
- WMAN_UL_SignalSrc_RF: Uplink RF signal source
- WMAN_UL_Src_FD: Uplink baseband signal source with frame duration
- WMAN_UL_Src_FD_RF: Uplink RF signal source with frame duration

Design Examples

This Fixed WiMAX wireless design library provides design examples of WirelessMAN-OFDM PHY transmitter and receiver. Three workspaces are provided in this Fixed WiMAX WDL,

- WMAN_OFDM_Tx_wrk
- WMAN_OFDM_Rx_wrk
- WMAN_OFDM_FrameDuration_wrk

WMAN_OFDM_Tx_wrk

This library provides transmitter design examples of WMAN WirelessMAN-OFDM PHY system. The transmitter measurements are EVM, constellation, spectrum mask and CCDF and etc.

- WMAN_OFDM_DL_TxEVM: measure downlink EVM (or RCE) and show the demodulated constellation
- WMAN_OFDM_DL_TxSpecFlat: measure downlink transmitter spectral flatness
- WMAN_OFDM_DL_TxWaveform: measure downlink transmitter CCDF, waveform and spectrum mask
- WMAN_OFDM_UL_TxEVM: measure uplink EVM (or RCE) and show the demodulated constellation

WMAN_OFDM_Rx_wrk

This library provides receiver design examples of WMAN WirelessMAN-OFDM PHY system. The receiver measurements are sensitivity, PER on fading channel and etc.

- WMAN_OFDM_DL_AWGN_BER: measure downlink BER/PER in AWGN environment
- WMAN_OFDM_DL_RxSentivity: measure downlink receiver minimum input level sensitivity
- WMAN_OFDM_UL_Fading_BER: measure uplink BER/PER in fading channel
- WMAN_OFDM_UL_RxAdjCh: measure uplink receiver adjacent and alternate channel rejection

WMAN_OFDM_FrameDuration_wrk

This workspace provides some design examples of transmitter and receiver to support frame duration in WirelessMAN-OFDM PHY system.

- WMAN_OFDM_DL_Fading_BER_FD: measure downlink BER/PER in fading channel with frame duration
- WMAN_OFDM_DL_TxEVM_FD: measure downlink EVM (or RCE) and show the demodulated constellation with frame duration
- WMAN_OFDM_DL_TxWaveform_FD: measure downlink transmitter CCDF, waveform and spectrum mask with frame duration
- WMAN_OFDM_UL_AWGN_BER_FD: measure uplink BER/PER in AWGN environment with frame duration
- WMAN_OFDM_UL_SubCh_TxEVM_FD: measure uplink EVM (or RCE) and show the demodulated constellation with subchannelization

Glossary of Terms

AWGN	addition white Gaussian noise
CCDF	complementary cumulative distribution function
CP	cyclic prefix
CSMA/CA	carrier sense multiple access/collision avoidance
DL	downlink
EVM	error vector magnitude
FEC	forward error correction
FFT	fast fourier transform
IEEE	Institute of Electrical and Electronic Engineering
IFFT	inverse fast fourier transform
MAC	medium access control
OFDM	orthogonal frequency division multiplexing
PA	power amplifier
PER	packet error rate
PHY	physical layer
PLCP	physical layer convergence protocol
PSDU	PLCP service data unit
QPSK	quadrature phase shift keying
RCE	relative constellation error
RF	radio frequency
RX	receive or receiver
SDU	service data unit
TX	transmit or transmitter
UL	uplink
WiMAX	worldwide interoperability for microwave access
WMAN	wireless metropolitan area networks
WDL	wireless design library

References

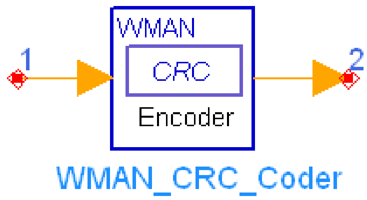
1. IEEE Std 802.16-2004, *Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY* , October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, *Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems* , September 2005.

WMAN Channel Coding Components

The channel coding models provide channel coding and scrambling in the transmitter end, and channel decoding in the receiving end.

- *WMAN CRC Coder (WMAN CRC Coder)* (wman)
- *WMAN FEC (WMAN Forward Error Correction Coder)* (wman)
- *WMAN FEC Decoder (WMAN Forward Error Correction Decoder)* (wman)
- *WMAN Puncturer (WMAN Puncturer)* (wman)
- *WMAN RSDecoder (WMAN Reed-Solomon Decoder)* (wman)
- *WMAN Scrambler (WMAN Scrambler)* (wman)

WMAN_CRC_Coder (WMAN CRC Coder)



Description CRC generator
Library WMAN, Channel Coding
Class SDFWMAN_CRC_Coder
Derived From WMAN_CRC_Base

Parameters

Name	Description	Default	Type	Range
ParityPosition	Parity bits position: Tail, Head	Tail	enum	
ReverseData	reverse the data sequence or not: NO, YES	NO	enum	
ReverseParity	reverse the parity bits or not: NO, YES	NO	enum	
ComplementParity	complement parity bits or not: NO, YES	NO	enum	
MessageLength	input message length	172	int	[1, ∞)
CRCLength	added CRC length, Polynomial's size is equal to (CRCLength+1)	12	int	(0, ∞)
InitialState	initial state of encoder, the same range as generator polynomial	{0,0,0,0,0,0,0,0,0,0,0,0,0}	int array	
Polynomial	generator polynomial	{1,1,1,1,1,0,0,0,1,0,0,1,1}	int array	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output data	int

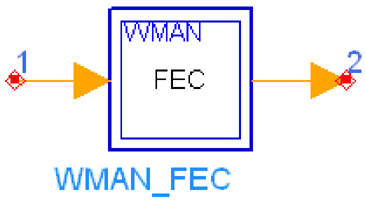
Notes/Equations

1. This model is used to add CRC bits to the input information, where the length of CRC bits can be greater than 32.
2. Each firing, (MessageLength + CRCLength) tokens are produced when MessageLength tokens are consumed. CRCLength is the length of CRC bits that is related with Polynomial, where CRCLength=Length(Polynomial)-1.
3. This mode performs the same operations as CRC_Coder. For more details, refer to CRC_Coder. The main difference is that the length of CRC bits can be greater than 32 in WMAN_CRC_Coder. For example, the CRC32 shall be calculated in WMAN OFDM using the following standard generator polynomial of degree 32:
   $G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$
   Then, Polynomial can be set to "1 0 0 0 0 0 1 0 0 1 1 0 0 0 0 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0 1 1 1".

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_FEC (WMAN Forward Error Correction Coder)



Description Forward error correction encoder
Library WMAN, Channel Coding
Class SDFWMAN_FEC

Parameters

Name	Description	Default	Type	Range
Rate_ID	Rate identifier	1	int	[0, 6]
DataLength	Data byte length before FEC	100	int	[1, ∞]
Subchannelization	Indication of subchannelization: NO, YES	NO	enum	
SubchannelIndex	Subchannel index	8	int	[1, 15] or [17, 31]

Pin Inputs

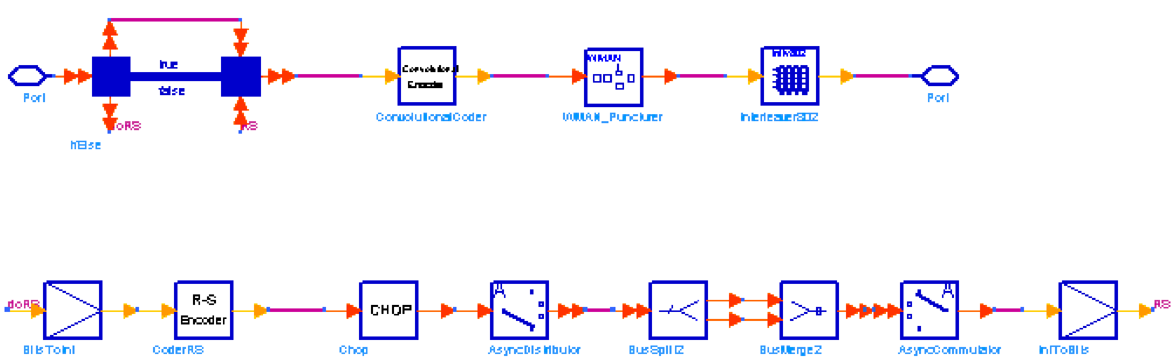
Pin	Name	Description	Signal Type
1	in	data before FEC	int

Pin Outputs

Pin	Name	Description	Signal Type
2	out	data after FEC	int

Notes/Equations

1. This subnetwork is used to do forward error correction coding, consisting of Reed-Solomon coder, Convolutional coder, puncturer and interleaver.
2. The schematic of this subnetwork is shown in WMAN_FEC schematic.

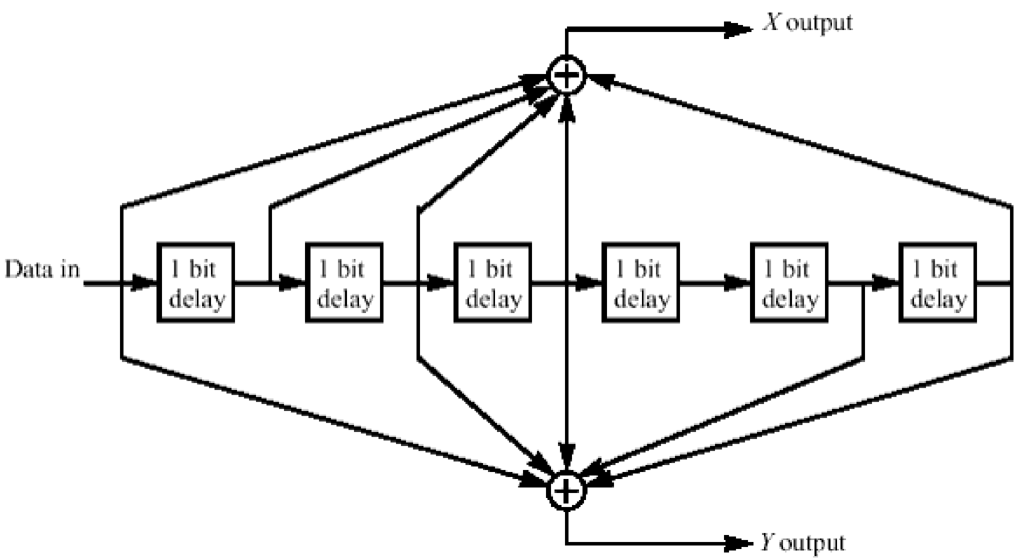


WMAN_FEC schematic

3. RS coder is used when Subchannelization=NO. Field Generator Polynomial is $x^8 + x^4 + x^3 + x^2 + 1$. Message length entered into RS coder (note when Rate_ID=0, RS coder is bypassed), code length

after RS coding is specified in *Data-Rate-Dependent Parameters* RS code section. The redundant bits are added after the input bits originally, but they need to be sent before the input bits. When Subchannelization=YES, RS coder is not employed. Input bits are put into CC coder directly.

4. The CC coder is native rate of 1/2. A constraint length equal to 7 and shall use the generator polynomials codes shown blow:
   $G_1 = 171_{OCT}$
   For X
   $G_2 = 133_{OCT}$
   For Y



Convolutional Encoder of Rate 1/2

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32, 24, 4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16QAM	48	96	1/2	(64,48,8)	2/3
4	16QAM	72	96	3/4	(80,72,4)	5/6
5	64QAM	96	144	2/3	(108,96,6)	3/4
6	64QAM	108	144	3/4	(120,108,6)	5/6

5. Puncturer is used to realize different code rate. When Subchannelization=NO, CC code rate is used as Puncturer rate; when Subchannelization=YES, RS encoder is bypassed, so the overall coding rate shall be used as Puncturer rate (*Inner Convolutional Code with Puncturing Configuration*).

Inner Convolutional Code with Puncturing Configuration

Rate	1/2	2/3	3/4	5/6
d_{free}	10	6	5	4
X	1	10	101	10101
Y	1	11	110	11010
XY	X_1 Y_1	X_1 Y_1 Y_2	X_1 Y_1 Y_2 X_3	X_1 Y_1 Y_2 X_3 Y_4 X_5

6. The interleaver has three parameters. I is set 12 here, $s = ceil((NBPSC)/2)$, NCBPS and NBPSC are set according to Block Sizes of the Bit Interveaver (NCBPS/NBPSC).

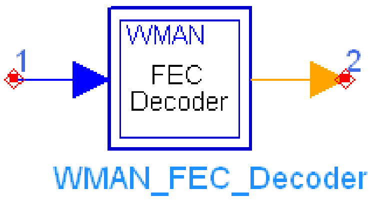
Block Sizes of the Bit Interveaver (NCBPS/NBPSC)

Modulation	No. of Subchannels				
	16 (Default)	**8**	**4**	**2**	**1**
BPSK	192/1	96/1	48/1	24/1	12/1
QPSK	384/2	192/2	96/2	48/2	24/2
16-QAM	768/4	384/4	192/4	96/4	48/4
64-QAM	1152/6	576/6	288/6	144/6	72/6

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_FEC_Decoder (WMAN Forward Error Correction Decoder)



Description Forward error correction decoder
Library WMAN, Channel Coding
Class SDFWMAN_FEC_Decoder

Parameters

Name	Description	Default	Type	Range
Rate_ID	rate identifier	1	int	[0, 6]
DataLength	data byte length before FEC encoding	100	int	[1, ∞]
Subchannelization	indication of subchannelization: NO, YES	NO	enum	
SubchannelIndex	subchannel index	8	int	[1, 15] or [17, 31]

Pin Inputs

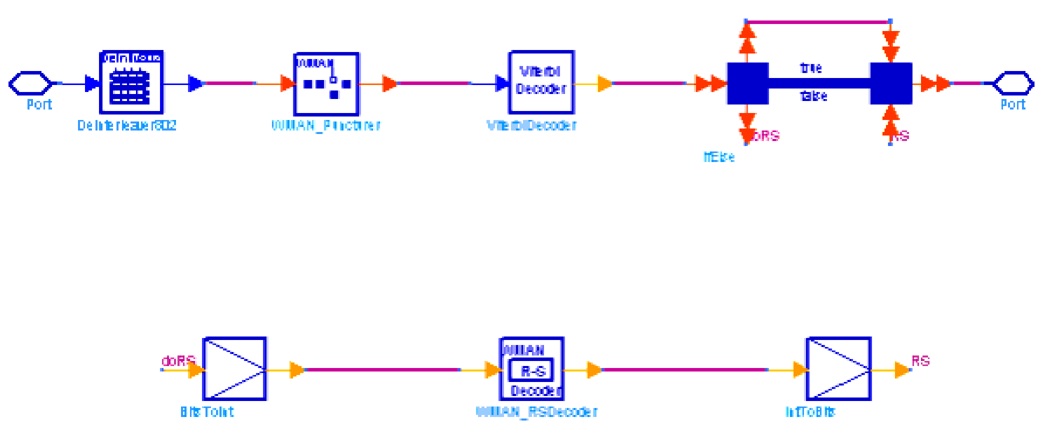
Pin	Name	Description	Signal Type
1	in	data before FEC encoding	real

Pin Outputs

Pin	Name	Description	Signal Type
2	out	data after FEC encoding	int

Notes/Equations

1. This subnetwork is used to do forward error correction decoding, consisting of Reed-Solomon decoder, Viterbi decoder, de-puncturer and de-interleaver.
2. If Subchannelization=NO, Viterbi decoder is followed by RS decoder; If Subchannelization=YES, Viterbi decoder results are output directly.
3. The schematic of this subnetwork is shown in WMAN_FEC_Decoder Schematic.

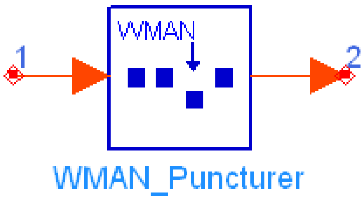


WMAN_FEC_Decoder Schematic

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_Puncturer (WMAN Puncturer)



Description Puncturer and Depuncturer
Library WMAN, Channel Coding
Class SDFWMAN_Puncturer

Parameters

Name	Description	Default	Type	Range
NumOfBranch	Number of convolution branch	2	int	[1, 3]
Pattern	Position mask code of reserved bits	{1,1}	int array	{0, 1}
PunctureMode	Selection of stealing or inserting: Stealing, Inserting	Stealing	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	in	input of puncture	anytype

Pin Outputs

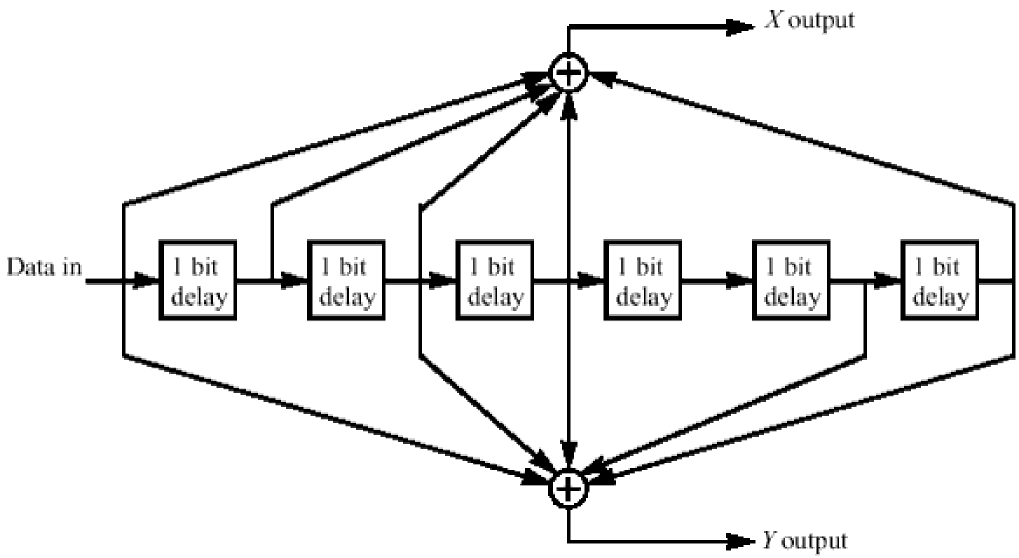
Pin	Name	Description	Signal Type
2	out	output of puncture	anytype

Notes/Equations

1. This model is used to do puncture or de-puncture depending on PunctureMode. De-puncture is reverse of puncture. Puncturing pattern and serialization order that shall be used to realize different code rates are defined in *Inner Convolutional Code with Puncturing Configuration*. In the table, "1" means a transmitted bit and "0" denotes a removed bit where X and Y are in reference to Convolutional Encoder of Rate 1/2. NumOfBranch is the number of output branches of convolutional coder, which has two branches (X,Y) here. For example, if PunctureMode=Stealing, Pattern="1 1 0 1", NumOfBranch=2, it means $X_1 Y_1 X_2 Y_2$ is consumed and $X_1 Y_1 Y_2$ is produced.If PunctureMode=Inserting, Pattern="1 1 0 1", NumOfBranch=2, it means $X_1 Y_1 Y_2$ is consumed and $X_1 Y_1 X_2 Y_2$ is produced.

Inner Convolutional Code with Puncturing Configuration

Rate	1/2	2/3	3/4	5/6
d_{free}	10	6	5	4
X	1	10	101	10101
Y	1	11	110	11010
XY	$X_1 Y_1$	$X_1 Y_1 Y_2$	$X_1 Y_1 Y_2 X_3$	$X_1 Y_1 Y_2 X_3 Y_4 X_5$

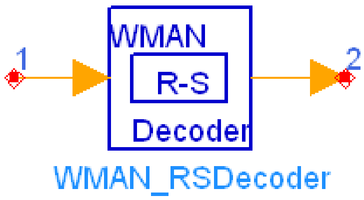


Convolutional Encoder of Rate 1/2

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_RSDecoder (WMAN Reed-Solomon Decoder)



Description Reed Solomon Decoder
Library WMAN, Channel Coding
Class SDFWMAN_RSDecoder

Parameters

Name	Description	Default	Sym	Type	Range
CodeLength	Length of input codewords	32	n	int	[16, 255]
MessageLength	Length of output message symbols	24	k	int	[1, CodeLength - 2]
ParityPlace	place of parity byte in coded array: Head, Tail	Tail		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	in	received symbol	int

Pin Outputs

Pin	Name	Description	Signal Type
2	out	decoded symbol	int

Notes/Equations

1. This model is used to perform Reed-Solomon error correcting decoding over the input signal. Each firing, $N_{codeLength}$ tokens are consumed at pin input and $N_{messageLength}$ tokens are produced.
2. This model is only used for WMAN RS decoder, the Galois field generator polynomial is $p(x) = x^8 + x^4 + x^3 + x^2 + 1$, the length of parity bytes N_{parity} is calculated as follows:
   $N_{parity} = N_{codeLength} - N_{messageLength}$ and the length of shortened bytes $N_{shortened}$ is calculated as follows:
   $N_{shortened} = 16 - N_{parity}$
   The parity bytes can be placed as prefix or postfix of the information bytes for flexibility.
3. Decoding Routines
   The Berlekamp iterative algorithm locates the error in RS code and generates an error location polynomial. By finding the root of the error location polynomial, the error position can be determined. If decoding is successful, the information symbols are output; otherwise, the received data is unaltered.
   For the shortened code, the same number of "0" symbols is inserted into the same position as in the RS encoder, and a inverse-free Berlekamp-Massey Reed-Solomon decoder is used to decode the block. After decoding, the padded symbols are discarded leaving the desired information symbols.Forney defines an errata locator polynomial using what are now called the Forney syndromes to correct both errors and erasures of RS codes.
   Getting Syndromes

Syndromes indicate an erroneous situation. When the generator polynomial g(x) and the received code word r(x) are given, the occurrence of one or more errors during transmission of an encoded block is known. Suppose that υ errors and s erasures occur in the received vector r with $s + 2v \le d - 1$. Let α be a primitive element in GF(2^m),then the syndromes are:

$$S_k = \sum_{i=0}^{n-1} r_i \alpha^{ik} = \sum_{i=1}^{s} W_i Z_i^k + \sum_{i=1}^{v} Y_i X_i^k \qquad ;(1 \le k \le d-1)$$

where Z_i is the ith erasure location,
W_i is the ith erasure amplitude,
X_i is the ith error location, and i is the ith error amplitude.

S_k is known for $1 \le k \le d-1$. So the syndrome polynomial is: $S(x) = \sum_{j=1}^{d-1} S_j x^{j-1}$

Let the erasure locator polynomial be defined by $\Lambda(x) = \prod_{j=1}^{s} (1 - Z_j x) = \sum_{j=0}^{s} \Lambda_j x^j$
where $\Lambda_0 = 1$
and the $\Lambda_j' s$
are known functions of $Z_1, Z_2, \ldots, Z_s$
for $1 \le j \le s$
and $\Lambda(x)$
is the polynomial with zeros at the inverse erasure location.
So the Forney syndrome is equal to:

$$T_k = \sum_{j=0}^{s} \Lambda_j S_{k+s-j} = \sum_{j=1}^{v} D_j X_j^k \qquad for(1 \le k \le d-1-s)$$

Here, T_k
is known for $1 \le k \le d-1-s$
since Λ_j
and S_j
are known, and

$$D_j = Y_j \sum_{i=0}^{s} \Lambda_i X_j^{s-i} \qquad for(1 \le j \le v)$$

are not known. It is clear that if $s = 0$, then $T_k = S_k$ for $1 \le k \le d-1$. Let $T(x)$ be the polynomial defined by $T(x) = \sum_{k=1}^{d-1-s} T_k x^k$ then we can get a substitution:
$(1 + T(x))\sigma(x) \equiv W(x)$

where $W(x) = \sigma(x) + P(x)$ and $\sigma(x) = \prod_{j=1}^{v} (1 + X_j x) = \sum_{j=0}^{v} \sigma_j x^j$ is the error locator polynomial with zeros at inverse error locations and $P(x) = \sum_{j=1}^{v} D_j X_j x \prod_{\lambda \ne j} (1 - X_\lambda x)$.

Inverse-free BM algorithm

Thus, an inverse-free BM algorithm can be used to find the error locator polynomial with syndromes replaced by the Forney syndromes. The modified BM algorithm is given as follows:

- Initially define $\mu^{(0)}(x) = 1$, $\lambda^{(0)}(x) = 1$, $\lambda^{(0)} = 0$, $k = 0$ and $\Upsilon^{(k)} = 1 \quad if(k \le 0)$.
- Set $k = k + 1$. If T_k is unknown, stop. Otherwise compute:

$$\delta^{(k)} = \sum_{j=0}^{\lambda^{(k-1)}} \mu_j^{(k-1)} T_{k-j}$$

$$\mu^{(k)}(x) = \Upsilon^{(k-1)}\mu^{(k-1)}(x) - \delta^{(k)}\lambda^{(k-1)}(x)x$$

$$\lambda^{(k)}(x) = \begin{cases} \lambda^{(k-1)} & ,if(\delta^{(k)} = 0)and(2\lambda^{(k-1)} > k-1) \\ k - \lambda^{(k-1)} & ,if(\delta^{(k)} \ne 0)and(2\lambda^{(k-1)} \le k-1) \end{cases}$$

$$\lambda^{(k)}(x) = \begin{cases} x \cdot \lambda^{(k-1)}(x) & ,if(\delta^{(k)} = 0)orif(2\lambda^{(k-1)} > k-1) \\ \mu^{(k-1)}x & ,if(\delta^{(k)} \ne 0)and(\lambda^{(k-1)} \le k-1) \end{cases}$$

$$\Upsilon^{(k)} = \begin{cases} \Upsilon^{(k-1)} & ,if(\delta^{(k)} = 0) \quad orif(2\lambda^{(k-1)} > k-1) \\ \delta^{(k)} & ,if(\delta^{(k)} \ne 0) \quad and(2\lambda^{(k-1)} \le k-1) \end{cases}$$

- return to step 2

Finally, the error locator polynomial is computed as $\sigma(x) = (\mu^{(d-1-s)}(x))/\Delta$, where $\Delta = \mu^{(d-1-s)}(0)$ is a field element in GF(!wman-4-6-70.gif!). The roots of $\sigma(x)$ are the inverse location of v errors, which are usually found by a Chien-search procedure. If the order of the polynomial is greater than $\lfloor d-1-s \rfloor/2$, which means the received codeword block has more than $\lfloor d-1-s \rfloor/2$ errors, the error cannot be corrected.

Determining Error Values

In the case of non-binary codes, error values must be known. Error values will be solved and corrected, unless the order of the error location polynomial is greater than $\lfloor d-1-s \rfloor/2$, in which case uncorrected information symbols will not be used.

The roots of $\sigma(x)$ and $\Lambda(x)$ are $\{\tilde{Z}_1^{-1}, \tilde{Z}_2^{-1}, \ldots, \tilde{Z}_{s+v}^{-1}\}$, which are the inverse location of the v errors and the s erasures. Then the errata values are determined by the equation:

$$\tilde{W}_\lambda = (A(\tilde{Z}_\lambda^{-1}))/(\tau'(\tilde{Z}_\lambda^{-1})) \qquad for(1 \le \lambda \le s+v)$$

where $A(x) \equiv S(x)\tau(x) mod x^{\lfloor (d-1-s)/2 \rfloor}$

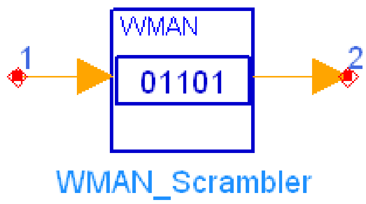
and $\tau(x) = \Lambda(x)\sigma(x) = \prod_{j=1}^{s+v}(1 - \tilde{Z}_j x) = \sum_{j=0}^{s+v}\tau_j x^j$ is the errata evaluator polynomial with where $\tau_0 = 1$ and $\tau'(\tilde{Z}_\lambda^{-1}) = \tilde{Z}_\lambda \prod_{j \ne \lambda}(1 - \tilde{Z}_j \tilde{Z}_\lambda^{-1})$ is the derivative of $\tau(x)$ with respect to x and evaluated at $x = \tilde{Z}_\lambda^{-1}$.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area

Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.
3. Trieu-Kien Truong, J.H.Heng, King-Chu Hung, Inversionless Decoding of Both Errors and Erasures of Reed-Solomon Code, IEEE Trans. on communications, vol.46, No.8, pp973-pp976, August 1998.
4. I.S.Reed, M.T.Shih, T.K.Truong, VLSI design of inverse-free Berlekamp-Massey algorithm, IEE Proceedings-E, vol138, No.5, pp295-pp298, September 1991.

WMAN_Scrambler (WMAN Scrambler)



Description Scrambler
Library WMAN, Channel Coding
Class SDFWMAN_Scrambler

Parameters

Name	Description	Default	Type	Range
ScrambleInit	Initial state of scrambler	{0}	int array	{0, 1}
Rate_ID	Rate identifier	1	int	[0, 6]
DataLength	Data byte length before padding and scrambling	100	int	[1, ∞]
Mode	Scramble or Descramble: scramble, descramble	scramble	enum	
Subchannelization	Indication of subchannelization: NO, YES	NO	enum	
SubchannelIndex	Subchannel index	8	int	[1, 15] or [17, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	in	input of scrambler	int

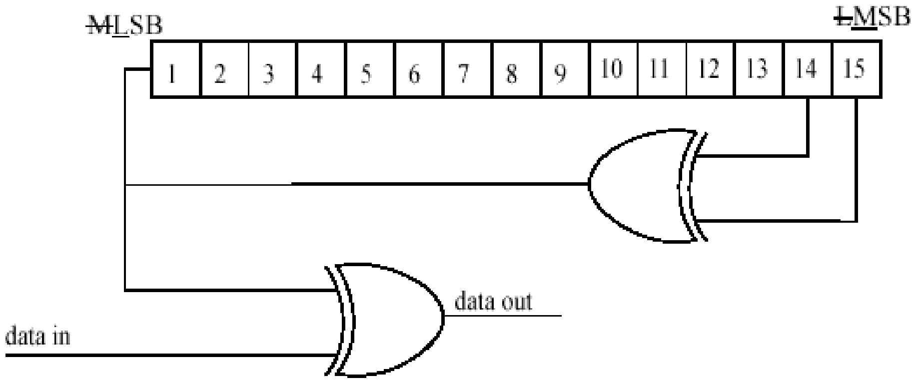
Pin Outputs

Pin	Name	Description	Signal Type
2	out	output of scrambler	int

Notes/Equations

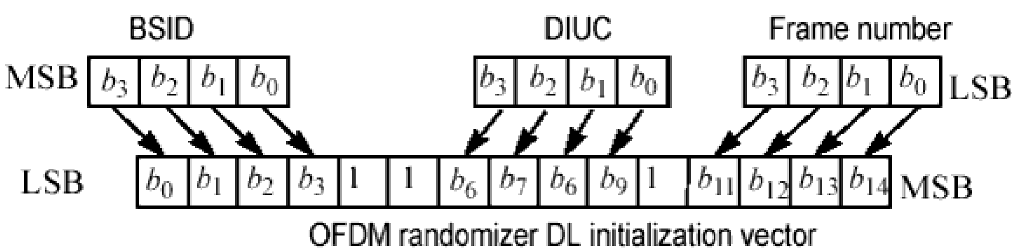
1. This model is used to do randomization and padding (Mode=scramble) in transmitter or derandomization and de-padding (Mode=descramble) in receiver. It can be used in downlink and uplink.
2. For descramble is reverse of scramble, only the process of scramble is illustrated below.
3. Each firing DataLength×8 bit tokens are consumed at Pin in. The number of tokens produced needs to be calculated out. The output data is input of FEC, which in condition of Subchannelization=NO is RS-CC and in condition of Subchannelization=YES (uplink only) is CC. Whatever FEC is, a 0x00 tail byte must be added to output data, so there are at least DataLength+1 byte data to be output. Every burst is allocated to integer number symbols, and data bits carried in one symbol depend on Rate_ID and Subchannelization and SubchannelIndex. The final output data length in byte is always larger than DataLength+1 and sometimes is not integer multiple of length in byte (in condition of Subchannelization=YES). This means some integer bytes and bits need to be padded into the DataLength+1 byte data. Integer bytes are padded with 0xFF and bits are padded with bit0. The sequence of output is DataLength+0xFF+one byte tail 0x00+bit0... The DataLength data and padded 0xFF will be randomized.
4. The PRBS generator shall be $1 + x^{14} + x^{15}$ as shown in PRBS for Data Randomization. Each data

byte to be transmitted shall enter sequentially into the randomizer. Preambles are not randomized. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst.



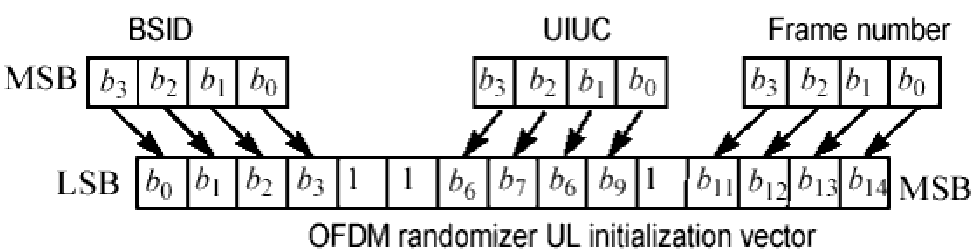
PRBS for Data Randomization

5. On the downlink, the randomizer shall be re-initialized at the start of each frame with the sequence:1 0 0 1 0 1 0 1 0 0 0 0 0 0 0. The randomizer shall not be reset at the start of burst#1. Because FCH is fixed, the sequence in the randomizer at the start of burst#1 is fixed to 1 1 0 1 0 0 0 1 0 1 1 0 1 1 1. At the start of subsequent bursts, the randomizer shall be initialized with the vector show in OFDM Randomizer Downlink Initialization Vector for Burst #2...N.



OFDM Randomizer Downlink Initialization Vector for Burst #2...N

6. On the uplink, the randomizer is initialized with the vector shown in OFDM Randomizer Uplink Initialization Vector.



OFDM Randomizer Uplink Initialization Vector

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area

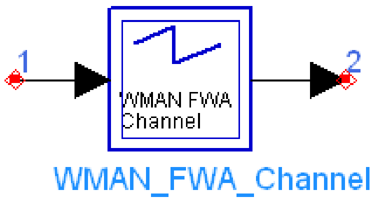
Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN Channel Components

The channel model provides fixed WiMAX channel model (SUI channel model).

- *WMAN FWA Channel (WMAN FWA Channel)* (wman)

WMAN_FWA_Channel (WMAN FWA Channel)



Description FWA channel model
Library WMAN, Channel Model
Class TSDFWMAN_FWA_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 SUI Channel number or User defined Channel: SUI_1, SUI_2, SUI_3, SUI_4, SUI_5, SUI_6, UserDefined	SUI_3		enum	
RxAntBeamwidth	the receive antenna beamwidth: omni, thirty	omni		enum	
CellCoverPercentage	the percentage of the cell location have Ricean_factors greater or equal to the Ricean_factor value specified: percent_90, percent_75, percent_50	percent_90		enum	
Delay	the delay of each tap in usec, effective only when ModelType is set as UserDefined	{0.0 , 0.4 , 0.9 }	sec	real array	[0, 1000.0]
Power	the power in each tap in dB, effective only when ModelType is set as UserDefined	{0.0 dB, -5.0 dB, -10.0 dB}		real array	(-, 0]
Ricean_factor	the Ricean K-factor in linear scale of each tap, effective only when ModelType is set as UserDefined	{1.0, 0.0, 0.0}		real array	[0.0, 1000.0]
DopplerFreq	the Doppler maximal frequency of each tap in Hz, effective only when ModelType is set as UserDefined	{0.4, 0.3, 0.5 }	Hz	real array	[0.0, 1000.0]
GainReductionFactor	the total mean power reduction for a non-omni antenna compared to an omni antenna in dB which should be added to the path loss, effective only when ModelType is set as UserDefined	0.0 dB		real	[0.0, 1000.0]
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]
Env	environment type options, effective only when PassLoss is set as YES: SuburbCentOrMediCity, MetropolitanCent	SuburbCentOrMediCity		enum	
Hroof	mean value of building heigh in meter, effective only when PassLoss is set as YES	20	m	real	(10, 500]
BldgSpace	mean value of building spacing in meter, effective only when PassLoss is set as YES	50	m	real	[1, 500]
StreetWidth	mean value of widths of street in meter, effective only when PassLoss is set as YES	30	m	real	[1, 500]
StreetOrient	the orientation of the road with respect to the Tx-Rx line, effective only when PassLoss is set as YES	90	deg	real	[0, 90]
AntHeigh_UE	UE antenna height above X-Y plane in meter, effective only when PassLoss is set as YES	6	m	real	[2, 10]
AntHeigh_BS	BS antenna height above X-Y plane in meter, effective only when PassLoss is set as YES	30	m	real	[4, 50]

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 fixed wireless applications.
2. This model is implemented following IEEE 802.16a-03/01.
   A set of 6 modified Stanford University Interim (SUI) channel models and the UserDefined type are constructed to simulate the multipath fading of the channel.
   For the 6 SUI channel models, the multipath fading is modeled as a tapped-delay line with 3 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, we use the method of filtered noise to generate channel coefficients with the specified distribution and spectral power density.
The definitions of the 6 specific SUI channels are shown in the following tables.

SUI-1 Channel

	Tap 1	Tap 2	Tap 3	Units
Delay	0	0.4	0.9	μs
Power (omni ant.) 90% K-fact. (omni) 75% K-fact. (omni)	0 4 20	-15 0 0	-20 0 0	dB
Power (30-deg. ant.) 90% K-fact. (30 deg.) 75% K-fact. (30 deg.)	0 16 72	-21 0 0	-32 0 0	dB
Doppler	0.4	0.3	0.5	Hz
Terrain Type		A	A	A
Antenna Correlation	$\rho_{ENV} = 0.7$			
Gain Reduction Factor	*RRF=0 dB*			
Normalization Factor	$F_{omni} = -0.1771$ dB $F_{30°} = -0.0371$ dB			

SUI-2 Channel

	Tap 1	Tap 2	Tap 3	Units
Delay	0	0.4	1.1	μs
Power (omni ant.) 90% K-fact. (omni) 75% K-fact. (omni)	0 2 11	-12 0 0	-15 0 0	dB
Power (30-deg. ant.) 90% K-fact. (30 deg.) 75% K-fact. (30 deg.)	0 8 36	-18 0 0	-27 0 0	dB
Doppler	0.2	0.15	0.25	Hz
Terrain Type		C	C	C
Antenna Correlation	$\rho_{ENV} = 0.5$			
Gain Reduction Factor	*GRF=2 dB*			
Normalization Factor	$F_{omni} = -0.3930$ dB $F_{30°} = -0.0768$ dB			

SUI-3 Channel

	Tap 1	Tap 2	Tap 3	Units
Delay	0	0.4	0.9	μs
Power (30-deg. ant.) 90% K-fact. (30 deg.) 75% K-fact. (30 deg.)	0 1 7	-5 0 0	-10 0 0	dB
Power (30-deg. ant.) 90% K-fact. (30 deg.) 75% K-fact. (30 deg.)	0 3 19	-11 0 0	-22 0 0	dB
Doppler	0.4	0.3	0.5	Hz
Terrain Type		B	B	B
Antenna Correlation	ρ_{ENV} = 0.4			
Gain Reduction Factor	*GRF=3 dB*			
Normalization Factor	$F_{omni} = -1.5113$ dB $F_{30°} = -0.3573$ dB			

SUI-4 Channel

	Tap 1	Tap 2	Tap 3	Units
Delay	0	1.5	4	μs
Power (omni ant.) 90% K-fact. (omni) 75% K-fact. (omni)	0 0 1	-4 0 0	-8 0 0	dB
Power (30-deg. ant.) 90% K-fact. (30 deg.) 75% K-fact. (30 deg.)	0 1 5	-10 0 0	-20 0 0	dB
Doppler	0.2	0.15	0.25	Hz
Terrain Type		B	B	B
Antenna Correlation	ρ_{ENV} = 0.3			
Gain Reduction Factor	*GRF=4 dB*			
Normalization Factor	$F_{omni} = -1.9218$ dB $F_{30°} = -0.4532$ dB			

SUI-5 Channel

	Tap 1	Tap 2	Tap 3	Units
Delay	0	4	10	μs
Power (omni ant.) 90% K-fact. (omni) 75% K-fact. (omni) 50% K-fact. (omni)	0 0 0 2	-5 0 0 0	-10 0 0 0	dB
Power (30-deg. ant.) 90% K-fact. (30 deg.) 75% K-fact. (30 deg.) 50% K-fact. (30 deg.)	0 0 2 7	-11 0 0 0	-22 0 0 0	dB
Doppler	2.0	1.5	2.5	Hz
Terrain Type		A	A	A
Antenna Correlation	ρ_{ENV} = 0.3			
Gain Reduction Factor	*GRF=4 dB*			
Normalization Factor	$F_{omni} = -1.5113$ dB $F_{30°} = -0.3573$ dB			

SUI-6 Channel

	Tap 1	Tap 2	Tap 3	Units
Delay	0	14	20	μs
Power (omni ant.) 90% K-fact. (omni) 75% K-fact. (omni) 50% K-fact. (omni)	0 0 0 1	-10 0 0 0	-14 0 0 0	dB
Power (30-deg. ant.) 90% K-fact. (30 deg.) 75% K-fact. (30 deg.) 50% K-fact. (30 deg.)	0 0 2 5	-16 0 0 0	-26 0 0 0	dB
Doppler	0.4	0.3	0.5	Hz
Terrain Type		A	A	A
Antenna Correlation	ρ_{ENV} = 0.3			
Gain Reduction Factor	*GRF=4 dB*			
Normalization Factor	$F_{omni} = -0.5683$ dB $F_{30°} = -0.1184$ dB			

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:

$$S(f) = \begin{cases} 1 - 1.72f_0^2 + 0.785f_0^4 & |f_0| \le 1 \\ 0 & |f_0| > 1 \end{cases}$$

where $f_0 = \frac{f}{f_m}$

The Gain Reduction Factor (GRF) is the total mean power reduction for a 30° antenna compared to an omni antenna. If 30° antennas are used and $PathLoss = YES$ the specified GRF should be added to the path loss.
K-factors for the 90% and 75% cell coverage are shown in the tables, i.e. 90% and 75% of the cell locations have K-factors greater or equal to the K-factor value specified, respectively. For the SUI-5 and SUI-6, 50% K-factor values are also shown.
The Antenna Correlation, which has to be considered if multiple channels are simulated, is not used in this model.
For the UserDefined channel, the number of taps, delay, power, K-factor and the maximum Doppler frequency of each tap can be set by the parameters Delay, Power, Ricean_factor, DopplerFreq and the GainReduction Factor.
The set of SUI channel models and the UserDefined type 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 is common to all of the models.
The COST 231 WALFISCH-IKEGAMI model with a correction term is used to simulate the path loss for both urban and suburban environments if the PathLoss is ON and other parameters are set according to the specific environment.

3. Parameter Details
    - ModelType specifies the type of SUI channel or the UserDefined type.
      The relationship of the SUI channel type and the terrain type is shown in *SUI Channel Type and Terrain Type*.

SUI Channel Type and Terrain Type

Terrain Type	SUI Channel
C	SUI-1, SUI-2
B	SUI-3, SUI-4
A	SUI-5, SUI-6

Terrain Type A is hilly terrain with moderate-to-heavy tree densities, while Terrain Type C is mostly flat terrain with light tree densities.
If ModelType is set as one of the SUI channels, the SUI channel type and all the microscopic statistical parameters are specified by parameters ModelType, RxAntBeamwidth and CellCoverPercentage as shown in the corresponding table.
If ModelType is set as UserDefined, RxAntBeamwidth and CellCoverPercentage are not used and all the microscopic statistical parameters are set by parameters Delay, Power, Ricean_factor, DopplerFreq and the GainReduction Factor.

- RxAntBeamwidth specifies the receive antenna beamwidth: omnidirectional (360°) and 30°.
- CellCoverPercentage specifies the percentage of the cell location with Ricean_factors greater or equal to the Ricean_factor value specified.
- Delay specifies the delay of each tap, which is effective only when ModelType is set as UserDefined.
- Power specifies the power of each tap, which is effective only when ModelType is set as UserDefined.
- Ricean_factor specifies the Ricean K-factor in linear scale of each tap, which is effective only when ModelType is set as UserDefined.
- DopplerFreq specifies the Doppler maximal frequency of each tap, which is effective only when ModelType is set as UserDefined.
- GainReductionFactor specifies the total mean power reduction for a non-omni antenna compared to an omni antenna in dB which should be added to the path loss, which is effective only when ModelType is set as UserDefined.
- PathLoss identifies whether the large-scale pathloss is included.
  if $PathLoss = NO$, the path loss is not included in this model and the parameters describing the environment are unused.
  if $PathLoss = YES$, the path loss for both urban and suburban environments is modeled by the COST 231 W-I model with a correction term. There are three terms which make up the model:
  $$L_b = L_0 + L_{rts} + L_{msd}$$
  L0 = free space loss
  Lrts= roof top to street diffraction
  Lmsd= multi-screen loss
  The correction term added to the COST 231 W-I model is given as follows:
  $$a(h_m) = -\left[\left(1.1\log\left(\frac{f}{MHz}\right) - 0.7\right)H_{UE} - \left(1.56\log\left(\frac{f}{MHz}\right) - A\right) + 20\log(H_{roof} - H_{UE}) - 20\log(H_{roof} - 3.5)\right]$$
  where
  $$A = 1.56\log\left(\frac{f}{MHz}\right) - \left(1.1\log\left(\frac{f}{MHz}\right) - 0.7\right)3.5$$
  HUE is the antenna height of the SS and the Hroof is the mean value of building height of this environment.
  Details about COST 231 W-I model can be found in reference[3]
- PropDistance specifies the distance of BS and SS.
- Env specifies the propagation environment type including urban and suburban.
- Hroof specifies the mean value of building height in the chosen environment.
- BldgSpace specifies the mean value of building spacing in the chosen environment.
- StreetWidth specifies the mean value of widths of street in the chosen environment.
- StreetOrient specifies the orientation of the road with respect to the Tx-Rx line.
- AntHeigh_UE and AntHeigh_BS specify the antenna height of the SS and BS.
  PropDistance, Env, Hroof, BldgSpace, StreetWidth, StreetOrient, AntHeigh_UE, AntHeigh_BS are used to calculate the path loss when the PathLoss is ON.

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

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.
3. IEEE 802.16a-03/01, Channel Models for Fixed Wireless Applications, June 27, 2003.

WMAN Design Examples

This section includes the WMAN OFDM transmitter, receiver, and frame duration design examples.

WMAN OFDM Transmitter Design Examples

The WMAN_OFDM_Tx workspace shows WMAN OFDM transmitter measurement characteristics including EVM, Spectrum flatness, Waveform and CCDF.
Designs for these measurements include:

- WMAN_OFDM_DL_TxEVM
- WMAN_OFDM_DL_TxSpecFlat
- WMAN_OFDM_DL_TxWaveform
- WMAN_OFDM_UL_TxEVM

Variables used in these designs are listed in VAR Parameters.

VAR Parameters

Parameter Name	Description	Default Value
FCarrier	RF frequency	3407 (MHz)
Bandwidth	Nominal bandwidth	1.75 (MHz)
Power	Signal power	0.01W
FFTSize	FFT size	256
CyclicPrefix	Cyclic prefix	1/4
OversamplingOption	Oversampling Option	Ratio 1

Downlink Transmitter Error Vector

Magnitude Measurement

WMAN_OFDM_DL_TxEVM

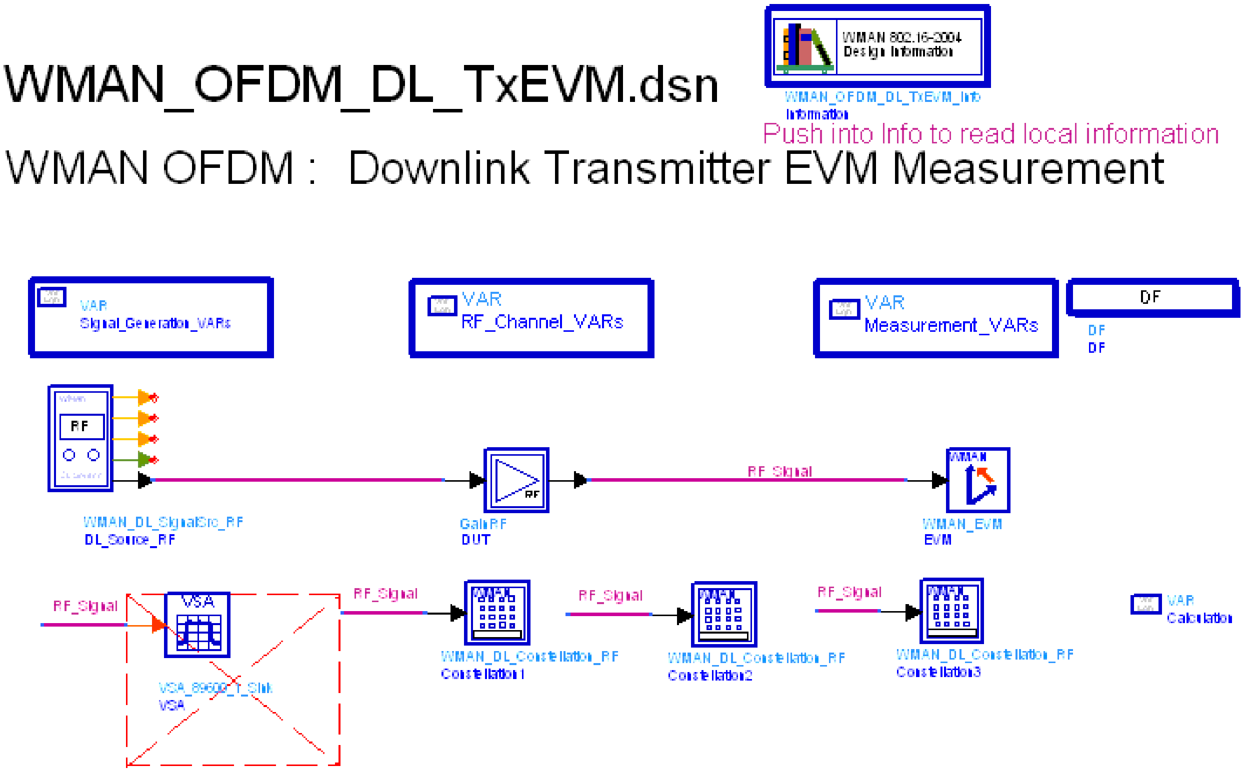
Features

- Support the EVM measurement for each data rate
- Support EVM measurement and constellation output
- Consistent measurement results with Agilent 89600 software

Description

This example measures transmit modulation accuracy of WMAN_OFDM_DL RF signal source. Users can change Rate_ID for all bursts from 0 to 6 in Signal_Generation_VARs to measure the EVM for each data rate and can set different Rate_ID for each burst to display the constellation.

The schematic for this design is shown in WMAN_OFDM_DL_TxEVM Schematic.



WMAN_OFDM_DL_TxEVM Schematic

WMAN_DL_SignalSrc_RF generates the ideal signal waveform which is fed to the Device Under Test (DUT) GainRF. Output signal of GainRF is the distorted signal to be measured.

Model WMAN_EVM is used to measure EVM (or Relative Constellation Error, RCE), carrier frequency offset, IQ_Offset as well as other aspects of the input signal. Model WMAN_EVM uses the same algorithm as that in Agilent 89600 VSA, and thus the measurement results shall be consistent with the latter. Note that, for getting reasonable measurement results, parameters of the WMAN_EVM model should be consistent with the corresponding input signal.

If *AverageType* is set to *OFF*, only one frame is analyzed. If *AverageType* is set to *RMS* (*Video*), after the first frame is analyzed the signal segment corresponding to it is discarded and new signal samples are collected from the input to fill in the signal buffer of length 2 x FrameDuration. The *SymbolTimingAdjust* parameter sets the percentage of symbol time by which we back away from the symbol end before we perform the FFT. The *TrackAmplitude*, *TrackPhase*, *TrackTiming*, and *EqualizerTraining* parameters determine the EVM measurement result. For more information, refer to WMAN_EVM.
Models Constellation1, 2, 3 are used to display the constellation of the first 3 bursts.

Simulation Results

Key Parameter Setting

Parameter	Value
Signal Power	10 (dBm)
Bandwidth	14 MHz
Oversampling Option	Ratio 1
Gain	10 (in dB)
NumberOfBurst	3
Rate_ID	{16-QAM-1/2, 16-QAM-1/2, 16-QAM-1/2}

Simulation results in the Data Display System are shown in Measurement results, which includes the average EVM (or RCE) measurement result in dB and percentage and the constellation of the first 3 bursts.

The relative constellation RMS error, averaged over subcarriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to Allowed relative constellation error versus data rate as defined in section 8.3.10.1.2, IEEE Std 802.16-2004.

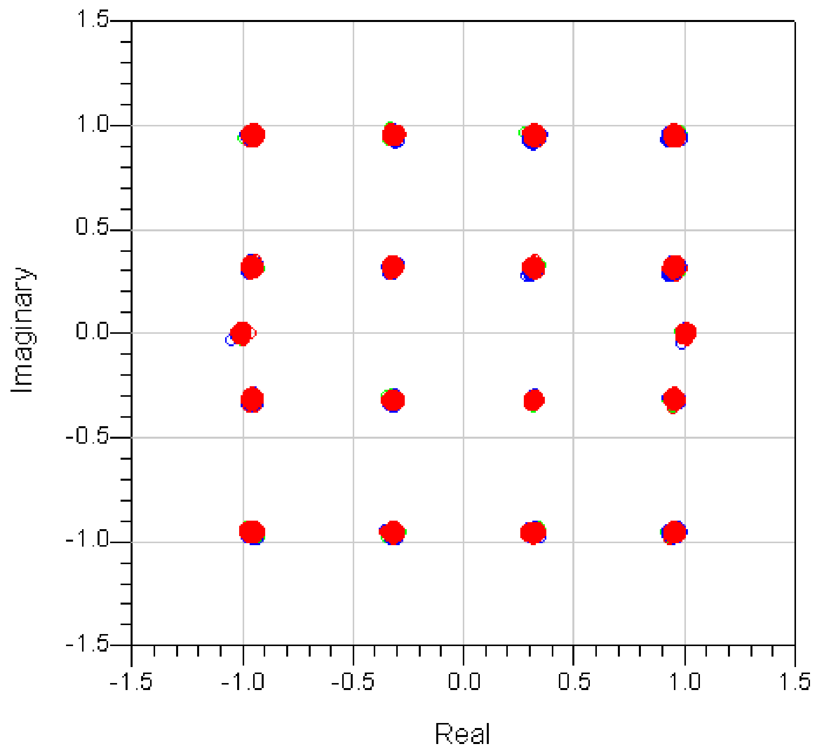
Allowed relative constellation error versus data rate

Burst type	Relative Constellation Error (dB)
BPSK-1/2	-13.0
QPSK-1/2	-16.0
QPSK-3/4	-18.5
16-QAM-1/2	-21.5
16-QAM-3/4	-25.0
64-QAM-2/3	-28.5
64-QAM-3/4	-31.0

EVM (or RCE)

RCE_dB	RCErms_percent
-36.661	1.469

Constellation



Measurement results

Benchmark

- Hardware platform: Pentium IV 2.26 GHz, 1024 MB memory
- Software platform: Windows 2000 Professional, ADS 2005A
- Simulation time: approximately 30 seconds

Downlink Transmitter Spectral Flatness Measurement

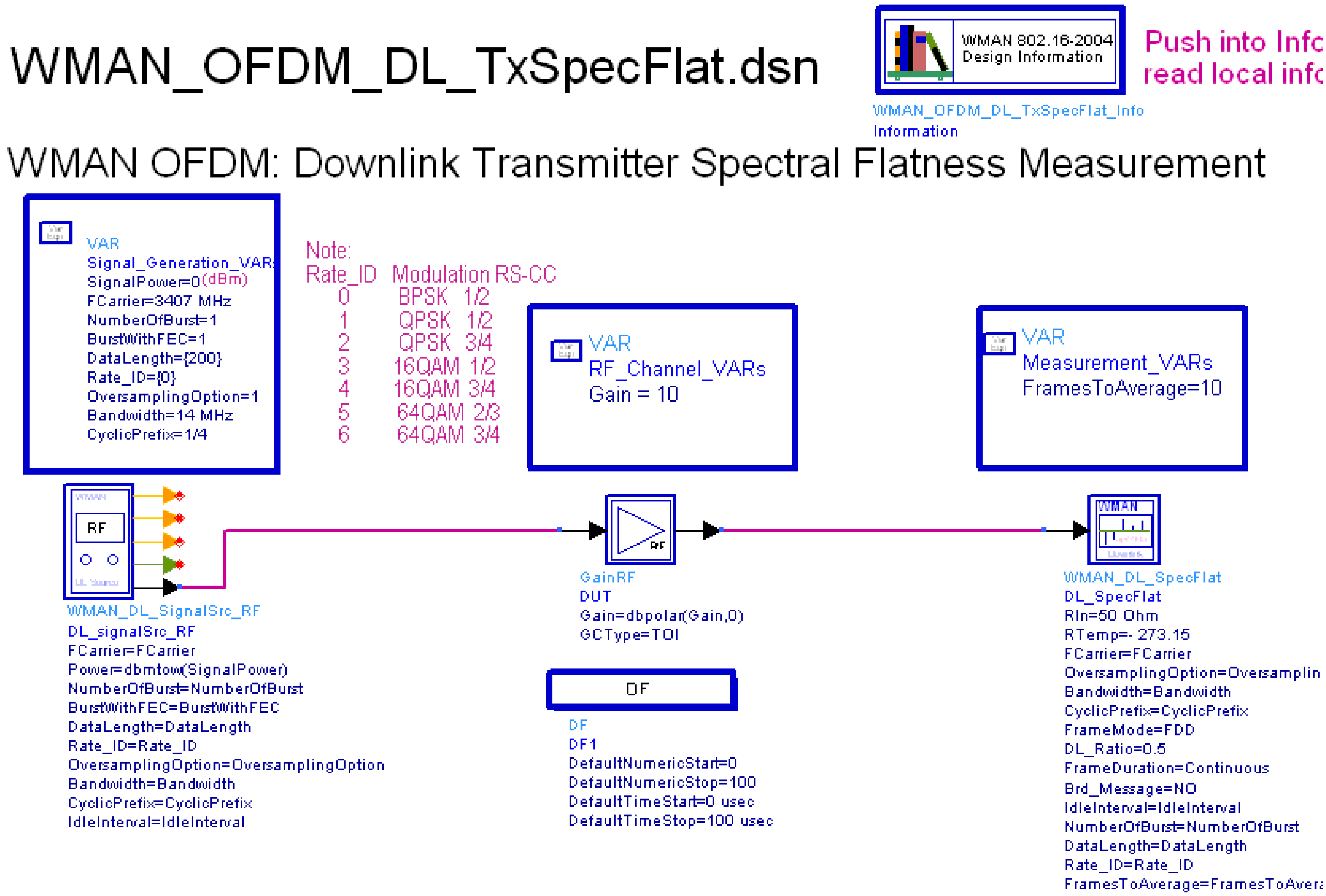
WMAN_OFDM_DL_TxSpecFlat Design

Features

- Transmitter spectral flatness measurement

Description

WMAN_OFDM_DL_TxSpecFlat measures downlink transmitter spectral flatness measurement. The schematic is shown in WMAN_OFDM_DL_TxSpecFlat Schematic.



WMAN_OFDM_DL_TxSpecFlat Schematic

In *Signal_Generation_VARs*, Users can change *Rate_ID* from 0 to 6 for different modulations and code rates, and other source parameters. In *RF_Channel_VARs*, the gain in RF DUT is defined. In *Measurement_Vars*, the number of frames to average the results (*FramesToAverage*) is defined.

The data for spectral flatness measurement are taken from channel impulse responses (CIR) after channel estimation. Only the CIRs in the burst with FEC-encoded are used to measure the spectral flatness. The results shall be the average of *FramesToAverage* downlink subframes.

The average energy of the constellations in each of the n spectral lines shall deviate no more than indicated in OFDM Spectral Flatness, as defined in Section 8.3.10.1.1, IEEE Std 802.16-2004.

OFDM Spectral Flatness

Spectral Lines	Spectral Flatness
Spectral lines from -50 to -1 and +1 to +50	+2/-2 dB from the measured energy averaged over all 200 active tones
Spectral lines from -100 to -50 and +50 to +100	+2/-4 dB from the measured energy averaged over all 200 active tones

The absolute difference between adjacent subcarriers shall not exceed 0.1 dB.

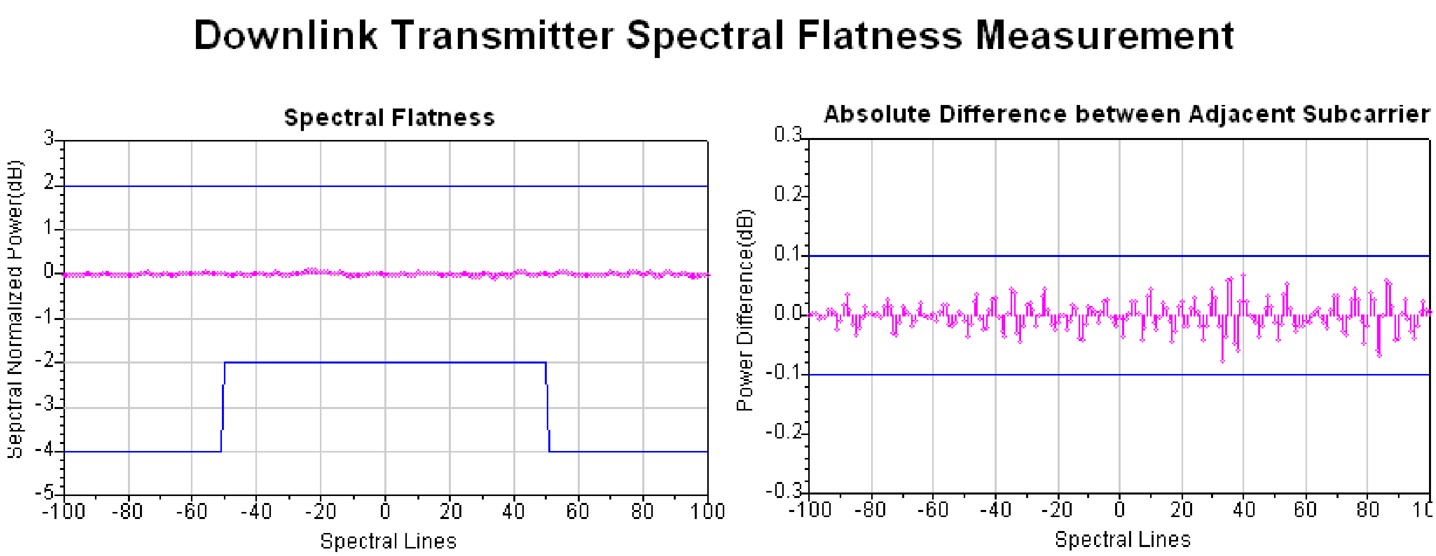
Simulation Results

In this example, The performance of downlink OFDM spectral flatness is given. Parameter Settings shows the parameter settings.

Parameter Settings

Parameter	Value
FCarrier	3407 MHz
Bandwidth	14 MHz
Frame Duration	N/A
Oversampling Option	Ratio 2
Cycylic Prefix	1/4
Packet Length in One Frame	200 Bytes
Rate ID	0 (BPSK 1/2)
Frames to Average	10

The curves have been generated averaging over 10 frames. Downlink Spectral Flatness Simulation Curve shows the simulation results.



Downlink Spectral Flatness Simulation Curve

Benchmark

- Hardware Platform: Pentium IV 2.66GHz, 1 GB memory

- Software Platform: Windows 2000, ADS 2005A
- Simulation Time: about 5 seconds for QPSK 1/2 (*Rate_ID=0*)

WMAN OFDM Downlink Transmitter Waveform Measurement

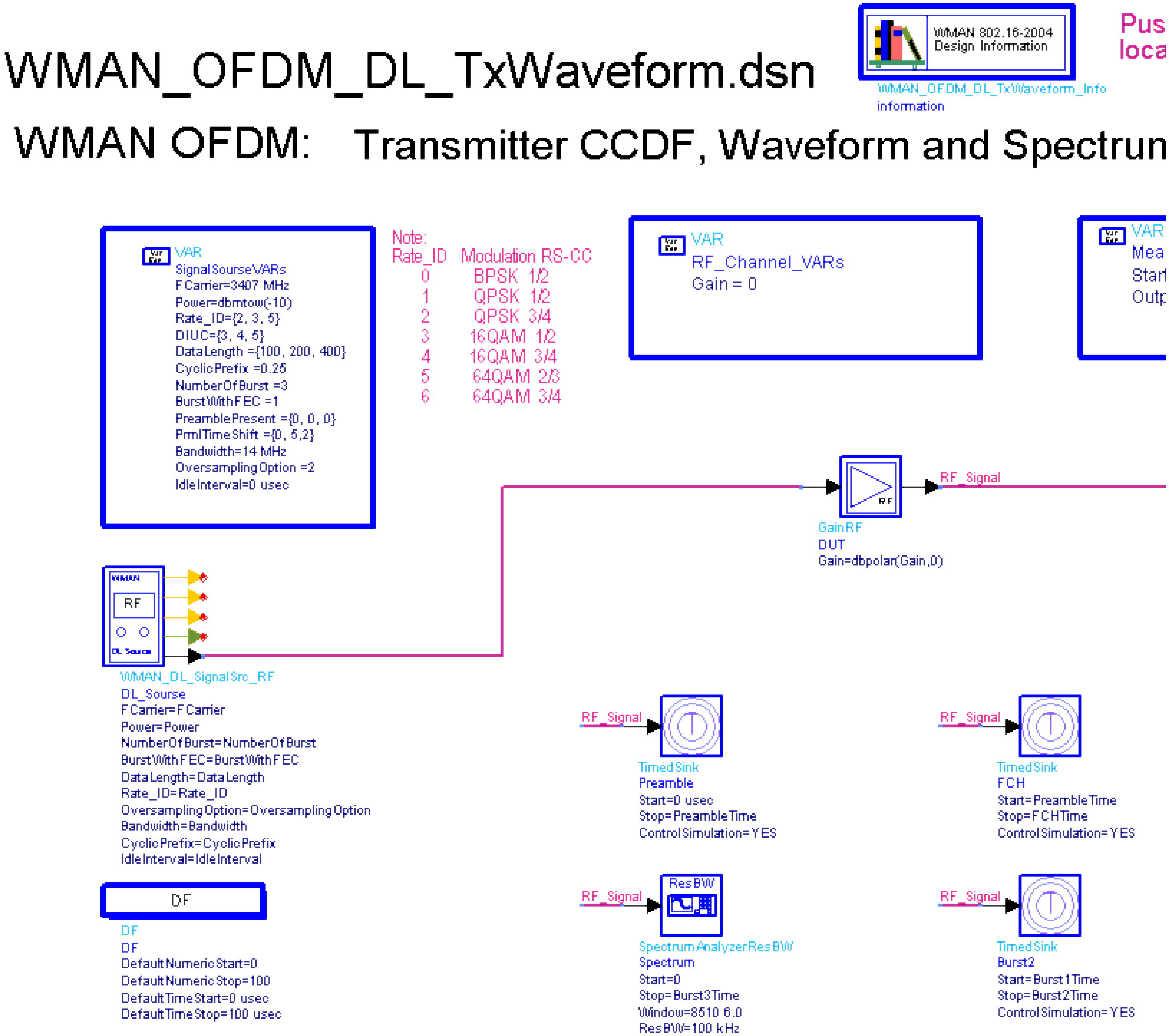
WMAN_OFDM_DL_TxWaveform Design

Features

- Transmitter CCDF
- Preamble Power, Mean Power and Peak Power
- Transmitter Waveform
- Transmitter Spectrum

Description

This example measures CCDF and Power of WMAN OFDM Downlink Transmitter. The schematic is shown in WMAN_OFDM_TxWaveform Schematic.



WMAN_OFDM_TxWaveform Schematic

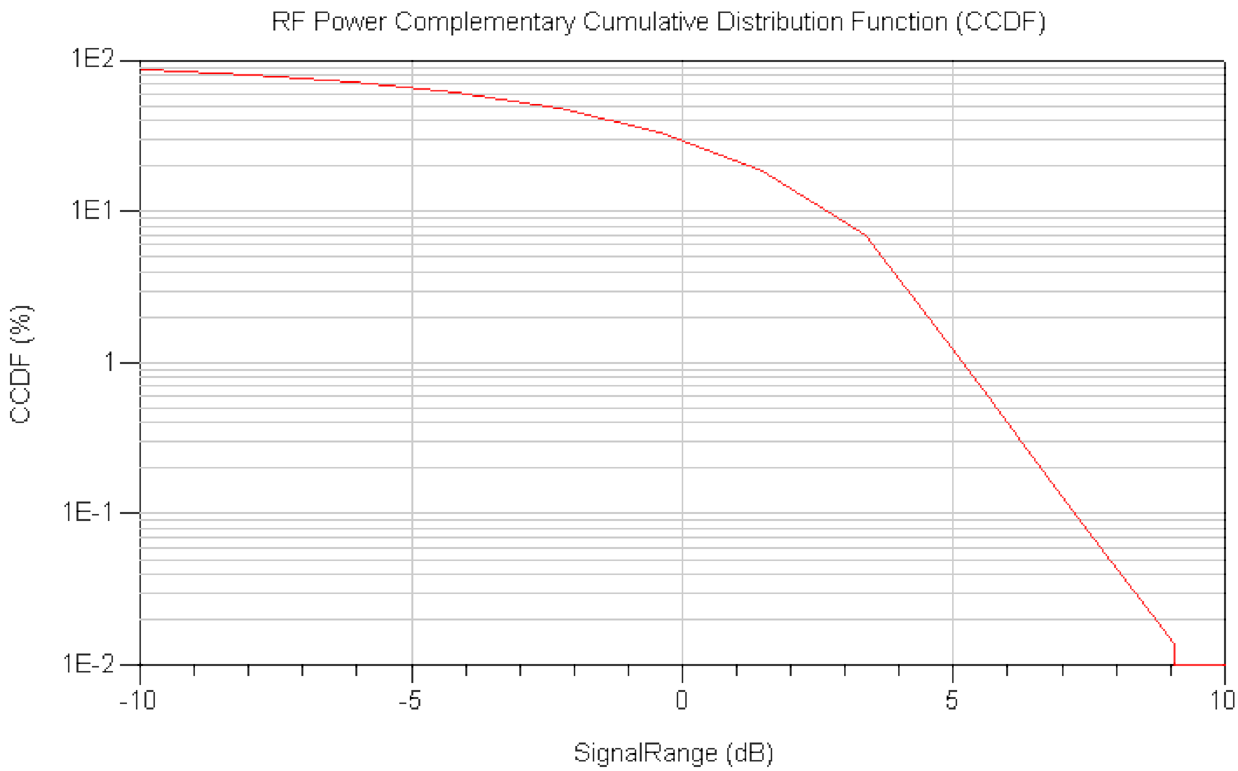
OutputPoint means how many parts will X-axis be divied into in the CCDF figure. The larger *OutputPoint* is, the closer measured curve is to reference curve. *SymNum* means the number of symbol measured. *StartSample* in the WMAN_RF_CCDF model is used to discard the first frame delay caused by receiver model.

Simulation Results

Parameter Setting lists some key parameters. Transmitter CCDF and Power Measurement shows transmitter CCDF and power measurement. Transmitter Waveform shows transmitter waveform. Spectrum shows transmitter spectrum. The nominal channel bandwidth of the transmitter is 14MHz, more information about transmitter Spectrum Mask is defined in 5.3.3 ETSI EN 301 021 V1.6.1(2003-07) and 8.5.2 IEEE Std 802.16-2004. Spectral density of the transmitted signal shall fall within the spectral mask.

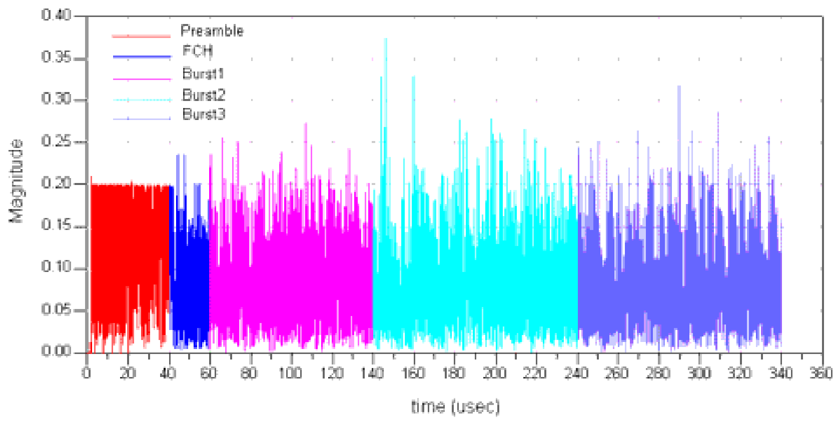
Parameter Setting

Parameter	**Value**
Signal Power	-10 (dBm)
Bandwidth	14 MHz
Oversampling Option	Ratio 2
Gain	0 (in dB)
Output Point	1000
SymNum	100

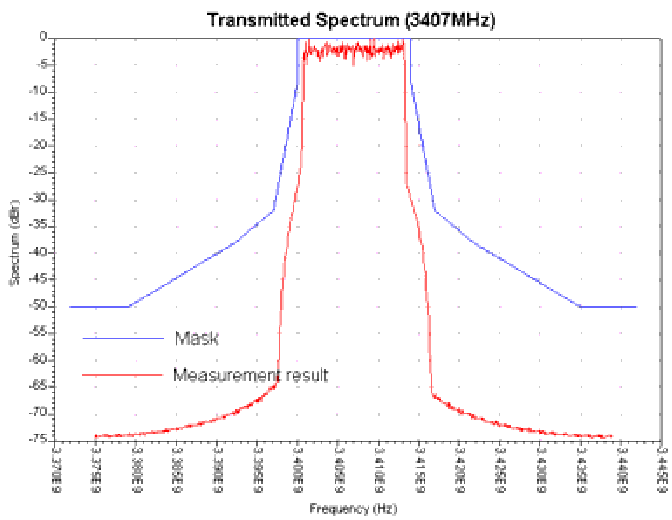


PeakPower_dBm	MeanPower_dBm	RF_Peak_to_Avg_dB
-0.449	-9.519	9.070

Transmitter CCDF and Power Measurement



Transmitter Waveform



Spectrum

Benchmark

- Hardware Platform: Pentium IV 2.2GHz, 1 GB memory
- Software Platform: Window 2000, ADS 2005A
- Simulation Time: 2 seconds

Uplink Transmitter Error Vector

Magnitude Measurement

WMAN_OFDM_UL_TxEVM

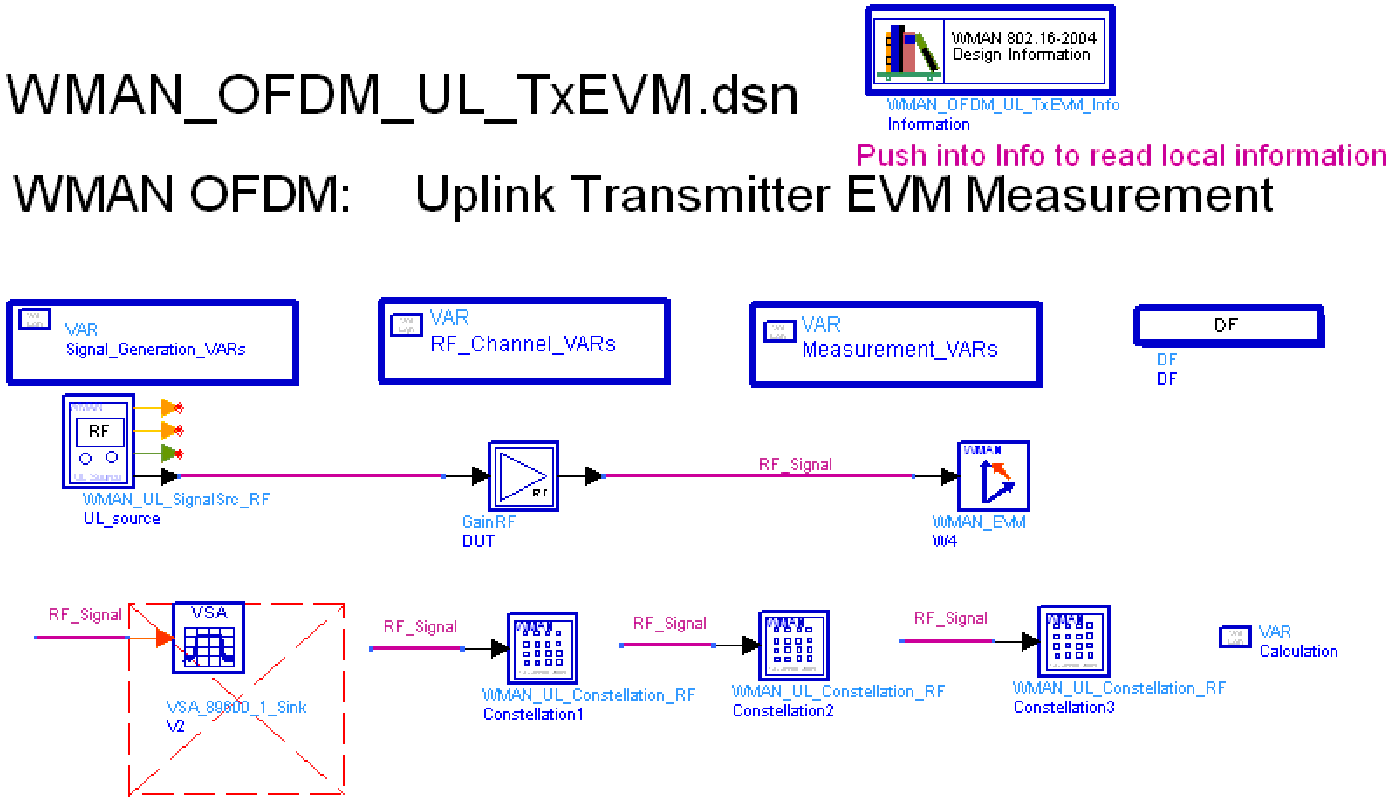
Features

- Support the EVM measurement for each data rate
- Support EVM measurement and constellation output
- Consistent measurement results with Agilent 89600 software

Description

This example measures transmit modulation accuracy of WMAN_OFDM_UL RF signal source. Users can change Rate_ID for each SS from 0 to 6 in Signal_Generation_VARs to measure the EVM for each data rate and can set different Rate_ID for each SS to display the constellation.

The schematic for this design is shown in WMAN_OFDM_UL_TxEVM Schematic.



WMAN_OFDM_UL_TxEVM Schematic

WMAN_UL_SignalSrc_RF generates the ideal signal waveform which is fed to the Device Under Test (DUT) GainRF. Output signal of GainRF is the distorted signal to be measured.

Model WMAN_EVM is used to measure EVM (or Relative Constellation Error, RCE), carrier frequency offset, IQ_Offset as well as other aspects of the input signal. Model WMAN_EVM uses the same algorithm as that in Agilent 89600 VSA, and thus the measurement results shall be consistent with the latter. Note that, for getting reasonable measurement results, parameters of the WMAN_EVM model should be consistent with the corresponding input signal.

If *AverageType* is set to *OFF*, only one frame is analyzed. If *AverageType* is set to *RMS* (*Video*), after the first frame is analyzed the signal segment corresponding to it is discarded and new signal samples are collected from the input to fill in the signal buffer of length 2 x *FrameDuration*. The *SymbolTimingAdjust* parameter sets the percentage of symbol time by which we back away from the symbol end before we perform the FFT. The *TrackAmplitude*, *TrackPhase*, *TrackTiming*, and *EqualizerTraining* parameters determine the EVM measurement result. For more information, refer to WMAN_EVM.
Models Constellation1, 2, 3 are used to display the constellation of the first 3 SSs.

Simulation Results

Key Parameter Setting

Parameter	**Value**
Signal Power	10 (dBm)
Bandwidth	14 MHz
Oversampling Option	Ratio 1
Gain	10 (in dB)
NumberOfSS	3
Rate_ID	{16-QAM-1/2, 16-QAM-1/2, 16-QAM-1/2}

Simulation results in the Data Display System are shown in Measurement results, which includes the average EVM (or RCE) measurement result in dB and percentage and the constellation of the first 3 SSs. The relative constellation RMS error, averaged over subcarriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to Allowed relative constellation error versus data rate as defined in section 8.3.10.1.2, IEEE Std 802.16-2004.

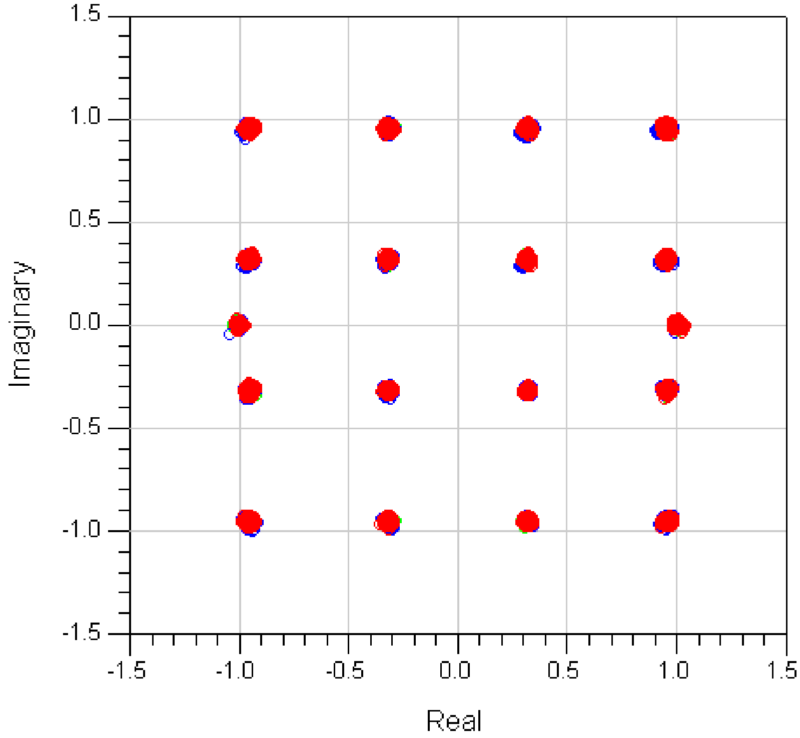
Allowed relative constellation error versus data rate

Burst type	**Relative Constellation Error (dB)**
BPSK-1/2	-13.0
QPSK-1/2	-16.0
QPSK-3/4	-18.5
16-QAM-1/2	-21.5
16-QAM-3/4	-25.0
64-QAM-2/3	-28.5
64-QAM-3/4	-31.0

EVM (or RCE)

RCE_dB	RCErms_percent
-36.558	1.486

Constellation



Measurement results

Benchmark

- Hardware platform: Pentium IV 2.26 GHz, 1024 MB memory
- Software platform: Windows 2000 Professional, ADS 2005A
- Simulation time: approximately 30 seconds

References

1. IEEE Std 802.16-2004, *Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY*, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN OFDM Receiver Design Examples

The WMAN_OFDM_Rx workspace shows WMAN OFDM receiver measurement characteristics including AWGN BER, Sensitivity, Fading BER and Adjacent channel rejection.

Designs for these measurements include:

- WMAN_OFDM_DL_AWGN_BER
- WMAN_OFDM_DL_RxSensitivity
- WMAN_OFDM_UL_Fading_BER
- WMAN_OFDM_UL_RxAdjCh

Variables used in these designs are listed in VAR Parameters.

VAR Parameters

Parameter Name	Description	Default Value
FCarrier	RF frequency	3407 (MHz)
Bandwidth	Nominal bandwidth	1.75 (MHz)
Power	Signal power	0.01W
FFTSize	FFT size	256
CyclicPrefix	Cyclic prefix	1/4
OversamplingOption	Oversampling Option	Ratio 1

Downlink BER and PER Measurement on AWGN Channel

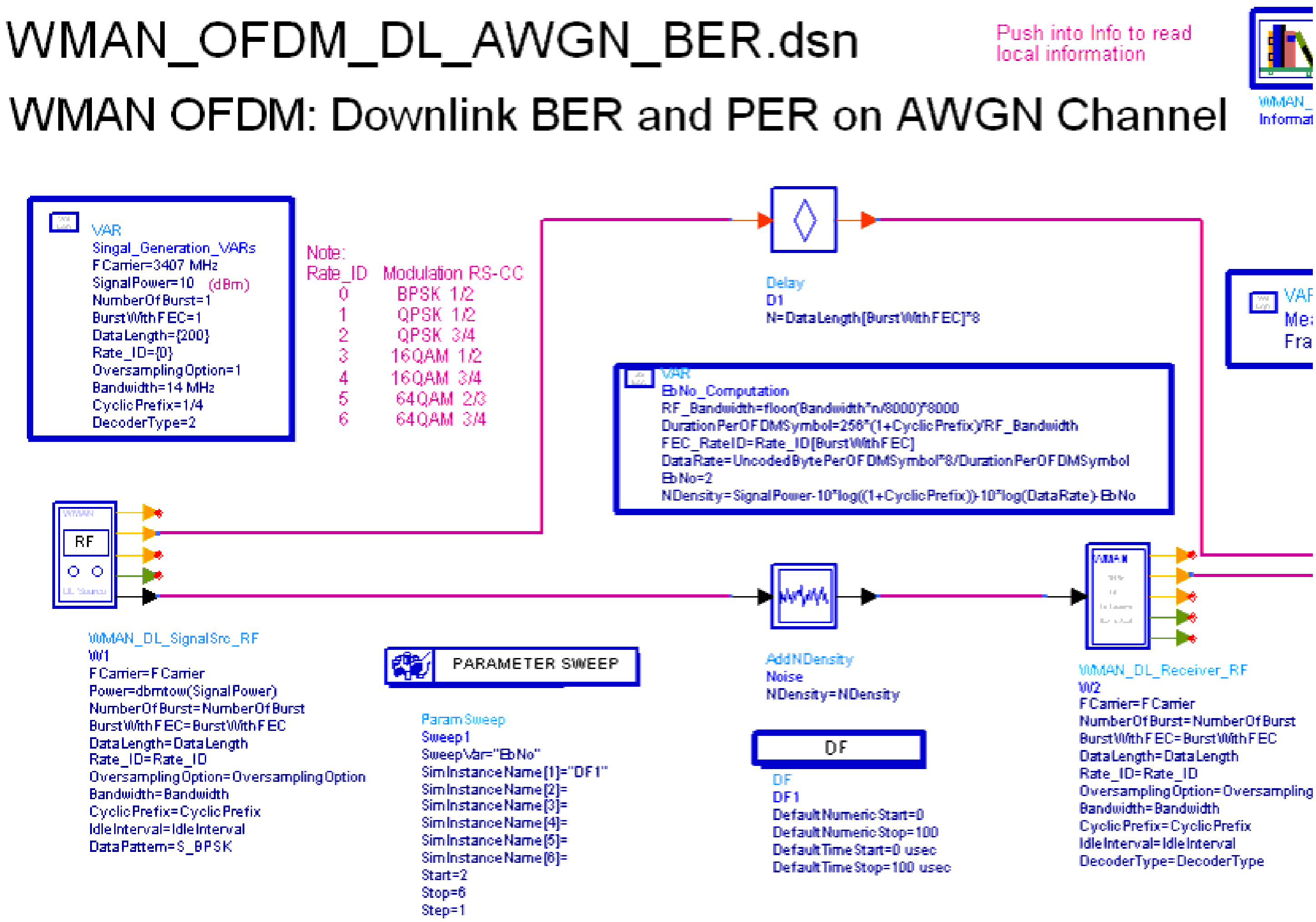
WMAN_OFDM_DL_AWGN_BER Design

Features

- BER and PER measurement on AWGN channel
- Three decoder types supported in downlink receiver: Hard, Soft or CSI
- Multiple Eb/N0 measurement points

Description

WMAN_OFDM_DL_AWGN_BER measures downlink BER and PER Measurement on AWGN channel. The schematic is shown in WMAN_OFDM_DL_AWGN_BER Schematic.



WMAN_OFDM_DL_AWGN_BER Schematic

In DL receiver, *DecoderType* can be selected with Hard, Soft or CSI.

Users can change *Rate_ID* from 0 to 6 in *Signal_Generation_VARs* and get BER and PER results for different modulations and code rates. In *EbNo_Computation*, the Eb/N0 is calculated. In Measurement_Vars, the number of frames for simulating BER/FER is defined.

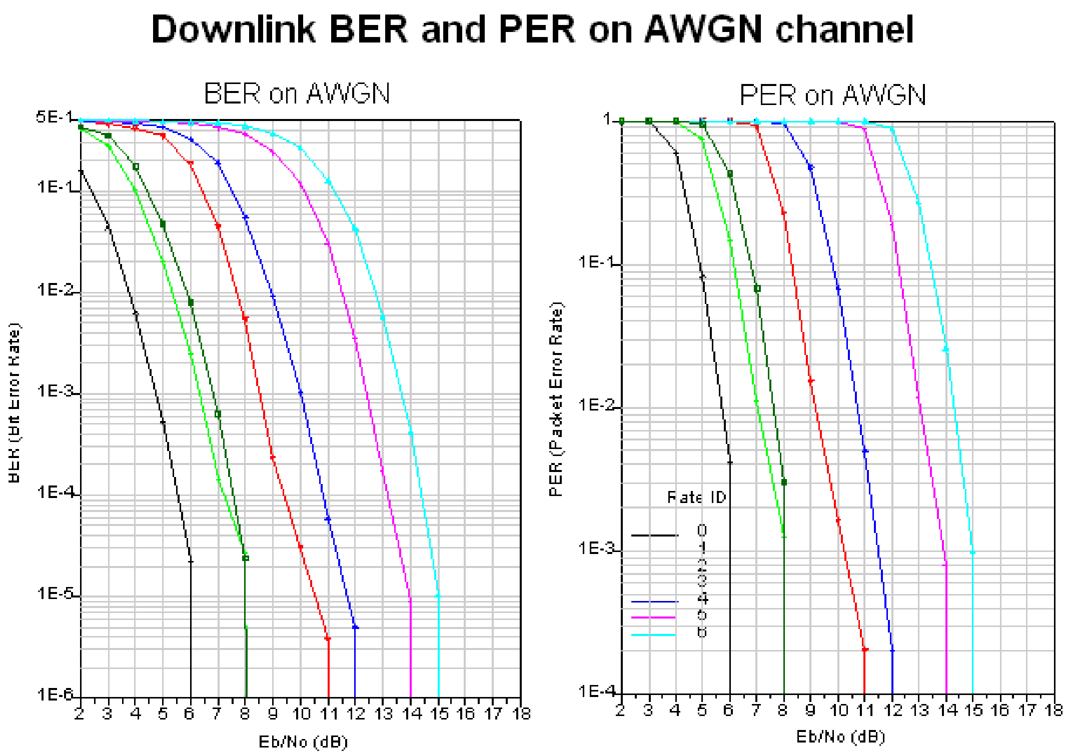
Simulation Results

In this example, The performances of downlink under AWGN channel for QPSK 1/2 (*Rate_ID=0*) to 64QAM 3/4 (*Rate_ID=6*) are given. Parameter Settings shows simulation conditions.

Parameter Settings

Parameter	Value
FCarrier	3407 MHz
Bandwidth	14 MHz
Frame Duration	N/A
Oversampling Option	Ratio 2
Cyclic Prefix	1/4
Packet Length in One Frame (Data Length)	200 Bytes
Rate ID	0, 1, 2, 3, 4, 5, 6
Channel	AWGN
Decoder Type	CSI

The curves have been generated averaging over 500 frames on AGWN fading channel. Downlink Spectral Flatness Simulation Curve shows the simulation results.



Downlink BER and FER Simulation Curve

Benchmark

- Hardware Platform: Pentium IV 2.66GHz, 1 GB memory
- Software Platform: Windows 2000, ADS 2005A
- Simulation Time: about 110 seconds

Downlink Receiver Sensitivity Measurement

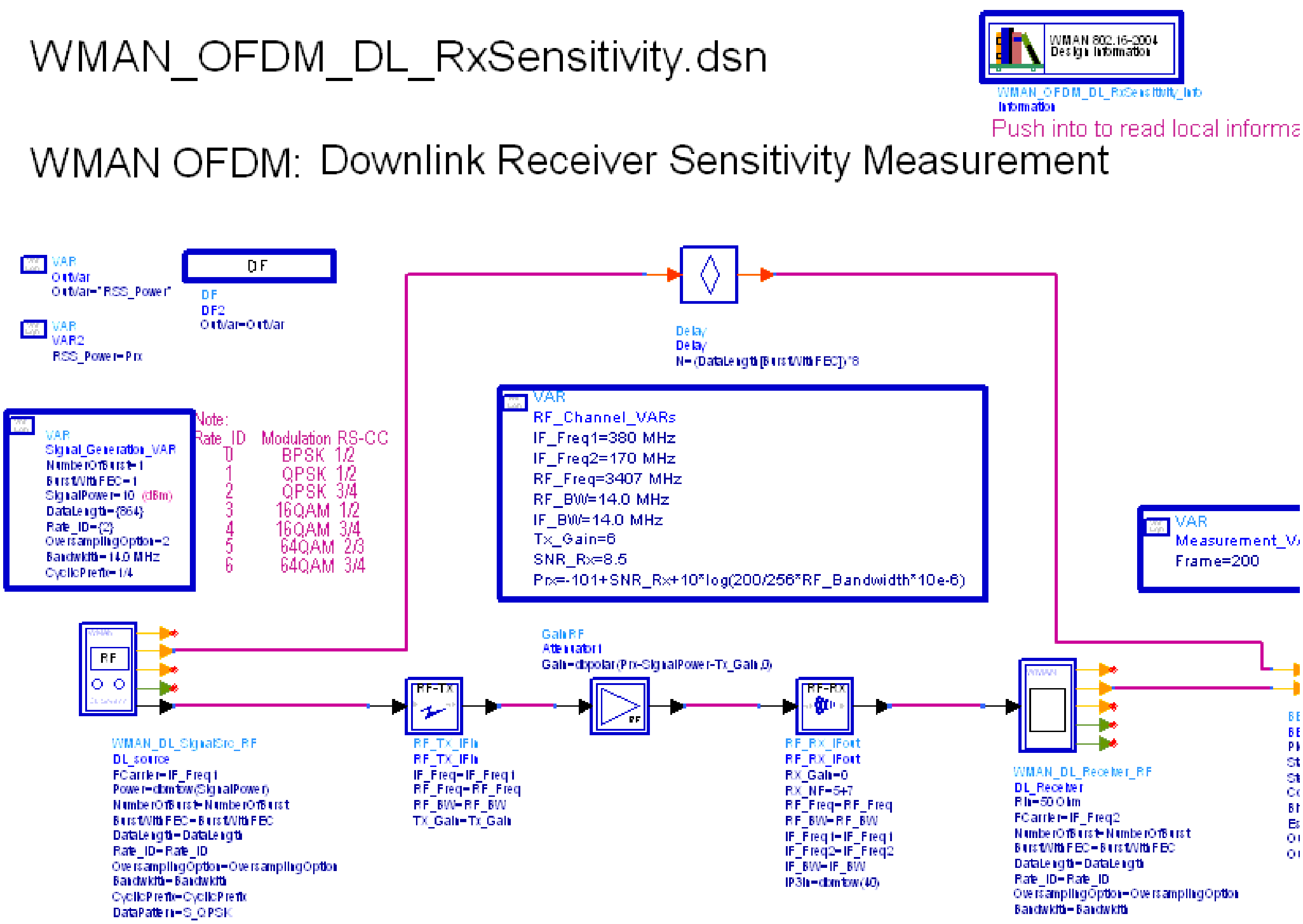
WMAN_OFDM_DL_RxSensitivity Design

Features

- Receiver minimum input level sensitivity measurement

Description

WMAN_OFDM_DL_RxSensitivity measures the BER and PER results. The BER measured after FEC shall be less than 10^(-6) at the power levels RSS defined in equation (98) of section 8.3.11.1 of *IEEE Std 802.16e-2005* (assuming 5dB implementation margin and 8dB Noise Figure). The schematic is shown in WMAN_OFDM_DL_RxSensitivity Schematic.



WMAN_OFDM_DL_RxSensitivity Schematic

In DL receiver, *DecoderType* can be selected with Hard, Soft or CSI.

Users can change *Rate_ID* from 0 to 6 in *Signal_Generation_VARs* and get BER and PER results for different modulations and code rates. In *Measurement_Vars*, the number of frames for simulating BER/FER is defined.

Simulation Results

In this example, the performance for QPSK 3/4 (*Rate_ID=2*) is given. *Parameter Settings* shows the simulation conditions and DL Receiver Sensitivity shows the simulation results averaging over 200 frames.

DL Receiver Sensitivity

Parameter	**Value**
FFT Size	256
Bandwidth	14 MHz
Oversampling Option	Ratio 2
Cyclic Prefix	1/4
Packet Length in One Frame (Data Length)	864 Bytes
Rate ID	QPSK 3/4
Decoder Type	Hard

Eqn RSS=real(RSS_Power)

RSS (dBm)	BER	FER
-69.831	0.000	0.000

DL Receiver Sensitivity

Benchmark

- Hardware Platform: Pentium IV 2.26GHz, 1 GB memory
- Software Platform: Window 2000, ADS 2005A
- Simulation Time: 5 minutes

Uplink BER and PER Measurement on SUI Fading Channel

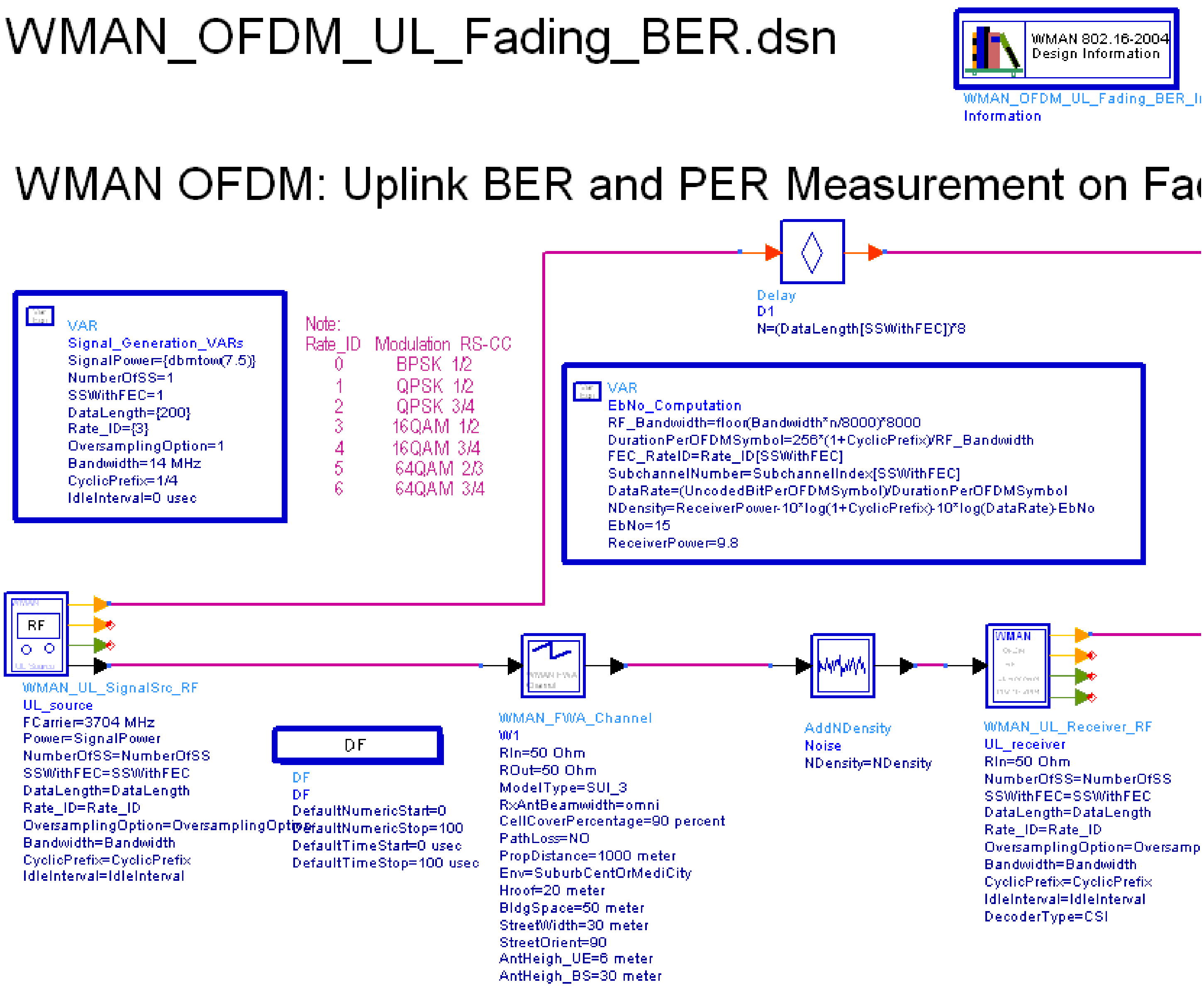
WMAN_OFDM_UL_Fading_BER Design

Features

- BER and PER measurement on SUI fading channel
- Three decoder types supported in uplink receiver: Hard, Soft or CSI
- Multiple Eb/N0 measurement points
- SUI fading channel conditions

Description

WMAN_OFDM_UL_Fading_BER measures uplink BER and PER Measurement on SUI fading channel. The schematic is shown in WMAN_OFDM_UL_Fading_BER Schematic.



WMAN_OFDM_UL_Fading_BER Schematic

The fading channel is SUI channel. Users can change channel type from SUI1 to SUI6. The SUI1 and SUI2 are mostly flat terrain with light tree densities and have minimum path loss. The SUI5 and SUI6 are hilly terrain with moderate-to-heavy tree densities and have maximum path loss. The SUI3 and SUI4 have intermediate pass loss.

In UL receiver, *DecoderType* can be selected with Hard, Soft or CSI.

Users can change *Rate_ID* from 0 to 6 in *Signal_Generation_VARs* and get BER and PER results for different modulations and code rates. In *EbNo_Computation*, the Eb/N0 is calculated. In

Measurement_Vars, the number of frames for simulating BER/FER is defined.

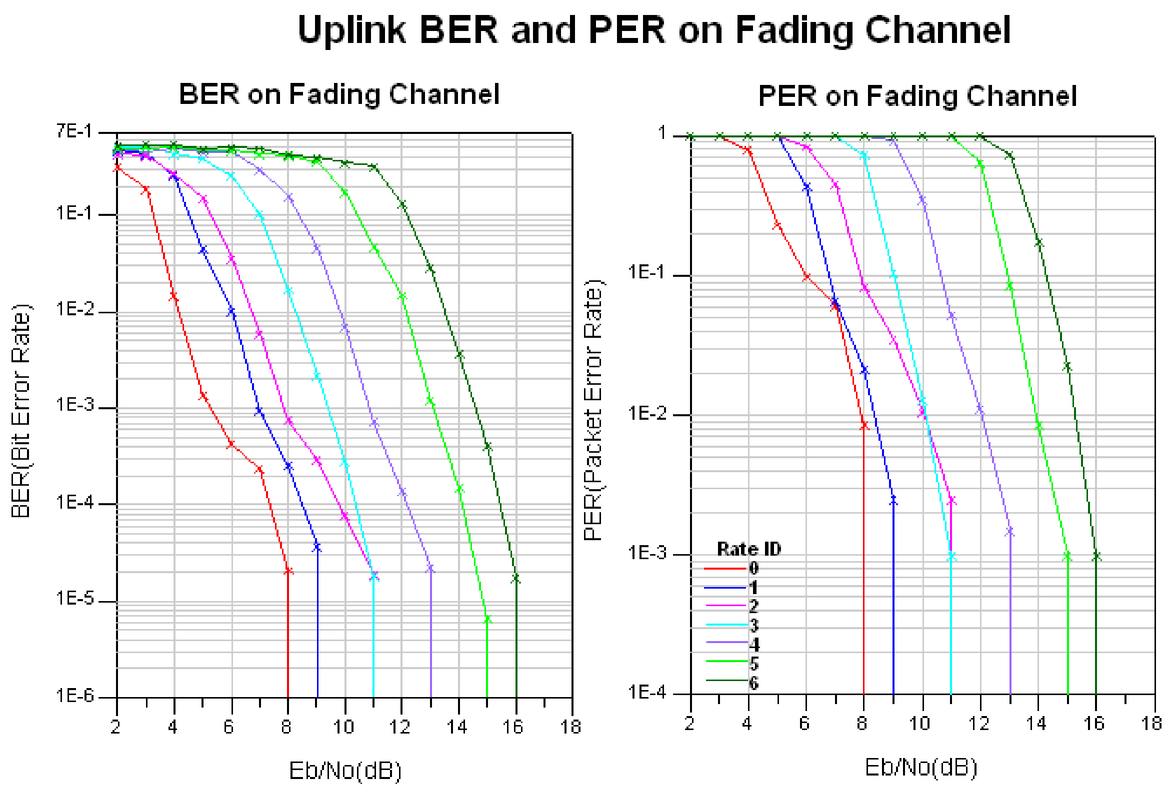
Simulation Results

In this example, The performances of downlink under ITU3 fading channel for QPSK 1/2 (*Rate_ID=0*) to 64QAM 3/4 (*Rate_ID=6*) are given. Parameter Settings shows simulation conditions.

Parameter Settings

Parameter	Value
FCarrier	3407 MHz
Bandwidth	14 MHz
Frame Duration	N/A
Oversampling Option	Ratio 2
Cyclic Prefix	1/4
Packet Length in One Frame (Data Length)	200 Bytes
Rate ID	0, 1, 2, 3, 4, 5, 6
Fading Channel	ITU 3
Decoder Type	CSI

The curves have been generated averaging over 2000 frames on ITU fading channel. Uplink BER and FER Simulation Curve shows the simulation results.



Uplink BER and FER Simulation Curve

Benchmark

- Hardware Platform: Pentium IV 2.66GHz, 1 GB memory
- Software Platform: Windows 2000, ADS 2005A
- Simulation Time: about 3.6 hours for 16QAM 1/2 (*Rate_ID=3*)

WMAN OFDM Uplink Receiver Adjacent and Alternate Channel Rejection

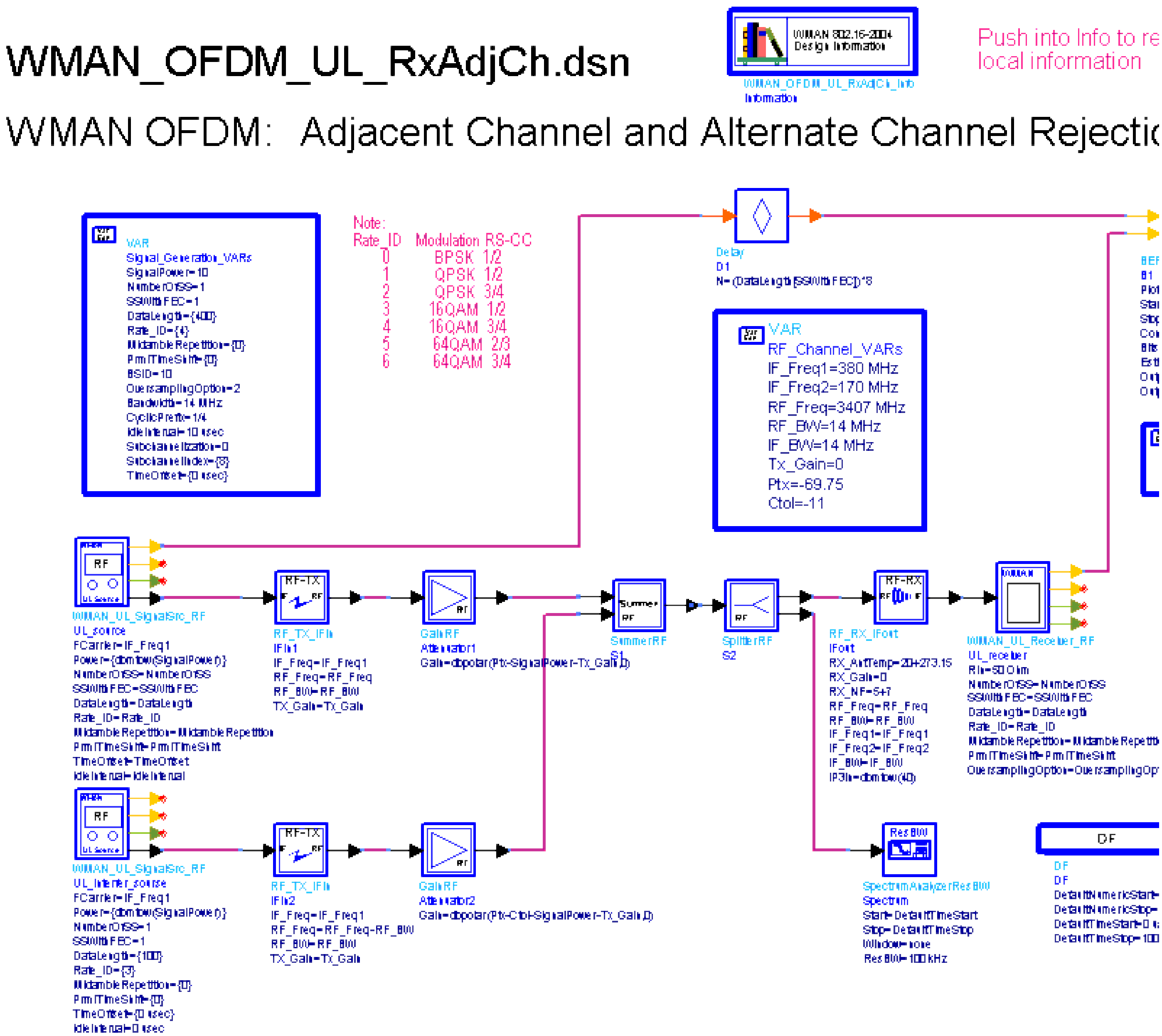
WMAN_OFDM_UL_RxAdjCh Design

Features

- Spectrum of desired signal and interference
- BER and FER measurement of desired signal

Description

This example measures the adjacent and alternate channel rejection defined in section 8.4.13.2 IEEE Std 802.16-2004. The schematic is shown in WMAN_OFDM_TxWaveform Schematic.



WMAN_OFDM_UL_RxAdjCh Schematic

The channel spacing (CS) is determined as the same as channel bandwidth of the desired system, except for systems with a bandwidth of 8.75MHz. For 8.75MHz channel BW, CS is defined as 9MHz. Adjacent channel Interference frequency offset is CS and Alternate channel Interference frequency offset is 2 × CS.
The desired signal's strength is set 3 dB above the rate dependent receiver sensitivity. When the interference signal's strength is set the value according to Specification requirements the BER should be less than 1e-6. For the BER_FER model 500 frame is to be measured and *EstRelVariance* =0.01.

Because the desired signal and interference use different transmit format, their frame structure , modulate type, frame length may be different. When measuring the spectrum of both signal, the *Start* and *Stop* should be set carefully to include both signal.

Specification requirements

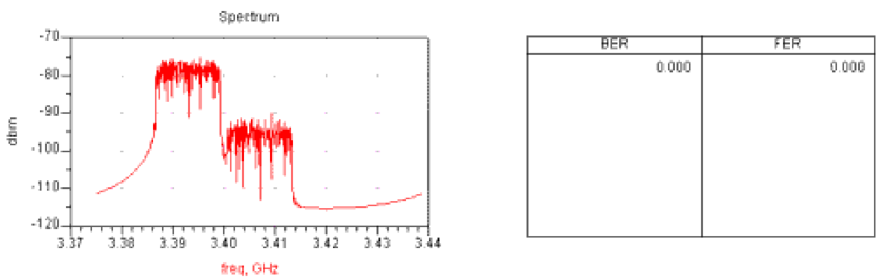
Modulation	<th	<th
16-QAM-3/4	-11	-30
64-QAM-2/3	-4	-23

Simulation Results

Parameter Setting lists some key parameters. Spectrum and BER_FER shows spectrum of desired signal and interference as well as BER and FER of desired signal.

Parameter Setting

Parameter	Value
RF_Freq	3407 MHz
RF_BW	14 MHz
IF_BW	14 MHz
CtoI	-11
Frame	500
EstRelVariance	0.01



Spectrum and BER_FER

Benchmark

- Hardware Platform: Pentium IV 2.66GHz, 1 GB memory
- Software Platform: Window 2000, ADS 2005A
- Simulation Time: 30 minutes

References

1. IEEE Std 802.16-2004, *Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY*, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, *Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems*, May 2005.

WMAN OFDM FrameDuration Design Examples

The WMAN_OFDM_FrameDuration workspace shows WMAN OFDM FrameDuration measurement characteristics including Fading BER, AWGN BER, EVM and Waveform.
Designs for these measurements include:

- WMAN_OFDM_DL_Fading_BER_FD
- WMAN_OFDM_DL_TxEVM_FD
- WMAN_OFDM_DL_TxWaveform_FD
- WMAN_OFDM_UL_AWGN_BER_FD
- WMAN_OFDM_UL_SubCh_TxEVM_FD
  Variables used in these designs are listed in VAR Parameters.

VAR Parameters

Parameter Name	Description	Default Value
FCarrier	RF frequency	3407 (MHz)
Bandwidth	Nominal bandwidth	1.75 (MHz)
Power	Signal power	0.01W
FFTSize	FFT size	256
CyclicPrefix	Cyclic prefix	1/4
OversamplingOption	Oversampling Option	Ratio 1
FrameMode	Frame Mode	FDD
DL_Ratio	Downlink Ratio	0.5
FrameDuration	Frame Duration	5 ms

VAR Parameters

Downlink BER and PER Measurement on SUI Fading Channel

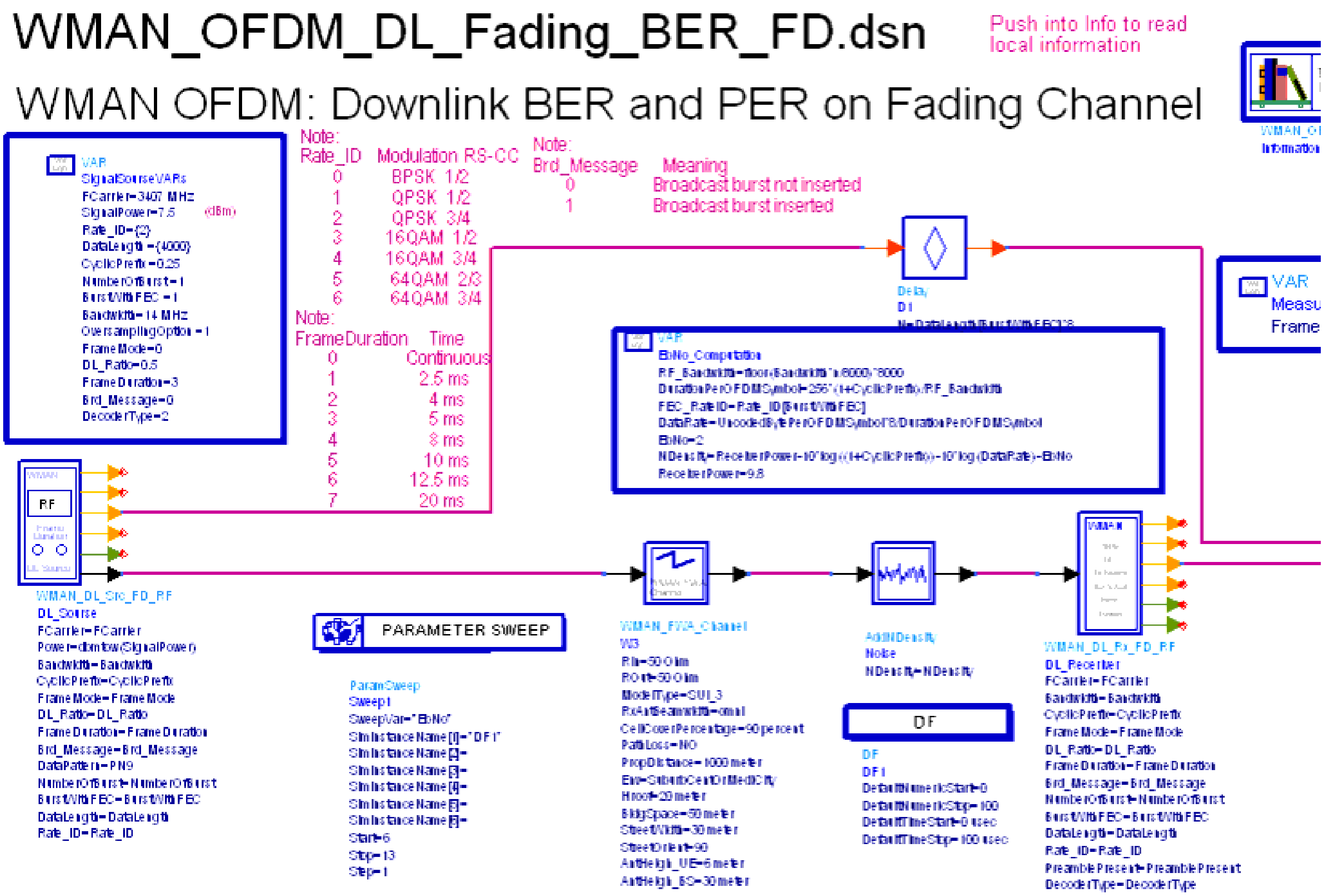
WMAN_OFDM_DL_Fading_BER_FD Design

Features

- BER and PER measurement on SUI fading channel
- Frame structure supported (*FrameDuation* from 2.5 msec to 20 msec)
- Three decoder types supported in downlink receiver: Hard, Soft or CSI
- Multiple Eb/N0 measurement points
- SUI fading channel conditions

Description

WMAN_OFDM_DL_Fading_BER_FD measures downlink BER and PER Measurement on SUI fading channel. The schematic is shown in WMAN_OFDM_DL_Fading_BER_FD Schematic.



WMAN_OFDM_DL_Fading_BER_FD Schematic

In DL source, the frame structure is supported.
The fading channel is SUI channel. Users can change channel type from SUI1 to SUI6. The SUI1 and SUI2 are mostly flat terrain with light tree densities and have minimum path loss. The SUI5 and SUI6 are hilly terrain with moderate-to-heavy tree densities and have maximum path loss. The SUI3 and SUI4 have intermediate pass loss.

In DL receiver, *DecoderType* can be selected with Hard, Soft or CSI.

Users can change *Rate_ID* from 0 to 6 in *SignalSourseVARs* and get BER and PER results for different modulations and code rates. In *EbNo_Computation*, the Eb/N0 is calculated. In *Measurement_Vars*, the number of frames for simulating BER/FER is defined.

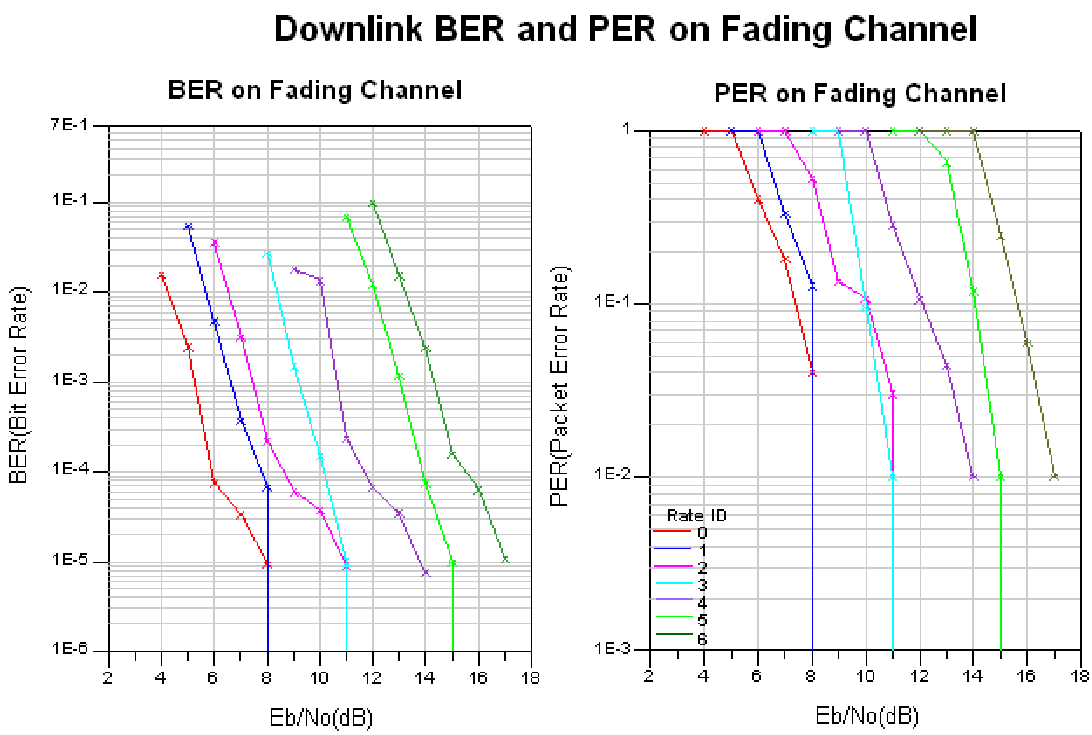
Simulation Results

In this example, The performances of downlink under ITU3 fading channel for QPSK 1/2 (*Rate_ID=0*) to 64QAM 3/4 (*Rate_ID=6*) are given. Parameter Settings shows simulation conditions.

Parameter Settings

Parameter	Value
FCarrier	3407 MHz
Bandwidth	14 MHz
Frame Duration	5 msec
Oversampling Option	Ratio 2
Cyclic Prefix	1/4
Packet Length in One Frame (Data Length)	4000 Bytes
Rate ID	0, 1, 2, 3, 4, 5, 6
Fading Channel	ITU 3
Decoder Type	CSI

The curves have been generated averaging over 100 frames on ITU fading channel. Downlink Spectral Flatness Simulation Curve shows the simulation results.



Downlink BER and FER Simulation Curve

Benchmark

- Hardware Platform: Pentium IV 2.66GHz, 1 GB memory
- Software Platform: Windows 2000, ADS 2005A
- Simulation Time: about 2 hours for QPSK 3/4 (*Rate_ID=2*)

Downlink Transmitter Error Vector

Magnitude Measurement with FrameDuration

WMAN_OFDM_DL_TxEVM_FD

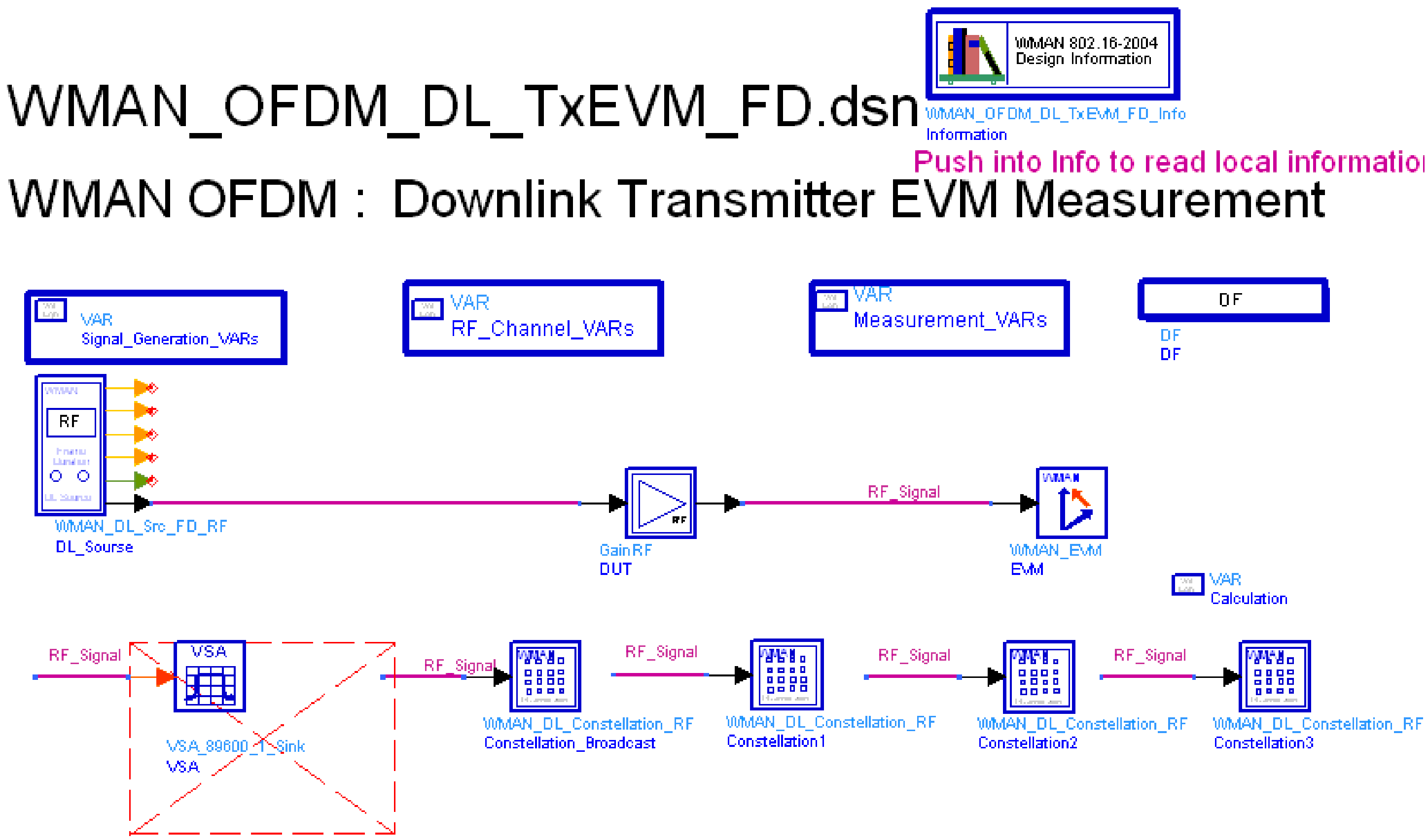
Features

- Support the EVM measurement for each data rate and frame duration
- Support EVM measurement and constellation output
- Consistent measurement results with Agilent 89600 software

Description

This example measures transmit modulation accuracy of WMAN_DL_Src_FD RF signal source. Users can change Rate_ID for all bursts from 0 to 6 in Signal_Generation_VARs to measure the EVM for each data rate and can set different Rate_ID for each burst to display the constellation.

The schematic for this design is shown in WMAN_OFDM_DL_TxEVM_FD Schematic.



WMAN_OFDM_DL_TxEVM_FD Schematic

WMAN_DL_Src_FD_RF generates the ideal signal waveform which is fed to the Device Under Test (DUT) GainRF. Output signal of GainRF is the distorted signal to be measured.

Model WMAN_EVM is used to measure EVM (or Relative Constellation Error, RCE), carrier frequency offset, IQ_Offset as well as other aspects of the input signal. Model WMAN_EVM uses the same algorithm as that in Agilent 89600 VSA, and thus the measurement results shall be consistent with the latter. Note that, for getting reasonable measurement results, parameters of the WMAN_EVM model should be consistent with the corresponding input signal.

If *AverageType* is set to *OFF*, only one frame is analyzed. If *AverageType* is set to *RMS* (*Video*), after the first frame is analyzed the signal segment corresponding to it is discarded and new signal samples are collected from the input to fill in the signal buffer of length 2 x *FrameDuration*. The *SymbolTimingAdjust* parameter sets the percentage of symbol time by which we back away from the symbol end before we perform the FFT. The *TrackAmplitude*, *TrackPhase*, *TrackTiming*, and *EqualizerTraining* parameters determine the EVM measurement result. For more information, refer to WMAN_EVM.

Models Constellation_Broadcast and Constellation1, 2, 3 are used to display the constellation of the broadcast message and other parts of the burst1, as well as the bursts2, 3.

Simulation Results

Key Parameter Setting

Parameter	Value
Signal Power	10 (dBm)
Bandwidth	14 MHz
Oversampling Option	Ratio 1
Gain	10 (in dB)
NumberOfBurst	3
Rate_ID	{16-QAM-1/2, 16-QAM-1/2, 16-QAM-1/2}
DL_Ratio	0.5
Frame Duration	5 ms

Simulation results in the Data Display System are shown in Measurement results, which includes the average EVM (or RCE) measurement result in dB and percentage and the constellation of the broadcast message and other parts of the burst1, as well as the bursts2, 3.

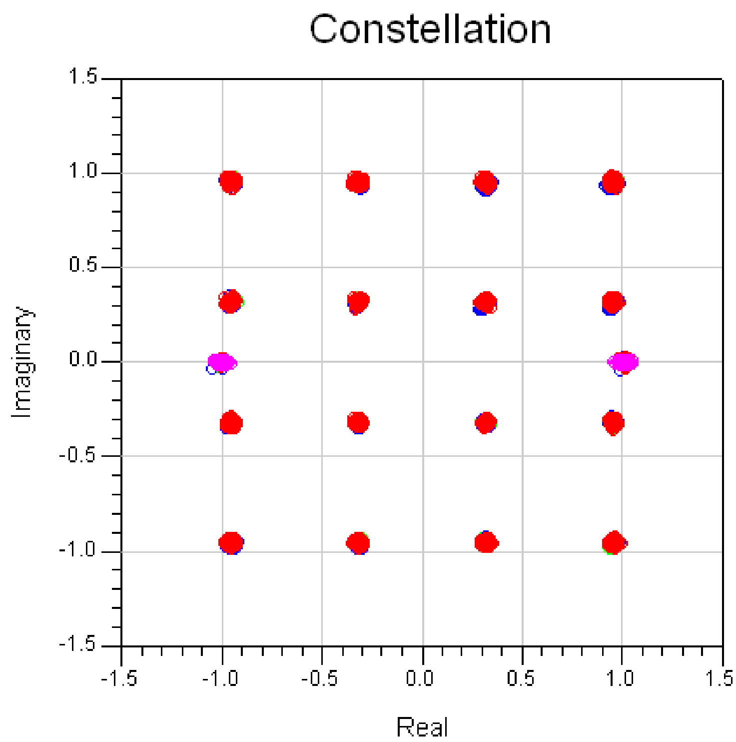
The relative constellation RMS error, averaged over subcarriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to *Allowed relative constellation error versus data rate* as defined in section 8.3.10.1.2, IEEE Std 802.16-2004 and 8.3.10.3, Cor1 D5.

Allowed relative constellation error versus data rate

Burst type	Relative Constellation Error (dB)
BPSK-1/2	-13.0
QPSK-1/2	-16.0
QPSK-3/4	-18.5
16-QAM-1/2	-21.5
16-QAM-3/4	-25.0
64-QAM-2/3	-28.5
64-QAM-3/4	-31.0

EVM (or RCE)

RCE_dB	RCErms_percent
-36.787	1.448



Measurement results

Benchmark

- Hardware platform: Pentium IV 2.66 GHz, 1024 MB memory
- Software platform: Windows 2000 Professional, ADS 2005A
- Simulation time: approximately 35 seconds

WMAN OFDM Downlink Transmitter Waveform Measurement with Frame Duration

WMAN_OFDM_DL_TxWaveform_FD Design

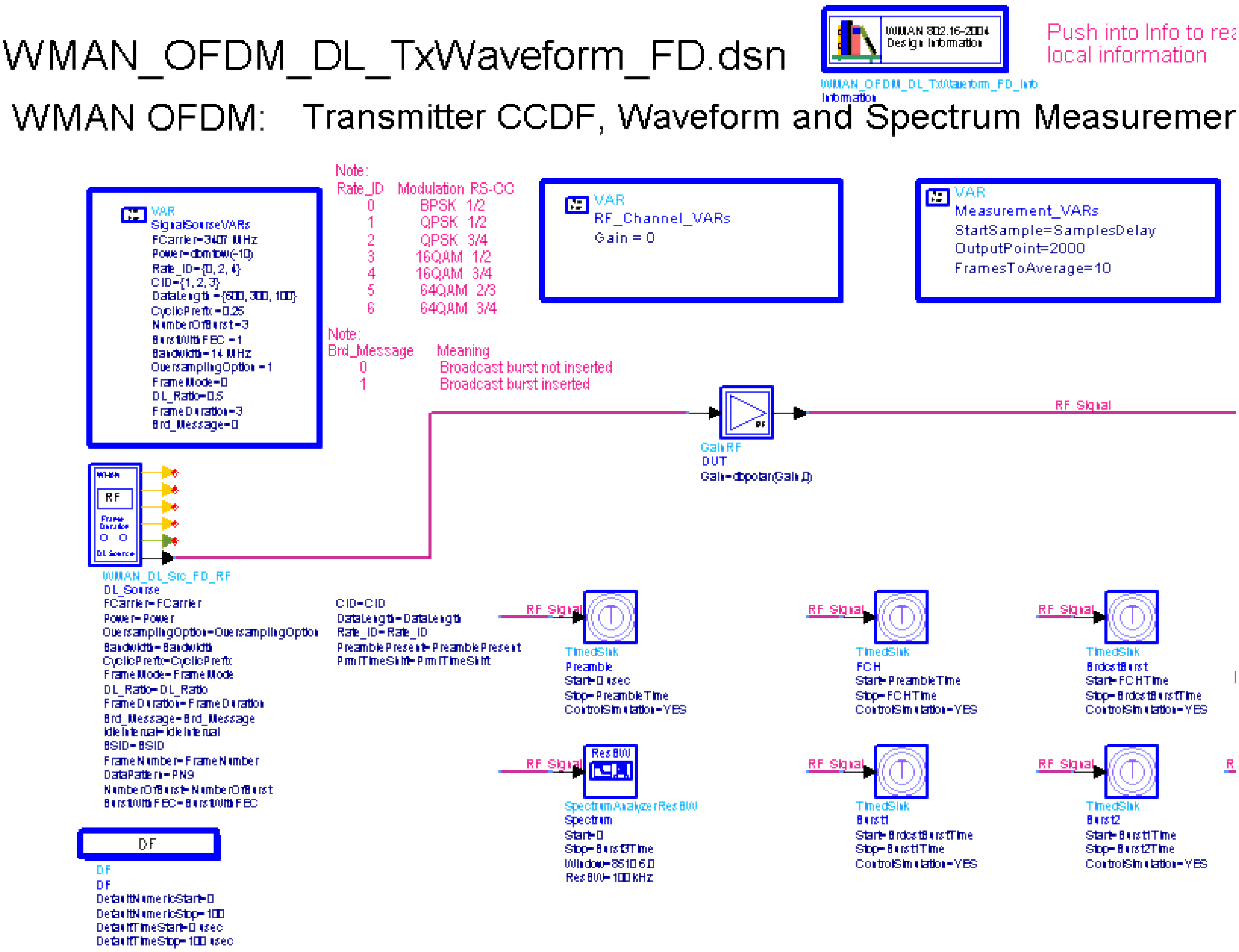
Features

- Transmitter CCDF

- Preamble Power, Mean Power and Peak Power
- Transmitter Waveform
- Transmitter Spectrum

Description

This example measures CCDF and Power of WMAN OFDM Downlink FD Transmitter.The schematic is shown in WMAN_OFDM_TxWaveform Schematic.



WMAN_OFDM_TxWaveform_FD Schematic

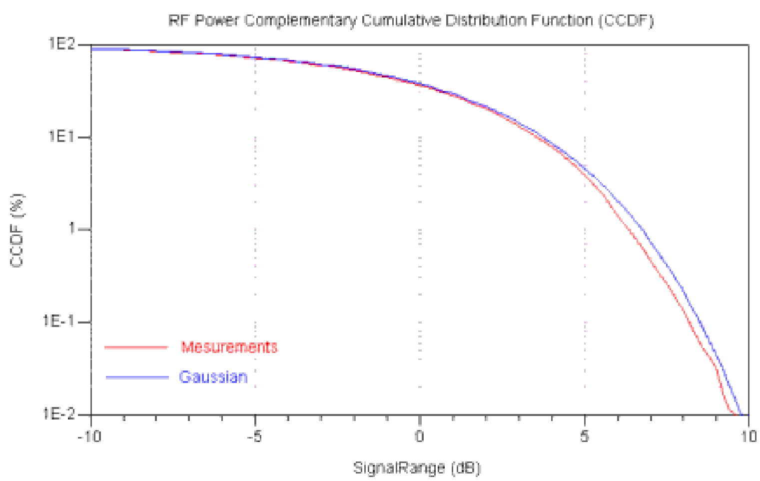
OutputPoint means how many parts will X-axis be divided into in the CCDF figure. The larger *OutputPoint* is, the closer measured curve is to reference curve. *SymNum* means the number of symbol measured. *StartSample* in the WMAN_RF_CCDF model is used to discard the first frame delay caused by receiver model.

Simulation Results

Parameter Setting lists some key parameters. Transmitter CCDF and Power Measurement shows transmitter CCDF and power measurement. Transmitter Waveform shows transmitter waveform. Spectrum shows transmitter spectrum. The nominal channel bandwidth of the transmitter is 14MHz, more information about transmitter Spectrum Mask is defined in 5.3.3 ETSI EN 301 021 V1.6.1(2003-07) and 8.5.2 IEEE Std 802.16-2004. Spectral density of the transmitted signal shall fall within the spectral mask.

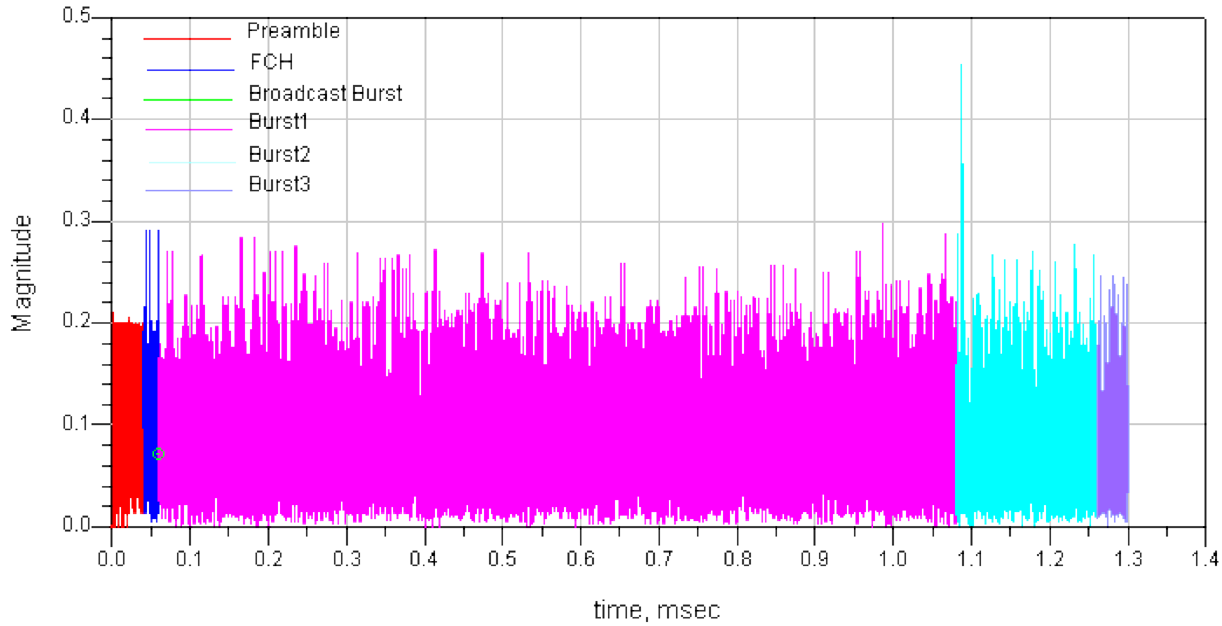
Parameter Setting

Parameter	Value
Signal Power	-10 (dBm)
Bandwidth	14 MHz
Oversampling Option	Ratio 2
Gain	0 (in dB)
Output Point	1000
SymNum	100

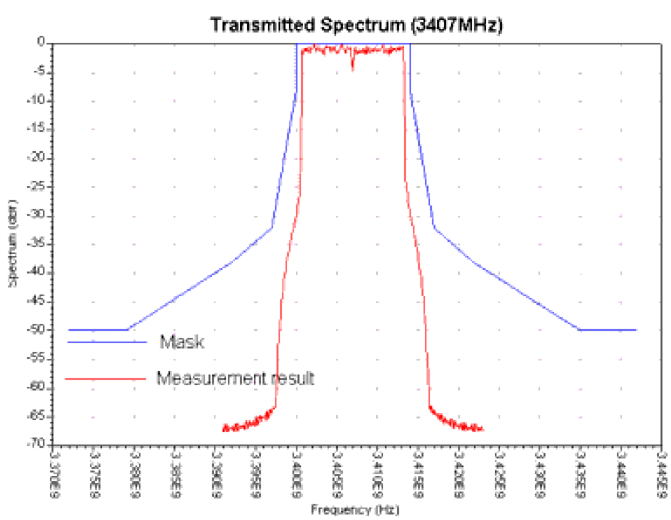


PeakPower_dBm	MeanPower_dBm	RF_Peak_to_Avg_dB
-1.500	-9.870	8.370

Transmitter CCDF and Power Measurement



Transmitter Waveform



Spectrum

Benchmark

- Hardware Platform: Pentium IV 2.2GHz, 1 GB memory
- Software Platform: Window 2000, ADS 2005A
- Simulation Time: 60 seconds

Uplink BER and PER Measurement on AWGN Channel with FrameDuration

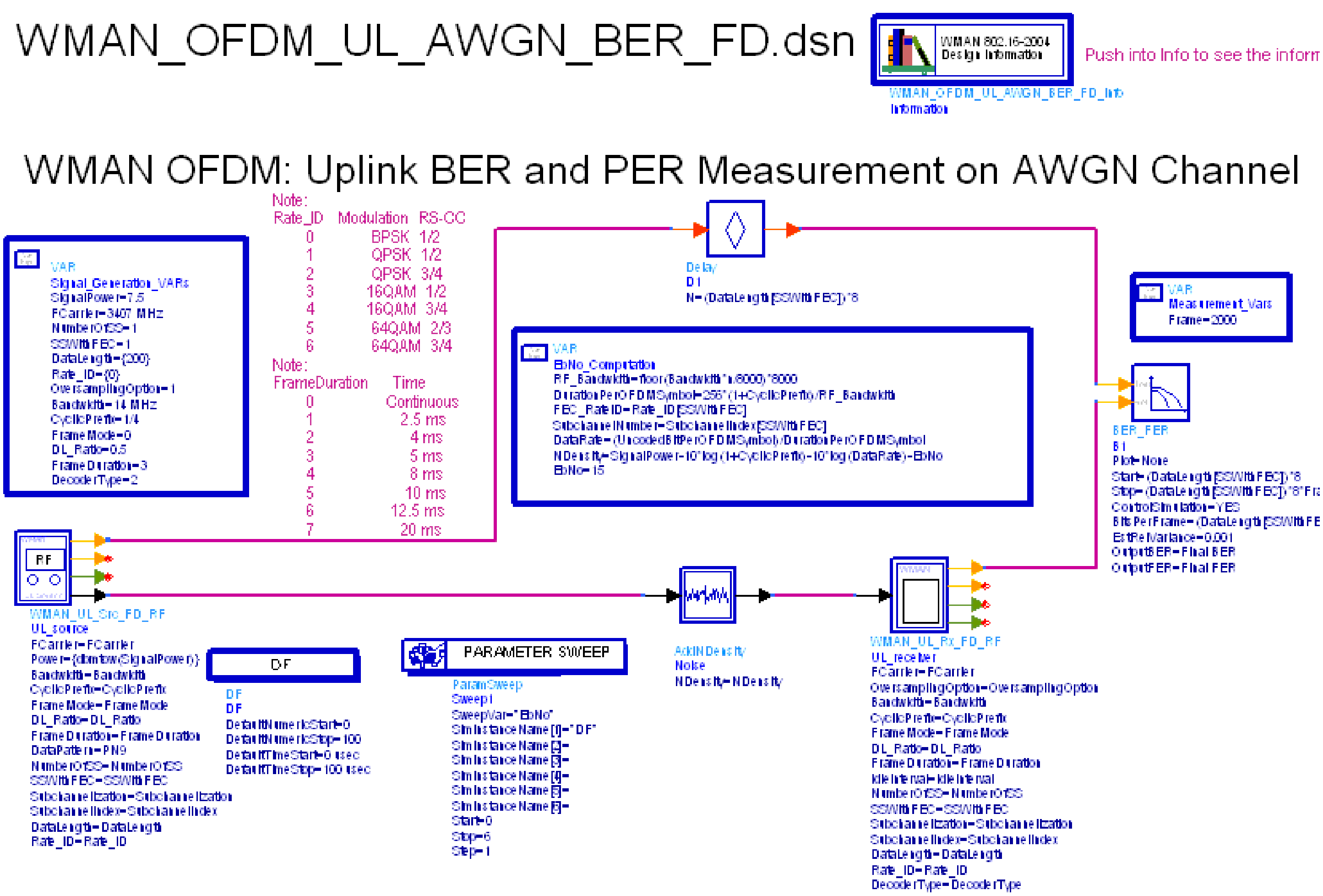
WMAN_OFDM_UL_AWGN_BER_FD Design

Features

- BER and PER measurement on AWGN channel
- Three decoder types supported in uplink receiver: Hard, Soft or CSI
- Multiple Eb/N0 measurement points

Description

WMAN_OFDM_UL_AWGN_BER_FD measures downlink BER and PER Measurement on AWGN channel. The schematic is shown in WMAN_OFDM_UL_AWGN_BER_FD Schematic.



WMAN_OFDM_UL_AWGN_BER_FD Schematic

Users can change *Rate_ID* from 0 to 6 in *Signal_Generation_VARs* and get BER and PER results for different modulations and code rates. In *EbNo_Computation*, the Eb/N0 and corresponding NDensity is calculated. In *Measurement_Var* s, the number of frames for simulating BER/FER is defined.

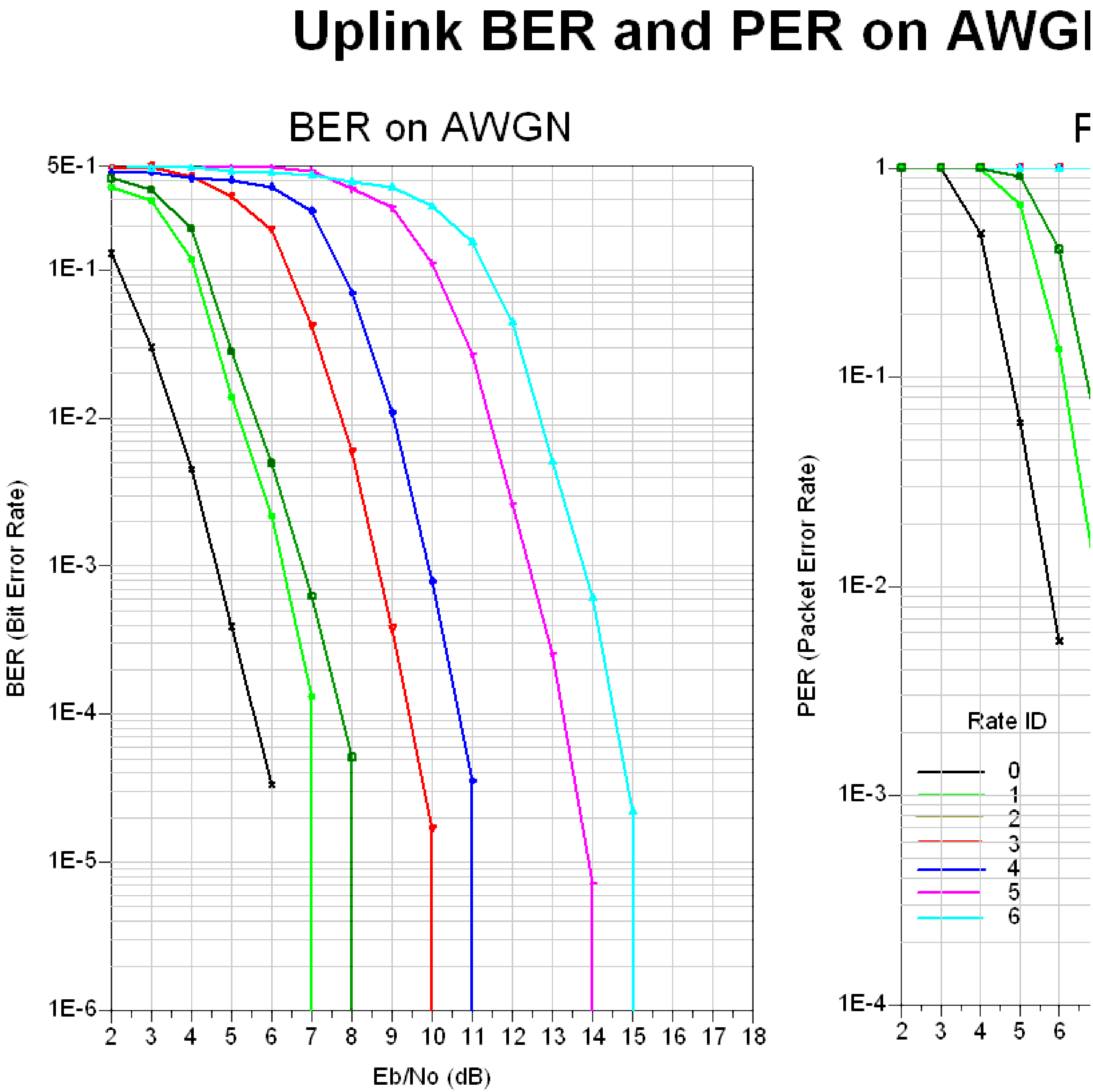
Simulation Results

In this example, The performances of uplink PUSC for BPSK 1/2 (*Rate_ID=0*), QPSK 1/2 (*Rate_ID=1*), QPSK 3/4 (*Rate_ID=2*), 16QAM 1/2 (*Rate_ID=3*), 16QAM 3/4 (*Rate_ID=4*), 64QAM 2/3 (*Rate_ID=5*) and 64QAM 3/4 (*Rate_ID=6*) are given. Parameter Settings shows the simulation conditions.

Parameter Settings

Parameter	**Value**
FCarrier	3407 MHz
Zone Type	UL PUSC
FFT Size	256
Bandwidth	14 MHz
Frame Duration	5 msec
Oversampling Option	Ratio 2
Cyclic Prefix	1/4
Packet Length in One Frame (Data Length)	200 Bytes
Rate ID	BPSK 1/2, QPSK 1/2, QPSK 3/4, 16QAM 1/2, 16QAM 3/4, 64QAM 2/3 and 64QAM 3/4
Decoder Type	CSI

The curves have been generated averaging over 2000 frames. Uplink BER and FER Simulation Curve shows the simulation results.



Uplink BER and FER Simulation Curve

Benchmark

- Hardware Platform: Centrino Duo 2.0GHz, 2 GB memory
- Software Platform: Windows XP, ADS 2005A
- Simulation Time: about 1.5 hours for QPSK 1/2 (Rate_ID=0)

Uplink Transmitter Subchannel Error Vector

Magnitude Measurement with FrameDuration

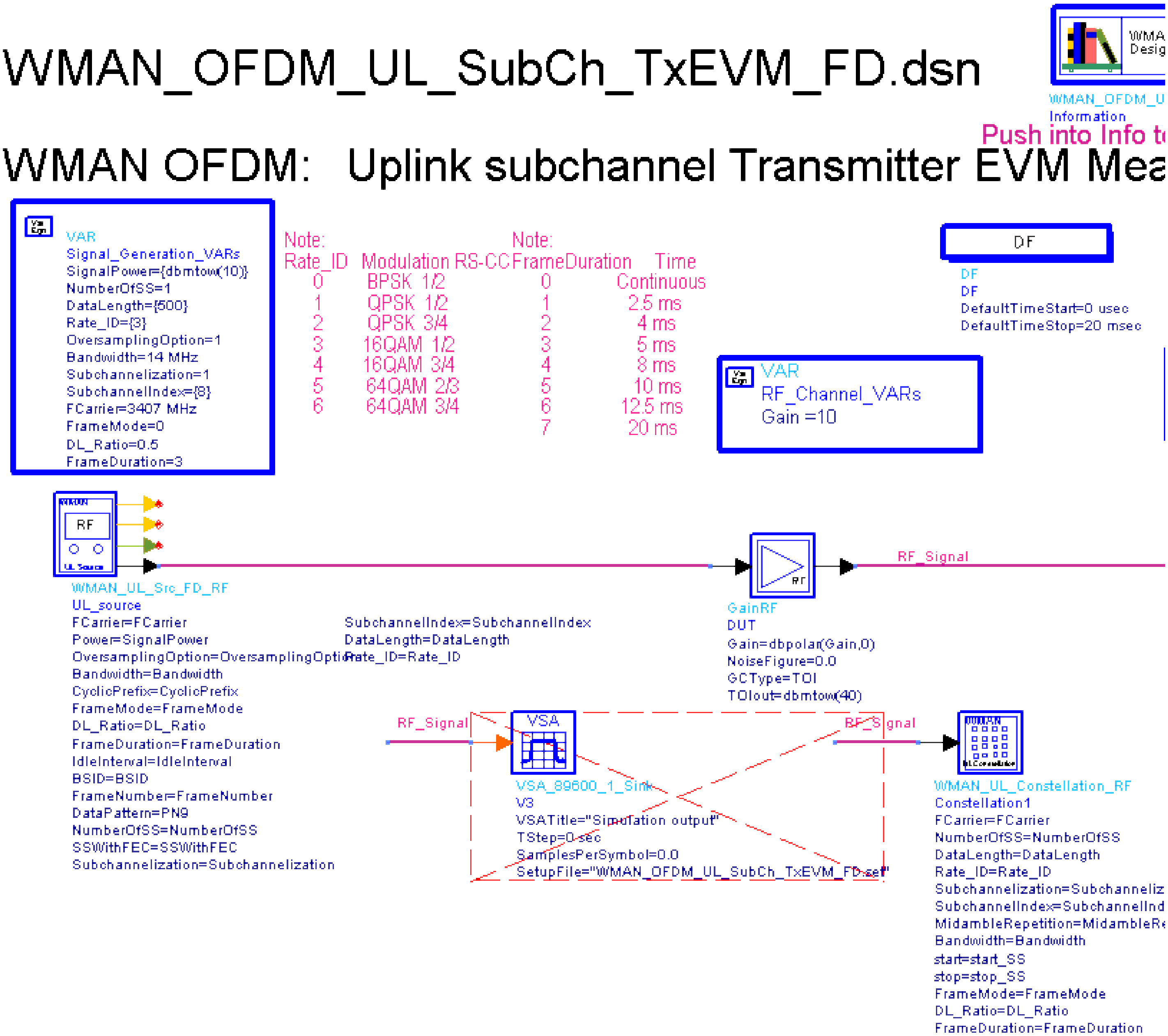
WMAN_OFDM_UL_SubCh_TxEVM_FD

Features

- Support the EVM measurement for each data rate and frame duration
- Support EVM measurement and constellation output
- Consistent measurement results with Agilent 89600 software

Description

This example measures transmit modulation accuracy of WMAN_UL_Src_FD RF signal source. Users can change Rate_ID for all bursts from 0 to 6 in Signal_Generation_VARs to measure the EVM for each data rate and can set different Rate_ID for each burst to display the constellation.
The schematic for this design is shown in WMAN_OFDM_UL_Subch_TxEVM_FD Schematic.



WMAN_OFDM_UL_Subch_TxEVM_FD Schematic

WMAN_UL_Src_FD_RF generates the ideal signal waveform which is fed to the Device Under Test (DUT) GainRF. Output signal of GainRF is the distorted signal to be measured.

Model WMAN_EVM is used to measure EVM (or Relative Constellation Error, RCE), carrier frequency offset, IQ_Offset as well as other aspects of the input signal. Model WMAN_EVM uses the same algorithm as that in Agilent 89600 VSA, and thus the measurement results shall be consistent with the latter. Note that, for getting reasonable measurement results, parameters of the WMAN_EVM model should be consistent with the corresponding input signal. For more details on WMAN_EVM, see document of this model.

Simulation Results

Parameter Setting

Parameter	Value
Signal Power	10 (dBm)
Bandwidth	14 MHz
Oversampling Option	Ratio 1
Gain	10 (in dB)
NumberOfSS	1
Rate_ID	16-QAM-1/2
DL_Ratio	0.5
Frame Duration	5 ms

Simulation results in the Data Display System are shown in Measurement results, which includes the average EVM (or RCE) measurement result in dB and percentage and the constellation of the broadcast message and other parts of the burst1, as well as the bursts2, 3.

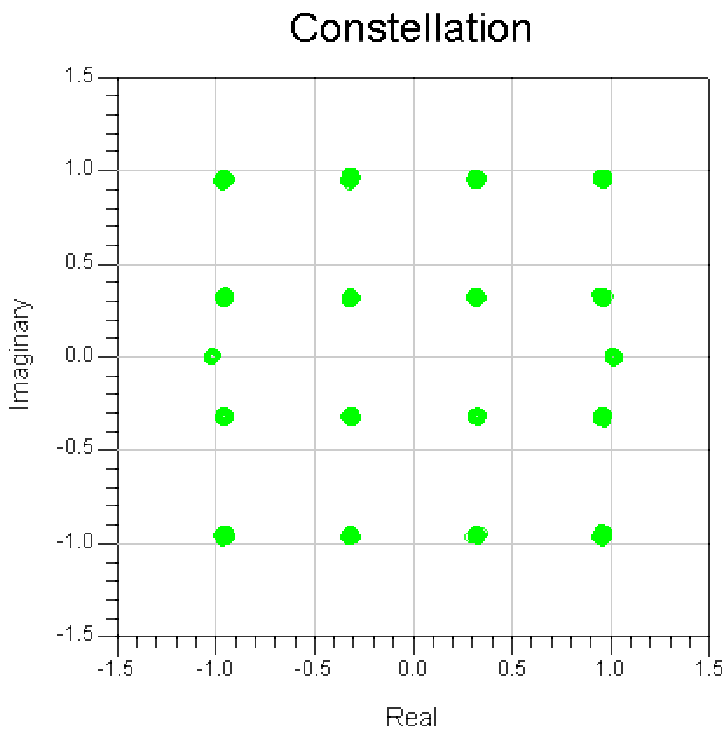
The relative constellation RMS error, averaged over subcarriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to Allowed relative constellation error versus data rate as defined in section 8.3.10.1.2, IEEE Std 802.16-2004 and 8.3.10.3, Cor1 D5.

Allowed relative constellation error versus data rate

Burst type	Relative Constellation Error (dB)
BPSK-1/2	-13.0
QPSK-1/2	-16.0
QPSK-3/4	-18.5
16-QAM-1/2	-21.5
16-QAM-3/4	-25.0
64-QAM-2/3	-29.0
64-QAM-3/4	-30.0

EVM (or RCE)

RCE_dB	RCErms_percent
-35.981	1.588



Measurement results

Benchmark

- Hardware platform: Pentium IV 2.66 GHz, 1024 MB memory
- Software platform: Windows 2000 Professional, ADS 2005A
- Simulation time: approximately 50 seconds

References

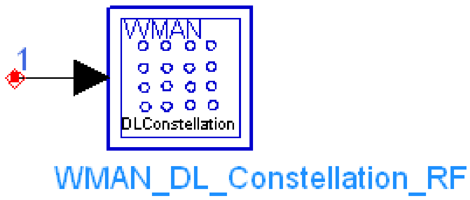
1. IEEE Std 802.16-2004, *Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY*, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, *Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems*, Sept. 2005.

WMAN Measurement Components

The measurement models provide basic measurements.

- *WMAN DL Constellation RF (WMAN Downlink Constellation Measurement)* (wman)
- *WMAN DL RF CCDF FD (WMAN Downlink RF CCDF FD)* (wman)
- *WMAN DL SpecFlat (WMAN Downlink Spectral Flatness Measurement)* (wman)
- *WMAN RF CCDF (WMAN RF CCDF)* (wman)
- *WMAN UL Constellation RF (WMAN Uplink Constellation Measurement)* (wman)
- *WMAN UL RF CCDF FD (WMAN Uplink RF CCDF FD)* (wman)
- *WMAN UL SpecFlat (WMAN Uplink SpecFlat)* (wman)

WMAN_DL_Constellation_RF (WMAN Downlink Constellation Measurement)



Description Downlink constellaton measurement with broadcast message and frame duration
Library WMAN, Measurement
Class TSDFWMAN_DL_Constellation_RF

Parameters

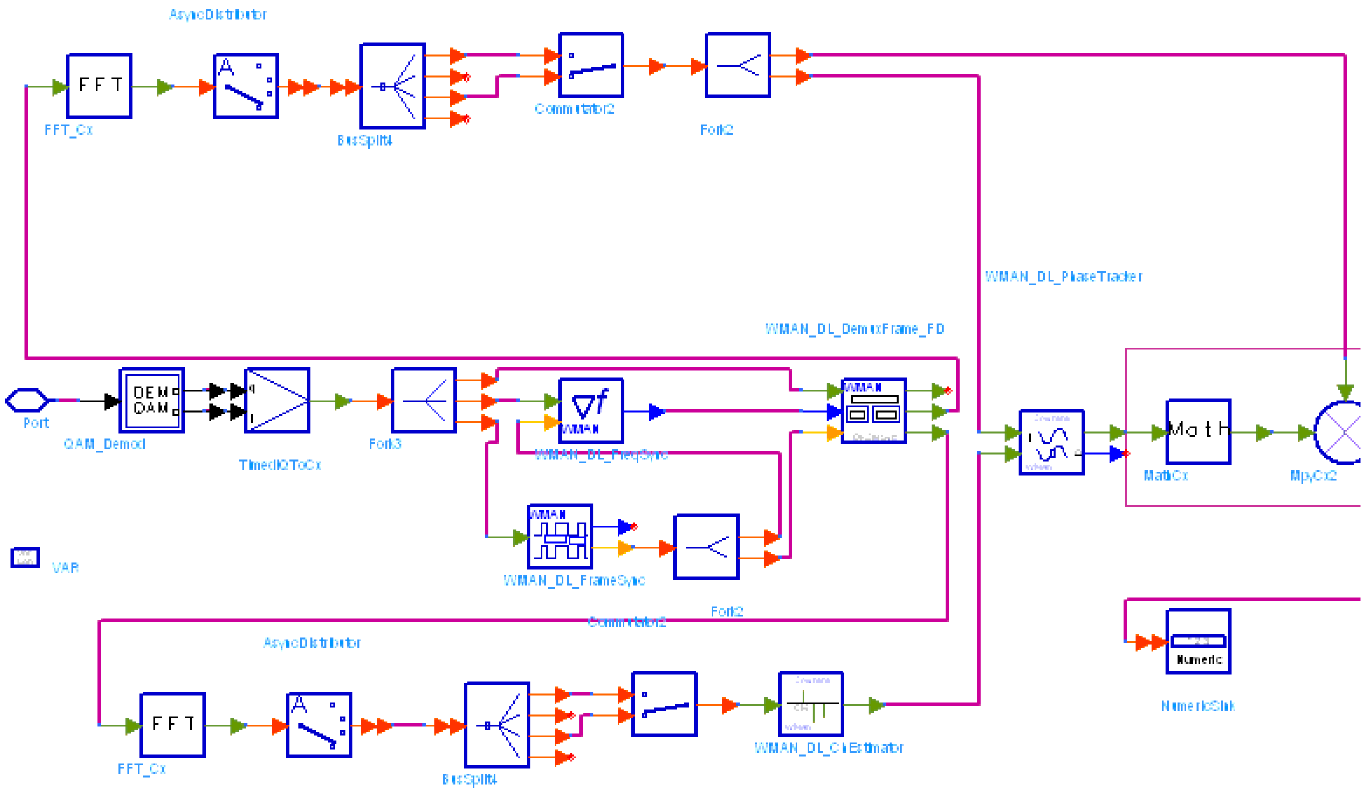
Name	Description	Default	Unit	Type	Range
RIn	Input resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	1900 MHz	Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	Reference phase in degrees	0.0	deg	real	(-∞, ∞)
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	(-∞, ∞)
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle interval	10.0 usec	sec	real	[0, 1000)
PilotPN_Phase	Pilot PN phase	0		int	[0, 4095]
start	Frame Number	1200		int	[0, ∞)
stop	Frame Number	2399		int	[start, ∞)
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Notes/Equations

1. This subnetwork is used to do WMAN downlink constellation measurement.
   The schematic for this subnetwork is shown in WMAN_DL_Constellation_RF Schematic.



WMAN_DL_Constellation_RF Schematic

2. The input timed signal is demodulated from RF to baseband by QAM_Demod. Then, frame synchronization, frequency offset, frame demultiplex, channel estimate, phase track and channel compensation are completed by WMAN_DL_FrameSync, WMAN_DL_FreqSync, WMAN_DL_ChEstimator and WMAN_DL_PhaseTracker respectively. The equalized data are collected by the Sink named Constellation.
   The constellations displayed in Data Display window depend on the parameters start, stop which decide which part of signal is measured and the number of constellation points and the parameter Rate_ID which decides the constellation-mapping.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_RF_CCDF_FD (WMAN Downlink RF CCDF FD)

Description Downlink CCDF measurment with broadcast message and frame duration
Library WMAN, Measurement
Class TSDFWMAN_DL_RF_CCDF_FD

Parameters

Name	Description	Default	Unit	Type	Range
RLoad	Source resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
StartSample	Sample from which measurement begin	0		int	
SymLen	length of input signal symbol	2560		int	
SymNum	Number of symbols	1		int	
OutputPoint	Indicate output precision	100		int	
RefR	Reference resistance	50 Ohm	Ohm	real	
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present	{0}		int array	{0, 1}
IdleInterval	Idle interval	10 usec	sec	real	[0, 1000]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	

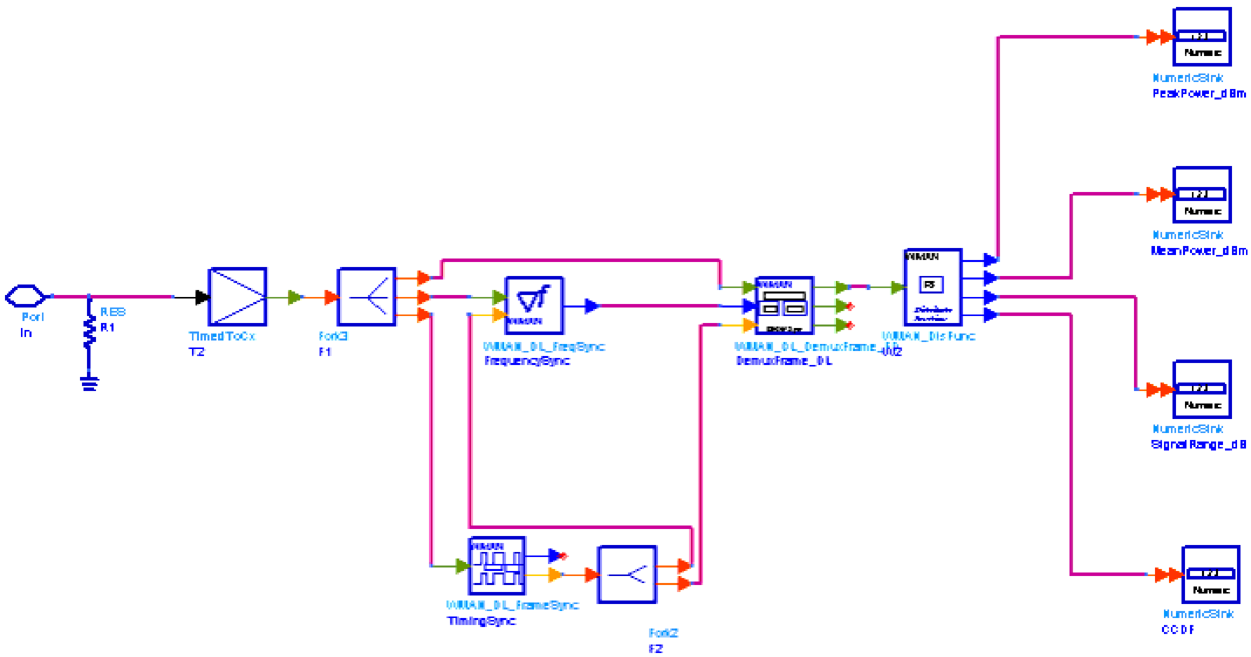
Pin Inputs

Pin	Name	Description	Signal Type
1	RF_Signal	received RF signal to be measured	timed

Notes/Equations

1. This subnetwork measures the complementary cumulative distribution function (CCDF) of the

WMAN OFDM downlink RF signal, PeakPower and MeanPower.
2. The distribution range is divided into segments according to the OutputPoint parameter and is sent to the SignalRange_dB NumericSink. The corresponding distribution probability is calculated based on these segments and sent to the CCDF NumericSink. 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. The schematic for this subnetwork is shown in WMAN_DL_RF_CCDF_FD Schematic.



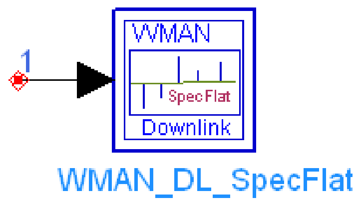
WMAN_DL_RF_CCDF_FD Schematic

4. 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.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DL_SpecFlat (WMAN Downlink Spectral Flatness Measurement)



Description Downlink spectral flatness measurement
Library WMAN, Measurement
Class TSDFWMAN_DL_SpecFlat

Parameters

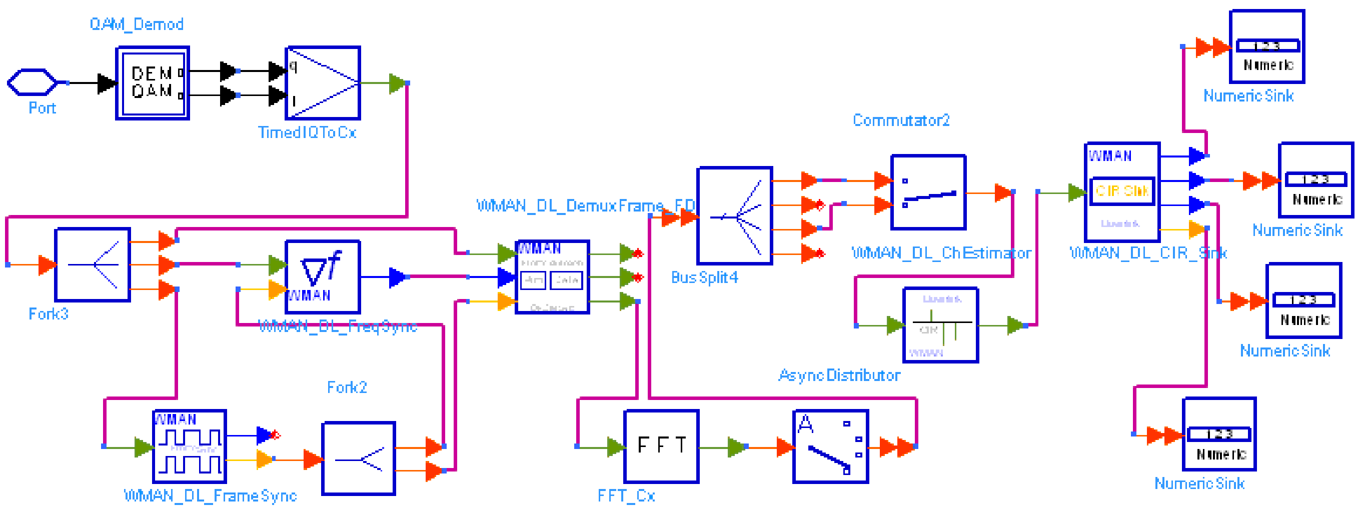
Name	Description	Default	Unit	Type	Range
RIn	Input resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	3407 MHz	Hz	real	(0, ∞)
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	
IdleInterval	Idle interval	0.0 usec	sec	real	[0, 1000)
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
FramesToAverage	Number of frames for the average CIR	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Notes/Equations

1. This subnetwork is used to measure the spectral flatness of WMAN OFDM Downlink subframe. The schematic for this subnetwork is shown in WMAN_DL_SpecFlat Schematic.



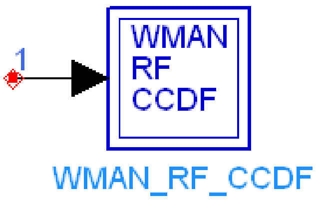
WMAN_DL_SpecFlat Schematic

1. In this subnetwork, the data (CIRs) are taken from the channel estimation to measure the spectral flatness. Only the CIRs in the burst with FEC-encoded are used to measure the spectral flatness. The results shall be the average of FramesToAverage downlink subframes, where FramesToAverage is set by users. The measurement results are output to Sink SpecEnergy. Meanwhile the difference energy between adjacent subcarriers from -100 to 100 are output to Sink SpecDiff, and spectral lines from -100 to 100 are output to Sink SpecLines. The number of subcarriers in which the spectral energies are out of the spectral mask and in which the difference between adjacent subcarriers exceed 0.1 dB are output to Sink StatParam.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_RF_CCDF (WMAN RF CCDF)



Description CCDF measurment
Library WMAN, Measurement
Class TSDFWMAN_RF_CCDF

Parameters

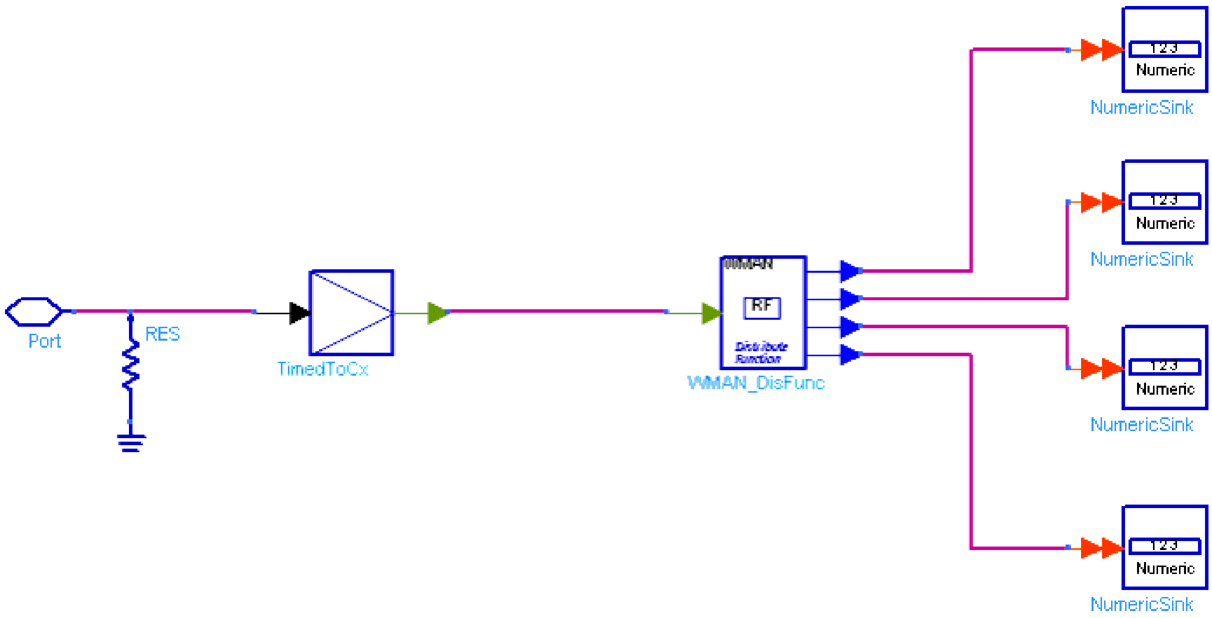
Name	Description	Default	Unit	Type	Range
RLoad	Source resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
StartSample	Sample from which measurement begin	0		int	
SymLen	length of input signal symbol	2560		int	
SymNum	Number of symbols	1		int	
OutputPoint	Indicate output precision	100		int	
RefR	Reference resistance	50 Ohm	Ohm	real	

Pin Inputs

Pin	Name	Description	Signal Type
1	RF_Signal	received RF signal to be measured	timed

Notes/Equations

1. This subnetwork measures the complementary cumulative distribution function (CCDF) of the RF signal, PeakPower and MeanPower.
2. $SymLen \times SymNum + StartSample$ tokens are consumed at Pin in and the latest $SymLen \times SymNum$ tokens are used for measurement.The distribution range is divided into segments according to the OutputPoint parameter and is sent to the SignalRange_dB NumericSink. The corresponding distribution probability is calculated based on these segments and sent to the CCDF NumericSink. 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. The schematic for this subnetwork is shown in WMAN_RF_CCDF Schematic.



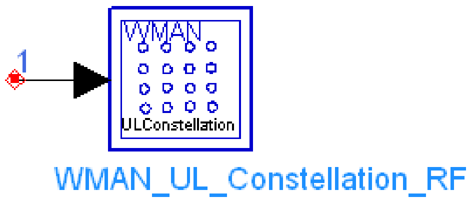
WMAN_RF_CCDF Schematic

4. 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.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_Constellation_RF (WMAN Uplink Constellation Measurement)



Description Uplink constellaton measurement with broadcast message and frame duration
Library WMAN, Measurement
Class TSDFWMAN_UL_Constellation_RF

Parameters

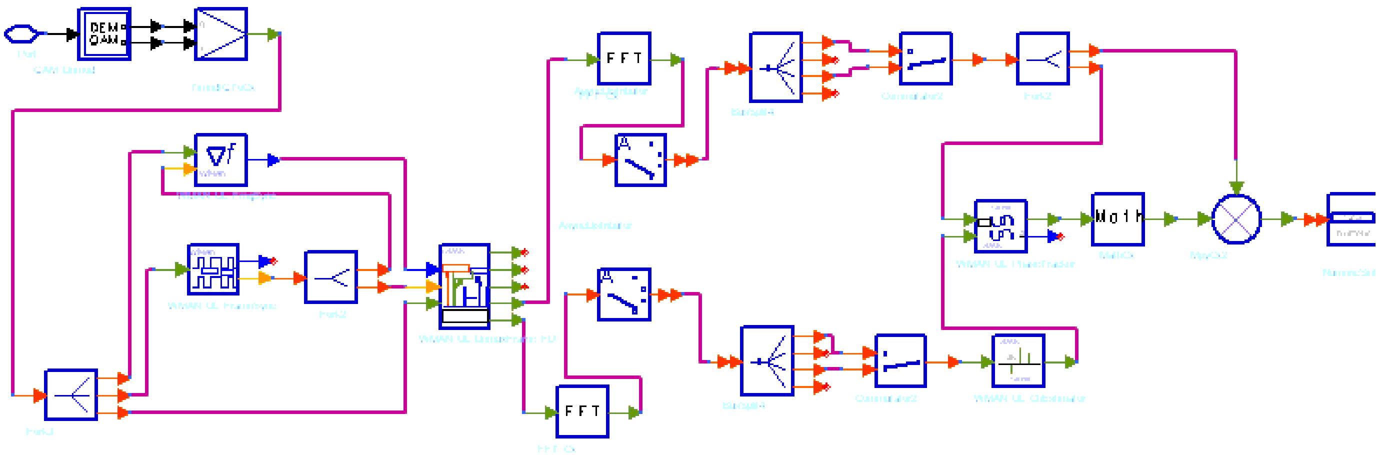
Name	Description	Default	Unit	Type	Range
RIn	Input resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	1900 MHz	Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	Reference phase in degrees	0.0	deg	real	(-∞, ∞)
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	(-∞, ∞)
NumberOfSS	Number of subscribes	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscribe	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each subscribe	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscribe	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscribe	{0}		int array	[0, 255]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
PilotPN_Phase	Pilot phase	0		int	[0, 4095]
start	Sample number to start collecting data for display the constellation	1200		int	[0, ∞)
stop	Sample number to stop collecting data for display the constellation	2399		int	[start, ∞)
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	

Parameters

Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Notes/Equations

1. This subnetwork is used to do WMAN uplink constellation measurement.
   The schematic for this subnetwork is shown in WMAN_UL_Constellation_RF Schematic.



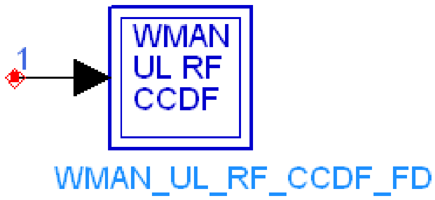
WMAN_UL_Constellation_RF Schematic

2. The input timed signal is demodulated from RF to baseband by QAM_Demod. Then frame synchronization, frequency offset, frame demultiplex, channel estimate, phase track and channel compensation are completed by WMAN_UL_FrameSync, WMAN_UL_FreqSync, WMAN_UL_DemuxFrame, WMAN_UL_ChEstimator and WMAN_UL_PhaseTracker respectively. The equalized data are collected by the Sink named Constellation.
   The constellations displayed in Data Display window depend on the parameters start, stop that decide which part of signal is measured and the number of constellation points and the parameter Rate_ID which decides the constellation-mapping.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_RF_CCDF_FD (WMAN Uplink RF CCDF FD)



Description Uplink CCDF measurment with broadcast message and frame duration
Library WMAN, Measurement
Class TSDFWMAN_UL_RF_CCDF_FD

Parameters

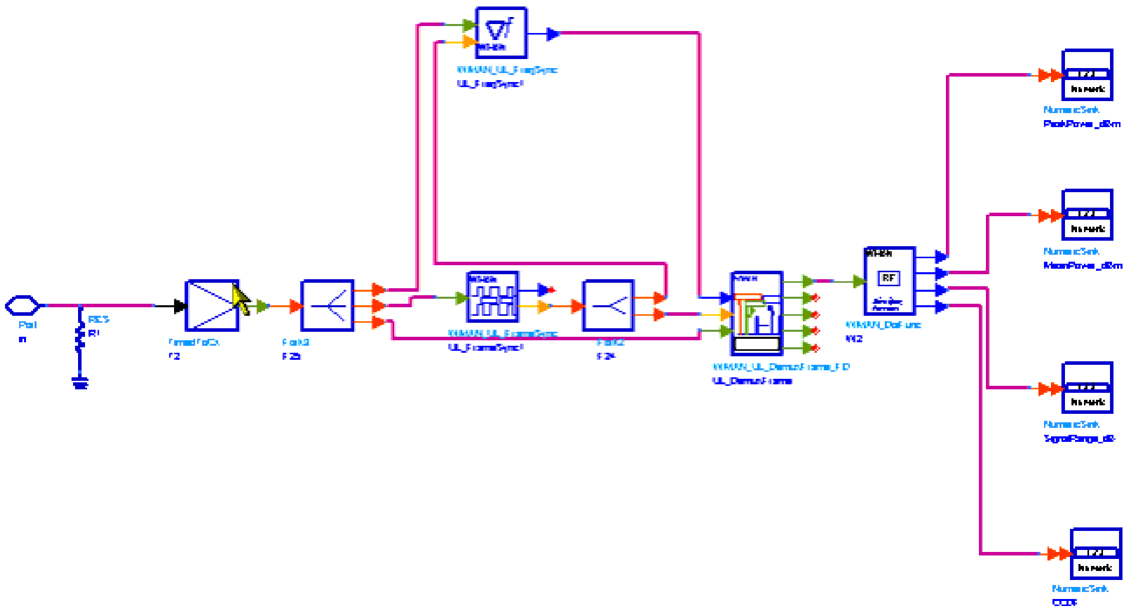
Name	Description	Default	Unit	Type	Range
RLoad	Source resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
StartSample	Sample from which measurement begin	0		int	
SymLen	length of input signal symbol	2560		int	
SymNum	Number of symbols	1		int	
OutputPoint	Indicate output precision	100		int	
RefR	Reference resistance	50 Ohm	Ohm	real	
NumberOfSS	Number of subscribers	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	RF_Signal	received RF signal to be measured	timed

Notes/Equations

1. This subnetwork measures the complementary cumulative distribution function (CCDF) of the WMAN OFDM uplink RF signal, PeakPower and MeanPower.
2. The distribution range is divided into segments according to the OutputPoint parameter and is sent to the SignalRange_dB NumericSink. The corresponding distribution probability is calculated based on these segments and sent to the CCDF NumericSink. 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. The schematic for this subnetwork is shown in WMAN_UL_RF_CCDF_FD Schematic.



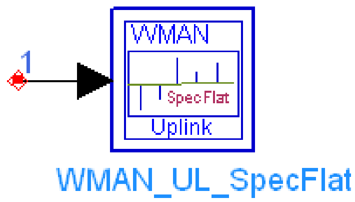
WMAN_UL_RF_CCDF_FD Schematic

4. 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.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_UL_SpecFlat (WMAN Uplink SpecFlat)



Description Uplink spectral flatness measurement
Library WMAN, Measurement
Class TSDFWMAN_UL_SpecFlat

Parameters

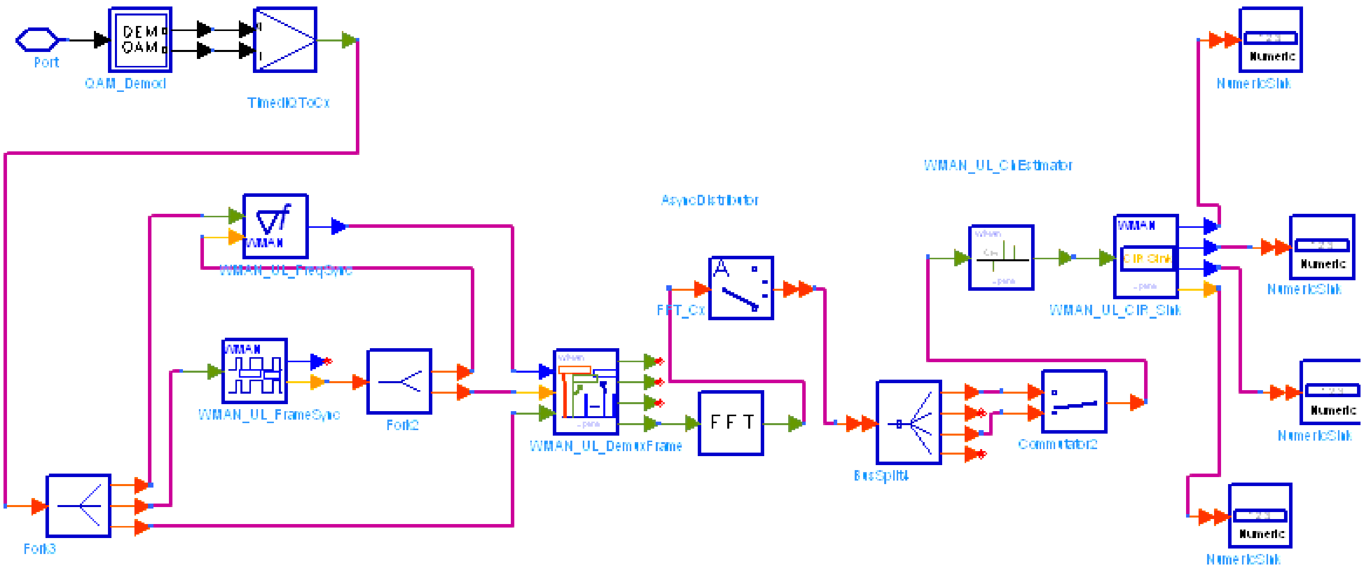
Name	Description	Default	Unit	Type	Range
RIn	Input resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	3407 MHz	Hz	real	(0, ∞)
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
IdleInterval	Idle Interval	0.0 usec	sec	real	[0, 1000]
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
TimeOffset	Time offset of each subscriber	{0 usec}	sec	real array	[0, IdleInterval]
FramesToAverage	Number of frames for the average CIR	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Notes/Equations

1. This subnetwork is used to measure the spectral flatness of WMAN OFDM Uplink subframe. The schematic for this subnetwork is shown in WMAN_UL_SpecFlat Schematic.



WMAN_UL_SpecFlat Schematic

2. In this subnetwork, the data (CIRs) are taken from the channel estimation to measure the spectral flatness. The results shall be the average of FramesToAverage uplink subframes, where FramesToAverage is set by users. The measurement results are output to Sink SpecEnergy. Meanwhile the difference energy between adjacent subcarriers from -100 to 100 are output to Sink SpecDiff, and spectral lines from -100 to 100 are output to Sink SpecLines. The number of subcarriers in which the spectral energies are out of the spectral mask and in which the difference between adjacent subcarriers exceed 0.1 dB are output to Sink StatParam. Note that for subchannelization mode, only the CIRs on the subcarriers allocated to SS with FEC-encoded are used to measure the spectral flatness, and the spectral energies on other subcarriers are set to zero.

References

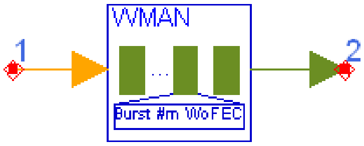
1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN Multiplex Components

The multiplex models provide framing and de-framing in WMAN transceivers.

- *WMAN BurstWoFEC (WMAN Burst Without FEC Generator)* (wman)
- *WMAN DemuxOFDMSym (WMAN OFDM demultiplexer)* (wman)
- *WMAN DL DemuxBurst (WMAN Downlink Demultiplex Burst)* (wman)
- *WMAN DL DemuxBurst FD (WMAN Downlink Demultiplex Burst FD)* (wman)
- *WMAN DL MuxBurst (WMAN Downlink Multiplex Burst)* (wman)
- *WMAN DL MuxBurst FD (WMAN Downlink Multiplex Burst FD)* (wman)
- *WMAN DL MuxFrame (WMAN Downlink Multiplex Frame)* (wman)
- *WMAN UL DemuxBurst (WMAN Uplink burst demultiplexer)* (wman)
- *WMAN UL MuxBurst (WMAN Uplink MuxBurst)* (wman)
- *WMAN UL MuxFrame (WMAN Uplink Frame Multiplexer)* (wman)
- *WMAN UL MuxOFDMSym (WMAN Uplink MuxOFDMSym)* (wman)

WMAN_BurstWoFEC (WMAN Burst Without FEC Generator)



WMAN_BurstWoFEC

Description Bursts without FEC generator
Library WMAN, Multiplex
Class SDFWMAN_BurstWoFEC
Derived From SDFWMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]

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 is used to generate data signal after constellation mapper of the bursts without FEC.
2. Each firing,
   - if $NumberOfSS = 1$, 1 tokens are consumed and produced and the output is 0.
   - if $NumberOfSS > 1$, Nbits tokens are consumed, where Nbits is defined as:

$$N_{bits} = 8 \times \sum_{i = 1,\, i \neq SSWithFEC}^{NumberOfSS} N_{Symbol}[i] \times CodedBlkSize[R[i]]$$

   and

$$192 \times \sum_{i = 1,\, i \neq SSWithFEC}^{NumberOfSS} N_{Symbol}[i]$$

   tokens are produced, where, NSymbol[i] is the number of

OFDM symbols of the ith SS and depends on DataLength[i] and Rate_ID[i].
The data-rate-dependent parameters are defined in *Data-Rate-Dependent Parameters*.

Data-Rate-Dependent Parameters

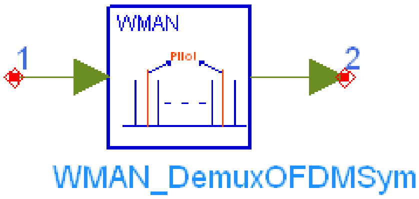
Rate_ID (R)	Modulation	Uncoded block size (bytes)	Coded block size (bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

3. If this model is used in downlink, the parameters NumberOfSS and SSWithFEC mean the NumberOfBurst and BurstWithFEC respectively.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DemuxOFDMSym (WMAN OFDM demultiplexer)



Description OFDM symbol demultiplexer
Library WMAN, Multiplex
Class SDFWMAN_DemuxOFDMSym

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	Input data	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	Output data	complex

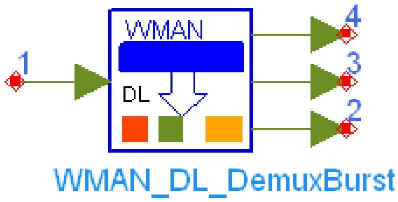
Notes/Equations

1. This model is used to de-multiplex the OFDM symbol into data and pilots. Data subcarriers are sent to the output and the pilot subcarriers are discarded.
2. Each firing,
   - 200 tokens are consumed at pin DataIn
   - 192 tokens are produced at pin DataOut
3. The data at DataIn pin are mapped from indices 0 to 199 to the frequency offset indices -100 to 100, excluding DC subcarriers with index 0. Then the data on pilot subcarriers whose frequency offset indices are {-88, -63, -38, -13, 13, 38, 63, 88} are removed. The rest are data subcarriers, which are output to pin DataOut.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_DemuxBurst (WMAN Downlink Demultiplex Burst)



Description Downlink bursts demultiplexer
Library WMAN, Multiplex
Class SDFWMAN_DL_DemuxBurst
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfBurst	Number of Burst	1	int	[1, 16]
BurstWithFEC	The number of burst with FEC	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input of downlink data before demultiplexer	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	FCH	FCH data	complex
3	DataFEC	output data with FEC	complex
4	DataWoFEC	input data without FEC	complex

Notes/Equations

1. This model is used to extract downlink data sequence in frequency domain into FCH, coded burst and uncoded bursts. In the downlink data sequence, the FCH is followed by one or multiple downlink bursts. The coded burst can occupy anywhere of downlink bursts. This is inverse function of WMAN_DL_MuxBurst.
2. Each firing, $192 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens are consumed at pin In where $N_{Symbol}[i]$ is the number of OFDM symbols of ith downlink burst. 192 means the number of data subcarriers in one OFDM symbol. Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Data-Rate-Dependent Parameters*, which is based on the specification.

Data-Rate-Dependent Parameters

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of ith downlink burst (!wman-6-04-010.gif!) is calculated as:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

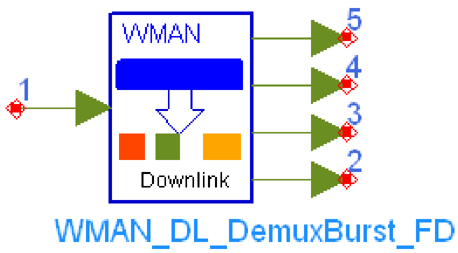
where

- The FCH burst is one OFDM symbol long, so 192 tokens are produced at pin FCH.
- $192 \times N_{Symbol}[butstWithFEC]$ tokens are produced at pin DataWithFEC.
- $192 \times \left(\sum_{i=1,\, i \neq burstWithFEC}^{NumberOfBurst} N_{Symbol}[i] \right)$ tokens are produced at pin DataWoFEC.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_DemuxBurst_FD (WMAN Downlink Demultiplex Burst FD)



Description Downlink bursts demultiplexer with broadcast message and frame duration
Library WMAN, Multiplex
Class SDFWMAN_DL_DemuxBurst_FD
Derived From WMAN_DL_Base

Parameter

Name	Description	Default	Type	Range
NumberOfBurst	Number of Burst	1	int	[1, 16]
BurstWithFEC	The number of burst with FEC	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]
Brd_Message	Broadcast message enabled or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input of downlink data before demultiplexer	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	FCH	FCH data	complex
3	DL_MAP	broadcast message	complex
4	DataFEC	output data with FEC	complex
5	DataWoFEC	input data without FEC	complex

Notes/Equations

1. This model is used to extract downlink data sequence in frequency domain into FCH, broadcast burst, coded burst and uncoded bursts. In the downlink data sequence, the FCH is followed by the broadcast burst and one or multiple downlink bursts. The coded burst can occupy anywhere of downlink bursts. This is the inverse function of WMAN_DL_MuxBurst_FD.
2. Each firing,
   - $192 \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens are consumed at pin In. where N_{Brdcst} is the

number of OFDM symbols of the broadcast burst where it is equal to 21 when Brd_Message is YES and is equal to 0 when Brd_Message is NO. $N_{Symbol}[i]$ is the number of OFDM symbols of ith downlink burst. 192 means the number of data subcarriers in one OFDM symbol. Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Data-Rate-Dependent Parameters*, which is based on the specification.

Data-Rate-Dependent Parameters

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of ith downlink burst(!wman-6-05-018.gif!) is calculated as follows:

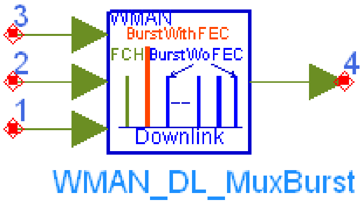
$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

- The FCH burst is one OFDM symbol long, so 192 tokens are produced at pin FCH.
- $192 \times N_{Symbol}[butstWithFEC]$ tokens are produced at pin DataWithFEC.
- $192 \times \left(\sum_{i = 1,\, i \neq burstWithFEC}^{NumberOfBurst} N_{Symbol}[i] \right)$ tokens are produced at pin DataWoFEC.
- $192 \times N_{BrdSym}$ tokens are produced at pin DL_MAP where N_{BrdSym} is 21.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DL_MuxBurst (WMAN Downlink Multiplex Burst)



Description Downlink bursts multiplexer
Library WMAN, Multiplex
Class SDFWMAN_DL_MuxBurst
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfBurst	Number of Burst	1	int	[1, 16]
BurstWithFEC	The number of burst with FEC	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]

Pin Inputs

Pin	Name	Description	Signal Type
1	FCH	FCH data	complex
2	DataFEC	input data with FEC	complex
3	DataWoFEC	input data without FEC	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	Out	output of downlink multiplexer	complex

Notes/Equations

1. This model is used to multiplex downlink FCH, coded burst and uncoded bursts into one downlink complete sequence in frequency domain. The FCH is followed by one or multiple downlink bursts. The coded burst can occupy anywhere of downlink bursts.
2. Each firing,
   - $$192 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$$ tokens are produced at pin Out.

   where $N_{Symbol}[i]$ is the number of OFDM symbols of the ith downlink burst. 192 means the number of data subcarriers in one OFDM symbol. Rate_ID (R) determines the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Data-Rate-Dependent Parameters*, which is based on the specification.

Data-Rate-Dependent Parameters

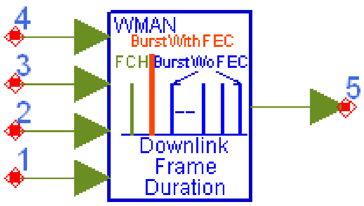
Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- The number of OFDM symbols of the ith downlink burst (!wman-6-06-027.gif!) is calculated as:
  $$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$
- The FCH burst is one OFDM symbol long, so 192 tokens are consumed at pin FCH.
- $192 \times N_{Symbol}[butstWithFEC]$ tokens are consumed at pin DataWithFEC.
- $192 \times \left(\sum_{i=1,\, i \neq burstWithFEC}^{NumberOfBurst} N_{Symbol}[i] \right)$ tokens are consumed at pin DataWoFEC.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_MuxBurst_FD (WMAN Downlink Multiplex Burst FD)



WMAN_DL_MuxBurst_FD

Description Downlink bursts multiplexer with broadcast message and frame duration
Library WMAN, Multiplex
Class SDFWMAN_DL_MuxBurst_FD
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfBurst	Number of Burst	1	int	[1, 16]
BurstWithFEC	The number of burst with FEC	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]
Brd_Message	Broadcast message enabled or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	FCH	FCH data	complex
2	DL_MAP	broadcast message	complex
3	DataFEC	input data with FEC	complex
4	DataWoFEC	input data without FEC	complex

Pin Outputs

Pin	Name	Description	Signal Type
5	Out	output of downlink multiplexer	complex

Notes/Equations

1. This model is used to multiplex downlink FCH, broadcast burst, coded burst and uncoded bursts into one downlink complete sequence in frequency domain. The FCH is followed by the broadcast burst and one or multiple downlink bursts. The coded burst can occupy anywhere of downlink bursts.
2. Each firing,

$$192 \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i] \right)$$

- tokens are produced at pin Out.

where N_{Brdcst}
is the number of OFDM symbols of the broadcast burst where it is equal to 21 when Brd_Message is YES and is equal to 0 when Brd_Message is NO. $N_{Symbol}[i]$
is the number of OFDM symbols of the ith downlink burst. 192 means the number of data subcarriers in one OFDM symbol. Rate_ID (R) determines the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Data-Rate-Dependent Parameters*, which is based on the specification.

Data-Rate-Dependent Parameters

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of the ith downlink burst(!wman-6-07-035.gif!) is calculated as

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

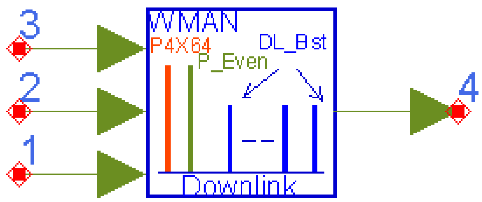
follows:

- The FCH burst is one OFDM symbol long, so 192 tokens are consumed at pin FCH.
- $192 \times N_{Symbol}[butstWithFEC]$
  tokens are consumed at pin DataWithFEC.
- $192 \times \left(\sum_{i = 1,\, i \neq burstWithFEC}^{NumberOfBurst} N_{Symbol}[i] \right)$
  tokens are consumed at pin DataWoFEC.
- $192 \times N_{BrdSym}$
  tokens are consumed at pin DL_MAP where N_{BrdSym} is 21.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DL_MuxFrame (WMAN Downlink Multiplex Frame)



Description Downlink frame multiplexer
Library WMAN, Multiplex
Class SDFWMAN_DL_MuxFrame
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present	{0}		int array	{0, 1}
IdleInterval	Idle interval	10 usec	sec	real	[0, 1000]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Prml_4X64	preamble with 4X64 subcarriers	complex
2	Prml_even	preamble with even subcarriers	complex
3	DL_Bursts	input of downlink burst	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	DL_Subframe	output of downlink frame	complex

Notes/Equations

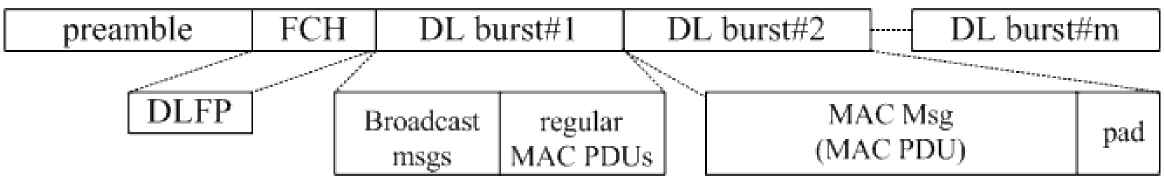
1. This model is used to multiplex preamble, FCH, broadcast message, multiple bursts and gaps into

one downlink subframe in time domain. Idle interval insertion and preamble shift are implemented.

2. Each firing,
   - $Samples_{Frame}$ tokens are produced at pin DL_Subframe.

     where $Samples_{Frame}$ is the number of total samples of one downlink subframe.
   - $2^{OversamplingOption} \times 256 \times (1+G)$ tokens are consumed at pin Prml_4X64 and pin Prml_even, where G denotes the parameter CyclicPrefix.
   - $Samples_{OFDM} \times \left(1 + N_{BroadcastMessage} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens are consumed at pin DL_Bursts.

     where $N_{Symbol}[i]$ is the number of OFDM symbols of the ith downlink burst.
     The variables all above are calculated in section 3.
3. WMAN DL Subframe Structure shows the downlink subframe format, which includes: long preamble, FCH, and one or multiple downlink bursts each transmitted with different burst profile.



WMAN DL Subframe Structure

One WMAN downlink subframe consists of long preamble, FCH, broadcast message and multiple downlink bursts. There is an idle interval (filled zeros) before preamble in this signal source and this idle interval is for Agilent connected solution.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol.
Rate_ID (R) determines the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Data-Rate-Dependent Parameters*, which is based on the specification.

Data-Rate-Dependent Parameters

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of the ith downlink burst (!wman-6-08-048.gif!) is calculated as:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If PreamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$

So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as:

$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i]) + N_{BroadcastMessage}$$

where $N_{BroadcastMessage} = 0$ if Brd_Message=NO and $N_{BroadcastMessage} = 21$ if Brd_Message=YES.
The number of samples per one OFDM symbol (!wman-6-08-057.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor(!wman-6-08-059.gif!) as follows: $F_s = floor((N_{factor} \times Bandwidth)/8000) \times 8000$
The sampling factors(!wman-6-08-061.gif!) are listed in *Sampling Factor Requirement*.

Sampling Factor Requirement

Sampling factor n	**Bandwidth**
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

The samples of IdleInterval(!wman-6-08-062.gif!) is calculated as follows:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

So, the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = \begin{cases} Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM} \\ \quad if \quad FrameDuration = Continuous \\ FrameDuration \times F_s \times 2^{OversamplingOption} \\ \quad if \quad FrameDuration \lozenge Continuous \end{cases}$$

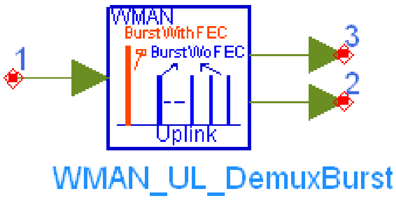
where F_s is the sampling frequency. FrameDuration can be selected as 2.5 ms, 4 ms, 5 ms, 8 ms, 10 ms, 12.5 ms and 20 ms according to the specification.

4. When FrameDuration=Continuous, both parameters FrameMode and DL_Ratio are inactive. This model just combines idle interval, preamble, FCH, broadcast message and multiple bursts as one signal stream (not the real downlink subframe) and outputs this stream. When FrameDuration<>Continuous, both parameters FrameMode and DL_Ratio are active. This model combines idle interval, preamble, FCH, broadcast message and multiple bursts and gaps as one downlink subframe and outputs this downlink subframe.
When FrameMode=FDD, the DL_Ratio is inactive and the full subframe can be loaded the downlink signal. The first part is idle interval (the number of zeros is Samplesidle), the second part is the downlink signal (the number is !wman-6-08-066.gif!), the third part is filled with zeros.
When FrameMode=TDD, the DL_Ratio is active. This DL_Ratio (or DLRatio in equation) parameter determines where to put the downlink subframe. DL_Ratio splits the frame into two parts. The first part (The number of samples is !wman-6-08-067.gif!) is to transmit downlink signal and the second part should be filled with zeros.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_DemuxBurst (WMAN Uplink burst demultiplexer)



Description Uplink burst demultiplexer
Library WMAN, Multiplex
Class SDFWMAN_UL_DemuxBurst
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataMux	input data including the data with FEC coding and without FEC coding	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DataWithFEC	output data with FEC	complex
3	DataWoFEC	output data without FEC	complex

Notes/Equations

1. This model is used to de-multiplex input chain into FEC-encoded burst and other uncoded bursts.
2. Each firing,
    - $$192 \times \left(\sum_{i=1}^{NumberOfSS} N_{Symbol}[i] \right)$$ tokens are consumed at pin DataMux for non-subchannelization mode and 192×NMaxDataSym tokens are consumed for subchannelization mode, where
The number of OFDM data symbols of ith uplink SS(!wman-6-09-070.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in *Number of Subchannels*.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

NMaxDataSym is the maximum number of data symbols among all SSs.

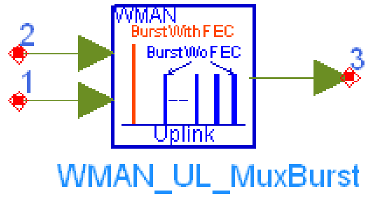
- 192×NSymbol[SSWithFEC] tokens are produced at pin DataWithFEC.
- $192 \times \left(\sum_{i=1,\, i \neq SSWithFEC}^{NumberOfSS} N_{Symbol}[i] \right)$ tokens are produced at pin DataWoFEC.

3. This mode performs the reverse operations against WMAN_UL_MuxBurst. For more details, refer to WMAN_UL_MuxBurst.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_MuxBurst (WMAN Uplink MuxBurst)



Description Uplink burst multiplexer
Library WMAN, Multiplex
Class SDFWMAN_UL_MuxBurst
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataWithFEC	input data with FEC	complex
2	DataWoFEC	input data without FEC	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	DataMux	output data including the data with FEC coding and without FEC coding	complex

Notes/Equations

1. This model is used to multiplex FEC-encoded SS and other uncoded SSs into a complete chain.
2. Each firing,
   - 192×NSymbol[SSWithFEC] tokens are consumed at pin DataWithFEC.
   - $192 \times \left(\sum_{i=1,\, i \neq SSWithFEC}^{NumberOfSS} N_{Symbol}[i] \right)$ tokens are consumed at pin DataWoFEC.
   - $192 \times \left(\sum_{i=1}^{NumberOfSS} N_{Symbol}[i] \right)$ tokens are produced at pin DataMux for non-subchannelization mode and 192×NMaxDataSym tokens are produced for subchannelization mode.
     where
     The number of OFDM data symbols of ith uplink SS(!wman-6-10-076.gif!) is calculated as

follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in *Number of Subchannels*.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

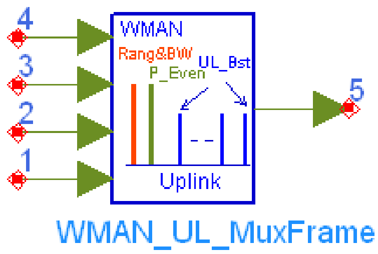
NMaxDataSym is the maximum number of data symbols among all SSs.

3. The OFDM data symbol has 192 data subcarriers. In non-subchannelization mode, The SS with FEC-encoded is inserted into SSs without FEC-encoded to form a bursts chain according to the parameter of SSWithFEC, where each SS occupies a burst.
   In subchannelization mode, all the SSs share one burst, which has NMaxDataSym OFDM data symbols. Each SS is assigned to a subchannel index which specifies the subcarriers that used by the SS. In this model, all the SSs' data will be mapped into corresponding data subcarriers, while other unused data subcarriers are set with zeros. Note that each SS has different length of data symbols which is determined by Datalength and Rate_ID, so in the case that, one SS has data to transmit and another SS has no more data to transmit in the same data symbol, the data subcarriers allocated to the SS which has no more data to transmit will be filled with zeros.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_MuxFrame (WMAN Uplink Frame Multiplexer)



Description Uplink frame multiplexer
Library WMAN, Multiplex
Class SDFWMAN_UL_MuxFrame
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfSS	Number of subscribers	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
TimeOffset	Time offset of each subscribe	{0 usec}	sec	real array	[0, IdleInterval]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
Power	Power of each subscribe	{0.01 w}	W	real array	(0, ∞)
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	UL_Bursts	input of uplink Subscribers	complex
2	Prml_Even	input of preamble with even subcarriers	complex
3	InitialRanging	input of Initial ranging contention slot	complex
4	BW_Requests	input of BW requests contention slot	complex

Pin Outputs

Pin	Name	Description	Signal Type
5	UL_Subframe	output of uplink Subframe	complex

Notes/Equations

1. This model is used to multiplex contention slot for Initial Ranging, contention slot for BW Requests, short preamble, data OFDM symbols and midambles into a complete uplink subframe. Also the idle interval is inserted before contention slot for Initial Ranging. The contention slot for Initial Ranging and contention slot for BW Requests have two OFDM symbols respectively.
2. Each firing,
   - SamplesOFDM tokens are consumed at pin Prml_Even when subchannelization is not employed. For subchannelization mode, NumberOfSS × SamplesOFDM tokens are consumed at pin Prml_Even.
     SamplesOFDM is the number of one OFDM symbol data, defined as
     $$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1+G)$$
   - For non-subchannelization mode, NBurst tokens are consumed at pin UL_Bursts; For subchannelization mode, SamplesOFDM× NMaxDataSym tokens are consumed at pin UL_Bursts.
     where,
     NBurst is
     $$N_{Burst} = \sum_{i=1}^{NumberOfSS} N_{Symbol}[i] \times Samples_{OFDM}$$
     The number of OFDM data symbols of ith uplink SS(!wman-6-11-081.gif!
) is calculated as follows:
     $$N_{Symbol}[i] = ceil((DataLength[i]+11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$
     Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in *Number of Subchannels*.

     Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

     NMaxDataSym is the maximum number of data symbols among all SSs.
   - SamplesOFDM ×2 tokens are consumed at pin InitialRanging.
   - SamplesOFDM ×2 tokens are consumed at pin BW_Requests.
   - Ntotal tokens are produced at pin UL_Subframe.
     Ntotal is the number of samples in one uplink subframe, containing the idle interval, contention slot for Initial Ranging, contention slot for BW Requests, preambles, data symbols and midambles.
     When FrameDuration=Continuous, for non-subchannelization mode
     $$N_{total} = Samples_{Idle} + \left(5 + \sum_{i=1}^{NumberOfSS} N_{Symbol}[i] + \sum_{i=1}^{NumberOfSS} Midamble[i]\right) \times Samples_{OFDM}$$
     When FrameDuration=Continuous, for subchannelization mode

$$N_{total} = Samples_{Idle} + max(5 + N_{Symbol}[i] + Midamble[i]) \times Samples_{OFDM}$$

When FrameDuration<>Continuous, for non-subchannelization mode and subchannelization mode, the number of samples per one frame is

$$N_{total} = Samples_{Idle} + FrameDuartion \times F_s \times 2^{Oversampling Option}$$

where, the samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s \times 2^{OversamplingOption}$$

Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth as follows:

$$F_s = floor((n \times Bandwidth)/8000) \times 8000$$

FrameDuration can be selected as 2.5 ms, 4 ms, 5 ms, 8 ms, 10 ms, 12.5 ms and 20 ms according to the specification.

$Midamble[i]$

represents the number of midamble symbols in ith uplink SS.

If $MidambleRepetition[i]$ is not zero

$$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

else

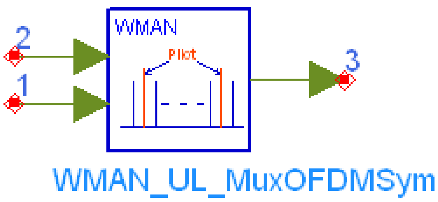
$$Midamble[i] = 0$$

3. For non-subchannelization mode, the transmission time of each SS will be adjusted according to the value in TimeOffset. 0 means the SS's signal arrives at BS exactly as scheduled. Two adjacent SSs signals may be overlapped if the TimeOffset are set with different values. Note that the actual time offset delay of each SS is the value in TimeOffset minus the last SS's value in TimeOffset. All the SSs should have the same time offset in subchannelization mode.
   In this model, for non-subchannelization mode, the output voltages of all SSs are adjusted according to Power. The first SS's output voltage is adjusted to be 1, by multiplying signal amplitude with Gain, where Gain is defined as:
   $$Gain = 256 \times 2^{OversamplingOption}/(\sqrt{200})$$
   For other SSs, the ith SS's output voltage is adjusted aligned with first SS's by multiplying signal amplitude with Gain[i] respectively, where Gain[i] is defined as:
   $$Gain[i] = Gain[1] \times \sqrt{(Power[i])/(Power[1])}$$
   Here Power[1] is the first SS's Power.
   In subchannelization mode, the first SS's output voltage is adjusted to be 1. For all the subcarriers have the same power, the output voltages of the SS are in proportion to the number of subcarriers the SS contain. So the first value in the array of Power is used to adjust the first SS's output voltage, and other SSs' output voltages are generated according to the number of subcarriers compared with the first SS's subcarriers.
4. When FrameDuration=Continuous, both parameters FrameMode and DL_Ratio are inactive. This model just combines idle interval, preamble and multiple bursts as one signal stream (not the real uplink subframe) and outputs this stream. When FrameDuration<>Continuous, both parameters FrameMode and DL_Ratio are active. This model combines idle interval, preamble, and multiple bursts and gaps as one uplink subframe and outputs this uplink subframe.
   When FrameMode=FDD, the DL_Ratio is inactive and the full subframe can be loaded the downlink signal. The first part is idle interval (the number of zeros is Samplesidle), the second part is the uplink signal (the number of samples is !wman-6-11-095.gif!), the third part is filled with zeros.
   When FrameMode=TDD, the DL_Ratio is active. This DL_Ratio (or DLRatio in equation) parameter determines where to put the uplink subframe. DL_Ratio splits the frame into two parts. The first part (The number of samples is !wman-6-11-096.gif!) should be filled with zeros and the second part is to transmit uplink subframe.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_MuxOFDMSym (WMAN Uplink MuxOFDMSym)



Description Uplink OFDM symbol multiplexer
Library WMAN, Multiplex
Class SDFWMAN_UL_MuxOFDMSym
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	input of data carriers	complex
2	Pilot	input of continual pilot value	complex

h5 Pin Outputs

Pin	Name	Description	Signal Type
3	Out	output of OFDM symbol	complex

Notes/Equations

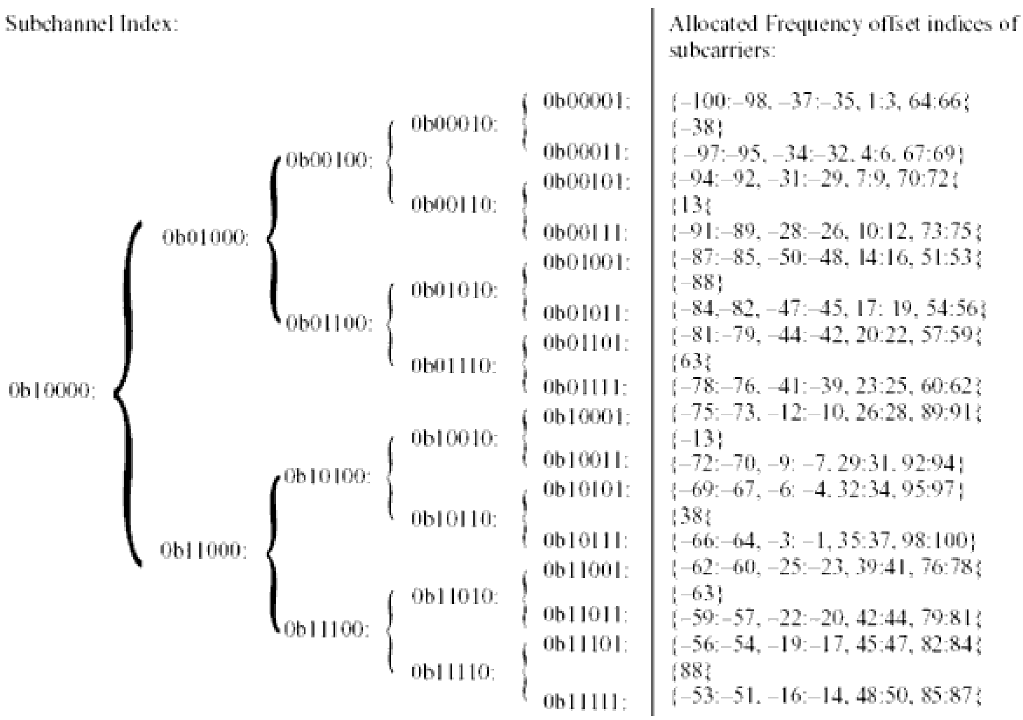
1. This model is used to multiplex data and pilot subcarriers into the OFDM symbol in the uplink.
2. Each firing,
   - For non-subchannelization mode, 192 tokens are consumed at pin Data, and for subchannelization mode, 192×NMaxDataSym tokens are consumed at pin Data. where NMaxDataSym is the maximum number of data symbols among all SSs.
     $N_{MaxDataSym} = max(N_{Symbol}[i])$
     The number of OFDM data symbols of ith uplink SS(!wman-6-12-099.gif!) is calculated as follows:
     $$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$
     Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in Number of Subchannels.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

- For non-subchannelization mode, 1 tokens are consumed at pin Pilot, and for subchannelization mode, NMaxDataSym tokens are consumed at pin Pilot.
- For non-subchannelization mode, 200 tokens are produced at pin Out, and for subchannelization mode, 200×NMaxDataSym tokens are produced at pin Out.

3. In non-subchannelization mode, the data at pin Data are mapped into data subcarriers. In every OFDM symbol, 192 data are mapped. The frequency offset indices of data subcarriers are from -100 to 100, excluding DC subcarriers of index 0 and pilot subcarriers. The frequency offset indices of pilot subcarriers are {-88, -63, -38, -13, 13, 38, 63, 88}. The basic values on pilot subcarriers are BasicValue = {1, -1, 1, -1, 1, 1, 1, 1}. Finally the values BasicValue×Pilot are mapped into pilot subcarriers, where Pilot is the value at pin Pilot.
In subchannelization mode, the data at pin Data are also mapped into data subcarriers. In every OFDM symbol, 192 data are mapped. The values on pilot subcarriers depend on corresponding subchannels. The relation of subchannel index with pilot subcarriers allocated is shown in Allocation of Subchannels. Note that pilot subcarriers are allocated only if two or more subchannels are allocated. The values BasicValue×Pilot are only mapped into the pilot subcarriers which the active SSs contain, while other non-active pilot subcarriers are filled with zeros. The values BasicValue×Pilot is the same as those in non-subchannelization mode.



Allocation of Subchannels

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.

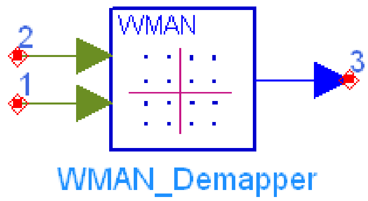
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN Receiver Components

The receiver models provide channel estimator, frame synchronization and frequency synchronization, top level baseband receivers and top level RF receivers.

- *WMAN Demapper (WMAN Demapper)* (wman)
- *WMAN DL ChEstimator (WMAN Downlink Channel Estimator)* (wman)
- *WMAN DL DemuxFrame (WMAN Downlink Demultiplex Frame)* (wman)
- *WMAN DL DemuxFrame FD (WMAN Downlink Demultiplex Frame FD)* (wman)
- *WMAN DL FrameSync (WMAN Downlink Frame Synchronizer)* (wman)
- *WMAN DL FreqSync (WMAN Downlink Frequency Synchronizer)* (wman)
- *WMAN DL PhaseTracker (WMAN Downlink Phase Tracker)* (wman)
- *WMAN DL Receiver (Downlink baseband receiver)* (wman)
- *WMAN DL Receiver RF (WMAN Downlink Receiver RF)* (wman)
- *WMAN DL Rx FD (WMAN DL Receiver with Frame Duration)* (wman)
- *WMAN DL Rx FD RF (WMAN DL Receiver RF with Frame Duration)* (wman)
- *WMAN UL ChEstimator (WMAN Uplink Channel Estimator)* (wman)
- *WMAN UL DemuxFrame (WMAN Uplink Frame Demultiplexer)* (wman)
- *WMAN UL DemuxFrame FD (WMAN Uplink Demultiplexer Frame FD)* (wman)
- *WMAN UL FrameSync (WMAN Uplink Subframe Synchronizer)* (wman)
- *WMAN UL FreqSync (WMAN Uplink Frequency Synchronizer)* (wman)
- *WMAN UL PhaseTracker (WMAN Uplink Phase Tracker)* (wman)
- *WMAN UL Receiver (WMAN Uplink Receiver)* (wman)
- *WMAN UL Receiver RF (WMAN Uplink Receiver RF)* (wman)
- *WMAN UL Rx FD (WMAN Uplink Receiver with Frame Duration)* (wman)
- *WMAN UL Rx FD RF (WMAN UL Receiver RF with Frame Duration)* (wman)

WMAN_Demapper (WMAN Demapper)



Description Soft demapper
Library WMAN, Receiver
Class SDFWMAN_Demapper

Parameters

Name	Description	Default	Type	Range
ModulationType	modulation type: BPSK, QPSK, QAM16, QAM64	QPSK	enum	
DecoderType	demapping type: Hard, Soft, CSI	CSI	enum	
Subchannelization	Indication of subchannelization: NO, YES	NO	enum	
SubchannelIndex	subchannel index	8	int	[1, 15] or [17, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be demodulated	complex
2	CSIBits	channel state information	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	output	decision bits	real

Notes/Equations

1. This model de-maps uniform BPSK, QPSK, 16QAM, and 64QAM to determine the soft-bit information that is used by Viterbi decoding.
2. Each firing,
   - the CSI and input pins consume $N_{demodulation}$ tokens each;
   - $N_{demodulation}$ tokens for BPSK, $2 \times N_{demodulation}$ tokens for QPSK, $4 \times N_{demodulation}$ tokens for 16QAM, or $6 \times N_{demodulation}$ tokens for 64QAM are generated at pin output.
   Subchannelization and SubchannelIndex determine the number of data subcarriers in one OFDM symbol which equals to demodulated constellation per OFDM symbol ($N_{demodulation}$).
   $N_{demodulation}$ is calculated as:
   $N_{demodulation} = 192 \times N_{subchannels} / 16$
   Here Nsubchannels is the number of subchannels. For non-subchannelization mode, Nsubchannels is equal to 16; For subchannelization mode, Nsubchannels is determined by SubchannelIndex, shown in *Number of Subchannels*.

Number of Subchannels

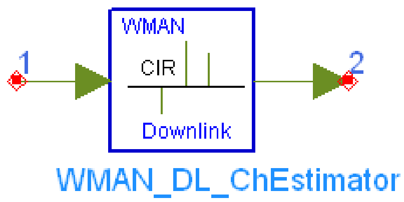
Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

3. Decision equations:
    - If input is multiplied by sqrt(42) and I is the real part of product and Q is the imaginary part, the decision equations for 64-QAM are:
      b0 = 2.0-|b1|; b1 = 4 - |Q|; b2 = -Q; b3-2.0|b4|; b4 = 4 - |I|; b5 = -I.
    - If input is multiplied by sqrt(10) and I is the real part of product and Q is the imaginary part, the decision equations for 16-QAM are:
      b0 = 2.0-|b1|; b1 = -Q; b2 = 2.0-|b3|; b3 = -I.
    - If 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.
    - The decision equation for BPSK is: b0 = -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 < -1.0, -1.0 is output; if b > 1.0, 1.0 is output, otherwise, b is output directly.
    - when DecoderType is set to CSI, b is multiplied by CSI (normalized channel response estimation) and output. Different bits which form one constellation have the same CSI.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_ChEstimator (WMAN Downlink Channel Estimator)



Description Downlink channel estimator
Library WMAN, Receiver
Class SDFWMAN_DL_ChEstimator
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfBurst	Number of Burst	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]
PreamblePresent	Preamble present	0	int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}	int array	[0, 255]
CyclicPrefix	Cyclic prefix	0.25	real	[0, 1]
Brd_Message	Broadcast message enabled or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	output signals from FFT	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	Coef	channel coefficient in active subcarriers	complex

Notes/Equations

1. This model is used to estimate WMAN downlink channel impulse response (CIR) based on the pilot channels and output the estimated channel impulse response (CIR) on the active subcarriers.
2. Each firing,
   - $\left(1 + \sum_{i=1}^{NumberOfBurst} Prml[i]\right) \times 200$ tokens are consumed at pin input.

   where $Prml[i]$ is the number of OFDM symbol per each preamble present. If PreamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$

- $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens are produced at pin coef.

  where $N_{Symbol}[i]$ is the number of OFDM symbols of the ith downlink burst. 200 means the number of used subcarriers in one OFDM symbol. Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Data-Rate-Dependent Parameters*, which is based on the specification.

Data-Rate-Dependent Parameters

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of ith downlink burst (!wman-7-03-017.gif!) is calculated as:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

3. This model uses preamble in which only even subcarriers are used, identified as P_{EVEN} to estimate the CIRs. The estimated CIRs are calculated using active subcarrier pilot channels. The P_{EVEN} training symbol includes 200 subcarriers, given by P_{EVEN} .

   $$P_{EVEN(k)} = \begin{cases} \sqrt{2} \times P_{ALL}(k) & k_{mod2} = 0 \\ 0 & k_{mod2} \neq 0 \end{cases}$$

   The sequence PALL is defined as:
   PALL(-100:100) = {1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j,-1-j, 1-j, -1+j, 1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j, -1-j, 1-j, -1+j, 1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j, -1-j, 1-j, -1+j, 1+j, 1+j, 1-j, -1+j, 1+j, 1+j, -1-j, 1+j, 1+j, 1+j, -1+j, 1-j, -1+j, -1+j, 1-j, -1+j, 1-j, 1-j,1+j, -1-j, -1-j, -1-j, -1+j, 1-j, -1-j, -1-j, 1+j, -1-j, -1-j, -1-j, 1-j, -1+j, 1-j, 1-j, -1+j, 1-j, -1+j,-1+j, -1-j, 1+j, 0, -1-j, 1+j, -1+j, -1+j, -1-j, 1+j, 1+j, 1+j, -1-j, 1+j, 1-j, 1-j, 1-j, -1+j, -1+j, -1+j, -1+j, 1-j, -1-j, -1-j, -1+j, 1-j, 1+j, 1+j, -1+j, 1-j, 1-j, 1-j, -1+j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, -1+j, -1+j, 1+j, -1-j, 1-j, 1-j, 1+j, -1-j, -1-j, -1-j, 1+j, -1-j, -1+j, -1+j, -1+j, 1-j, 1-j, 1-j, 1-j, -1+j, 1+j, 1+j, -1-j, 1+j, -1+j, -1+j, -1-j, 1+j, 1+j, 1+j, -1-j, 1+j, 1-j, 1-j, 1-j, -1+j, -1+j, -1+j, -1+j, 1-j, -1-j, -1-j, 1-j, -1+j, -1-j, -1-j, 1-j, -1+j, -1+j, -1+j, 1-j, -1+j,1+j, 1+j, 1+j, -1-j, -1-j, -1-j, -1-j, 1+j, 1-j, 1-j}

   Set $x_0, x_1, \ldots, x_{199}$ are the input signals, $h_0, h_1, \ldots, h_{199}$ are the estimated CIRs. The estimated CIR in even subcarriers can be calculated as:

   $$h_i = x_i / P_{EVEN_i}$$

   where

   $$i = 0, 2, \ldots, 198 \qquad i\,mod2 = 0$$.

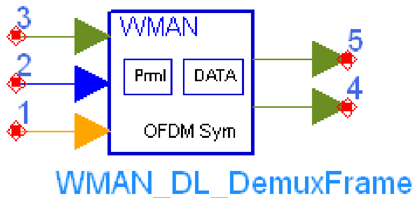
   The estimated CIR in odd subcarriers are interpolated by raised cosine filter.
4. If a downlink burst starts with short preamble, the short preamble will be used to estimate its CIR, otherwise, the previous preamble will be used.

References

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_DemuxFrame (WMAN Downlink Demultiplex Frame)



Description Downlink frame demultiplexer
Library WMAN, Receiver
Class SDFWMAN_DL_DemuxFrame
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present	{0}		int array	{0, 1}
IdleInterval	Idle interval	10 usec	sec	real	[0, 1000]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]

Pin Inputs

Pin	Name	Description	Signal Type
1	index	synchronization index	int
2	DeltaF	carrier frequency offset	real
3	input	input of downlink frame	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	preamble	output preamble for channel estimation	complex
5	data	output data sequence	complex

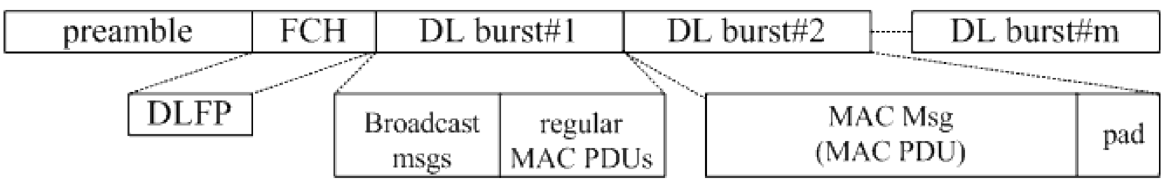
Notes/Equations

1. This model is used to demultiplex downlink subframe into data symbol and preamble which is used for channel estimation. Idle interval and cyclic prefix are removed, and time and carrier frequency offsets are compensated before demultiplexing.
2. Each firing,
   - $Samples_{Frame}$
     tokens are consumed at pin Input,

where $Samples_{Frame}$
is the number of total samples of one downlink subframe.

- 1 token is consumed at pin index which indicates the value of synchronization index.
- 1 token is consumed at pin DeltaF which indicates the value of carrier frequency offset.
- $256 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ ~~ tokens are produced at pin Data,
  where $N_{Symbol}[i]$
  is the number of OFDM symbols of the ith downlink burst.
- $1 + \sum_{i=1}^{NumberOfBurst} Prml[i]$ tokens are produced at pin Preamble,
  where $Prml[i]$ is the number of preamble of the ith downlink burst and 1 indicates only the second symbol of the long preamble is output.
  The variables all above are calculated in *note 3*.

3. Parameters calculation:
   WMAN DL Subframe Structure shows the downlink subframe format, which includes: long preamble, FCH, and one or multiple downlink bursts each transmitted with different burst profile.



WMAN DL Subframe Structure

One WMAN downlink subframe consists of long preamble, FCH and multiple downlink bursts.
There is an idle interval before preamble in this signal source and this idle interval is for Agilent connected solution.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol.
Rate_ID (R) determines the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to Data-Rate-Dependent Parameters, which is based on the specification.

Data-Rate-Dependent Parameters

Rate_ID (R)	Modulation	Uncoded block size (bytes)	Coded block size (bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of the ith downlink burst (!wman-7-04-035.gif!
) is calculated as:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If PreamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$

So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as:

$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

The number of samples per one OFDM symbol (!wman-7-04-042.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where G denotes the parameter CyclicPrefix.

Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor(!wman-7-04-044.gif!) as, $F_s = floor((N_{factor} \times Bandwidth)/8000) \times 8000$

The sampling factors(!wman-7-04-046.gif!) are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

The samples of IdleInterval (!wman-7-04-047.gif!) is calculated as:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

So, the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

4. Output pin delay adjustment

Because of the transmission delay, a detected frame usually falls into 2 consecutive received blocks, so the buffer length for input Pin is $2 \times Samples_{Frame}$. The start point of the detected frame is determined by the input signal at pin index. Only after receiving the second input block, this model can output one actual subframe. So this model causes one subframe delay.

The DeltaF pin inputs the estimated frequency offset (!wman-7-04-052.gif!) of each received frame.The ith estimated frequency offset (!wman-7-04-053.gif!) compensates for the phase in the current frame only. Assume $x_0, x_1, \ldots, x_{Samples_{Frame} - 1}$ is the input signal from the input pin starting from the first point of the frame, $y_0, y_1, \ldots, y_{Samples_{Frame} - 1}$ is the sequence, whose phase caused by frequency offset is removed, then: $y_k = x_k \times e^{-j2\pi\Delta f_i k T_{Step}}$

where

Δf_i

is frequency offset of the ith received frame which is the input at pin DeltaF,

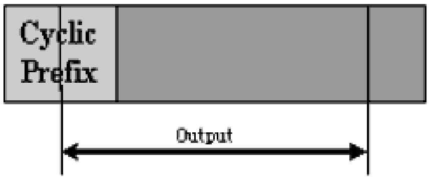
$$T_{Step} = \frac{1}{F_s \times 2^{OversamplingOption}}$$

is the sample time interval in WMAN system.

After making frequency offset compensation, the actual WMAN downlink data payload will be extracted and output at pin data, the P_{EVEN}

in long preamble and the preamble of each burst will be extracted and output consecutively in

ascending order at pin preamble, the Idle and $P_{4 \times 64}$
in long preamble parts should be discarded. Pin Index inputs the start point of a detected WMAN downlink subframe (excluding Idle). The output data extracted from the OFDM symbol begin from half position of the CP, i.e. 0.5×256×CyclicPrefix×2OversamplingOption, for better robust performance against timing synchronization error, CP of each OFDM symbol is also discarded. The cyclic prefix removal process is shown in Cyclic Prefix Removal.



Cyclic Prefix Removal

The equation is:

$$z_k = y_{k + Index + Sampels_{idle} + 2^{OversamplingOption} \times 256 \times (1 + CyclicPrefix/2)}$$

where

$$k = 0, \ldots, N_{FFTpoint} \times N_{totalSymbol} - 1$$

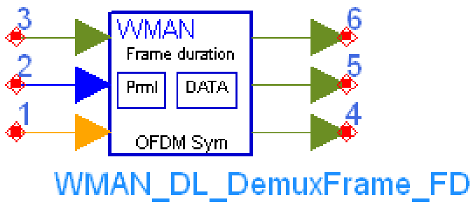
$$z_0, z_1, \ldots, z_{(N_{FFTPoint} \times (N_{totalSymbol} - 1)) - 1}$$

are samples including data payload and preamble.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_DemuxFrame_FD (WMAN Downlink Demultiplex Frame FD)



Description Downlink frame demultiplexer with broadcast message and frame duration
Library WMAN, Receiver
Class SDFWMAN_DL_DemuxFrame_FD
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present	{0}		int array	{0, 1}
IdleInterval	Idle interval	10 usec	sec	real	[0, 1000]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	

Pin Inputs

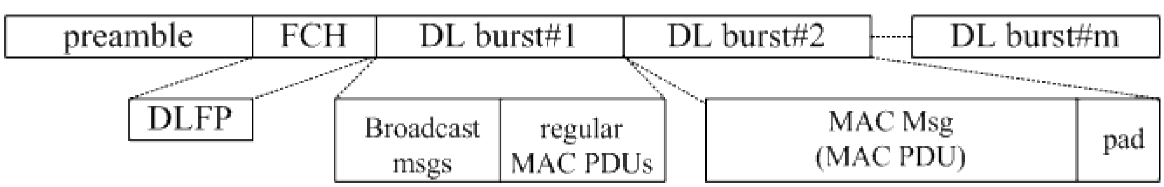
Pin	Name	Description	Signal Type
1	index	synchronization index	int
2	DeltaF	carrier frequency offset	real
3	input	input of downlink frame	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	preamble	output preamble for channel estimation	complex
5	data	output data sequence	complex
6	all_bursts	output all the preamble and data sequences	complex

Notes/Equations

1. This model is used to demultiplex downlink subframe into data symbol and preamble which is used for channel estimation. Idle interval and cyclic prefix are removed, and time and carrier frequency offsets are compensated before demultiplexing.
2. Each firing,
   - $Samples_{Frame}$ tokens are consumed at pin Input,
     where $Samples_{Frame}$ is the total sample of one downlink subframe.
   - 1 token is consumed at pin index which indicates the value of synchronization index.
   - 1 token is consumed at pin DeltaF which indicates the value of carrier frequency offset.
   - $$256 \times 2^{OversamplingOption} \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$$ tokens are produced at pin Data,
     where $N_{Symbol}[i]$
     is the number of OFDM symbols of the ith downlink burst. N_{Brdcst}
     is the number of OFDM symbols of the broadcast burst where it is equal to 21 when Brd_Message is YES and is equal to 0 when Brd_Message is NO
   - $$256 \times 2^{OversamplingOption} \times \left(1 + \sum_{i=1}^{NumberOfBurst} Prml[i]\right)$$ tokens are produced at pin Preamble,
     where $Prml[i]$ is the number of preamble of the ith downlink burst.
     All above variables are calculated in section 3.
   - $$256 \times 2^{OversamplingOption} \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i] + 1 + \sum_{i=1}^{NumberOfBurst} Prml[i]\right)$$ tokens are produced at pin all_bursts where the output is all the data symbols and preambles
3. Parameters calculation:
   WMAN DL Subframe Structure shows the downlink subframe format, which includes: long preamble, FCH, broadcast burst and one or multiple downlink bursts each transmitted with different burst profile. If a frame duration is specified, zero gaps will be inserted at then end to form a complete frame.



WMAN DL Subframe Structure

In WMAN Library, one WMAN downlink subframe consists of Idle, long preamble, FCH, broadcast burst and downlink bursts each including only one MAC PDU or zero gaps added.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol.
The broadcast burst consists of 21 consecutive OFDM symbols.
FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and

FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the downlink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the downlink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
Rate_ID (R) determines the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to Data-Rate-Dependent Parameters, which is based on the specification.

Data-Rate-Dependent Parameter

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of the ith downlink burst(!wman-7-05-075.gif!) is calculated as

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

follows:
PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$
So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as

$$N_{totalSymbol} = 2 + 1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

follows:
The number of samples per one OFDM symbol (!wman-7-05-082.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as

$$F_s = floor((N_{factor} \times Bandwidth)/8000) \times 8000$$

follows,
The sampling factors are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

If FrameDuration is Continuous, the total samples of one downlink frame $Samples_{Frame}$

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

is
Otherwise, if FrameDuration is set to other values (2.5 ms, 4 ms, 5 ms, 8 ms, 10 ms, 12.5 ms or 20 ms), the total samples of one downlink frame $Samples_{Frame}$

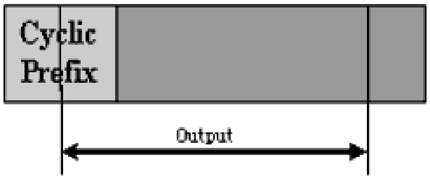
$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

is

4. Output pin delay adjustment
   Because of the transmission delay, a detected frame usually falls into 2 consecutive received blocks, so the buffer length for input Pin is $2 \times Samples_{Frame}$. The start point of the detected frame is determined by the input signal at pin index. Only after receiving the second input block, this model can output one actual subframe. So this model causes one subframe delay.
5. The DeltaF pin inputs the estimated frequency offset (!wman-7-05-092.gif!) of each received frame.The ith estimated frequency offset (!wman-7-05-093.gif!) compensates for the phase in the current frame only. Assume $x_0, x_1, \ldots, x_{Samples_{Frame}-1}$ sequences are the input signals from the input pin starting from Index, $y_0, y_1, \ldots, y_{Samples_{Frame}-1}$ are the sequences, whose phase caused by frequency offset, are removed, then:

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

   where
   Δf_i is frequency offset of the ith received frame which is the input at pin DeltaF,
   $$T_{Step} = \frac{1}{F_s \times 2^{OversamplingOption}}$$
   is the sample time interval in WMAN system.
   After making frequency offset compensation, the actual WMAN downlink data payload will be extracted and output at pin data, the P_{EVEN} in long preamble and the preamble of each burst will be extracted and output consecutively in ascending order at pin preamble, the Idle and $P_{4 \times 64}$ in long preamble parts should be discarded. Pin Index inputs the start point of a detected WMAN downlink subframe (including Idle). The output data extracted from the OFDM symbol begin from half position of the CP, i.e. 0.5×256×ΧψχlιχΠρεφιξ×2OversamplingOption, for better robust performance against timing synchronization error. The cyclic prefix removal process is shown in Cyclic Prefix Removal.



Cyclic Prefix Removal

The equation is:

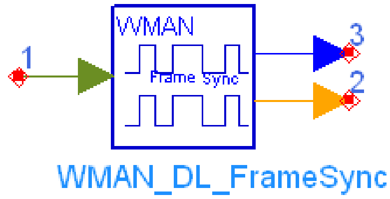
$$z_k = y_{k + Index + Sampels_{Idle} + 2^{OversamplingOption} \times 256 \times (1 + cyclicPrefix/2)}, k = 0, \ldots, N_{FFTpoint} \times N_{totalSymbol} - 1$$

$z_0, z_1, \ldots, z_{(N_{FFTPoint} \times (N_{totalSymbol} - 1)) - 1}$
sequences including data payload and preamble.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DL_FrameSync (WMAN Downlink Frame Synchronizer)



Description Downlink frame synchronization
Library WMAN, Receiver
Class SDFWMAN_DL_FrameSync
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present	{0}		int array	{0, 1}
IdleInterval	Idle interval	10 usec	sec	real	[0, 1000]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	downlink frame	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	index	synchronization frame start position	int
3	corr	correlation result	real

Notes/Equations

1. This Model is used to achieve downlink frame synchronization.

2. Each firing, $Samples_{Frame}$ tokens are consumed at Pin input, where $Samples_{Frame}$ is the total sample number per downlink frame; 1 token is produced at Pin index which indicates the value of synchronization index; $Samples_{Frame}$ tokens are produced at pin corr which indicate the autocorrelation values.
3. One WMAN downlink frame consists of Idle, long preamble, FCH and multiple downlink bursts. The downlink long preamble consists of two consecutive OFDM symbols.
   FCH is transmitted in one OFDM symbol. The number of OFDM symbols of ith downlink burst ($N_{Symbol}[i]$) is calculated as:
   $N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[RateID[i]]))$
   PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If PreamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise $Prml[i] = 0$.
   So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as:

$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i]) + N_{BroadcastMessage}$$

   where NBroadcastMessage=0 if Brd_Message=NO, NBroadcastMessage=21 if Brd_Message=YES.
   The number of samples per one OFDM symbol ($Samples_{OFDM}$) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

   The samples of IdleInterval (N_{idle}) is calculated as:

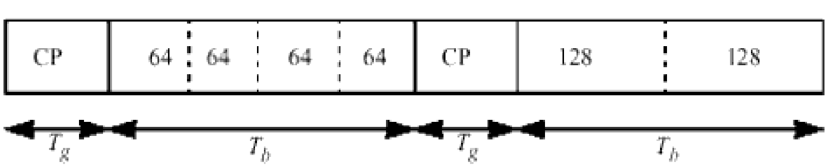
$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

   The total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = \begin{cases} Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM} \\ \quad if \quad FrameDuration = Continuous \\ Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption} \\ \quad if \quad FrameDuration \Diamond Continuous \end{cases}$$

4. The preamble in the downlink consists of two consecutive OFDM symbols. The first OFDM symbol uses only subcarriers the indices of which are a multiple of 4. As a result, the time domain of the first symbol consists of four repetitions of 64-sample fragment, preceded by a CP. The second OFDM symbol utilizes only even subcarriers, resulting in time domain structure composed of two repetition of a 128-sample fragment, preceded by a CP. The time domain structure is shown in Downlink Long Preamble Structure.

Downlink Long Preamble Structure



5. The synchronization algorithm is based on autocorrelation of the repetitive fragments of the first preamble symbol. Autocorrelation is calculated between two sequences. The sequences length are $L = 2^{OversamplingOption} \times (256 \times (1 + G) - 64)$. The distance between the first sequence and the

second sequence is $N = 2^{OversamplingOption} \times 64$. So In the absence of noise autocorrelation get maximum when the first sequence is at the start of the preamble. Autocorrelation is calculated as below:

$$Correlation_i = \left| \sum_{l=0}^{L-1} Sample_{i+l} \times (Sample)^*{}_{i+N+l} \right|$$

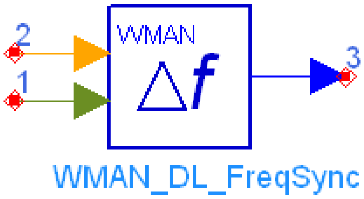
i= 0... $Samples_{Frame} - L - N$

6. When the start of long preamble is found, the start point subtracts $Samples_{idle}$ and is output at Pin index.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_FreqSync (WMAN Downlink Frequency Synchronizer)



Description Downlink frequency synchronizer
Library WMAN, Receiver
Class SDFWMAN_DL_FreqSync
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfBurst	Number of Burst	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present	{0}		int array	{0, 1}
IdleInterval	Idle interval	10 usec	sec	real	[0, 1000]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	downlink frame	complex
2	index	downlink frame start index	int

Pin Outputs

Pin	Name	Description	Signal Type
3	DeltaF	frequency offset	real

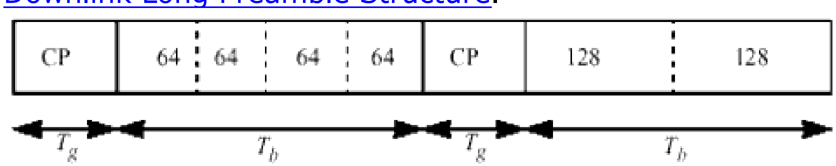
Notes/Equations

1. This Model is used to achieve downlink frequency synchronization.
2. Each firing, $Samples_{Frame}$ tokens are consumed at Pin input, where $Samples_{Frame}$ is the total

sample per downlink frame; 1 token is consumed at Pin index which indicates the value of synchronization index; 1 token is produced at Pin DeltaF which indicates the value of frequency offset.

3. One WMAN downlink frame consists of Idle, long preamble, FCH and multiple downlink bursts. The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol. The number of OFDM symbols of ith downlink burst(!wman-7-07-130.gif!) is calculated as:
$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[RateID[i]]))$ PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If PreamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise $Prml[i] = 0$.
So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as:
$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i]) + N_{BroadcastMessage}$$
where NBroadcastMessage=0 if Brd_Message=NO, NBroadcastMessage=21 if Brd_Message=YES.
The number of samples per one OFDM symbol (!wman-7-07-137.gif!) is calculated as:
$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$
The samples of IdleInterval(!wman-7-07-139.gif!) is calculated as:
$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$
So the total samples of one downlink frame $Samples_{Frame}$
$$Samples_{Frame} = \begin{cases} Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM} \\ if \quad FrameDuration = Continuous \\ Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption} \\ if \quad FrameDuration \Diamond Continuous \end{cases}$$
is

4. The preamble in the downlink consists of two consecutive OFDM symbols. The first OFDM symbol uses only subcarriers the indices of which are a multiple of 4. As a result, the time domain of the first symbol consists of four repetitions of 64-sample fragment, preceded by a CP. The second OFDM symbol utilizes only even subcarriers, resulting in time domain structure composed of two repetition of a 128-sample fragment, preceded by a CP. The time domain structure is shown in Downlink Long Preamble Structure.



Downlink Long Preamble Structure

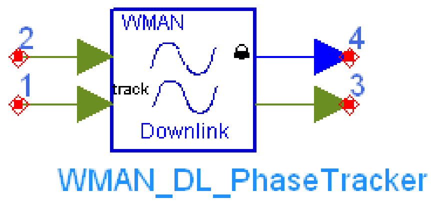
5. The algorithm is based on correlation of the repetitive fragments of the first preamble symbol. Autocorrelation is calculated between two sequences.
The sequence length is $L = 2^{OversamplingOption} \times (256 \times (1 + G) - 64 - 20)$
The distance between the two sequences is
$$N = 2^{OversamplingOption} \times 64$$
$$start = index + 10 \times 2^{OversamplingOption}$$
$$F_s = (floor((N_{factor} \times Bandwidth)/8000) \times 8000)$$

$$\Delta f = -\arg\left(\sum_{l=0}^{L-1} Sample_{start+l} \times (Sample)^*_{start+N+l}\right) \times F_s / (2\pi \times 64)$$

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_PhaseTracker (WMAN Downlink Phase Tracker)



Description Downlink phase tracker
Library WMAN, Receiver
Class SDFWMAN_DL_PhaseTracker
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfBurst	Number of Burst	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]
PreamblePresent	Preamble present	0	int array	{0, 1}
PilotPN_Phase	the Pilot PN phase	0	int	[0, 2047]
Brd_Message	Broadcast message enabled or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	input of data symbol	complex
2	CIR_Raw	estimated channel impulse response input	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	CIR_Track	channel impulse response after phase track	complex
4	Theta	phase difference between current CIR and estimated CIR	real

Notes/Equations

1. This model is used to track the phase offset in downlink demodulation systems, and update the estimated CIR (Channel impulse response) using the phase offset detected in the phase tracking algorithm.
2. Each firing,
   - 200NTotalDataSym tokens are consumed at pin Data.
     where
     NTotalDataSym is the sum of each burst's data symbols, defined as:

$$N_{TotalDataSym} = \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i] + N_{BroadcastMessage}$$

where NBroadcastMessage=0 if Brd_Message=NO, NBroadcastMessage=21 if Brd_Message=YES.

The number of OFDM data symbols of ith downlink burst ($N_{Symbol}[i]$) is calculated as:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

- 200NTotalDataSym tokens are consumed at pin CIR_Raw.
- 200NTotalDataSym tokens are produced at pin CIR_Track
- NTotalDataSym token are produced at pin Theta.

3. The eight pilots at frequency offset indices of {-88, -63, -38, -13, 13, 38, 63, 88} are used to obtain the current estimated CIR of these subcarriers. Then the maximum likelihood algorithm is used to detect the phase offset θ between the CIRs at pin CIR_Raw which are obtained by the preamble, and the current estimated CIRs. The equation is:

$$\theta = \arg\left(\sum_{k=1}^{8} \hat{H}_k \times conj(H'_k)\right)$$

Where,

$\hat{H}_k$ is the current estimated CIR.

H'_k is the previous estimated CIR obtained by the preamble.

The estimated CIRs from pin CIR_Raw are updated by the phase offset θ.

Set H0, H1, ... , H199 and H'_0, H'_1, ... , H'_{199} are the input CIR_Raw and updated CIRs, respectively. Then

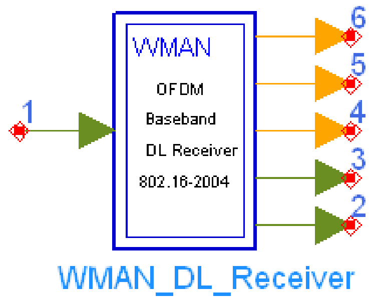
$$H'_i = H_i \times e^{j\theta}$$

The updated CIRs are output at pin CIR_Track. The phase offset is output at pin Theta.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_Receiver (Downlink baseband receiver)



Description Downlink baseband receiver
Library WMAN, Receiver
Class SDFWMAN_DL_Receiver

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
DIUC	DIUC of each burst	{1}		int array	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle interval	10.0 usec	sec	real	[0, 1000)
PilotPN_Phase	Pilot PN phase	0		int	[0, 4095]
DecoderType	soft decision viterbi decoding type: Hard, Soft, CSI	Soft		enum	

Pin Inputs

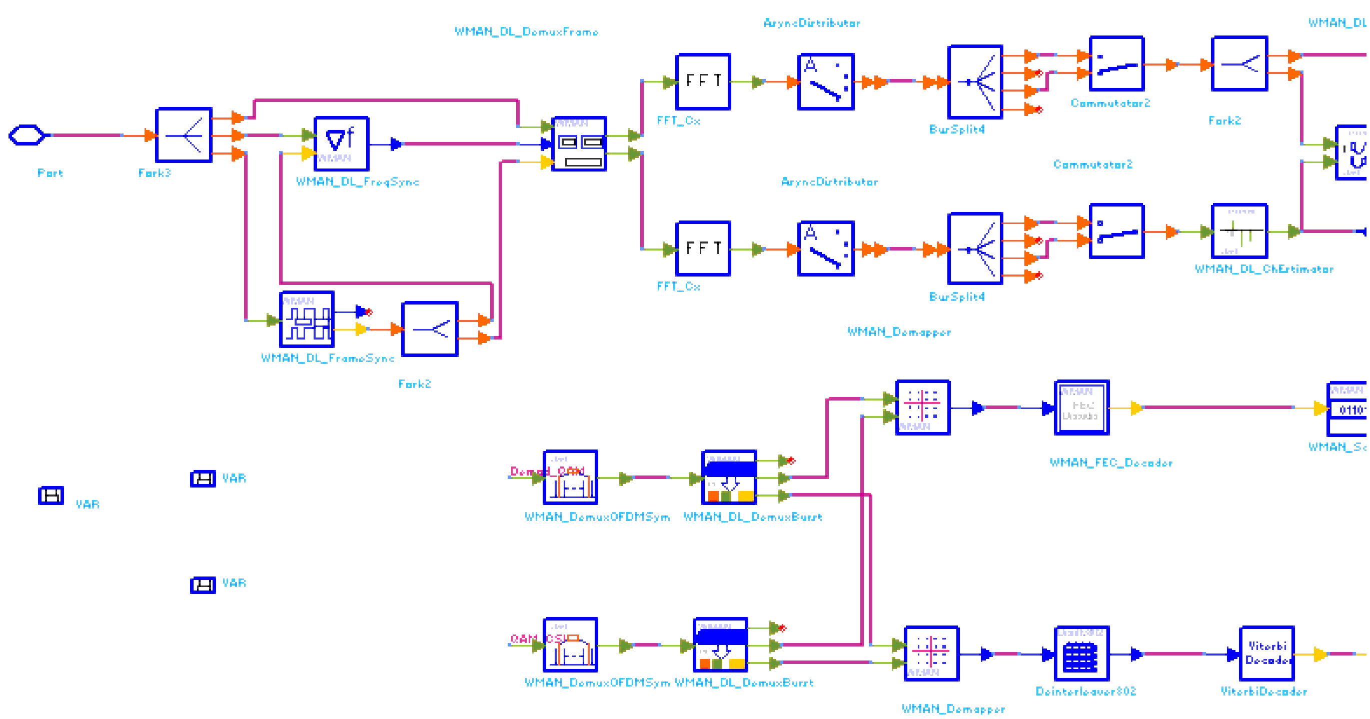
Pin	Name	Description	Signal Type
1	FrameData	input of DL Frame data	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int
6	DLFP	output of DLFP bits	int

Notes/Equations

1. This subnetwork model implements WMAN OFDM downlink baseband receiver following IEEE 802.16-2004 specification. The downlink baseband receiver schematic is shown in WMAN_DL_Receiver Schematic.



WMAN_DL_Receiver Schematic

2. Receiver functions are implemented as follows.
Start of frame is detected. WMAN_DL_FrameSync calculates the correlation between the received signal and the preambles, and selects the index with the maximum correlation value as the start of subframe.
Frequency offset is estimated. WMAN_DL_FreqSync calculates the frequency offset.
The packet is de-rotated according to the estimated frequency offsets (frequency synchronization). The phase effect caused by the frequency offset is compensated by WMAN_DL_DemuxFrame. WMAN_DL_DemuxFrame outputs channel estimation sequences for channel estimator and the OFDM symbols for FCH and multi-bursts. This WMAN_DL_DemuxFrame component introduces one subframe delay.
Complex channel impulse responses (CIR) are estimated and interpolated for each subcarrier (channel estimation). First, gets CIRs for the even subcarriers by pilots in the short preambles. Then, WMAN_DL_ChEstimator gets CIRs for the odd subcarriers by interpolating even subcarriers' CIRs. These CIRs are output at pin CIR. The output signal can be used to measure spectral flatness and etc.
Each OFDM symbol is transformed into 200 subcarriers by FFT. Phase of the pilot subcarriers are

estimated, then all subcarrier values are de-rotated according to the estimated phase. WMAN_DL_PhaseTracker implements these functions.
Each subcarrier value is divided by a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented in the receiver.
After equalization, the demodulated OFDM symbols for FCH and multi-bursts are output at pin For_EVM. The signal can be used to show the demodulated constellation and to calculate the RCE (relative constellation error) or EVM.
WMAN_DemuxOFDMSym de-multiplexes 200 subcarriers into 192 data subcarriers and 8 pilot subcarriers. WMAN_DemuxOFDMSym just outputs signal at 192 data subcarriers.
The burst with FEC-encoded is separated from the multi-bursts in WMAN_DL_DemuxBurst.
The demodulated OFDM symbols of burst with FEC are then de-mapped by WMAN_Demapper. Three demapper types (CSI, Soft and Hard) are supported in WMAN_Demaper.
After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are achieved, which are divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PDUFCS and PSDU respectively.
The demodulated FCH OFDM symbol is also de-mapped by WMAN_Demapper. After FEC decoding, de-interleaving, de-scrambling, the decoded DLFP is output at pin DLFP.

3. Parameter Details
    - NumberOfBurst specifies the number of active downlink bursts.
    - BurstWithFEC specifies the downlink burst with FEC.
    - DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

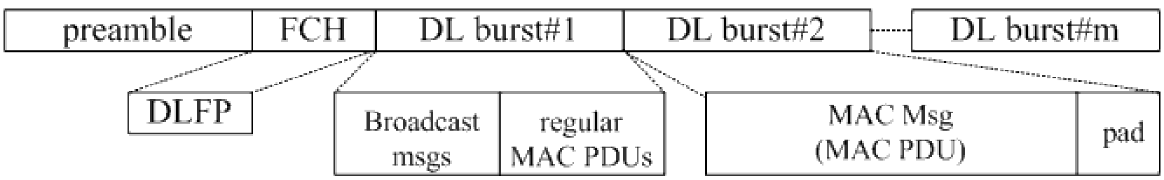
    - PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1," preamble is placed before the burst, otherwise preamble is not placed before the burst.
    - PrmlTimeShift is an array parameter. Its size should be same as NumberOfBurst and it determine the number of samples of cyclic shift delay in time for the preamble symbols
    - DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
    - OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this receiver. For example, if OversamplingOption = Ratio 2, it means the IFFT size is 512.
    - Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows, $F_s = floor((n \times Bandwidth)/8000) \times 8000$
    The sampling factors are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from 0 to 1.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- DecoderType specifiers the Viterbi decoder type chosen from CSI, Soft and Hard.

4. Output Pin Delay Adjustment
Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
WMAN DL Subframe Structure shows the downlink subframe format, it includes: long preamble, FCH, and one or multiple downlink bursts each transmitted with different burst profile.



WMAN DL Subframe Structure

One WMAN downlink subframe consists of long preamble, FCH and multiple downlink bursts. There is an idle interval before preamble in this signal source and this idle interval is for Agilent connected solution.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol. The number of OFDM symbols of ith downlink burst (!wman-7-09-166.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$.
So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

The number of samples per one OFDM symbol (!wman-7-09-173.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

The samples of IdleInterval (!wman-7-09-175.gif!) is calculated as:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

So, the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

This model works on frame by fame. Each firing, $Samples_{Frame}$ tokens are consumed at Pin FrameData.
For_EVM pin has one WMAN OFDM DL frame delay. This pin outputs all the number of OFDM

symbols in one subframe except preambles. Each firing, pin For_EVM produces $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens. Moreover, the first $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ output signals at the For_EVM pin are zeros.

PSDUFCS has one frame delay. This pin outputs demodulated PSDU and FCS information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC] + 80$. The first $8 \times DataLength[BurstWithFEC] + 80$ bits at the PSDUFCS pin are zeros.

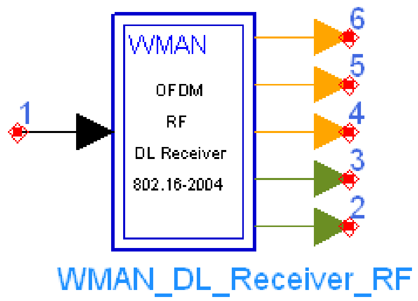
PSDU also has one frame delay. This pin outputs demodulated PSDU information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC]$. The first $8 \times DataLength[BurstWithFEC]$ bits at the PSDU pin ares zero.

CIR output pin also has one frame delay. Each firing, pin CIR produces $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i]\right)$ tokens. The first $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i]\right)$ output signals at the CIR pin are zeros.

References

1. IEEE Std 802.16-2004, "Part 16: Air Interface for Fixed Broadband Wireless Access Systems", Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, "Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems", May 2005.

WMAN_DL_Receiver_RF (WMAN Downlink Receiver RF)



Description Downlink RF receiver
Library WMAN, Receiver
Class TSDFWMAN_DL_Receiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	3407 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	(-∞, ∞)
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
DIUC	DIUC of each burst	{1}		int array	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle interval	10.0 usec	sec	real	[0, 1000)
PilotPN_Phase	Pilot PN phase	0		int	[0, 4095]
DecoderType	soft decision viterbi decoding type: Hard, Soft, CSI	Soft		enum	

Pin Inputs

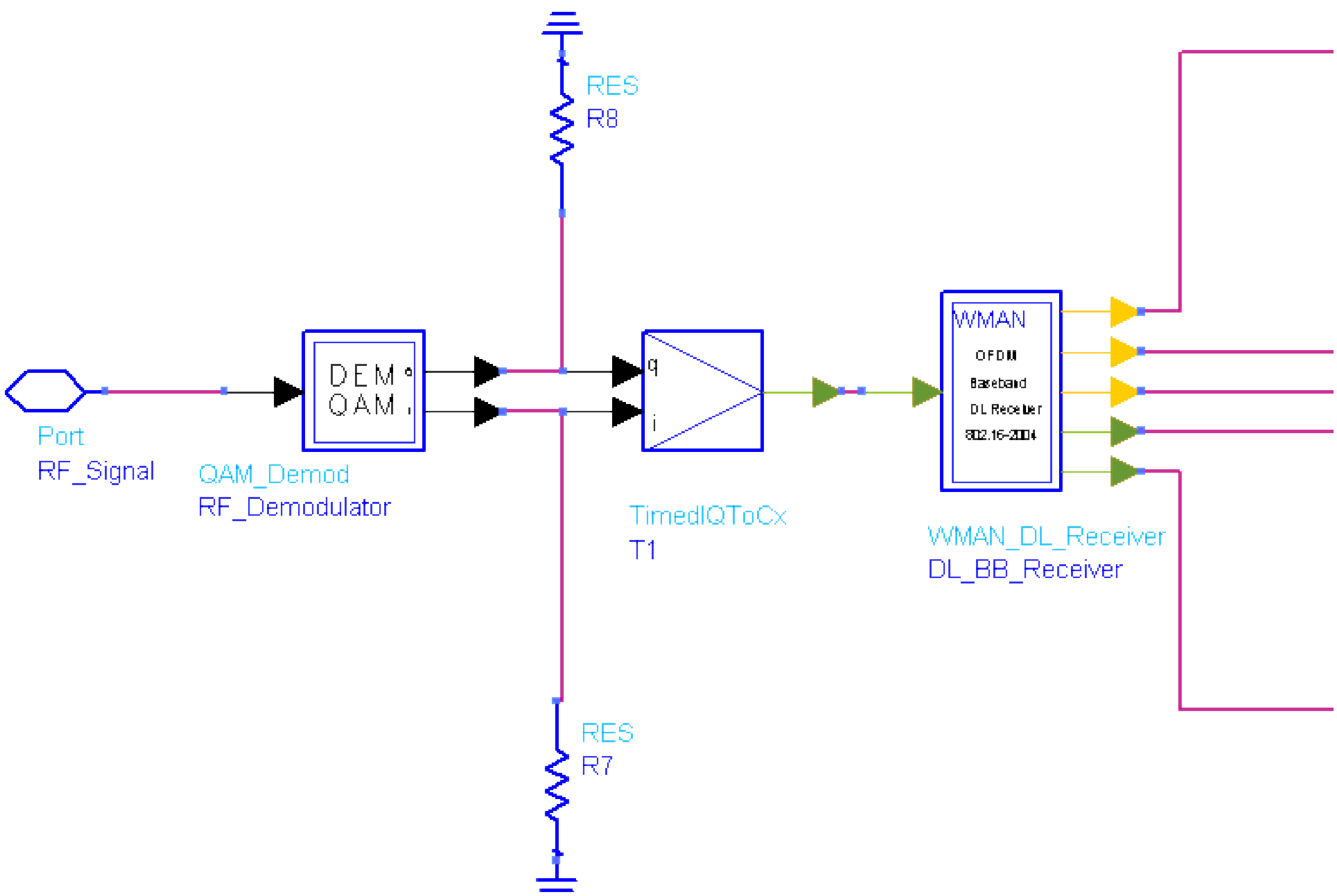
Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int
6	DLFP	output of DLFP bits	int

Notes/Equations

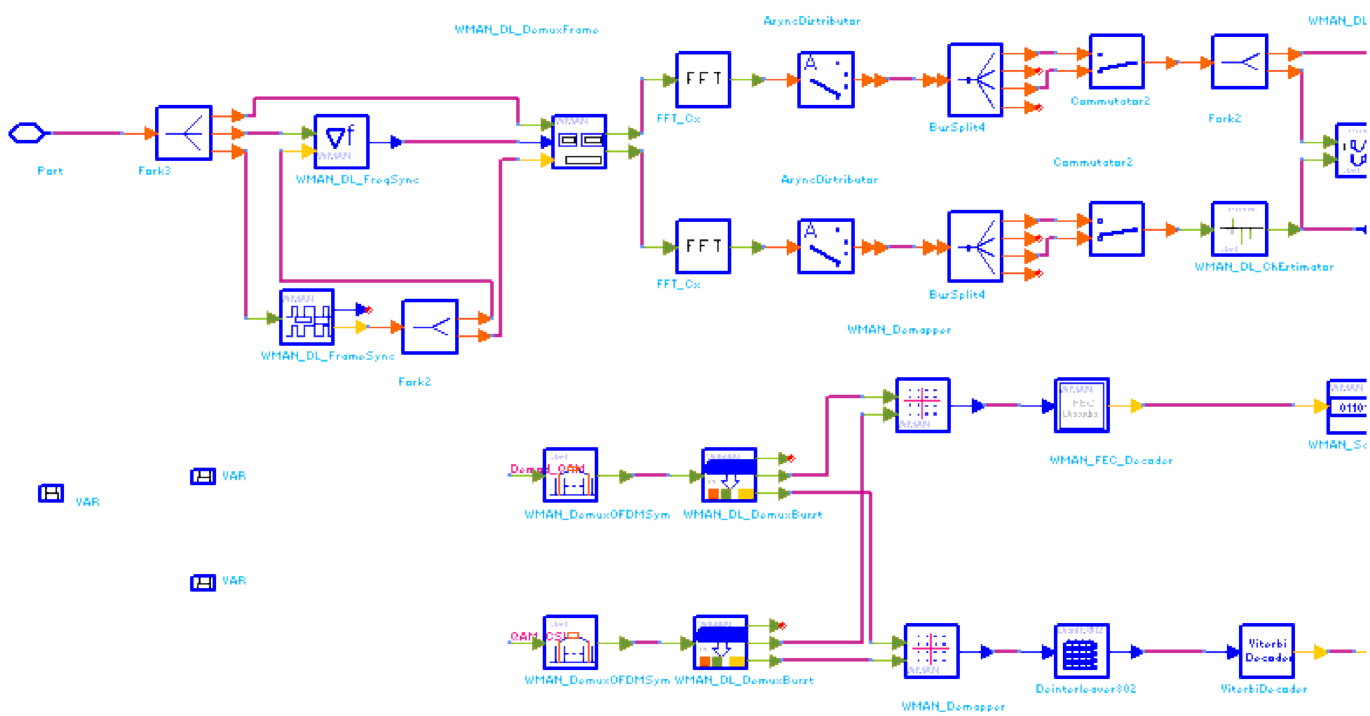
1. This subnetwork demodulates and decodes signal-band WMAN downlink RF signals. The schematic for this subnetwork is shown in WMAN_DL_Receiver_RF Schematic.



WMAN_DL_Receiver_RF Schematic

The received RF signal is demodulated by QAM_Demod, the demodulated signal is then fed to the baseband receiver for baseband processing.

2. The schematic of WMAN OFDM downlink baseband receiver is shown in WMAN_DL_Receiver Schematic.



WMAN_DL_Receiver Schematic

3. Receiver functions are implemented as follows:
   Start of frame is detected. WMAN_DL_FrameSync calculates the correlation between the received signal and the preambles, and selects the index with the maximum correlation value as the start of subframe.
   Frequency offset is estimated. WMAN_DL_FreqSync calculates the frequency offset.
   The packet is de-rotated according to the estimated frequency offsets (frequency synchronization). The phase effect caused by the frequency offset is compensated by WMAN_DL_DemuxFrame. WMAN_DL_DemuxFrame outputs channel estimation sequences for channel estimator and the OFDM symbols for FCH and multi-bursts. This WMAN_DL_DemuxFrame component introduces one frame delay.
   Complex channel impulse responses (CIR) are estimated and interpolated for each subcarrier (channel estimation). First, gets CIRs for the even subcarriers by pilots in the short preambles. Then, WMAN_DL_ChEstimator gets CIRs for the odd subcarriers by interpolating even subcarriers' CIRs. These CIRs are output at pin CIR. The output signal can be used to measure spectral flatness and etc.
   Each OFDM symbol is transformed into 200 subcarriers by FFT. Phase of the pilot subcarriers are estimated, then all subcarrier values are de-rotated according to the estimated phase. WMAN_DL_PhaseTracker implements these functions.
   Each subcarrier value is divided by a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented in the receiver.
   After equalization, the demodulated OFDM symbols for FCH and multi-bursts are output at pin For_EVM. The signal can be used to show the demodulated constellation and to calculate the RCE (relative constellation error) or EVM.
   WMAN_DemuxOFDMSym de-multiplexes 200 subcarriers into 192 data subcarriers and 8 pilot subcarriers. WMAN_DemuxOFDMSym just outputs signal at 192 data subcarriers.
   The burst with FEC-encoded is separated from the multi-bursts in WMAN_DL_DemuxBurst.
   The demodulated OFDM symbols of burst with FEC are then de-mapped by WMAN_Demapper. Three demapper types (CSI, Soft and Hard) are supported in WMAN_Demapper.
   After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are achieved, which are

divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PSDUFCS and PSDU respectively.
The demodulated FCH OFDM symbol is also de-mapped by WMAN_Demapper. After FEC decoding, de-interleaving, de-scrambling, the decoded DLFP is output at pin DLFP.

4. 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. The output rms voltage is given by sqrt(2×ROut×Power)
   - NumberOfBurst specifies the number of active downlink bursts.
   - BurstWithFEC specifies the downlink burst with FEC.
   - DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

   - PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1," preamble is placed before the burst, otherwise preamble is not placed before the burst.
   - PrmlTimeShift is an array parameter. Its size should be same as NumberOfBurst and it

determines the number of samples of cyclic shift delay in time for the preamble symbols
- DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
- OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this receiver. For example, if OversamplingOption = Ratio 2, it means the IFFT size is 512.
- Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows,

$$F_s = (floor((N_{factor} \times Bandwidth)/8000) \times 8000) \times 2^{OversamplingOption}$$

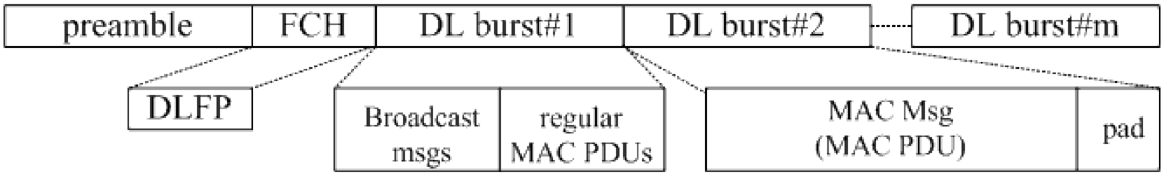
The sampling factors are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from 0 to 1.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- DecoderType specifies the Viterbi decoder type chosen from CSI, Soft and Hard.

5. Output Pin Delay Adjustment
Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
WMAN DL Frame Structure shows the downlink frame format, it includes: long preamble, FCH, and one or multiple downlink bursts each transmitted with different burst profile.



WMAN DL Frame Structure

One WMAN downlink subframe consists of long preamble, FCH and multiple downlink bursts. There is an idle interval before preamble in this signal source and this idle interval is for Agilent connected solution.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol. The number of OFDM symbols of the ith downlink burst (!wman-7-10-196.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If PreamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$.
So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

The number of samples per one OFDM symbol (!wman-7-10-203.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

The samples of IdleInterval (!wman-7-10-205.gif!) is calculated as follows:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

So, the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

This model work on frame by fame. Each firing, $Samples_{Frame}$ tokens are consumed at Pin FrameData.

For_EVM pin has one WMAN OFDM DL frame delay. This pin outputs all the number OFDM symbols except preambles. Each firing, pin For_EVM produces $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens. Moreover, the first $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ output signals at the For_EVM pin are zeros.

PSDUFCS has one frame delay. This pin outputs demodulated PSDU and FCS information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC] + 80$.

The first $8 \times DataLength[BurstWithFEC] + 80$ bits at the PSDUFCS pin are zeros.

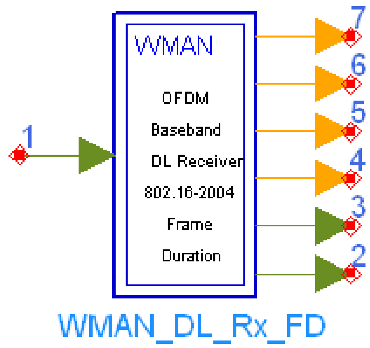
PSDU also has one frame delay. This pin outputs demodulated PSDU information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC]$. The first $8 \times DataLength[BurstWithFEC]$ bits at the PSDU pin ares zero.

CIR output pin also has one frame delay. Each firing, pin CIR produces $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i]\right)$ tokens. The first $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i]\right)$ output signals at the CIR pin are zeros.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_Rx_FD (WMAN DL Receiver with Frame Duration)



Description Downlink baseband receiver with broadcast message and frame duration
Library WMAN, Receiver
Class SDFWMAN_DL_Rx_FD

Parameters

Name	Description	Default	Unit	Type	Range
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	
IdleInterval	Idle interval	0.0 usec	sec	real	[0, 1000)
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
PilotPN_Phase	Pilot PN phase	0		int	[0, 4095]
DecoderType	soft decision viterbi decoding type: Hard, Soft, CSI	Soft		enum	

Pin Inputs

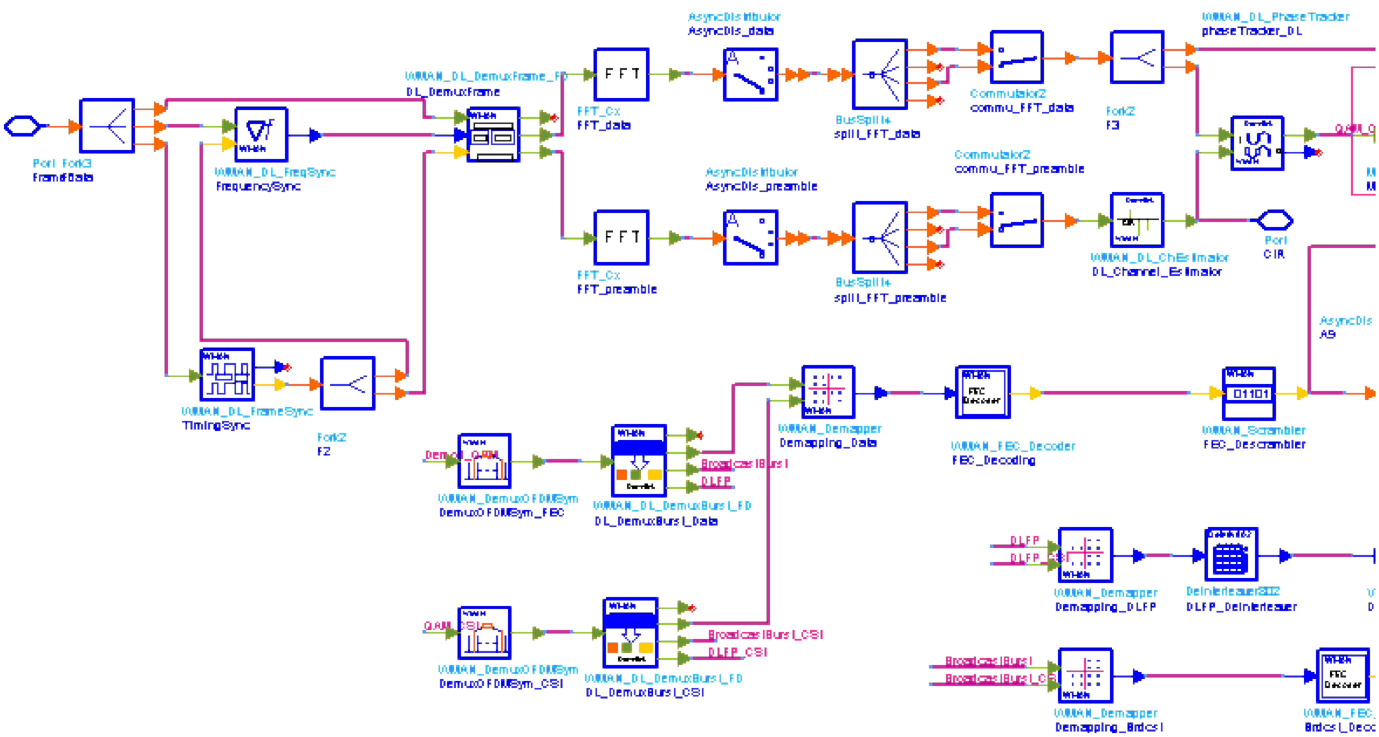
Pin	Name	Description	Signal Type
1	FrameData	input of DL Frame data	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int
6	DLFP	output of DLFP bits	int
7	Brd_message	output of broadcast message	int

Notes/Equations

1. This subnetwork model implements WMAN OFDM downlink baseband receiver following IEEE 802.16-2004 specification. The downlink baseband receiver schematic is shown in WMAN_DL_Rx_FD Schematic.



WMAN_DL_Rx_FD Schematic

2. Receiver functions are implemented as follows:
Start of frame is detected. WMAN_DL_FrameSync calculates the correlation between the received signal and the preambles, and selects the index with the maximum correlation value as the start of frame.
Frequency offset is estimated. WMAN_DL_FreqSync calculates the frequency offset and makes frequency synchronization using the preambles.
The packet is de-rotated according to the estimated frequency offsets (frequency synchronization). The phase effect caused by the frequency offset is compensated by WMAN_DL_DemuxFrame_FD. WMAN_DL_DemuxFrame_FD outputs channel estimation sequences

and the OFDM symbols for FCH, broadcast burst and multi-bursts. This WMAN_DL_DemuxFrame_FD component introduces one frame delay.
Complex channel impulse responses (CIR) are estimated and interpolated for each subcarrier (channel estimation). First, WMAN_DL_ChEstimator gets CIRs for the even subcarriers by pilots in the short preambles or midambles. Then, WMAN_DL_ChEstimator gets CIRs for the odd subcarriers by interpolating even subcarriers' CIRs. These CIRs are output at pin CIR. The output signal can be used to measure spectral flatness and etc.
Each OFDM symbol is transformed into 200 subcarriers by FFT. Phase of the pilot subcarriers are estimated, then all subcarrier values are de-rotated according to the estimated phase. WMAN_DL_PhaseTracker implements these functions.
Each subcarrier value is divided by a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented in the receiver.
After equalization, the demodulated OFDM symbols for FCH and multi-bursts are output at pin For_EVM. The signal can be used to show the demodulated constellation and to calculate the RCE (relative constellation error) or EVM.
WMAN_DemuxOFDMSym de-multiplexes 200 subcarriers into 192 data subcarriers and 8 pilot subcarriers. WMAN_DemuxOFDMSym just outputs signal at 192 data subcarriers.
The burst with FEC-encoded is separated from the multi-bursts in WMAN_DL_DemuxBurst_FD.
The demodulated OFDM symbols of burst with FEC are then de-mapped by WMAN_Demapper.
Three demapper types (CSI, Soft and Hard) are supported in WMAN_Demaper.
After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are achieved, which are divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PDUFCS and PSDU respectively.
The demodulated FCH OFDM symbol is also de-mapped by WMAN_Demapper. After FEC decoding, de-interleaving, de-scrambling, the decoded DLFP is output at pin DLFP.
The decoded broadcast messages are output at pin Brd_message.

3. Parameter Details
   - NumberOfBurst specifies the number of active downlink bursts.
   - BurstWithFEC specifies the downlink burst FEC.
   - DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

   - PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1," preamble is placed before the burst, otherwise preamble is not placed before the burst.
   - PrmlTimeShift is an array parameter. It's size should be same as NumberOfBurst, which determine the number of samples of cyclic shift delay in time for the preamble symbols
   - DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
   - OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this receiver. For example, if

OversamplingOption = Ratio 2, it means the IFFT size is 512.

- Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows,

$$F_s = floor((n \times Bandwidth)/8000) \times 8000$$

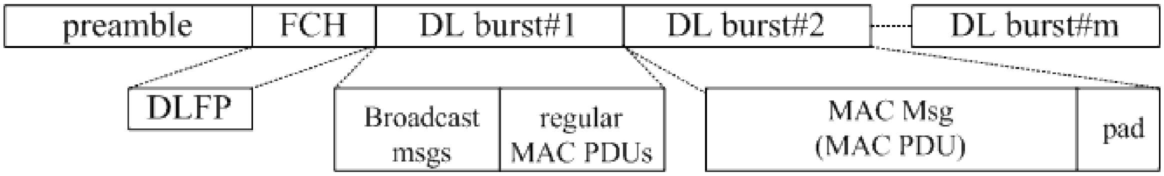
The sampling factors are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from 0 to 1.
- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the downlink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the downlink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
- Brd_Message specifies whether the broadcast burst is inserted or not. The broadcast burst is transmitted with BPSK 1/2 after FCH burst and before the data bursts. The number of OFDM symbols in the broadcast burst is 21.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- DecoderType specifiers the Viterbi decoder type chosen from CSI, Soft and Hard.

4. Output Pin Delay Adjustment
Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
WMAN DL Subframe Structure shows the downlink subframe format, it includes: long preamble, FCH, broadcast burst and one or multiple downlink bursts each transmitted with different burst profile.



WMAN DL Subframe Structure

One WMAN downlink frame consists of Idle, long preamble, FCH, broadcast burst and multiple downlink bursts.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol. The number of OFDM symbols of ith downlink burst(!wman-7-11-222.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$.
So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

N_{Brdcst} is the number of OFDM symbols of the broadcast burst where it is equal to 21 when Brd_Message is YES, and is equal to 0 when Brd_Message is NO.
The number of samples per one OFDM symbol (!wman-7-11-230.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

The samples of IdleInterval(N_{idle}) is calculated as follows:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

If FrameDuration is Continuous, the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

Otherwise, if FrameDuration is set to other values (2.5 ms, 4 ms, 5 ms, 8 ms, 10 ms, 12.5 ms or 20 ms), the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

This model work on frame by fame. Each firing, $Samples_{Frame}$ tokens are consumed at Pin FrameData.
For_EVM pin has one WMAN OFDM DL frame delay. This pin outputs all the number OFDM symbols except preambles. Each firing, pin For_EVM produces

$$200 \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$$

tokens. Moreover, the first

$$200 \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$$

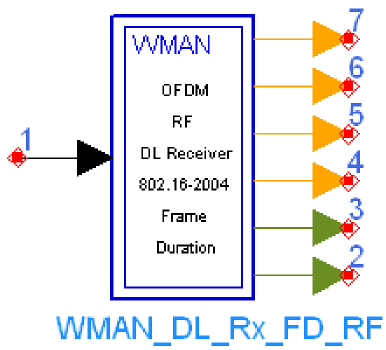
output signals at the For_EVM pin are zeros.
PSDUFCS has one frame delay. This pin outputs demodulated PSDU and FCS information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC] + 80$. The first $8 \times DataLength[BurstWithFEC] + 80$

bits at the PSDUFCS pin ares zero.
PSDU also has one frame delay. This pin outputs demodulated PSDU information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC]$. The first $8 \times DataLength[BurstWithFEC]$ bits at the PSDU pin ares zero.
CIR output pin also has one frame delay. Each firing, pin CIR produces $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i]\right)$ tokens. the first $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i]\right)$ output signals at the CIR pin are zeros.

References

1. IEEE Std 802.16-2004, "Part 16: Air Interface for Fixed Broadband Wireless Access Systems", Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DL_Rx_FD_RF (WMAN DL Receiver RF with Frame Duration)



Description Downlink RF receiver with broadcast message and frame duration
Library WMAN, Receiver
Class TSDFWMAN_DL_Rx_FD_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	50 Ohm	Ohm	int	(0,)
RTemp	TEMPERATURE	−273.15	Celsius	real	[\−273.15,]
FCarrier	Carrier frequency	3407 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	(-,)
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	
IdleInterval	Idle interval	0.0 usec	sec	real	[0, 1000)
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
DecoderType	soft decision viterbi decoding type: Hard, Soft, CSI	Soft		enum	

Pin Inputs

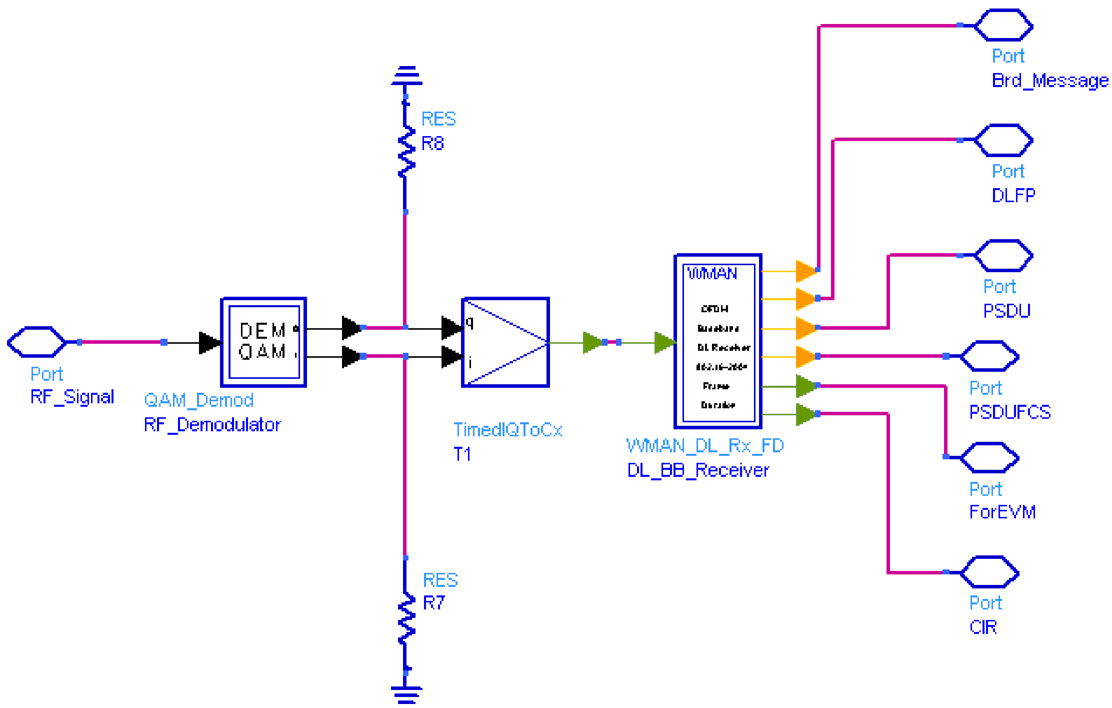
Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int
6	DLFP	output of DLFP bits	int
7	Brd_message	output of broadcast message	int

Notes/Equations

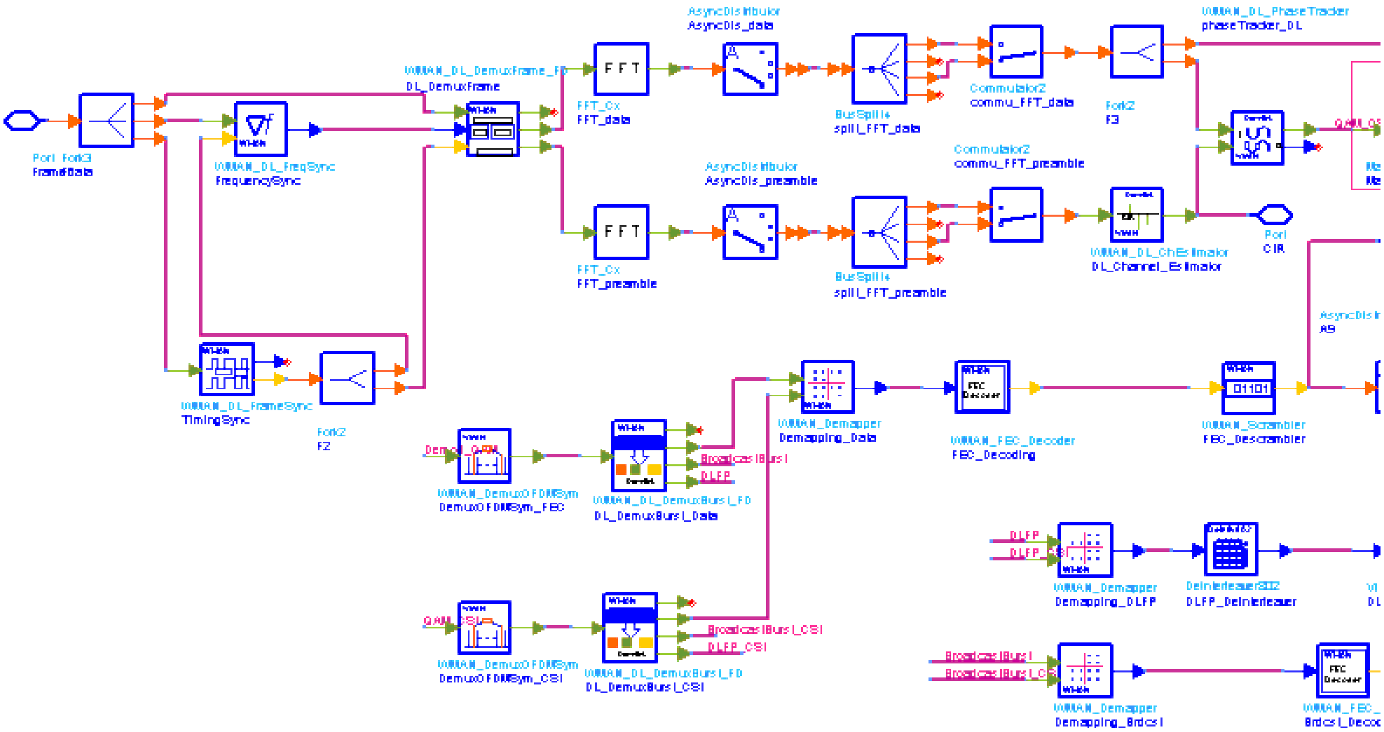
1. This subnetwork demodulates and decodes signal-band WMAN downlink RF signals. The schematic for this subnetwork is shown in WMAN_DL_Rx_FD_RF Schematic.



WMAN_DL_Rx_FD_RF Schematic

The received RF signal is demodulated by QAM_Demod, the demodulated signal is then fed to the baseband receiver for baseband processing.

2. The schematic of WMAN OFDM downlink baseband receiver is shown in WMAN_DL_Rx_FD Schematic.



WMAN_DL_Rx_FD Schematic

3. Receiver functions are implemented as follows:
Start of frame is detected. WMAN_DL_FrameSync calculates the correlation between the received signal and the preambles, and selects the index with the maximum correlation value as the start of frame.
Frequency offset is estimated. WMAN_DL_FreqSync calculates the frequency offset and makes frequency synchronization using the preambles.
The packet is de-rotated according to the estimated frequency offsets (frequency synchronization). The phase effect caused by the frequency offset is compensated by WMAN_DL_DemuxFrame_FD. WMAN_DL_DemuxFrame_FD outputs channel estimation sequences and the OFDM symbols for FCH, broadcast burst and multi-bursts. This WMAN_DL_DemuxFrame_FD component introduces one frame delay.
Complex channel impulse responses (CIR) are estimated and interpolated for each subcarrier (channel estimation). First, WMAN_DL_ChEstimator gets CIRs for the even subcarriers by pilots in the short preambles or midambles. Then, WMAN_DL_ChEstimator gets CIRs for the odd subcarriers by interpolating even subcarriers' CIRs. These CIRs are output at pin CIR. The output signal can be used to measure spectral flatness and etc.
Each OFDM symbol is transformed into 200 subcarriers by FFT. Phase of the pilot subcarriers are estimated, then all subcarrier values are de-rotated according to the estimated phase. WMAN_DL_PhaseTracker implements these functions.
Each subcarrier value is divided by a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented in the receiver.
After equalization, the demodulated OFDM symbols for FCH and multi-bursts are output at pin For_EVM. The signal can be used to show the demodulated constellation and to calculate the RCE (relative constellation error) or EVM.
WMAN_DemuxOFDMSym de-multiplexes 200 subcarriers into 192 data subcarriers and 8 pilot subcarriers. WMAN_DemuxOFDMSym just outputs signal at 192 data subcarriers.
The burst with FEC-encoded is separated from the multi-bursts in WMAN_DL_DemuxBurst_FD.
The demodulated OFDM symbols of burst with FEC are then de-mapped by WMAN_Demapper.

Three demapper types (CSI, Soft and Hard) are supported in WMAN_Demaper.
After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are achieved, which are divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PDUFCS and PSDU respectively.
The demodulated FCH OFDM symbol is also de-mapped by WMAN_Demapper. After FEC decoding, de-interleaving, de-scrambling, the decoded DLFP is output at pin DLFP.
The decoded broadcast messages are output at pin Brd_message.

4. 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
      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(2ROutPower)
    - NumberOfBurst specifies the number of active downlink bursts.
    - BurstWithFEC specifies the downlink burst FEC.
    - DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

    - PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1," preamble is placed before the burst, otherwise preamble is not placed before the burst.

- PrmlTimeShift is an array parameter. It's size should be same as NumberOfBurst, which determine the number of samples of cyclic shift delay in time for the preamble symbols
- DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
- OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this receiver. For example, if OversamplingOption = Ratio 2, it means the IFFT size is 512.
- Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows,

$$F_s = (floor((N_{factor} \times Bandwidth)/8000) \times 8000) \times 2^{OversamplingOption}$$

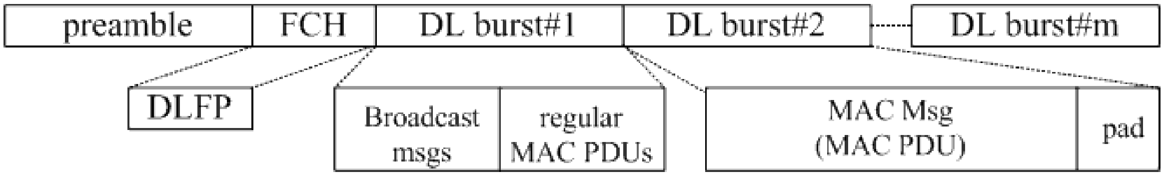
The sampling factors are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from 0 to 1.
- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the downlink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the downlink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
- Brd_Message specifies whether the broadcast burst is inserted or not. The broadcast burst is transmitted with BPSK 1/2 after FCH burst and before the data bursts. The number of OFDM symbols in the broadcast burst is 21.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- DecoderType specifies the Viterbi decoder type chosen from CSI, Soft and Hard.

5. Output Pin Delay Adjustment
Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
WMAN DL Frame Structure shows the downlink frame format, it includes: long preamble, FCH, broadcast burst and one or multiple downlink bursts each transmitted with different burst profile.



WMAN DL Frame Structure

One WMAN downlink frame consists of Idle, long preamble, FCH, broadcast burst and multiple downlink bursts.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol. The number of OFDM symbols of ith downlink burst($N_{Symbol}[i]$) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$.
So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as

$$N_{totalSymbol} = 2 + 1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

follows:
N_{Brdcst} is the number of OFDM symbols of the broadcast burst where it is equal to 21 when Brd_Message is YES, and is equal to 0 when Brd_Message is NO.
The number of samples per one OFDM symbol ($Samples_{OFDM}$) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

The samples of IdleInterval(N_{idle}) is calculated as follows:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

If FrameDuration is Continuous, the total samples of one downlink frame $Samples_{Frame}$ is
Otherwise, if FrameDuration is set to other values (2.5 ms, 4 ms, 5 ms, 8 ms, 10 ms, 12.5 ms or 20 ms), the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

This model work on frame by fame. Each firing, $Samples_{Frame}$ tokens are consumed at Pin FrameData.
For_EVM pin has one WMAN OFDM DL frame delay. This pin outputs all the number OFDM symbols except preambles. Each firing, pin For_EVM produces

$$200 \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$$

tokens. Moreover, the first

$200 \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i] \right)$ output signals at the For_EVM pin are zeros.

PSDUFCS has one frame delay. This pin outputs demodulated PSDU and FCS information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC] + 80$. The first $8 \times DataLength[BurstWithFEC] + 80$ bits at the PSDUFCS pin ares zero.

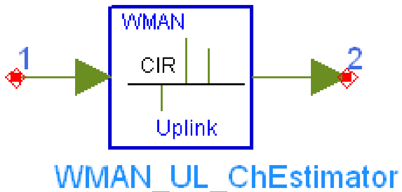
PSDU also has one frame delay. This pin outputs demodulated PSDU information bits after fully decoding (de-interleaving, Viterbi decoding and De-scrambling). So, the delay of PSDUFCS is $8 \times DataLength[BurstWithFEC]$. The first $8 \times DataLength[BurstWithFEC]$ bits at the PSDU pin ares zero.

CIR output pin also has one frame delay. Each firing, pin CIR produces $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i] \right)$ tokens. the first $200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} prml[i] \right)$ output signals at the CIR pin are zeros.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_UL_ChEstimator (WMAN Uplink Channel Estimator)



Description Uplink channel estimator
Library WMAN, Receiver
Class SDFWMAN_UL_ChEstimator
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	100	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	1	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	0	int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}	int array	[0, 255]
CyclicPrefix	Cyclic prefix	0.25	real	[0, 1]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	output signals from FFT	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	Coef	channel coefficient in active subcarriers	complex

Notes/Equations

1. This model is used to estimate WMAN uplink channel impulse response (CIR) based on the pilot channels and output the estimated channel impulse response (CIR) on the active subcarriers.
2. Each firing,
   if subchannelization is not used
   - $200 \times \left(\sum_{i=1}^{NumberOfSS} Midamble[i] \right)$ tokens are consumed at pin input.
     where $Midamble[i]$ is the number of midamble of the ith uplink SS;

- $\left(\sum_{i=1}^{NumberOfSS} N_{Symbol}[i]\right) \times 200$ tokens are produced at pin coef where $N_{Symbol}[i]$ is the number of OFDM symbols of the ith uplink SS.

  if subchannelization is used
- $200 \times max(Midamble[i])$ tokens are consumed at pin input.

  where $max(Midamble[i])$ is the maximum of $Midamble[i]$.
- $200 \times max(N_{Symbol}[i])$ tokens are produced at pin coef.

  where $max(N_{Symbol}[i])$ is the maximum of $N_{Symbol}[i]$.

  MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. MidambleRepetition and number of OFDM symbols of SS(!wman-7-13-291.gif!)determine $Midamble[i]$, which is calculated as follows:

  if $MidambleRepetition[i]$ is not zero,

  $$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

  else $Midamble[i] = 0$ round means if the decimal is not less than 0.5, the quotient should be plus one.

  The number of OFDM data symbols of ith uplink SS(!wman-7-13-296.gif!) is calculated as follows:

  $$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

  Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; for subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in Number of Subchannels, uncodedBlockSize is date-rate-dependent parameter as Data-Rate-Dependent Parameters.

  Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

  NMaxDataSym is the maximum number of data symbols among all SSs.

  Data-Rate-Dependent Parameters

Rate_ID (R)	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

3. This model uses the uplink short preambles to estimate the CIRs. If an uplink burst have midambles, the proximate midamble will be used to estimate CIRs. The estimated CIRs are calculated using active subcarrier pilot channels.
4. If subchannelization is not employed in this uplink subframe, CIR estimation is performed as

downlink CIR estimation.
The P_{EVEN} training symbol includes 200 subcarriers, given by P_{EVEN} .

$$P_{EVEN(k)} = \begin{cases} \sqrt{2} \times P_{ALL}(k) & k_{mod2} = 0 \\ 0 & k_{mod2} \neq 0 \end{cases}$$

The sequence PALL is defined as follows:
PALL(-100:100) = {1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j,-1-j, 1-j, -1+j, 1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j, -1-j, 1-j, -1+j, 1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j, -1-j, 1-j, -1+j, 1+j, 1+j, 1-j, -1+j, 1+j, 1+j, -1-j, 1+j, 1+j, 1+j, -1+j, 1-j, -1+j, -1+j, 1-j, -1+j, 1-j, 1-j,1+j, -1-j, -1-j, -1-j, -1+j, 1-j, -1-j, -1-j, 1+j, -1-j, -1-j, -1-j, 1-j, -1+j, 1-j, 1-j, -1+j, 1-j, -1+j,-1+j, -1-j, 1+j, 0, -1-j, 1+j, -1+j, -1+j, -1-j, 1+j, 1+j, 1+j, -1-j, 1+j, 1-j, 1-j, 1-j, -1+j, -1+j, -1+j, -1+j, 1-j, -1-j, -1-j, -1+j, 1-j, 1+j, 1+j, -1+j, 1-j, 1-j, 1-j, -1+j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, -1+j, -1+j, 1+j, -1-j, 1-j, 1-j, 1+j, -1-j, -1-j, -1-j, 1+j, -1-j, -1+j, -1+j, -1+j, 1-j, 1-j, 1-j, 1-j, -1+j, 1+j, 1+j, -1-j, 1+j, -1+j, -1+j, -1-j, 1+j, 1+j, 1+j, -1-j, 1+j, 1-j, 1-j, 1-j, -1+j, -1+j, -1+j, -1+j, 1-j, -1-j, -1-j, 1-j, -1+j, -1-j, -1-j, 1-j, -1+j, -1+j, -1+j, 1-j, -1+j,1+j, 1+j, 1+j, -1-j, -1-j, -1-j, -1-j, 1+j, 1-j, 1-j}

Set $x_0, x_1, \ldots, x_{199}$
are the input signals, $h_0, h_1, \ldots, h_{199}$
are the estimated CIRs.The estimated CIR in even subcarriers can be calculated as follows:

$$h_i = x_i / P_{EVEN_i}$$

where $i = 0, 2, \ldots, 198 \quad i mod 2 = 0$.
The estimated CIR in odd subcarriers is interpolated by raised cosine filter.

5. If subchannelization is employed in this uplink subframe, the preamble is referred to as the subchannelization preamble defined by P_{SUB}. Preamble subcarriers that do not fall within the allocated subchannels are set to zero. Although the uplink bursts occupy different subcarriers of the same OFDM symbol, its CIR will be estimated separately. The estimated CIR in allocated subcarriers can be calculated as follows:

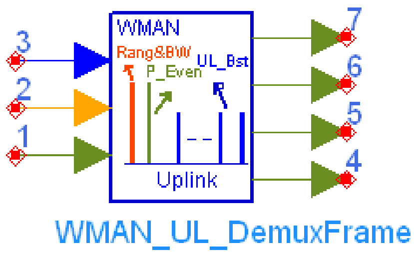
$$h_i = x_i / P_{SUB_i}$$

The sequence P_{SUB} is defined as follows:
PSUB(-100:100) = {1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, 1+j, 1-j, 1+j,1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, -1-j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, 0,1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, -1-j, 1+j, -1-j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, -1+j, 1+j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, -1-j, -1-j, 1+j, -1-j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, -1+j, 1+j, -1+j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, -1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j}
the unallocated subcarriers of the uplink burst will be set to zero.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_DemuxFrame (WMAN Uplink Frame Demultiplexer)



Description Uplink frame demultiplexer
Library WMAN, Receiver
Class SDFWMAN_UL_DemuxFrame
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfSS	Number of subscribers	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]

Pin Inputs

Pin	Name	Description	Signal Type
1	UL_Subframe	received frame signals	complex
2	Index	synchronization index of each burst	int
3	DeltaF	carrier frequency offset	real

Pin Outputs

Pin	Name	Description	Signal Type
4	Prml	output of preamble and midamble	complex
5	UL_Bursts	output of uplink data symbol	complex
6	InitialRanging	output of Initial ranging contention slot	complex
7	BW_Requests	output of BW requests contention slot	complex

Notes/Equations

1. This model is used to de-multiplex the uplink subframe into contention slot for Initial Ranging, contention slot for BW Requests, short preambles, data OFDM symbols and midambles. The idle interval and cyclic prefix of each OFDM symbol are also removed, and the time and carrier frequency offset is compensated.
2. Each firing,
   - For non-subchannelization mode, NumberOfSS tokens are consumed at pin Index, while one tokens are consumed for subchannelization mode.
   - For non-subchannelization mode, NumberOfSS tokens are consumed at pin DeltaF. For subchannelization mode, the pin DeltaF is useless.
   - Nprml tokens are produced at pin Prml for non-subchannelization mode. For subchannelization mode, 2562OversamplingOption (1+NMaxMidamble) tokens are produced at pin Prml.
     where
     $$N_{prml} = \sum_{i=1}^{NumberOfSS} 256 \times 2^{OversamplingOption} \times (1 + Midamble[i])$$
     Nprml is Midamble[i] is the number of midambles the ith SS's contains according to parameter MidambleRepetition. If $MidambleRepetition[i]$ is not zero
     $$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$
     else
     NMaxMidamble is the maximum number of midambles among all SSs.
   - For non-subchannelization mode, NBurst tokens are produced at pin UL_Bursts. For subchannelization mode, 2562OversamplingOption NMaxDataSym tokens are produced at pin UL_Bursts.
     $$N_{Burst} = \sum_{i=1}^{NumberOfSS} 256 \times 2^{oversamplingOption} \times N_{Symbol}[i]$$
     where NBurst is defined as:
     The number of OFDM data symbols of ith uplink SS($N_{Symbol}[i]$) is calculated as follows:
     $$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$
     Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in Number of Subchannels.

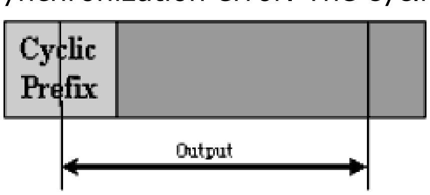
     Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

     NMaxDataSym is the maximum number of data symbols among all SSs.

- SamplesOFDM2 tokens are produced at pin InitialRanging.
- SamplesOFDM2 tokens are produced at pin BW_Requests.
- Ntotal tokens are consumed at pin UL_Subframe.
  Ntotal is the number of samples in one Uplink frame, containing idle interval, contention slot for Initial Ranging, contention slot for BW Requests, preambles, data symbols and midambles, defined as following.
  For non-subchannelization mode
  $$N_{total} = Samples_{Idle} + \left(5 + \sum_{i=1}^{NumberOfSS} N_{Symbol}[i] + \sum_{i=1}^{NumberOfSS} Midamble[i]\right) \times Samples_{OFDM}$$
  For subchannelization mode
  $$N_{total} = Samples_{Idle} + max(5 + N_{Symbol}[i] + Midamble[i]) \times Samples_{OFDM}$$
  where, SamplesOFDM is the number of samples within one OFDM symbol, defined as:
  $$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$:
  The samples of IdleInterval ($Samples_{idle}$) is calculated as follows:
  $$Samples_{idle} = IdleInterval \times F_s$$

3. The buffer length for input pin UL_Subframe is 2 Ntotal, and Ntotal tokens are consumed at each firing.
   1. Non-subchannelization mode
   The first point of the ith received uplink SS is determined according to the ith input value at pin Index. Then the frequency offset will be removed after the first point of the ith burst is determined. Assume x0, x 1 , ... , xN-1 are the samples from the first point of the ith burst (SS), and y0, y1, ... , yN-1 are the samples after removing the phase caused by the frequency offset, where N is the number of the received ith SS's samples including the preamble, data symbols and midambles.
   Then the equation of frequency offset removal is
   $$y_k = x_k \times e^{-j2\pi\Delta f_i k T_{Step}}$$
   where Δf_i is frequency offset of the ith received SS which is the input at pin DeltaF,
   $$T_{Step} = \frac{1}{F_s \times 2^{OversamplingOption}}$$
   is the sample time interval in WMAN system.
   The sampling frequency (Fs) implemented in the design is decided by Bandwidth and related sampling factor.
   For each SS, the removal of frequency offset should be performed. Then the cyclic prefix is removed. The output data are extracted from the OFDM symbol ahead with half the CP length, 0.5256CyclicPrefix2OversamplingOption for better robust performance against timing synchronization error. The cyclic prefix removal process is shown in Cyclic Prefix Removal.



Cyclic Prefix Removal

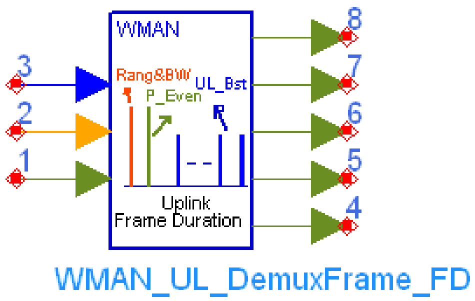
After the removal of cyclic prefix, the data symbols are output at pin UL_Bursts; The preambles and midambles are extracted and output at pin Prml. Also the data in contention slot for Initial Ranging and contention slot for BW Requests are extracted and output at InitialRanging and BW_Requests respectively.

2. Subchannelization mode
Since all the SSs share one time slot (burst), only one value at pin Index is consumed each firing. The first point of the burst is determined according to the value at pin Index. Then the cyclic prefix is removed which is the same as that in non-subchannelization mode. Note that no frequency offset compensation is done in subchannelization mode.
This model causes one frame delay.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_DemuxFrame_FD (WMAN Uplink Demultiplexer Frame FD)



Description Uplink frame demultiplexer with broadcast message and frame duration
Library WMAN, Receiver
Class SDFWMAN_UL_DemuxFrame_FD
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfSS	Number of subscribers	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
IdleInterval	Idle Interval	10 μsec	sec	real	[0, 1000]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	UL_Subframe	received frame signals	complex
2	Index	synchronization index of each burst	int
3	DeltaF	carrier frequency offset	real

Pin Outputs

Pin	Name	Description	Signal Type
4	Prml	output of preamble and midamble	complex
5	UL_Bursts	output of uplink data symbol	complex
6	InitialRanging	output of Initial ranging contention slot	complex
7	BW_Requests	output of BW requests contention slot	complex
8	all_bursts	output all the preamble and data sequences	complex

Notes/Equations

1. This model is used to de-multiplex the uplink subframe into contention slot for Initial Ranging, contention slot for BW Requests, short preambles, data OFDM symbols and midambles. The idle interval and cyclic prefix of each OFDM symbol are also removed, and the carrier frequency offset is compensated according to the value achieved at pin DeltaF.
2. Each firing,
   - For non-subchannelization mode, NumberOfSS tokens are consumed at pin Index, while one tokens are consumed for subchannelization mode.
   - For non-subchannelization mode, NumberOfSS tokens are consumed at pin DeltaF. For subchannelization mode, the pin DeltaF is useless.
   - Nprml tokens are produced at pin Prml for non-subchannelization mode. For subchannelization mode, 256×2OversamplingOption ×(1+NMaxMidamble) tokens are produced at pin Prml.
     where
     Nprml is

     $$N_{prml} = \sum_{i=1}^{NumberOfSS} 256 \times 2^{OversamplingOption} \times (1 + Midamble[i])$$

     Midamble[i] is the number of midambles the ith SS's contains according to parameter MidambleRepetition.

     $$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

     If $MidambleRepetition[i]$ is not zero
     else

     $$Midamble[i] = 0$$

     NMaxMidamble is the maximum number of midambles among all SSs.
   - For non-subchannelization mode, NBurst tokens are produced at pin UL_Bursts. For subchannelization mode, 256×2OversamplingOption × NMαξΔαταΣψμ tokens are produced at pin UL_Bursts.
     where NBurst is defined as:

     $$N_{Burst} = \sum_{i=1}^{NumberOfSS} 256 \times 2^{oversamplingOption} \times N_{Symbol}[i]$$

     The number of OFDM data symbols of ith uplink SS($N_{Symbol}[i]$) is calculated as follows:

     $$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels})$$

     Here Nsubchannels is the number of subchannels. For non-subchannelization mode, Nsubchannels is equal to 16; For subchannelization mode, Nsubchannels is determined by

SubchannelIndex, shown in Number of Subchannels.

Number of Subchannels

Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

NΜαξΔαταΣψμ is the maximum number of data symbols among all SSs.

- SamplesOFDM×2 tokens are produced at pin InitialRanging.
- SamplesOFDM×2 tokens are produced at pin BW_Requests.
- Nallbursts tokens are output at pin all_bursts.
  The Nallbursts is defined as follows:
  For non-subchannelization mode

$$N_{allbursts} = \left(1 + \sum_{i=1}^{NumberOfSS} N_{Symbol}[i] + \sum_{i=1}^{NumberOfSS} Midamble[i]\right) \times Samples_{OFDM}$$

  For subchannelization mode

$$N_{allbursts} = max(1 + N_{Symbol}[i] + Midamble[i]) \times Samples_{OFDM}$$

  where, SamplesOFDM is the number of one OFDM symbol data, defined as

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1+G)$$

:

- Ntotal tokens are consumed at pin UL_Subframe.
  Ntotal is the number of samples in one Uplink frame, containing idle interval, contention slot for Initial Ranging, contention slot for BW Requests, preambles, data symbols and midambles, defined as following.
  For non-subchannelization mode when FrameDuration=Continuous

$$N_{total} = Samples_{Idle} + \left(5 + \sum_{i=1}^{NumberOfSS} N_{Symbol}[i] + \sum_{i=1}^{NumberOfSS} Midamble[i]\right) \times Samples_{OFDM}$$

  For subchannelization mode

$$N_{total} = Samples_{Idle} + max(5 + N_{Symbol}[i] + Midamble[i]) \times Samples_{OFDM}$$

  when FrameDuration=Continuous
  When FrameDuration<>Continuous, the total number of samples per one frame is

$$N_{total} = Samples_{Idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

  where, SamplesOFDM is the number of one OFDM symbol data, defined as

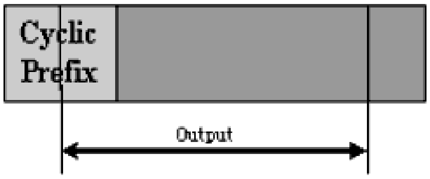
$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1+G)$$

:

  The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s \times 2^{OversamplingOption}$$

3. The buffer length for input pin UL_Subframe is 2× Ntotal, and Ntotal tokens are consumed at each firing. The first point of the received uplink burst of each SS is determined according to the input value at pin Index. The cyclic prefix and frequency offset will be removed after the true burst is determined. The output data extracted from the OFDM symbol begin ahead with half the CP length, 0.5×256×ΧψχλιχΠρεφιξ×2OversamplingOption, for better robust performance against timing synchronization error. The cyclic prefix removal process is shown in Cyclic Prefix Removal.



Cyclic Prefix Removal

Note that the frequency offset will be removed only for subchannelization mode.
Assume x0, x [1] , ... , xN-1 are the received signals from the first point of the ith burst (SS), and y0, y1, ... , yN-1 are the signals after removing the phase caused by the frequency offset, where N is the number of the received SS's signals, including the preamble, data symbols and midambles.
Then the equation of frequency offset removal is

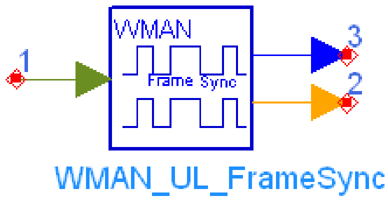
$$y_k = x_k \times e^{-j2\pi\Delta f_i k T_{Step}}$$

where
Δf_i is frequency offset of the ith received SS which is the input at pin DeltaF,
$T_{Step} = \frac{1}{F_s \times 2^{OversamplingOption}}$ is the sample time interval in WMAN system.
The sampling frequency (Fs) implemented in the design is decided by Bandwidth and related sampling factor.
This model causes one frame delay.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_UL_FrameSync (WMAN Uplink Subframe Synchronizer)



Description Uplink frame synchronization
Library WMAN, Receiver
Class SDFWMAN_UL_FrameSync
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfSS	Number of subscribers	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
PrmlTimeShift	Preamble time shift of each subscribe	{0}		int array	[0, 255]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	

Pin Inputs

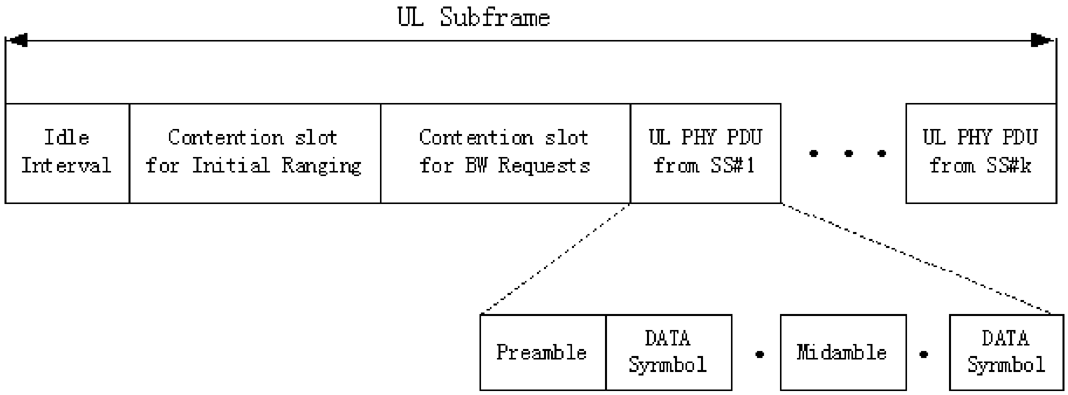
Pin	Name	Description	Signal Type
1	input	uplink frame	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	index	synchronization burst start position	int
3	corr	correlation result	real

Notes/Equations

1. This model is used to achieve uplink subframe synchronization.
2. Each firing, $Samples_{Frame}$ tokens are consumed at Pin input, where $Samples_{Frame}$ is the number of total samples per uplink subframe; $NumberOfBurst$ tokens are produced at Pin index which indicate the value of synchronization indices (Note when Subchannelization=YES, $NumberOfBurst$ is 1; when Subchannelization=NO, $NumberOfBurst = NumberOfSS$); $Samples_{Frame}$ tokens are produced at Pin corr which indicate the correlation values.
3. The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-subchannelization Mode.



Uplink Subframe Format for Non-subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts.
Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively.
Each uplink burst consists of one short preamble, data symbols and midambles.
The short preamble consists of one OFDM symbols.
The number of OFDM data symbols of ith uplink SS(!wman-7-16-354.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst,
if $MidambleRepetition[i]$ is not zero,

$$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

else, $Midamble[i] = 0$

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol (!wman-7-16-362.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where G is the CyclicPrefix.

The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s \times 2^{OversamplingOption}$$

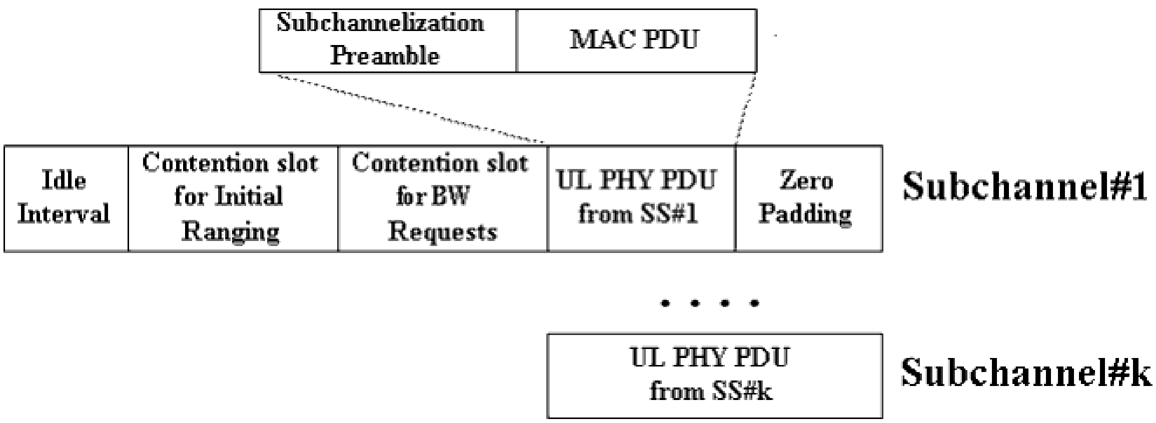
When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

When FrameDuration<>Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Subchannelization Mode.



Uplink Subframe Format for Subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS(!wman-7-16-371.gif!
) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[RateID[i]]) \times 16/N_{subchannels})$$

Here Nsubchannels is the number of subchannels. Nsubchannels is determined by SubchannelIndex, shown in Number of Subchannels.

Number of Subchannels

Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

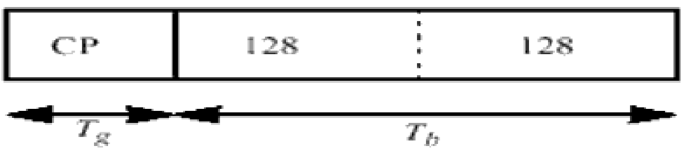
So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

So the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

4. Uplink subframe synchronization method varies according to Subchannelization parameter. The scope of uplink synchronization is limited to round about the exact start of the preamble assuming coarse synchronization is set up in downlink.
Case 1: Subchannelization=NO
When Subchannelization=NO, the entire 16 subchannels are used. The data preamble consists of one OFDM symbol utilizing only even subcarriers. The time domain waveform consists of 2 times 128 samples preceded by a CP. The time domain structure is shown in PEVEN Time Domain Structure.



P_{EVEN} Time Domain Structure

The synchronization algorithm is based on autocorrelation of the repetitive fragments of the first preamble symbol. Autocorrelation is calculated between two sequences. The sequences length are $L = 2^{OversamplingOption} \times (256 \times (1 + G) - 128)$. The distance between the first sequence and the second sequence is $N = 2^{OversamplingOption} \times 128$. So In the absence of noise autocorrelation get maximum when the first sequence is at the start of the preamble. Autocrrelation is calculated as:

$$Correlation_i = \left| \sum_{l=0}^{L-1} Sample_{i+l} \times (Sample)^*_{i+N+l} \right|$$

i= 0... $Samples_{Frame} - L - N$
Case 2: Subchannelization=YES
When subchannelization transmission is employed, the data preamble consists of a 256 samples sequence preceded by a CP. The frequency domain sequence for the 256 samples is defined by P_{SUB}. Preamble subcarriers that do not fall within the allocated subchannels shall be set to zero.
The sequence PSUB is defined as follows:
PSUB(-100:100) = {1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, 1+j, 1-j, 1+j,1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, -1-j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, 0,1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, -1-j, 1+j, -1-j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, -1+j, 1+j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, -1-j, -1-j, 1+j, -1-j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, -1+j, 1+j, -1+j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, -1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j}
The synchronization algorithm is based on correlation between received signal and local preamble. Frequency offset of the users are assumed to be zero. Received signal is the sum in time domain of all the users. Local preamble is the sum of all the users.

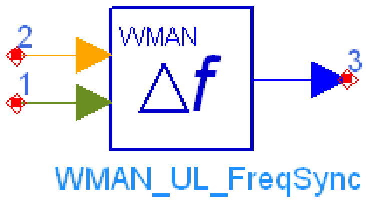
5. When the start of the preamble is found, the start of the preamble subtracts $Samples_{idle}$ and is

output at Pin index.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_FreqSync (WMAN Uplink Frequency Synchronizer)



Description Uplink frequency synchronizer
Library WMAN, Receiver
Class SDFWMAN_UL_FreqSync
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfSS	Number of subscribers	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	Continuous		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	uplink frame	complex
2	index	synchronization burst start position	int

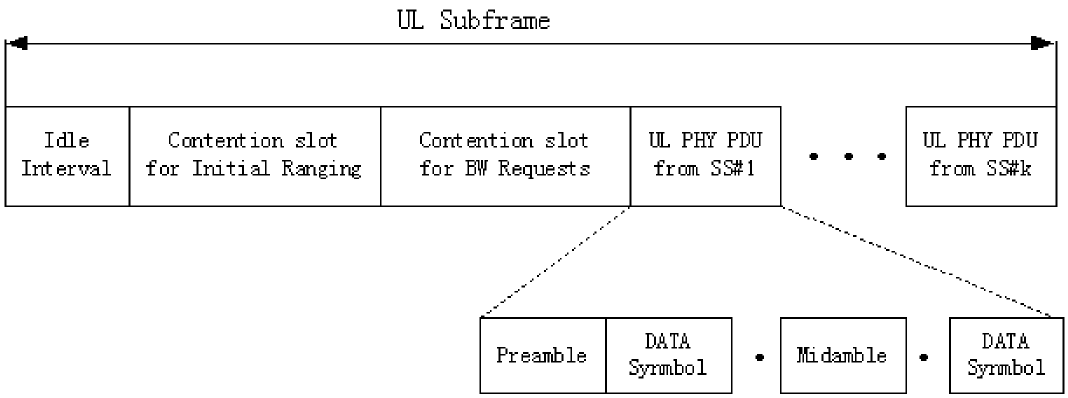
Pin Outputs

Pin	Name	Description	Signal Type
3	DeltaF	frequency offset	real

Notes/Equations

1. This model is used to do uplink frequency synchronization.

2. Each firing, $Samples_{Frame}$ tokens are consumed at Pin input, where $Samples_{Frame}$ is the total sample per uplink subframe; $NumberOfBurst$ tokens are consumed at Pin index which indicate the value of synchronization indices; $NumberOfBurst$ tokens are produced at Pin DeltaF which indicate the value of frequency offsets. Note when Subchannelization=YES, $NumberOfBurst$ is 1; when Subchannelization=NO, $NumberOfBurst = NumberOfSS$.
3. The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-subchannelization Mode.



Uplink Subframe Format for Non-subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts.
Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively.
Each uplink burst consists of one short preamble, data symbols and midambles.
The short preamble consists of one OFDM symbols.
The number of OFDM data symbols of ith uplink SS(!wman-7-17-392.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst, if $MidambleRepetition[i]$ is not zero, $Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$
else, $Midamble[i] = 0$

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol (!wman-7-17-400.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where G is the CyclicPrefix.

The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s \times 2^{OversamplingOption}$$

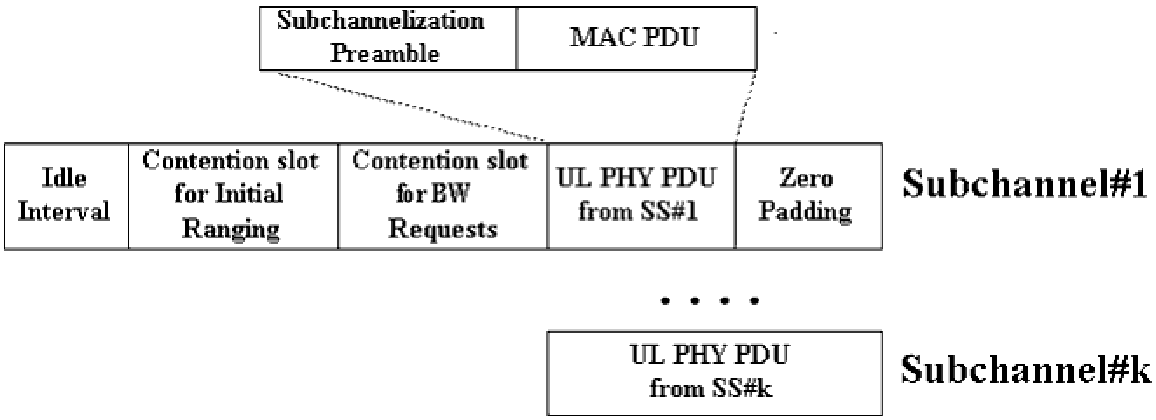
When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

When FrameDuration<>Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Subchannelization Mode.



Uplink Subframe Format for Subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS(!wman-7-17-409.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11) / (uncodedBlockSize[RateID[i]]) \times 16 / N_{subchannels})$$

Here Nsubchannels is the number of subchannels. Nsubchannels is determined by SubchannelIndex, shown in Number of Subchannels.

Number of Subchannels

Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

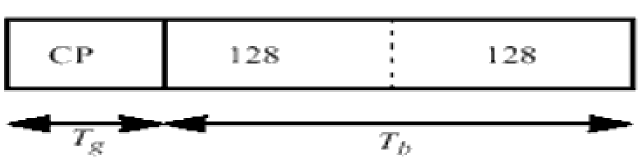
So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

So the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

4. **Case 1: Subchannelization=NO**
When the entire 16 subchannels are used, the data preamble consists of one OFDM symbol utilizing only even subcarriers. The time domain waveform consists of 2 times 128 samples preceded by a CP. The time domain structure is shown in PEVEN Time Domain Structure.



P_{EVEN} Time Domain Structure

The algorithm is based on autocorrelation of the repetitive fragments of the first preamble symbol. Autocorrelation is calculated between two sequences.

The sequence length is $L = 2^{OversamplingOption} \times (256 \times (1 + G) - 128 - 20)$

The distance between the two sequences is

$$N = 2^{OversamplingOption} \times 128$$

$$start = index + 10 \times 2^{OversamplingOption}$$

$$F_s = (floor((N_{factor} \times Bandwidth)/8000) \times 8000)$$

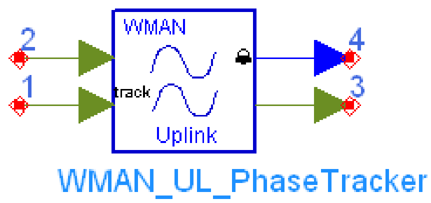
$$\Delta f = -\arg\left(\sum_{l=0}^{L-1} Sample_{start+l} \times (Sample)^*{}_{start+N+l}\right) \times F_s/(2\pi \times 128)$$

5. **Case 2: Subchannelization=YES**
   The frequency offsets are assumed to be zero.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_PhaseTracker (WMAN Uplink Phase Tracker)



Description Uplink phase tracker
Library WMAN, Receiver
Class SDFWMAN_UL_PhaseTracker
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	0	int array	[0, 3]
PilotPN_Phase	the Pilot PN phase	0	int	[0, 2047]

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	input of data symbol	complex
2	CIR_Raw	estimated channel impulse response input	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	CIR_Track	channel impulse response after phase track	complex
4	Theta	phase difference between current CIR and estimated CIR	real

Notes/Equations

1. This model is used to track the phase in pilot subcarriers caused by the doppler shift in uplink demodulation systems, and update the estimated CIR (Channel impulse response) using the phase offset detected in the phase tracking algorithm.
2. Each firing,
   - 200×NTotalDataSym tokens are consumed at pin Data.
     where
     NTotalDataSym is the number of total OFDM data symbols.
     For non-subchannelization mode, NTotalDataSym is the sum of each SS's data symbols.

$$N_{TotalDataSym} = \sum_{i=1}^{NumberOfSS} N_{Symbol}[i]$$

Where, the number of OFDM data symbols of ith uplink SS(!wman-7-18-423.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in Number of Subchannels.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

For subchannelization mode, NTotalDataSym is the maximum number of data symbols among all SSs.

$$N_{TotalDataSym} = max(N_{Symbol}[i])$$

- 200×NTotalDataSym tokens are consumed at pin CIR_Raw.
- 200×NTotalDataSym tokens are produced at pin CIR_Track.
- NTotalDataSym tokens are produced at pin Theta.

3. For non-subchannelization mode, all the eight pilot subcarriers at frequency offset indices of {-88, -63, -38, -13, 13, 38, 63, 88} are used to obtain the current estimated CIR of these subcarriers. Then the maximum likelihood algorithm is used to detect the phase offset θ between the CIRs at pin CIR_Raw which are obtained by the preamble or midambles, and the current estimated CIRs. The equation is:

$$\theta = \arg\left(\sum_{k=1}^{8} \hat{H}_k \times conj(H'_k)\right)$$

where,
$\hat{H}_k$
is the current estimated CIR.
H'_k
is the previous estimated CIR obtained by the preamble or midambles
For subchannelization mode, only the pilot subcarriers assigned to the SS are used to detect the phase offset, assuming each SS has the different phase offset.
Finally the estimated CIRs from pin CIR_Raw are updated by the phase offset θ. For subchannelization mode, each SS's phase offset θ is only used to update CIR_Raw data belong to the same SS.

In non-subchannelization mode, set H0, H1, ... , H199 and H'_0, H'_1, ... , H'_{199} are the input CIR_Raw and updated CIRs, respectively. Then

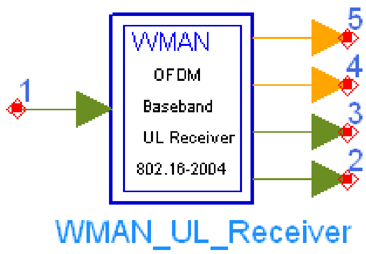
$$H'_i = H_i \times e^{j\theta}$$

The updated CIRs are output at pin CIR_Track. The phase offset is output at pin Theta for non-subchannelization mode, and for subchannelization mode, the phase offset of the SS with FEC-encoded is output at pin Theta.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_Receiver (WMAN Uplink Receiver)



Description Uplink baseband receiver
Library WMAN, Receiver
Class SDFWMAN_UL_Receiver

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
UIUC	UIUC of each subscriber	{1}		int	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
PilotPN_Phase	Pilot phase	0		int	[0, 4095]
DecoderType	demapping type: Hard, Soft, CSI	CSI		enum	

Pin Inputs

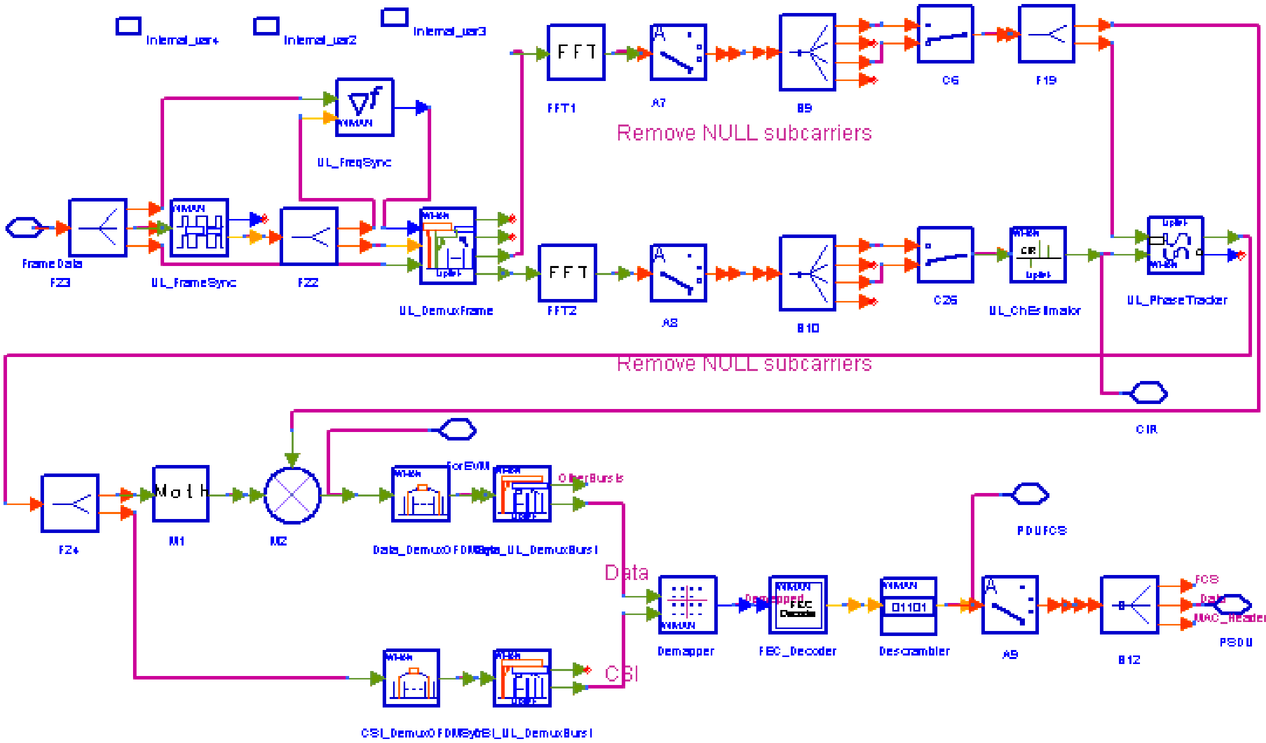
Pin	Name	Description	Signal Type
1	FrameData	input of baseband signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int

Notes/Equations

1. This subnetwork implements the uplink baseband receiver algorithm for WMAN OFDM according to the specification.
2. The schematic WMAN_UL_Receiver is shown in WMAN_UL_Receiver Schematic.



WMAN_UL_Receiver Schematic

3. In WMAN uplink, non-subchannelization and subchannelization modes are supported.
The following description of receiver functions assumes that the non-subchannelization mode is employed. Starts of uplink subframe bursts are detected in WMAN_UL_FrameSync.
WMAN_FrameSync calculates the correlation between the first half part and the second half part of the received short preambles, and selects the index with the maximum correlation value as the start of each SS's burst. The start of each burst is send to WMAN_UL_DemuxFrame.
Frequency offsets are estimated in WMAN_UL_FreqSync. WMAN_UL_FreqSync calculates the frequency offset using the short preamble and sends the frequency offset to WMAN_UL_DemuxFrame.
According to the starts of uplink subframe bursts, the uplink subframe is de-multiplex into several parts in WMAN_UL_DemuxFrame, including contention slots for Initial Ranging and BW Requests, the short preamble, midambles and data symbols. The phase effect caused by the frequency offset is compensated, and the idle interval and the cyclic prefix of each OFDM symbol are also removed in WMAN_UL_DemuxFrame.
The data symbols, short preamble and midambles are passed into frequency domain through FFT transformation. The short preamble and midambles used for channel estimation, where channel estimation is done in WMAN_UL_ChEstimation.

WMAN_UL_ChEstimation uses the preambles and midambles to get the channel impulse response (CIR) coefficients. First the CIRs in the even subcarriers are calculated by a simple divider, then the CIRs in the odd subcarriers are interpolated by a FIR filter. Finally WMAN_UL_ChEstimation duplicates the estimated CIRs the number of data symbols. The channel estimation result is output at pin CIR.
WMAN_UL_PhaseTracker is used to track the phase caused by doppler frequency shift by comparing the previous CIRs and the CIRs in pilot subcarriers of the current data symbols. Then the estimated CIR is updated according to the phase offset detected.
After the estimated CIRs going through WMAN_UL_PhaseTracker, they are used for channel equalization which is implemented by a simple divider. The equalized data are output at pin ForEVM for EVM measurements.
Then the pilot subcarriers are removed from the equalized signals in WMAN_DemuxOFDMSym, and the burst with FEC-encoded is separated from the bursts chain in WMAN_DemuxBurst which is send to WMAN_Demapper. In WMAN_Demapper, Three demapper types (CSI, Soft and Hard) are supported.
After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are obtained, which are divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PDUFCS and PSDU respectively.
In subchannelization mode, because all SSs share one burst using different subchannels, only one start of uplink subframe burst will be detected in WMAN_UL_FrameSync. And WMAN_UL_FreqSync will do nothing, resulting in no frequency offset compensation is needed in WMAN_DemuxFrame. In WMAN_UL_ChEstimation, no interpolation is needed because the CIRs in all data subcarriers are available for each subchannel. The process after WMAN_UL_DemuxBurst is the same as that in non-subchannelization mode.

4. Parameter Details
   - NumberOfSS specifies the number of active subscribers (SS).
   - SSWithFEC specifies the SS which goes through FEC encoding and decoding.
   - DataLength is the array of each SS's MAC PDU payload byte length.Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

   - Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
   - SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
   - MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. Midamble Repetition Interval shows the meaning each MidambleRepetition value corresponds to.

Midamble Repetition Interval

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

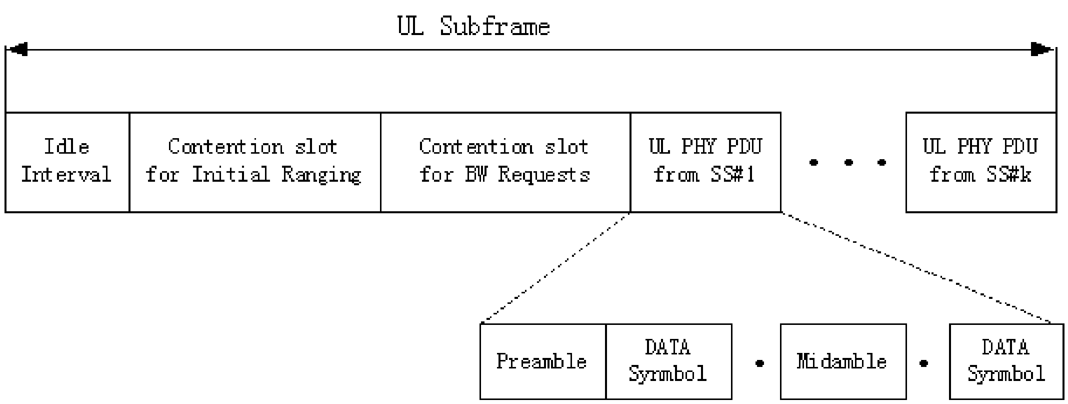
- UIUC, FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
- Bandwidth is the nominal channel bandwidth. The sampling frequency implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows,
  $$F_s = floor((n \times Bandwidth)/8000) \times 8000$$
  The sampling factors are listed inSampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.
- PrmlTimeShift indicates the number of samples of cyclic shift which are delayed in time in the preamble and midamble symbols.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- DecoderType specifiers the Viterbi decoder type chosen from CSI, Soft and Hard.

5. Output Pin Delay Adjustment
   Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
   The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-subchannelization Mode.



Uplink Subframe Format for Non-subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts.
Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively.
Each uplink burst consists of one short preamble, data symbols and midambles.
The short preamble consists of one OFDM symbols.
The number of OFDM data symbols of ith uplink SS (!wman-7-19-440.gif!) is calculated as follows.

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst,
if $MidambleRepetition[i]$ is not zero

$$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

else
$Midamble[i] = 0$

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol (!wman-7-19-448.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

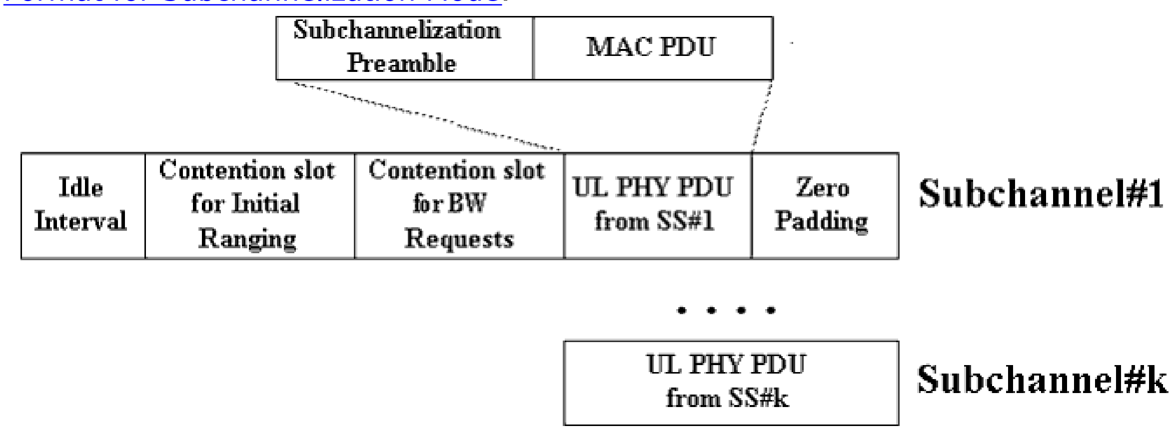
where, G is the CyclicPrefix.
The samples of IdleInterval(!wman-7-19-450.gif!) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s$$

So, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Subchannelization Mode.



Uplink Subframe Format for Subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS(!wman-7-19-455.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

Here Nsubchannels[i] is the number of subchannels. Nsubchannels[i] is determined by SubchannelIndex[i], shown in Number of Subchannels.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

So, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

In the receiver, one frame delay occurs.

$$200 \times \left(\sum_{i=1}^{NumberOfSS} N_{Symbol}[i] \right)$$

delay is introduced at pin ForEVM and CIR for non-subchannelization mode and $200 \times max(N_{Symbol}[i])$ delay for subchannelization mode.

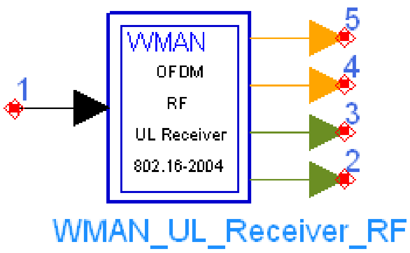
$8 \times DataLength[BurstWithFEC] + 80$ bits delay is introduced at pin PDUFCS, where 80 bits are the MAC Header and CRC attached.

$8 \times DataLength[BurstWithFEC]$ bits delay is introduced at pin PSDU.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_Receiver_RF (WMAN Uplink Receiver RF)



Description Uplink RF receiver
Library WMAN, Receiver
Class TSDFWMAN_UL_Receiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	▪ 273.15	Celsius	real	[- 273.15, ∞]
FCarrier	Carrier frequency	3407 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	(-∞, ∞)
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
UIUC	UIUC of each subscriber	{1}		int	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
PilotPN_Phase	Pilot phase	0		int	[0, 4095]
DecoderType	demapping type: Hard, Soft, CSI	CSI		enum	

Pin Inputs

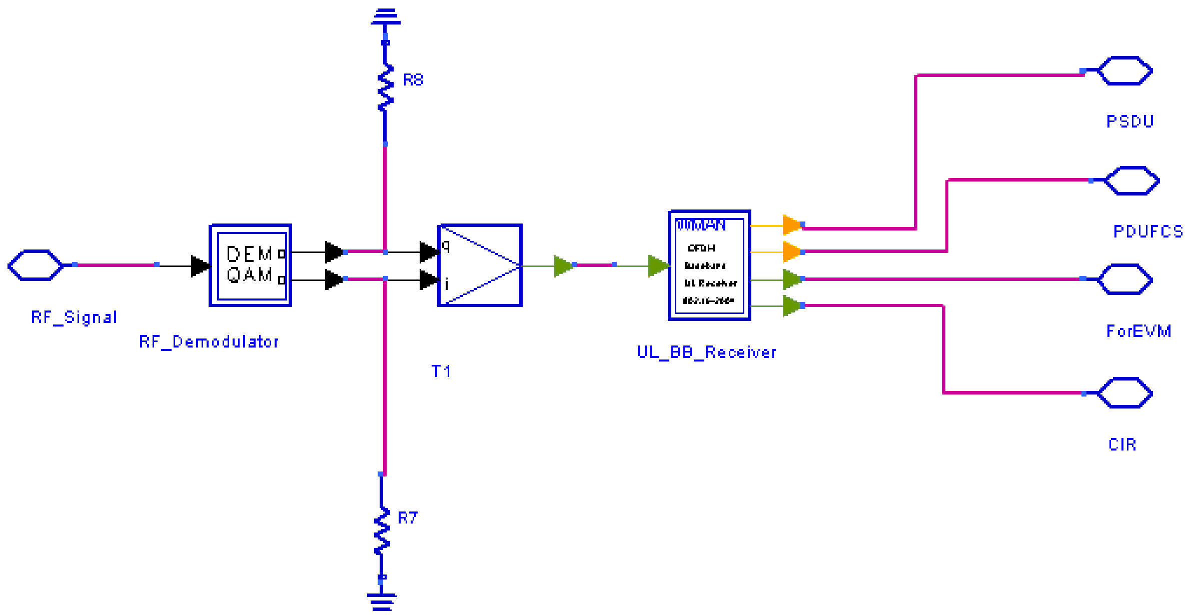
Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int

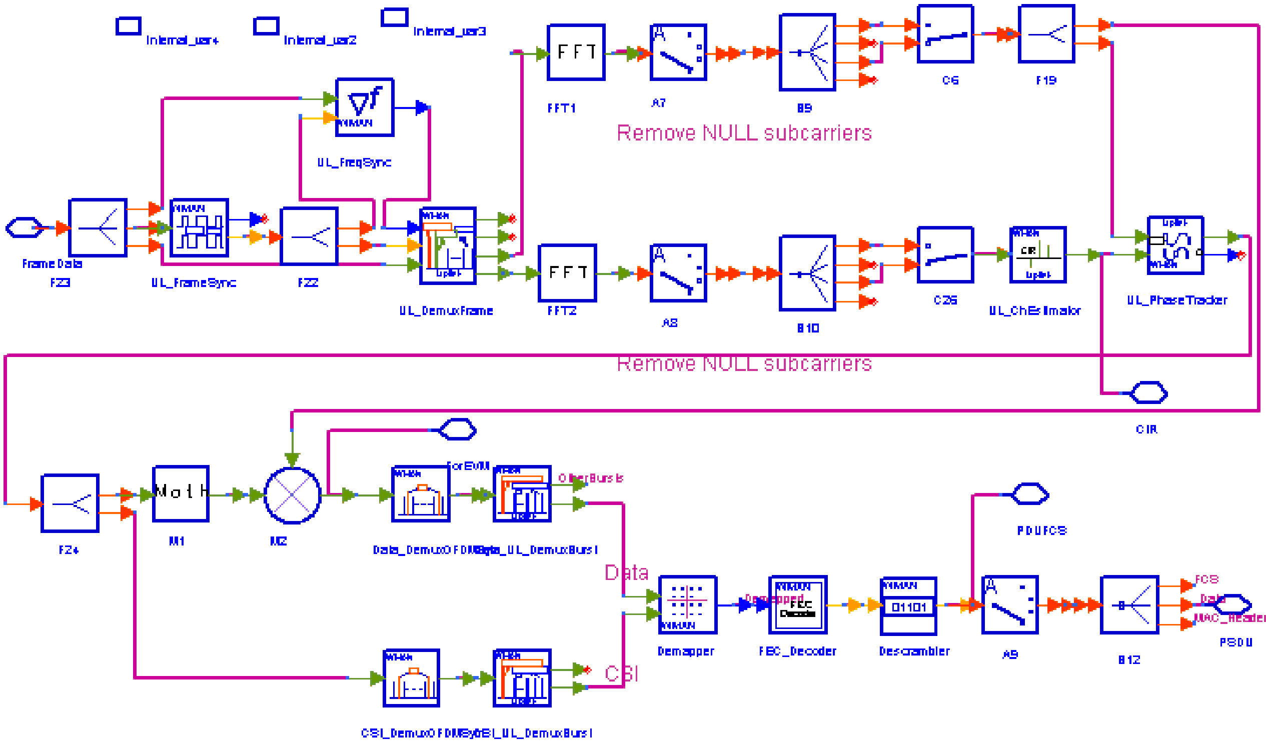
Notes/Equations

1. This subnetwork is used to demodulate and decode WMAN uplink RF signals. The schematic for this subnetwork is shown in WMAN_UL_Receiver_RF Schematic.



WMAN_UL_Receiver_RF Schematic

2. The input timed signal is demodulated from RF to baseband by QAM_Demod and fed into the WMAN OFDM baseband receiver. The WMAN OFDM baseband receiver schematic is shown in WMAN_UL_Receiver Schematic.



WMAN_UL_Receiver Schematic

3. Receiver functions are implemented as specified in the IEEE 802.16-2004 Standard. In WMAN uplink, non-subchannelization and subchannelization modes are supported.
The following description of receiver functions assumes that the non-subchannelization mode is employed. Starts of uplink subframe bursts are detected in WMAN_UL_FrameSync.
WMAN_FrameSync calculates the correlation between the first half part and the second half part of the received short preambles, and selects the index with the maximum correlation value as the start of each SS's burst. The start of each burst is send to WMAN_UL_DemuxFrame.
Frequency offsets are estimated in WMAN_UL_FreqSync. WMAN_UL_FreqSync calculates the frequency offset using the short preamble and sends the frequency offset to WMAN_UL_DemuxFrame.
According to the starts of uplink subframe bursts, the uplink subframe is de-multiplex into several parts in WMAN_UL_DemuxFrame, including contention slots for Initial Ranging and BW Requests, the short preamble, midambles and data symbols. The phase effect caused by the frequency offset is compensated, and the idle interval and the cyclic prefix of each OFDM symbol are also removed in WMAN_UL_DemuxFrame.
The data symbols, short preamble and midambles are passed into frequency domain through FFT transformation. The short preamble and midambles used for channel estimation, where channel estimation is done in WMAN_UL_ChEstimation.
WMAN_UL_ChEstimation uses the preambles and midambles to get the channel impulse response (CIR) coefficients. First the CIRs in the even subcarriers are calculated by a simple divider, then the CIRs in the odd subcarriers are interpolated by a FIR filter. Finally WMAN_UL_ChEstimation duplicates the estimated CIRs the number of data symbols. The channel estimation result is output at pin CIR.
WMAN_UL_PhaseTracker is used to track the phase caused by doppler frequency shift by comparing previous CIRs and the CIRs in pilot subcarriers of the current data symbols. Then the estimated CIR is updated according to the phase offset detected.
After the estimated CIRs going through WMAN_UL_PhaseTracker, they are used for channel equalization which is implemented by a simple divider. The equalized data are output at pin ForEVM for EVM measurements.
Then the pilot subcarriers are removed from the equalized signals in WMAN_DemuxOFDMSym,

and the burst with FEC-encoded is separated from the bursts chain in WMAN_DemuxBurst which is send to WMAN_Demapper. In WMAN_Demapper, Three demapper types (CSI, Soft and Hard) are supported.
After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are obtained, which are divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PDUFCS and PSDU respectively.
In subchannelization mode, because all SSs share one burst using different subchannels, only one start of uplink subframe burst will be detected in WMAN_UL_FrameSync. And WMAN_UL_FreqSync will do nothing, resulting in no frequency offset compensation is needed in WMAN_DemuxFrame. In WMAN_UL_ChEstimation, no interpolation is needed because the CIRs in all data subcarriers are available for each subchannel. The process after WMAN_UL_DemuxBurst is the same as that in non-subchannelization mode.

4. 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.
    - FCarrier parameter is the RF signal frequency.
    - GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added as described here.
      The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
      $$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\Phi\pi}{180}\right)\right)$$
      where V1(t) is the in-phase RF envelope, V2(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.
    - NumberOfSS specifies the number of active subscribers (SS).
    - SSWithFEC specifies the SS which goes through FEC encoding and decoding.
    - DataLength is the array of each SS's MAC PDU payload byte length.Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

    - Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
    - SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
    - MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. Midamble Repetiton Interval shows the meaning each MidambleRepetition value corresponds to.

Midamble Repetiton Interval

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

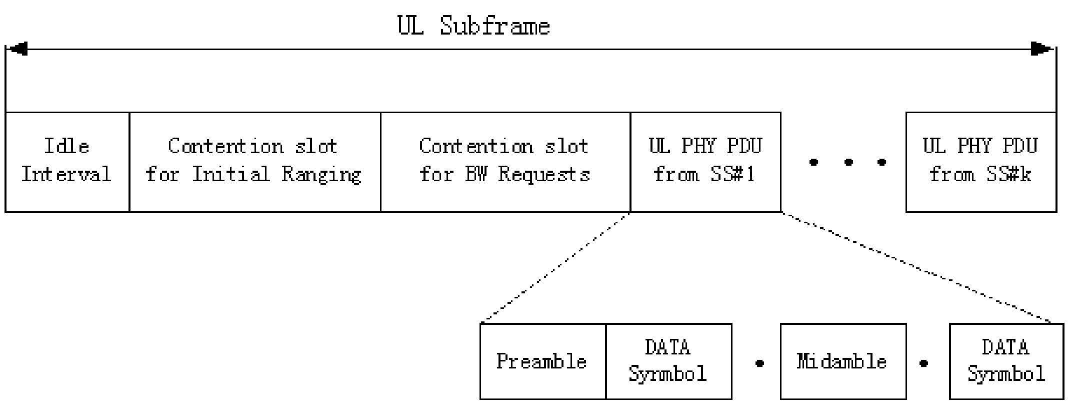
- UIUC, FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
- Bandwidth is the nominal channel bandwidth. The sampling frequency implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows:
  $$F_s = floor((n \times Bandwidth)/8000) \times 8000$$
  The sampling factors are listed in Sampling Factor Requirements.

Sampling Factor Requirements

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.
- PrmlTimeShift indicates the number of samples of cyclic shift which are delayed in time in the preamble and midamble symbols.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- DecoderType specifiers the Viterbi decoder type chosen from CSI, Soft and Hard.

5. Output Pin Delay Adjustment
   Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
   The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-subchannelization Mode.



Uplink Subframe Format for Non-subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts.
Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively.
Each uplink burst consists of one short preamble, data symbols and midambles.
The short preamble consists of one OFDM symbols.
The number of OFDM data symbols of ith uplink SS (!wman-7-20-473.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst,
if $MidambleRepetition[i]$ is not zero $Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$
else
$Midamble[i] = 0$

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol (!wman-7-20-481.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

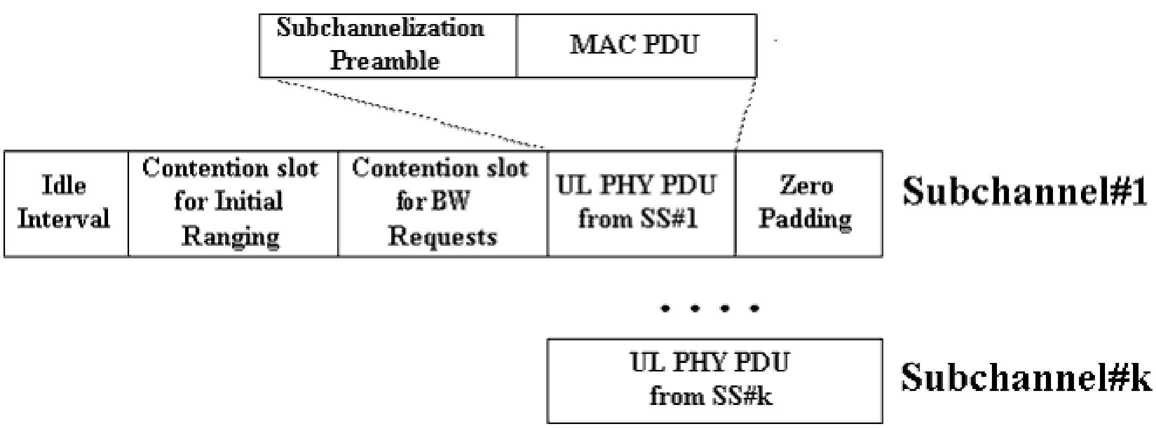
where, G is the CyclicPrefix.
The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s$$

So, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Subchannelization Mode.



Uplink Subframe Format for Subchannelization Mode

One WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS (!wman-7-20-488.gif!) is calculated as

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

follows:
Here Nsubchannels[i] is the number of subchannels. Nsubchannels[i] is determined by SubchannelIndex[i], shown in Number of Subchannels.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

So, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

In the receiver, one frame delay occurs.

$$200 \times \left(\sum_{i=1}^{NumberOfSS} N_{Symbol}[i] \right)$$

delay is introduced at pin ForEVM and CIR for non-subchannelization mode and $200 \times max(N_{Symbol}[i])$ delay for subchannelization mode.

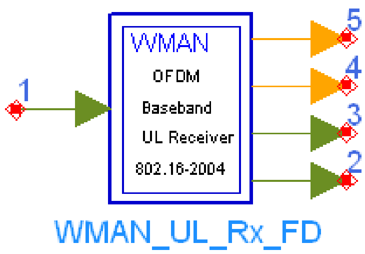
$8 \times DataLength[BurstWithFEC] + 80$ bits delay is introduced at pin PDUFCS, where 80 bits are the MAC Header and CRC attached.

$8 \times DataLength[BurstWithFEC]$ bits delay is introduced at pin PSDU.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_Rx_FD (WMAN Uplink Receiver with Frame Duration)



Description Uplink baseband receiver with broadcast message and frame duration
Library WMAN, Receiver
Class SDFWMAN_UL_Rx_FD

Parameters

Name	Description	Default	Unit	Type	Range
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
IdleInterval	Idle Interval	0.0 µsec	sec	real	[0, 1000]
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
PilotPN_Phase	Pilot phase	0		int	[0, 4095]
DecoderType	demapping type: Hard, Soft, CSI	CSI		enum	

Pin Inputs

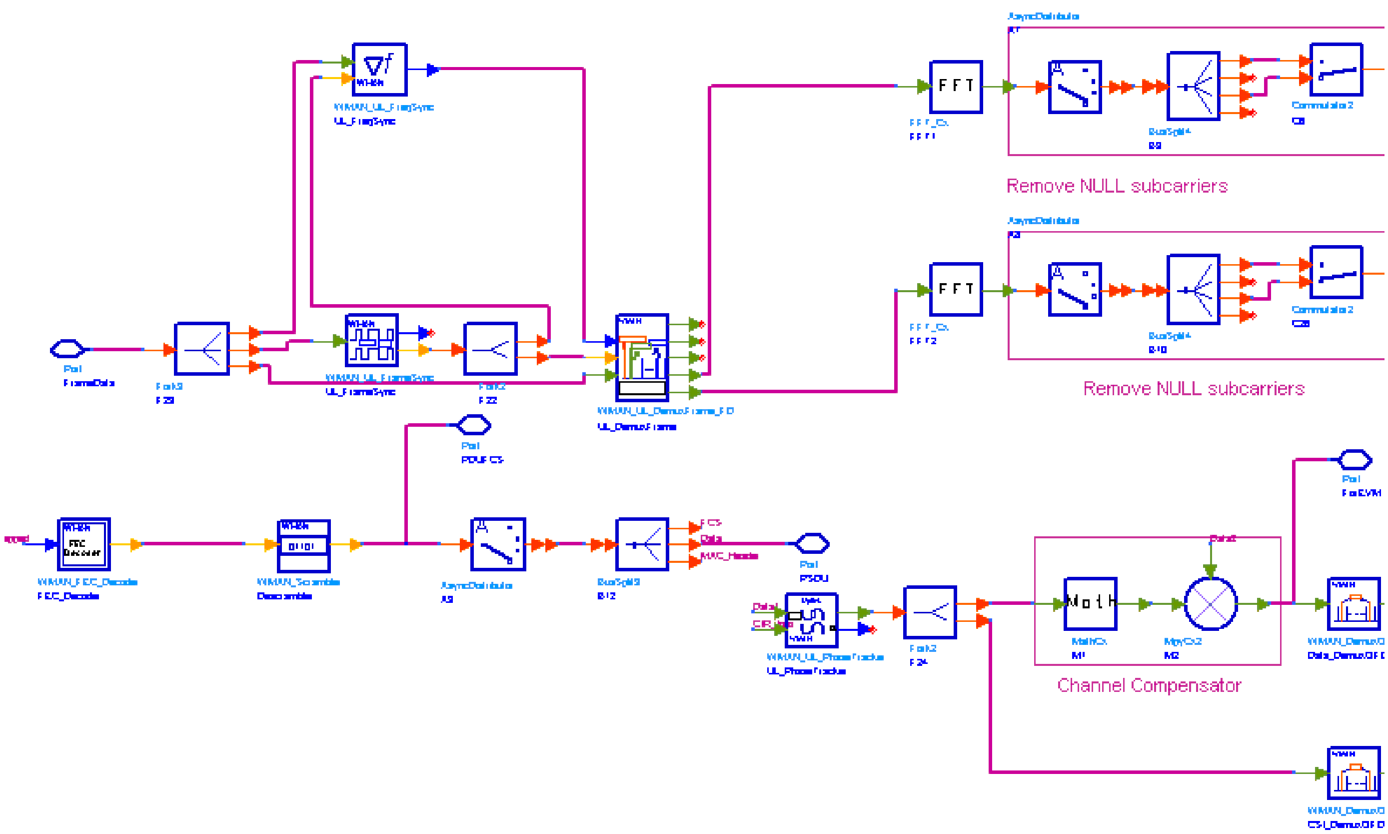
Pin	Name	Description	Signal Type
1	FrameData	input of baseband signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int

Notes/Equations

1. This subnetwork implements the uplink baseband receiver algorithm for WMAN OFDM according to the specification.
   The schematic WMAN_UL_Receiver is shown in WMAN_UL_Rx_FD Schematic.



WMAN_UL_Rx_FD Schematic

2. In WMAN uplink, non-subchannelization and subchannelization modes are supported.
   The following description of receiver functions assumes that the non-subchannelization mode is employed. Starts of uplink subframe bursts are detected in WMAN_UL_FrameSync. WMAN_FrameSync calculates the correlation between the received signal and the short preambles, and selects the index with the maximum correlation value as the start of each SS's burst. The start of each burst is send to WMAN_UL_DemuxFrame_FD.
   Frequency offsets are estimated in WMAN_UL_FreqSync. WMAN_UL_FreqSync calculates the frequency offset using the short preamble and sends the frequency offset to WMAN_UL_DemuxFrame_FD.
   According to the starts of uplink subframe bursts, the uplink subframe is de-multiplex into several parts in WMAN_UL_DemuxFrame_FD, including contention slots for Initial Ranging and BW

Requests, the short preamble, midambles and data symbols. The phase effect caused by the frequency offset is compensated, and the idle interval and the cyclic prefix of each OFDM symbol are also removed in WMAN_UL_DemuxFrame_FD.
The data symbols, short preamble and midambles are passed into frequency domain through FFT transformation. The short preamble and midambles used for channel estimation, where channel estimation is done in WMAN_UL_ChEstimation.
WMAN_UL_ChEstimation uses the preambles and midambles to get the complex channel response coefficients (CIR). First the CIRs in the even subcarriers are counted by a simple divider, then the CIRs in the odd subcarriers are interpolated by a FIR filter. Finally WMAN_UL_ChEstimation duplicates the estimated CIRs the number of data symbols. The channel estimation result is output at pin CIR.
WMAN_UL_PhaseTracker is used to track the phase caused by doppler shift by comparing the previous CIRs and the CIRs in pilot subcarriers of the current data symbols. Then the estimated CIR is updated according to the phase offset detected.
After the estimated CIRs going through WMAN_UL_PhaseTracker, they are used for channel equalization which is implemented by a simple divider. The equalized data are output at pin ForEVM for EVM measurements.
Then the pilot subcarriers are removed from the equalized signals in WMAN_DemuxOFDMSym, and the burst with FEC-encoded is separated from the bursts chain in WMAN_DemuxBurst which is send to WMAN_Demapper. In WMAN_Demapper, Three demapper types (CSI, Soft and Hard) are supported.
After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are achieved, which are divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PDUFCS and PSDU respectively.
In subchannelization mode, because all SSs share one burst using different subchannels, only one start of uplink subframe burst will be detected in WMAN_UL_FrameSync. And WMAN_UL_FreqSync will do nothing, resulting in no frequency offset compensation is needed in WMAN_DemuxFrame. In WMAN_UL_ChEstimation, no interpolation is needed because the CIRs in all data subcarriers are available for each subchannel. The process after WMAN_UL_DemuxBurst is the same as that in non-subchannelization mode.

3. Parameter Details
   - OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
   - Bandwidth defines the nominal bandwidth. According to the specification, the supported nominal bandwidths are 1.25MHz, 1.5MHz, 1.75 MHz, 2.5 MHz, 3 MHz, 3.5 MHz, 5 MHz, 5.5 MHz, 6 MHz, 7 MHz, 10 MHz, 11 MHz, 12 MHz, 14 MHz, 15 MHz, 20 MHz, 24 MHz and 28 MHz. This parameter type is floating. Other bandwidth except the above is also supported. The sampling frequency implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows:

$$F_s = floor((n \times Bandwidth)/8000) \times 8000$$

     The sampling factors are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

   - CyclicPrefix specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.

- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the uplink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the uplink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
- IdleInterval specifies the time of idle interval between two consecutive subframes. The default value is 0.0 µsec.
- FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- NumberOfSS specifies the number of active subscribes (SS).
- SSWithFEC specifies the SS which goes through FEC encoding and decoding.
- Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
- SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
- DataLength is the array of each SS's MAC PDU payload byte length.
- Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. Midamble Repetition Interval shows the meaning each MidambleRepetition value corresponds to.

Midamble Repetition Interval

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

- PrmlTimeShift indicates the number of samples of cyclic shift are delayed in time in the preamble and midamble symbols
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0
- DecoderType specifiers the Viterbi decoder type chosen from CSI, Soft and Hard.

4. Output Pin Delay Adjustment
Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts. Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively. Each uplink burst consists of one short preamble, data symbols and midambles. The short preamble consists of one OFDM symbols.
The number of OFDM data symbols of ith uplink SS (!wman-7-21-501.gif!) is calculated as

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

follows:
MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst,
if $MidambleRepetition[i]$ is not zero

$$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

$$Midamble[i] = 0$$

else
So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol (!wman-7-21-509.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where, G is the CyclicPrefix.
The samples of IdleInterval ($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

When FrameDuration<>Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

For subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS (!wman-7-21-517.gif!) is calculated as

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels})$$

follows:
Here Nsubchannels is the number of subchannels. Nsubchannels is determined by

SubchannelIndex, shown in Number of Subchannels as follows:

Number of Subchannels

Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

In the receiver, one frame delay occurs.

$200 \times \left(\sum_{i=1}^{NumberOfSS} N_{Symbol}[i]\right)$ delay is introduced at pin ForEVM and CIR for non-subchannelization mode and $200 \times max(N_{Symbol}[i])$ delay for subchannelization mode.

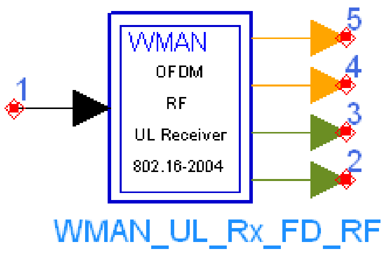
$8 \times DataLength[BurstWithFEC] + 80$ bits delay is introduced at pin PDUFCS, where 80 bits are the MAC Header and CRC attached.

$8 \times DataLength[BurstWithFEC]$ bits delay is introduced at pin PSDU.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_UL_Rx_FD_RF (WMAN UL Receiver RF with Frame Duration)



Description Uplink RF receiver with broadcast message and frame duration
Library WMAN, Receiver
Class TSDFWMAN_UL_Rx_FD_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	▪ 273.15	Celsius	real	[- 273.15, ∞]
FCarrier	Carrier frequency	3407 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	(-∞, ∞)
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
IdleInterval	Idle Interval	0.0 µsec	sec	real	[0, 1000]
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
DecoderType	demapping type: Hard, Soft, CSI	CSI		enum	

Pin Inputs

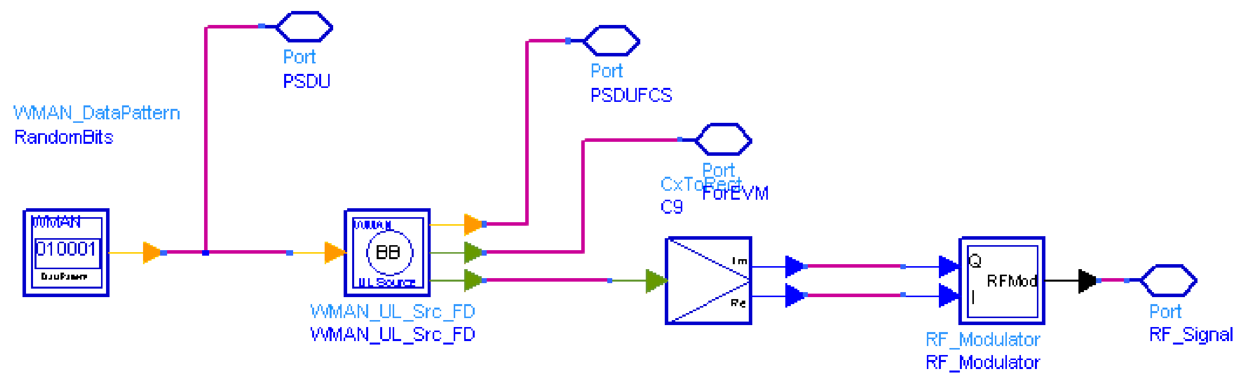
Pin	Name	Description	Signal Type
1	RF_Signal	input of RF signal	timed

Pin Outputs

Pin	Name	Description	Signal Type
2	CIR	output of channel estimation of all bursts	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	PSDU	output of PSDU bits	int

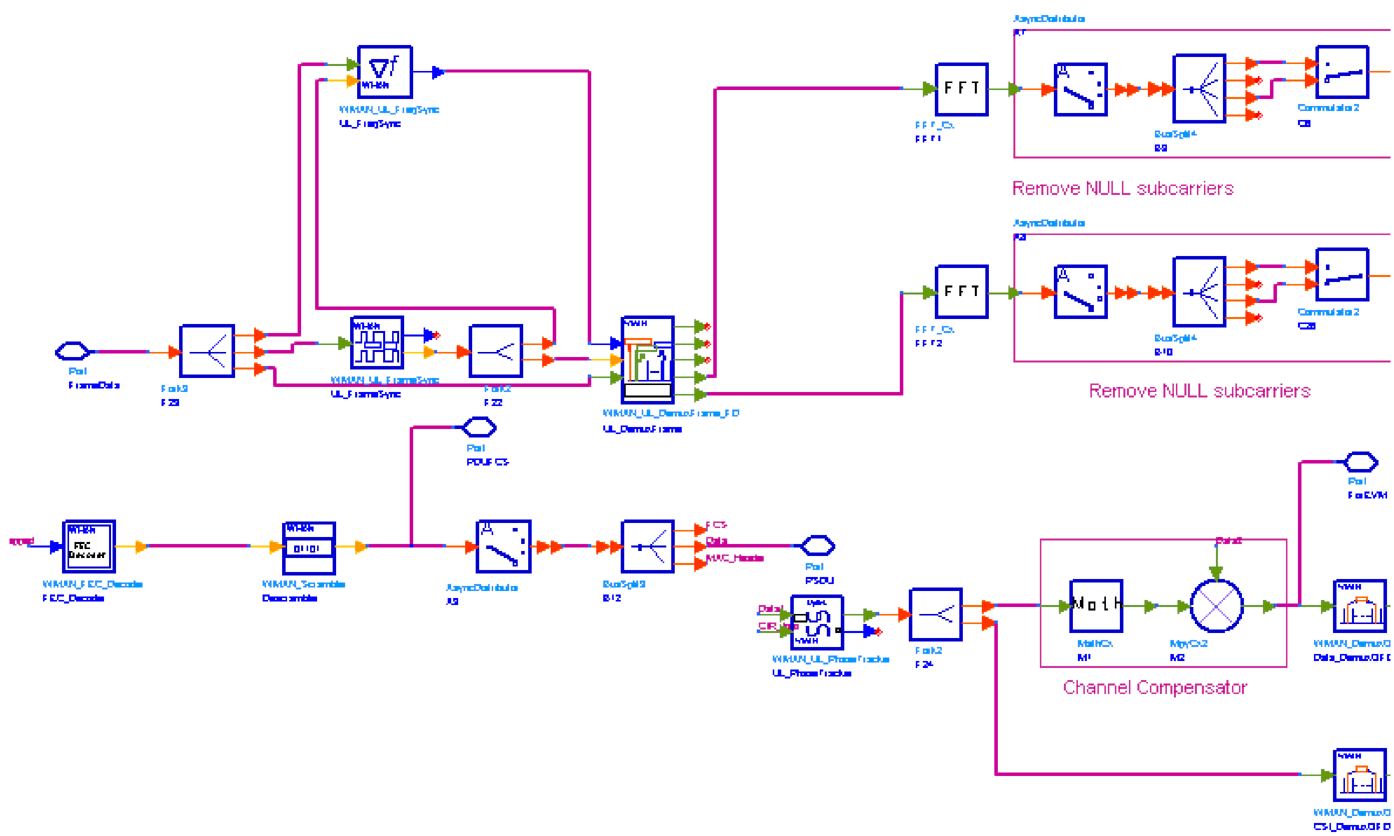
Notes/Equations

1. This subnetwork is used to demodulate and decode WMAN uplink RF signals. The schematic for this subnetwork is shown in WMAN_UL_Rx_FD_RF Schematic.



WMAN_UL_Rx_FD_RF Schematic

2. The input timed signal is demodulated from RF to baseband by QAM_Demod and fed into the WMAN OFDM baseband receiver. The WMAN OFDM baseband receiver schematic is shown in WMAN_UL_Rx_FD Schematic.



WMAN_UL_Rx_FD Schematic

3. Receiver functions are implemented as specified in the IEEE 802.16-2004 Standard.In WMAN uplink, non-subchannelization and subchannelization modes are supported.
The following description of receiver functions assumes that the non-subchannelization mode is employed. Starts of uplink subframe bursts are detected in WMAN_UL_FrameSync. WMAN_FrameSync calculates the correlation between the received signal and the short

preambles, and selects the index with the maximum correlation value as the start of each SS's burst. The start of each burst is send to WMAN_UL_DemuxFrame_FD.
Frequency offsets are estimated in WMAN_UL_FreqSync. WMAN_UL_FreqSync calculates the frequency offset using the short preamble and sends the frequency offset to WMAN_UL_DemuxFrame_FD.
According to the starts of uplink subframe bursts, the uplink subframe is de-multiplex into several parts in WMAN_UL_DemuxFrame_FD, including contention slots for Initial Ranging and BW Requests, the short preamble, midambles and data symbols. The phase effect caused by the frequency offset is compensated, and the idle interval and the cyclic prefix of each OFDM symbol are also removed in WMAN_UL_DemuxFrame_FD.
The data symbols, short preamble and midambles are passed into frequency domain through FFT transformation. The short preamble and midambles used for channel estimation, where channel estimation is done in WMAN_UL_ChEstimation.
WMAN_UL_ChEstimation uses the preambles and midambles to get the complex channel response coefficients (CIR). First the CIRs in the even subcarriers are counted by a simple divider, then the CIRs in the odd subcarriers are interpolated by a FIR filter. Finally WMAN_UL_ChEstimation duplicates the estimated CIRs the number of data symbols. The channel estimation result is output at pin CIR.
WMAN_UL_PhaseTracker is used to track the phase caused by doppler shift by comparing the previous CIRs and the CIRs in pilot subcarriers of the current data symbols. Then the estimated CIR is updated according to the phase offset detected.
After the estimated CIRs going through WMAN_UL_PhaseTracker, they are used for channel equalization which is implemented by a simple divider. The equalized data are output at pin ForEVM for EVM measurements.
Then the pilot subcarriers are removed from the equalized signals in WMAN_DemuxOFDMSym, and the burst with FEC-encoded is separated from the bursts chain in WMAN_DemuxBurst which is send to WMAN_Demapper. In WMAN_Demapper, Three demapper types (CSI, Soft and Hard) are supported.
After FEC decoding, de-interleaving, de-scrambling, the MAC PDU data are achieved, which are divided into MAC header, MAC PDU payloads and CRC. The MAC PDU and its payloads are output at pin PDUFCS and PSDU respectively.
In subchannelization mode, because all SSs share one burst using different subchannels, only one start of uplink subframe burst will be detected in WMAN_UL_FrameSync. And WMAN_UL_FreqSync will do nothing, resulting in no frequency offset compensation is needed in WMAN_DemuxFrame. In WMAN_UL_ChEstimation, no interpolation is needed because the CIRs in all data subcarriers are available for each subchannel. The process after WMAN_UL_DemuxBurst is the same as that in non-subchannelization mode.

4. 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.
    - FCarrier parameter is the RF signal frequency.
    - GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added as described here.
      The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
      $$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\Phi\pi}{180}\right)\right)$$
      where V1(t) is the in-phase RF envelope, V2(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.
    - OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio

of transmission signal is 1, 2, ... , 32.

- Bandwidth defines the nominal bandwidth. According to the specification, the supported nominal bandwidths are 1.25MHz, 1.5MHz, 1.75 MHz, 2.5 MHz, 3 MHz, 3.5 MHz, 5 MHz, 5.5 MHz, 6 MHz, 7 MHz, 10 MHz, 11 MHz, 12 MHz, 14 MHz, 15 MHz, 20 MHz, 24 MHz and 28 MHz. This parameter type is floating. Other bandwidth except the above is also supported. The sampling frequency implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows:

$$F_s = floor((n \times Bandwidth)/8000) \times 8000$$

The sampling factors are listed in Sampling Factor Requirement.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.
- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the uplink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the uplink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
- IdleInterval specifies the time of idle interval between two consecutive subframes. The default value is 0.0 μsec.
- FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- NumberOfSS specifies the number of active subscribes (SS).
- SSWithFEC specifies the SS which goes through FEC encoding and decoding.
- Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
- SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
- DataLength is the array of each SS's MAC PDU payload byte length.
- Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to Mandatory Channel Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. *Midamble Repetition Interval* shows the meaning each MidambleRepetition value corresponds to,

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

- PrmlTimeShift indicates the number of samples of cyclic shift are delayed in time in the preamble and midamble symbols.
- DecoderType specifiers the Viterbi decoder type chosen from CSI, Soft and Hard.

5. Output Pin Delay Adjustment
   Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
   The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts. Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively. Each uplink burst consists of one short preamble, data symbols and midambles. The short preamble consists of one OFDM symbols.
   The number of OFDM data symbols of ith uplink SS ($N_{Symbol}[i]$) is calculated as follows:

   $$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

   MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst,

   $$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

   if $MidambleRepetition[i]$ is not zero

   $$Midamble[i] = 0$$

   else
   So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

   $$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

   The number of samples per one OFDM symbol ($Samples_{OFDM}$) is calculated as:

   $$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where, G is the CyclicPrefix.
The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

When FrameDuration<>Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

For subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS(!wman-7-22-550.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels})$$

Here Nsubchannels is the number of subchannels. Nsubchannels is determined by SubchannelIndex, shown in Number of Subchannels as follows:

Number of Subchannels

Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

In the receiver, one frame delay occurs.
$200 \times \left(\sum_{i=1}^{NumberOfSS} N_{Symbol}[i]\right)$ delay is introduced at pin ForEVM and CIR for non-subchannelization mode and $200 \times max(N_{Symbol}[i])$ delay for subchannelization mode.
$8 \times DataLength[BurstWithFEC] + 80$ bits delay is introduced at pin PDUFCS, where 80 bits are the MAC Header and CRC attached.
$8 \times DataLength[BurstWithFEC]$ bits delay is introduced at pin PSDU.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area

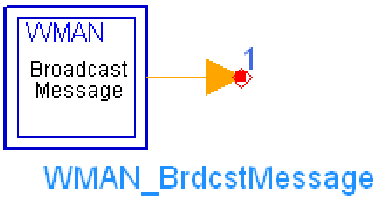
2.
Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN Signal Source Components

The signal source models provide models to generate downlink and uplink signal sources.

- *WMAN BrdcstMessage (WMAN Broadcast Message)* (wman)
- *WMAN DataPattern (WMAN Data Pattern)* (wman)
- *WMAN DCD (WMAN DCD)* (wman)
- *WMAN DLFP (WMAN Downlink Frame Prefix)* (wman)
- *WMAN DL MAP (WMAN Downlink MAP)* (wman)
- *WMAN DL Pilot (WMAN Downlink Pilot Generator)* (wman)
- *WMAN DL SignalSrc (WMAN Downlink Signal Source)* (wman)
- *WMAN DL SignalSrc RF (WMAN Downlink Signal Source RF)* (wman)
- *WMAN DL Src FD (WMAN DL Signal Source with FrameDuration)* (wman)
- *WMAN DL Src FD RF (WMAN DL Source RF with FrameDuration)* (wman)
- *WMAN MACHeader (WMAN MAC Header)* (wman)
- *WMAN MACPDU (WMAN MAC PDU)* (wman)
- *WMAN Preamble (WMAN Preamble Generator)* (wman)
- *WMAN UCD (WMAN UCD)* (wman)
- *WMAN UL MAP (WMAN Uplink MAP)* (wman)
- *WMAN UL Pilot (WMAN Uplink Pilot Generator)* (wman)
- *WMAN UL SignalSrc (WMAN Uplink Signal Source)* (wman)
- *WMAN UL SignalSrc RF (WMAN Uplink Signal Source RF)* (wman)
- *WMAN UL Src FD (WMAN Uplink Signal Source with Frame Duration)* (wman)
- *WMAN UL Src FD RF (WMAN UL Source RF with Frame Duration)* (wman)

WMAN_BrdcstMessage (WMAN Broadcast Message)



Description Broadcast messages
Library WMAN, Signal Source
Class SDFWMAN_BrdcstMessage

Parameters

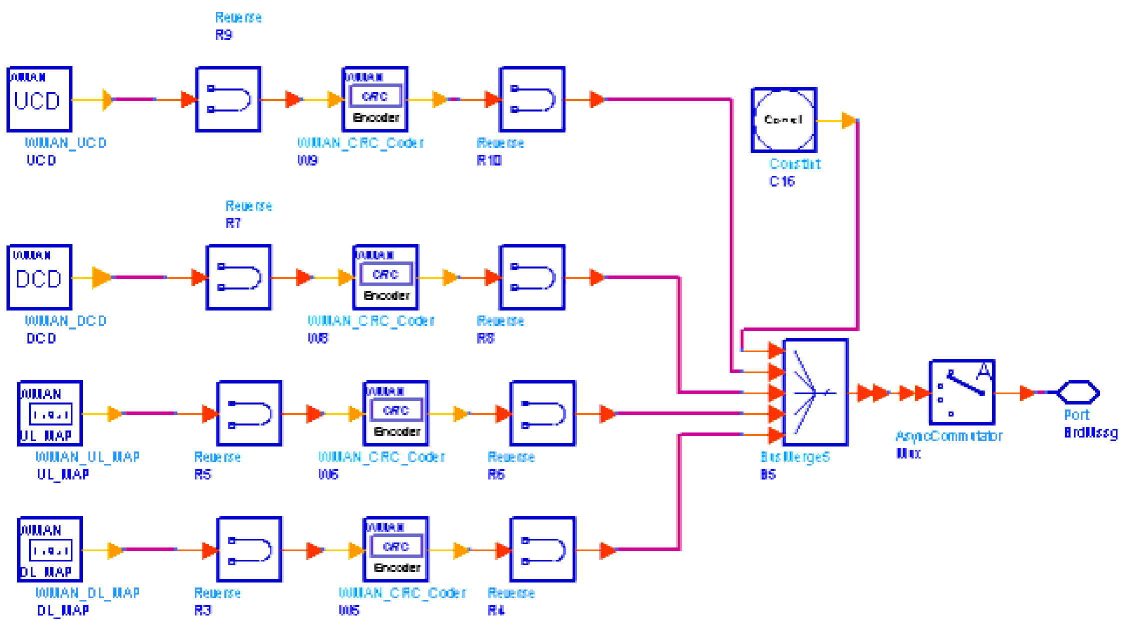
Name	Description	Default	Unit	Type	Range
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame number	0		int	[0, 15]
DL_ChannelID	Downlink channel ID	0		int	[0, 255]
DCD_Count	DCD count	0		int	[0, 255]
UCD_Count	UCD count	0		int	[0, 255]
NumberOfBurst	Number of Burst	1		int	[1, 15]
CID	CID	{1}		int array	[1, 0xffff]
PreamblePresent	Preamble present indication	{0}		int array	{ 0, 1 }
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
UL_ChannelID	Uplink channel ID	0		int	[0, 255]
UL_NumberOfSS	Uplink number of subscribers	1		int	[1, 16]
UL_CID	Uplink CID	{0}		int array	[0, 65535]
UL_DataLength	Uplink MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
UL_Rate_ID	Uplink Rate ID of each subscriber	{1}		int array	[0, 6]
UL_Subchannelization	Uplink Subchannelization or not: NO, YES	NO		enum	
UL_SubchannelIndex	Uplink list of each subchannel index	{8}		int array	[1, 15] or [17, 31]
UL_MidambleRepetition	Uplink Midamble repetition of each subscriber	{0}		int array	[0, 3]
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]

Pin Outputs

Pin	Name	Description	Signal Type
1	BrdMssg	output of broadcast messages	int

Notes/Equations

1. This model is used to generate the broadcast message including DL-MAP, UL-MAP, DCD and UCD. The DL-MAP, UL-MAP, DCD and UCD are added with CRC32 (HCS) in the this subnetwork. The number of OFDM symbols in the broadcast burst is 21, and the broadcast burst is transmitted with BPSK 1/2 (RateID 0). If the amount of data (including DL-MAP, UL-MAP, DCD and UCD) to transmit does not fit exactly the amount of data allocated in the broadcast burst, padding of 0xFF shall be added to the end of the transmission block. The schematic for this subnetwork is shown in WMAN_BrdcstMessage Schematic.

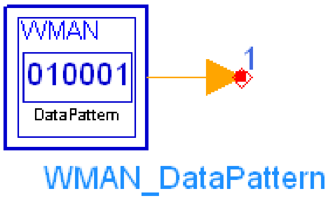


WMAN_BrdcstMessage Schematic

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DataPattern (WMAN Data Pattern)



Description Data pattern
Library WMAN, Signal Source
Class SDFWMAN_DataPattern

Parameters

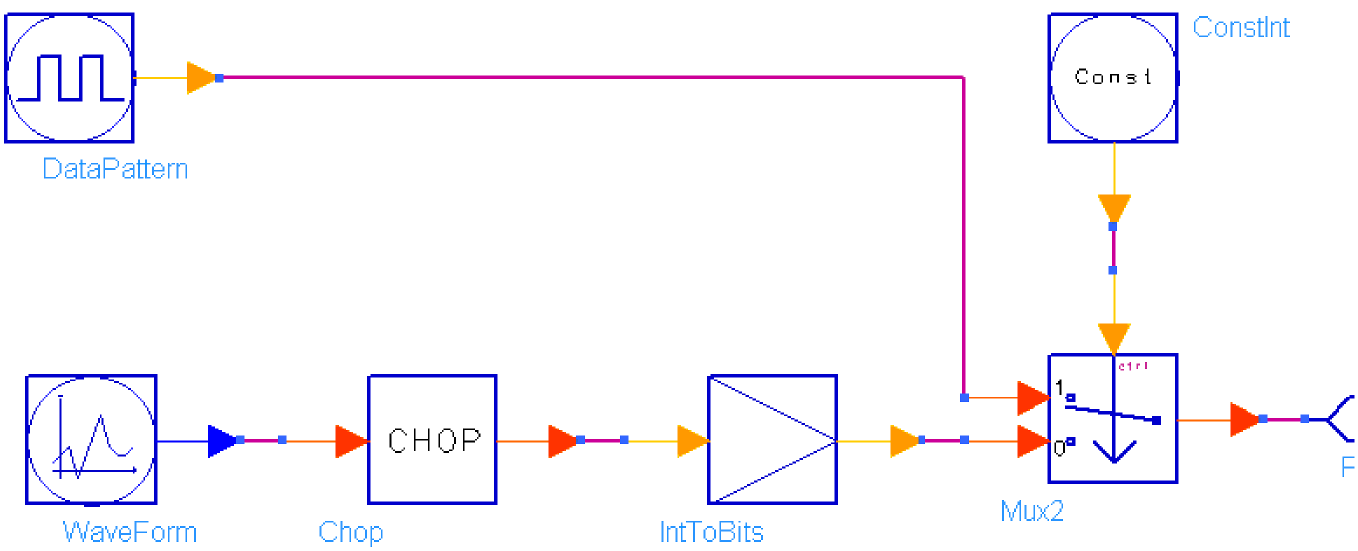
Name	Description	Default	Type	Range
Pattern	WMAN data pattern: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0, S_BPSK, S_QPSK, S_16-QAM, S_64-QAM	PN9	enum	
DataLength	payload byte length	100	int	[1, 4095]

Pin Outputs

Pin	Name	Description	Signal Type
1	pattern	data pattern	int

Notes/Equations

1. This subnetwork is used to generate Data Pattern.
2. The schematic of this subnetwork is shown in WMAN_DataPattern Schematic.



WMAN_DataPattern Schematic

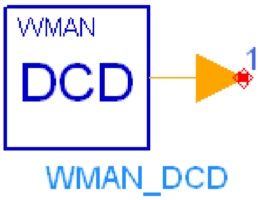
3. For the Pattern parameter:
   - if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT

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.
- if S_BPSK, S_QPSK, S_16-QAM or S_64-QAM is selected, sequences below are generated. These are test messages for receiver sensitivity measurement.
  S_BPSK = [0xE4,0xB1]
  S_QPSK = [0xE4, 0xB1, 0xE1, 0xB4]
  S_16-QAM = [0xA8, 0x20, 0xB9, 0x31, 0xEC, 0x64, 0xFD, 0x75]
  S_64-QAM = [0xB6, 0x93, 0x49, 0xB2, 0x83, 0x08, 0x96, 0x11, 0x41, 0x92, 0x01, 0x00, 0xBA, 0xA3, 0x8A, 0x9A, 0x21, 0x82, 0xD7, 0x15, 0x51, 0xD3, 0x05, 0x10, 0xDB, 0x25, 0x92, 0xF7, 0x97, 0x59, 0xF3, 0x87, 0x18, 0xBE, 0xB3, 0xCB, 0x9E, 0x31, 0xC3, 0xDF, 0x35, 0xD3, 0xFB, 0xA7, 0x9A, 0xFF, 0xB7, 0xDB]

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.
3. CCITT, Recommendation O.151(10/92).
4. CCITT, Recommendation O.153(10/92).

WMAN_DCD (WMAN DCD)



Description DCD generator
Library WMAN, Signal Source
Class SDFWMAN_DCD

Parameters

Name	Description	Default	Type	Range
DL_ChannelID	Downlink channel ID	0	int	[0, 255]
DCD_Count	DCD count	0	int	[0, 255]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms	enum	
FrameNumber	Frame number	0	int	[0, 15]
AutoMACHeaderSetting	Auto MAC Header setting or not: NO, YES	NO	enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}	int array	[0, 255]

Pin Outputs

Pin	Name	Description	Signal Type
1	out	DCD	int

Notes/Equations

1. This model is used to generate Downlink Channel Descriptor (DCD) message for WMAN OFDM system. A DCD shall be transmitted by the BS to define the characteristics of a downlink physical channel. In this DCD message format, DIUC from 1 to 7 are defined with different burst profiles (Rate ID), shown as follows.

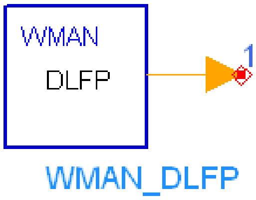
DIUC	Rate ID
1	0 (BPSK 1/2)
2	1 (QPSK 1/2)
3	2 (QPSK 3/4)
4	3 (16-QAM 1/2)
5	4 (16-QAM 3/4)
6	5 (64-QAM 2/3)
7	6 (64-QAM 3/4)

2. Each firing, $(MACHeader + DCDHeaderLength + DCDIELength \times DCDIENumber) \cdot 8$ tokens are produced. MACHeader is 6. DCDHeaderLength is 11. DCDIELength is 6. DCDIENumber is 7.
3. Note that DCD of the model generated does not include HCS, which will be added later.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DLFP (WMAN Downlink Frame Prefix)



Description Downlink frame prefix generator
Library WMAN, Signal Source
Class SDFWMAN_DLFP

Parameters

Name	Description	Default	Type	Range
BSID	Base station identifier	0	int	[0, 15]
DIUC	Downlink interval usage code	{0}	int array	[0, 15]
FrameNumber	Frame index	0	int	[0, 15]
NumOfBurst	Number of burst	1	int	[1, 16]
Rate_ID	Rate identifier	{1}	int array	[0, 6]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
PreamblePresent	Preamble present indication	{0}	int array	{ 0, 1 }
Brd_Message	Broadcast message or not: NO, YES	NO	enum	
Rate_ID_Brd	Rate ID of broadcast message	0	int	[0, 6]
DIUC_Brd	Downlink interval usage code for broadcast message	0	int	[0, 15]

Pin Outputs

Pin	Name	Description	Signal Type
1	out	downlink frame prefix	int

Notes/Equations

1. This model is used to generate Downlink Frame Prefix (DLFP). The FCH contains DLFP to specify burst profile and length of one or several downlink bursts immediately following the FCH.
2. Each firing 10×8 bit tokens are produced at Pin out. The content in DLFP is specified in the following table.

OFDM Downlink Frame Prefix Format

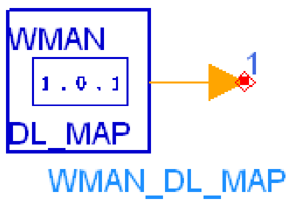
Syntax	size	Notes
DL_Frame_Prefix_Format(){		
Base_Station_ID	4 bits	4 LSB of BS ID.The burst specified by the DLFP shall not be decoded if these bits do not match those of the BS on which it is registered.
Frame_Number	4 bits	4 LSB of the Frame Number of current frame
Configuration_Change_Count	4 bits	4 LSB of Change Count value as specified in 6.3.2.3.1.
reserved	4 bits	Shall be set to zero
Rate_ID	4 bits	Encoded according to the Table 224
reserved	1 bits	Shall be set to zero
Length	11 bits	Number of OFDM symbols in the first burst including preamble if present
for(n=0;n<3;n++){		
DL_Frame_Prefix_IE(){		
DIUC	4 bits	Defines the burst profile of the corresponding burst
if(DIUC!=0){		
Preamble present	1 bits	If "1",preamble is placed at the first symbol in the burst
Length	11 bits	Number of OFDM symbols in the burst
} else {		
Start Time	12 bits	Start time of STC zone in units of symbol duration counted from the beginning of the frame
}}}		
HCS	8 bits	An 8-bit Header Check Sequence; calculated as specified in Table 5.
}		

3. Note that DLFP of the model generated does not include HCS, which will be added later. The Section of Configuration_Change_Count is filled with zero. The Section of Start Time is not used here and filled with zero.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_MAP (WMAN Downlink MAP)



Description Downlink map generator
Library WMAN, Signal Source
Class SDFWMAN_DL_MAP

Parameters

Name	Description	Default	Type	Range
DCD_Count	DCD count	0	int	[0, 255]
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}	int array	[0, 255]
NumberOfBurst	Number of Burst	1	int	[1, 15]
CID	CID	{1}	int array	[1, 0xffff]
DIUC	Downlink interval usage code	{0}	int array	[0, 15]
PreamblePresent	Preamble present indication	{0}	int array	{ 0, 1 }
AutoStartTimeSetting	Auto setting of start time or not: NO, YES	NO	enum	
StartTime	start time	{1}	int array	[1, 0x07ff]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]
AutoMACHeaderSetting	Auto MAC deader setting or not: NO, YES	NO	enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}	int array	[0, 255]

Pin Outputs

Pin	Name	Description	Signal Type
1	DLMAP	output DL MAP	int

Notes/Equations

1. This model is used to generate DL-MAP IE for WMAN OFDM system. DL-MAP is a MAC Layer Message that tells a subscriber station (SS) about the construction of the downlink OFDM signal. This allows the SS to decode the DL transmission and extract any messages that are either specifically designated for a particular SS or any broadcast messages that the BTS is sending to all SS's.
2. Each firing, $(MACHeader + DLMAPHeaderLength + DLMAPIELength \times DLMAPIENumber) \cdot 8$ tokens are produced.
   MACHeader is 6.
   DLMAPHeaderLength is 8.

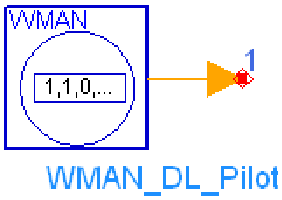
DLMAPIELength is 4.
When $NumberOfBurst < 4$, DLMAPIENumber is 1 which is the End MAP IE.
When $NumberOfBurst \geq 4$, DLMAPIENumber is $NumberOfBurst - 3 + 1$ which are the End MAP IE and the data bursts excluding the first three data bursts.
The DL-MAP IEs for the first four bursts (Broadcast burst and the first three data bursts) are defined in the DLFP.

3. When AutoStartTimeSetting is set to YES, the starting time for each DL-MAP IE is calculated automatically. Otherwise the values in the parameter StartTime are used. When AutoMACHeaderSetting is set to YES, the MAC header is calculated automatically. Otherwise the values in the parameter MAC_Header are used.
4. Note that DL-MAP of the model generated does not include HCS, which will be added later.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DL_Pilot (WMAN Downlink Pilot Generator)



Description Downlink pilot generator
Library WMAN, Signal Source
Class SDFWMAN_DL_Pilot
Derived From WMAN_DL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfBurst	Number of Burst	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}	int array	[0, 6]
PreamblePresent	Preamble present	{0}	int array	{0, 1}
PilotPN_Phase	the Pilot PN phase	0	int	[0, 2047]
Brd_Message	Broadcast message or not: NO, YES	NO	enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	output	a sequence for the downlink pilot modulation	int

Notes/Equations

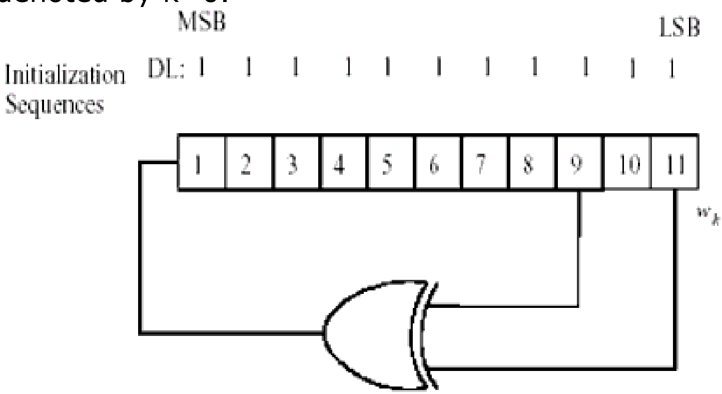
1. This model is used to generate the sequence used for pilot modulation in OFDM downlink symbols following the frame preamble, including the FCH burst and one or multiple downlink bursts.
2. Each firing, $1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i] + N_{BroadcastMessage}$ tokens are produced, where 1 is the number of OFDM symbol of FCH, NSymbol[i] is the number of data symbols of the ith downlink burst which is determined by the DataLength and Rate_ID (R). NBroadcastMessage is the number of OFDM symbols of broadcast message, NBroadcastMessage=0 if Brd_Message=NO and NBroadcastMessage=21 if Brd_Message=YES. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to values listed in the following table, which is based on the specification.

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

The number of OFDM symbols of ith downlink burst(!wman-8-06-014.gif!) is calculated as:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

3. The pseudo-random binary sequence (PRBS) generator is shown in Pseudo-Random Binary Sequence (PRBS) Generator, for which the polynomial is $X^{11} + X^{9} + 1$. The output value used for the pilot modulation for OFDM symbol k is derived by $1 - 2w_k$. The index k represents the symbol index relative to the beginning of the downlink subframe and the first symbol of the preamble is denoted by k=0.



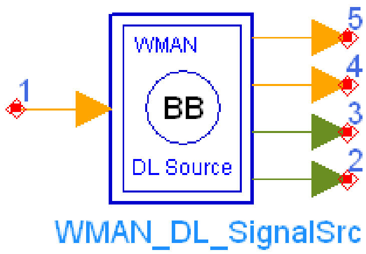
Pseudo-Random Binary Sequence (PRBS) Generator

PreamblePresent indicates whether the downlink bursts starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If PreamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$. If $Prml[i] = 1$, then the indices of the OFDM symbols after this preamble add 1. PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_SignalSrc (WMAN Downlink Signal Source)



Description Downlink baseband signal source
Library WMAN, Signal Source
Class SDFWMAN_DL_SignalSrc

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
DIUC	DIUC of each burst	{1}		int array	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle interval	10.0 usec	sec	real	[0, 1000)
PilotPN_Phase	Pilot PN phase	0		int	[0, 4095]
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}		int array	[0, 255]

Pin Inputs

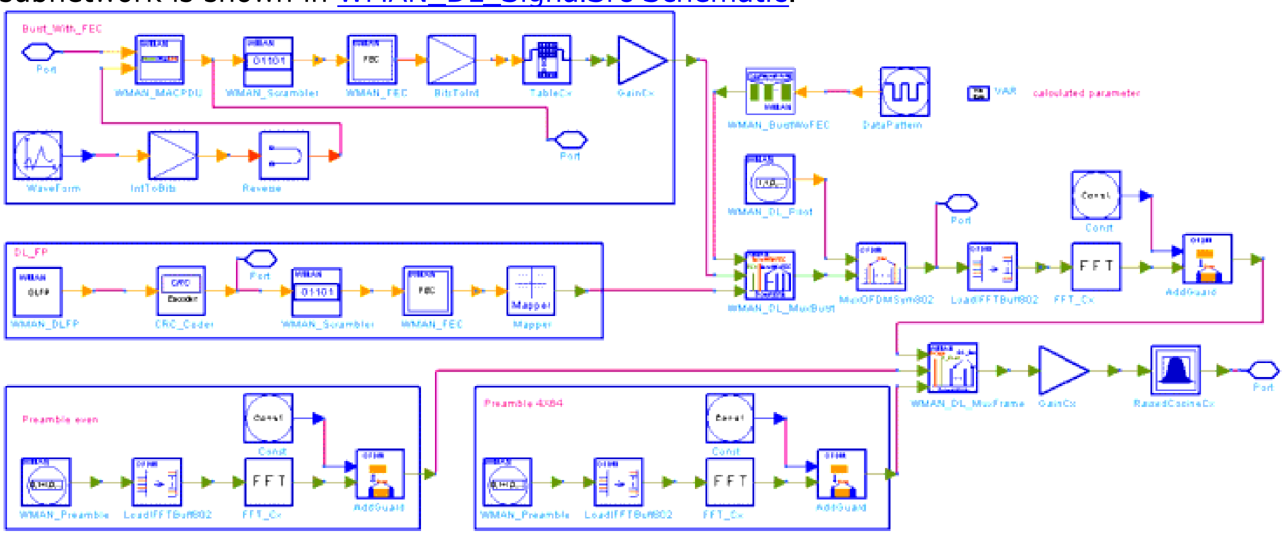
Pin	Name	Description	Signal Type
1	MAC_Data	input of raw data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	FrameData	output of DL Subframe	complex
3	ForEVM	output of DL multiplexed data for EVM test	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	DLFP	output of DLFP bits	int

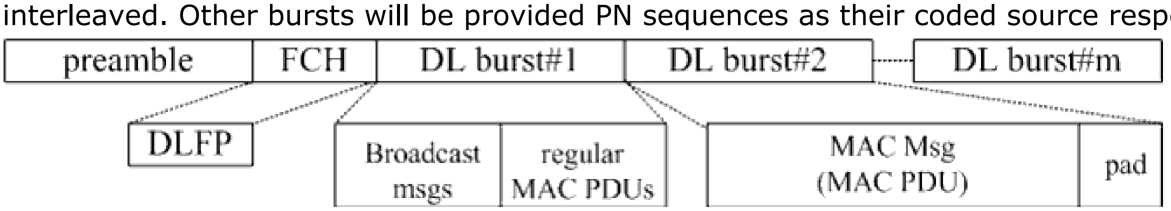
Notes/Equations

1. This subnetwork generates a WMAN Downlink subsystem baseband signal. The schematic for this subnetwork is shown in WMAN_DL_SignalSrc Schematic.



WMAN_DL_SignalSrc Schematic

2. The input of this subnetwork is MAC PDU data of the FEC-encoded burst; MAC header data is specified by MAC_Header.
3. WMAN_DL_SignalSrc is implemented according to specification.
WMAN DL frame structure shows the downlink frame format. It includes the long preamble, FCH, and one or several downlink bursts carrying MAC PDUs. In WMAN Library, one downlink frame contains maximum 16 bursts except FCH and each burst contains only one MAC PDU. Among these bursts, only one FEC-encoded bursted is supported which is randomized, RS-CC coded and interleaved. Other bursts will be provided PN sequences as their coded source respectively.



WMAN DL frame structure

The downlink long preamble consists of two consecutive OFDM symbols. The first OFDM symbol uses only subcarriers the indices of which are a multiple of 4 identified as $P_{4\times64}$ and the second OFDM symbol utilizes only even subcarriers identified as P_{EVEN} . The basic sequence for one OFDM symbol time domain packet is implemented by WMAN_Preamble.
The FCH is coded in the following manner:

- WMAN_DLFP generates the DLFP, then an 8 bit Header Check Sequence is padded.

- Randomized by WMAN_Scramble with initial state 100101010000000.
- Convolutional encoded and interleaved by WMAN_FEC.
  The FEC-encoded burst is coded in the following manner:
- Add MAC header with parameter MAC_Header.
- Randomized by WMAN_Scramble.
- RS-CC encoded, punctured (by WMAN_Puncture) and interleaved by WMAN_FEC.
  After encoding, the FCH and coded burst will be mapped to the constellation respectively. Other bursts without FEC, will be provided PN sequence as their coded bits and mapped to the constellation according to their Rate_ID by WMAN_BurstWoFEC.
  The FCH, FEC-encoded burst are concatenated with non-coded bursts by WMAN_DL_MuxBurst.
  WMAN_DL_Pilot generates modulated pilot for downlink bursts. After IFFT and cyclic prefix insertion, the $P_{4\times64}$ and P_{EVEN} are combined with downlink payload (including FCH and downlink bursts) in WMAN_DL_MuxFrame. At last, oversampling is implemented by a transmitter filter.

4. Parameter Details.
   - NumberOfBurst specifies the number of active downlink bursts.
   - BurstWithFEC specifies the downlink burst FEC.
   - DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Mandatory Channel Coding per Modulation*, which is based on the specification.

Rate_ID	**Modulation**	**Uncoded block size(bytes)**	**Coded block size(bytes)**	**Overall coding rate**	**RS code**	**CC code rate**
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

   - PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1", preamble is placed before the burst, otherwise preamble is not placed before the burst.
   - PrmlTimeShift is an array parameter. Its size should be the same as NumberOfBurst, which determines the number of samples of cyclic shift delay in time for the preamble symbols.
   - DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
   - OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this source. For example, if OversamplingOption = Ratio 2, it means the IFFT size is 512.
   - Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor (!wman-8-07-030.gif!) as:
     $$F_s = floor((N_{factor} \times Bandwidth)/8000) \times 8000$$
     The sampling factors are listed in *Sampling Factor Requirement*.

sampling factor n	**bandwidth**
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

   - CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from

0 to 1.
- IdleInterval specifies the time of idle interval between two consecutive frames.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- MAC_Header specifies the MAC header of FEC-encoded burst.

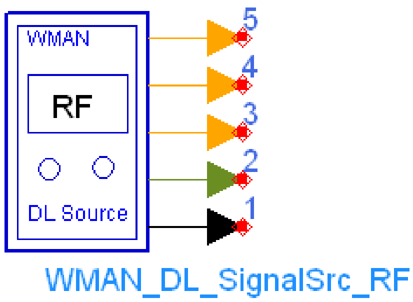
5. Samples per frame
One WMAN downlink frame consists of Idle, long preamble, FCH and multiple downlink bursts. The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol. The number of OFDM symbols of the ith downlink burst (!wman-8-07-032.gif!) is calculated as:
$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$
PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$.
So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as:
$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$
The number of samples per one OFDM symbol (!wman-8-07-039.gif!) is calculated as:
$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$
The samples of IdleInterval($Samples_{idle}$) is calculated as:
$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$
So, the total samples of one downlink frame $Samples_{Frame}$ is
$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$
This model work on frame by frame. Each firing,
$8 \times DataLength$ tokens are consumed at pin MAC_PDU,
$Samples_{Frame}$ tokens are produced at pin FrameData,
$200 \times \left(1 + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens are produced at pin ForEVM,
$8 \times DataLength + 80$ tokens are produced at pin PSDUFCS, and 11 tokens are produced at pin DLFP.

6. Output delay
$30 \times 2^{oversamplingOption}$ delay is introduced by the transmitter filter in the design WMAN_DL_SignalSrc, where the delay are equal to $(Length - 1)/2$. Length is the parameter in the transmitter filter.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_SignalSrc_RF (WMAN Downlink Signal Source RF)



Description Downlink RF signal source
Library WMAN, Signal Source
Class TSDFWMAN_DL_SignalSrc_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	Source resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	3407 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	(−∞, ∞)
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
DIUC	DIUC of each burst	{1}		int array	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle interval	10.0 usec	sec	real	[0, 1000)
PilotPN_Phase	Pilot PN phase	0		int	[0, 4095]
DataPattern	WMAN Data Pattern: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0, S_BPSK, S_QPSK, S_16-QAM, S_64-QAM	PN9		enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}		int array	[0, 255]

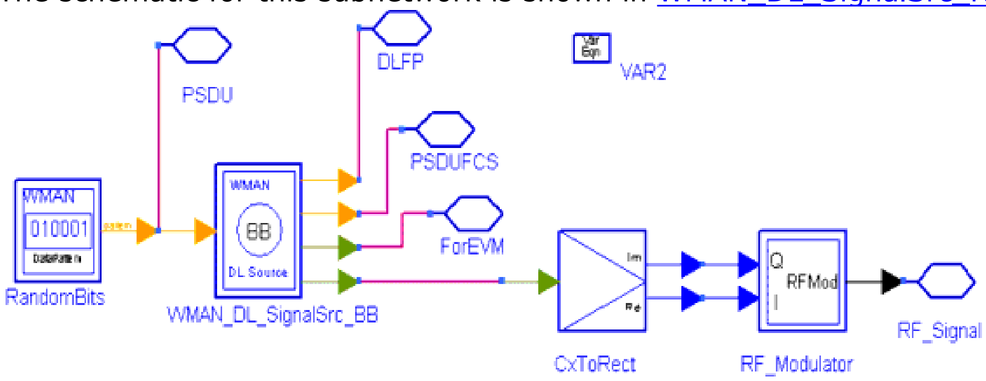
Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Signal	output of RF signal	timed
2	ForEVM	output of DL multiplexed data for EVM test	complex
3	PDUFCS	output of MAC PDU data of burst with FEC	int
4	PSDU	output of PSDU bits	int
5	DLFP	output of DLFP bits	int

Notes/Equations

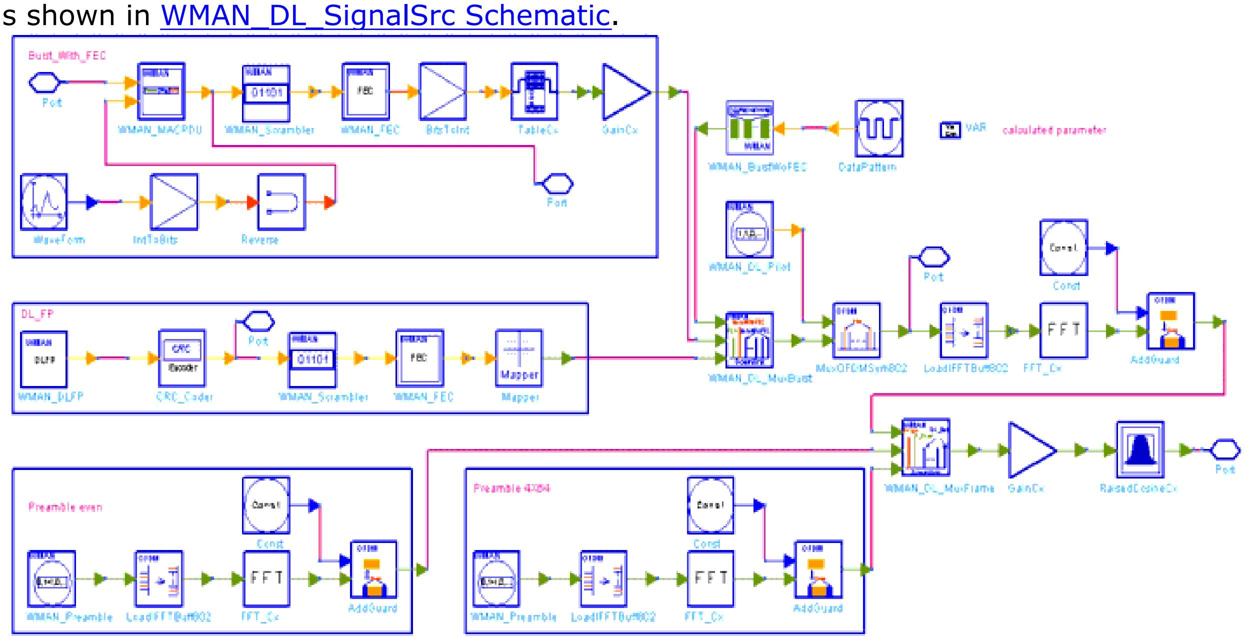
1. This subnetwork generates a WMAN Downlink subsystem RF signal. The subnetwork includes

WMAN_DL_SignalSrc, which generates the downlink baseband signal of WMAN Downlink subsystem, and the RF_Modulator.
The schematic for this subnetwork is shown in WMAN_DL_SignalSrc_RF Schematic.



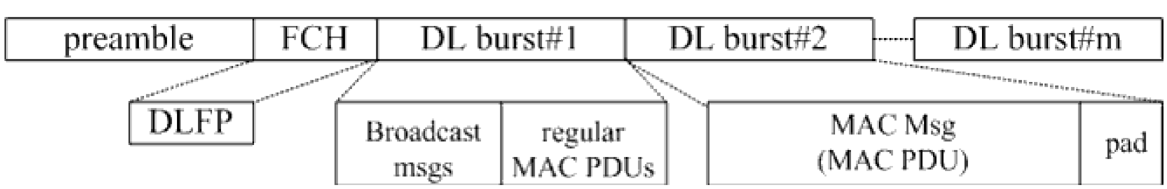
WMAN_DL_SignalSrc_RF Schematic

2. The WMAN OFDM downlink baseband signal source format follows the specification. The schematic is shown in WMAN_DL_SignalSrc Schematic.



WMAN_DL_SignalSrc Schematic

3. Source functions are implemented as follows:
The input of this subnetwork is MAC PDU data of the FEC-encoded burst; MAC header data is specified by MAC_Header.
WMAN DL frame structure shows the downlink frame format. It includes the long preamble, FCH, and one or several downlink bursts carrying MAC PDUs. In WMAN Library, one downlink frame contains maximum 16 bursts except FCH and each burst contains only one MAC PDU. Among these bursts, only one FEC-encoded bursted is supported which is randomized, RS-CC coded and interleaved. Other bursts will be provided PN sequences as their coded source respectively.



WMAN DL frame structure

The downlink long preamble consists of two consecutive OFDM symbols. The first OFDM symbol uses only subcarriers the indices of which are a multiple of 4 identified as $P_{4\times64}$ and the second OFDM symbol utilizes only even subcarriers identified as P_{EVEN} . The basic sequence for one OFDM symbol time domain packet is implemented by WMAN_Preamble.
The FCH is coded in the following manner:

- WMAN_DLFP generates the DLFP, then an 8 bit Header Check Sequence is padded.
- Randomized by WMAN_Scramble with initial state 100101010000000.
- Convolutional encoded and interleaved by WMAN_FEC.
  The FEC-encoded burst is coded in the following manner:
- Add MAC header with parameter MAC_Header.
- Randomized by WMAN_Scramble.
- RS-CC encoded, punctured (by WMAN_Puncture) and interleaved by WMAN_FEC.
  After encoding, the FCH and coded burst will be mapped to the constellation respectively. Other bursts without FEC, will be provided PN sequence as their coded bits and mapped to the constellation according to their Rate_ID by WMAN_BurstWoFEC.
  The FCH, FEC-encoded burst are concatenated with non-coded bursts by WMAN_DL_MuxBurst.
  WMAN_DL_Pilot generates modulated pilot for downlink bursts. After IFFT and cyclic prefix insertion, the $P_{4\times64}$ and P_{EVEN} are combined with downlink payload (including FCH and downlink bursts) in WMAN_DL_MuxFrame.
  At last, oversampling is implemented by a transmitter filter.

4. 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, !wman-8-08-061.gif!(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).
   - NumberOfBurst specifies the number of active downlink bursts.
   - BurstWithFEC specifies the downlink burst FEC.
   - DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R)

determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to the values listed in the following table, which is based on the specification.

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1", preamble is placed before the burst, otherwise preamble is not placed before the burst.
- PrmlTimeShift is an array parameter. Its size should be the same as NumberOfBurst, which determines the number of samples of cyclic shift delay in time for the preamble symbols.
- DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
- OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this source. For example, if OversamplingOption = Ratio 2, it means the IFFT size is 512.
- Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor (!wman-8-08-062.gif!) as:

  $$F_s = floor((N_{factor} \times Bandwidth)/8000) \times 8000$$

  The sampling factors are listed in the following table.

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from 0 to 1.
- IdleInterval specifies the time of idle interval between two consecutive frames.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- MAC_Header specifies the MAC header of FEC-encoded burst.

5. Key parameter calculation:
   One WMAN downlink frame consists of Idle, long preamble, FCH and multiple downlink bursts. The downlink long preamble consists of two consecutive OFDM symbols.
   FCH is transmitted in one OFDM symbol. The number of OFDM symbols of ith downlink burst(!wman-8-08-064.gif!) is calculated as:

   $$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

   PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$.
   So the total number of OFDM symbols $N_{totalSymbol}$
   for the downlink frame is calculated as:

$$N_{totalSymbol} = 2 + 1 + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

The number of samples per one OFDM symbol (!wman-8-08-071.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

The samples of IdleInterval(!wman-8-08-073.gif!) is calculated as:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

So, the total samples of one downlink frame $Samples_{Frame}$ is

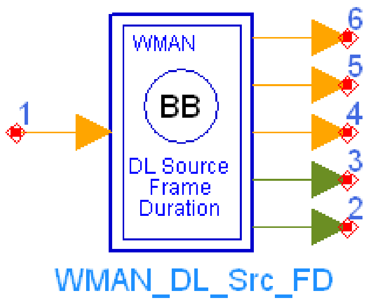
$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

6. Output delay
   $30 \times 2^{oversamplingOption}$
   delay is introduced by the transmitter filter in the design WMAN_DL_SignalSrc, where the delay are equal to $(Length - 1)/2$. Length is the parameter in the transmitter filter.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_DL_Src_FD (WMAN DL Signal Source with FrameDuration)



Description Downlink baseband signal source with broadcast message and frame duration
Library WMAN, Signal Source
Class SDFWMAN_DL_Src_FD

Parameters

Name	Description	Default	Unit	Type	Range
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	
IdleInterval	Idle interval	0.0 usec	sec	real	[0, 1000)
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
DL_ChannelID	Downlink channel ID	0		int	[0, 255]
DCD_Count	DCD count	1		int	[0, 255]
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
CID	CID of each burst	{1}		int array	[0, 65535]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
PilotPN_Phase	Pilot PN phase	0		int	[0, 4095]
AutoMACHeaderSetting	Auto MAC header setting or not: NO, YES	YES		enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}		int array	[0, 255]
UL_ChannelID	Uplink channel ID	0		int	[0, 255]
UCD_Count	UCD count	1		int	[0, 255]
UL_NumberOfSS	Uplink number of subscribers	1		int	[1, 16]
UL_CID	Uplink CID	{0}		int array	[0, 65535]
UL_DataLength	Uplink MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
UL_Rate_ID	Uplink Rate ID of each subscriber	{1}		int array	[0, 6]
UL_Subchannelization	Uplink Subchannelization or not: NO, YES	NO		enum	
UL_SubchannelIndex	Uplink list of each subchannel index	{8}		int array	[1, 15] or [17, 31]
UL_MidambleRepetition	Uplink Midamble repetition of each subscriber	{0}		int array	[0, 3]

Pin Inputs

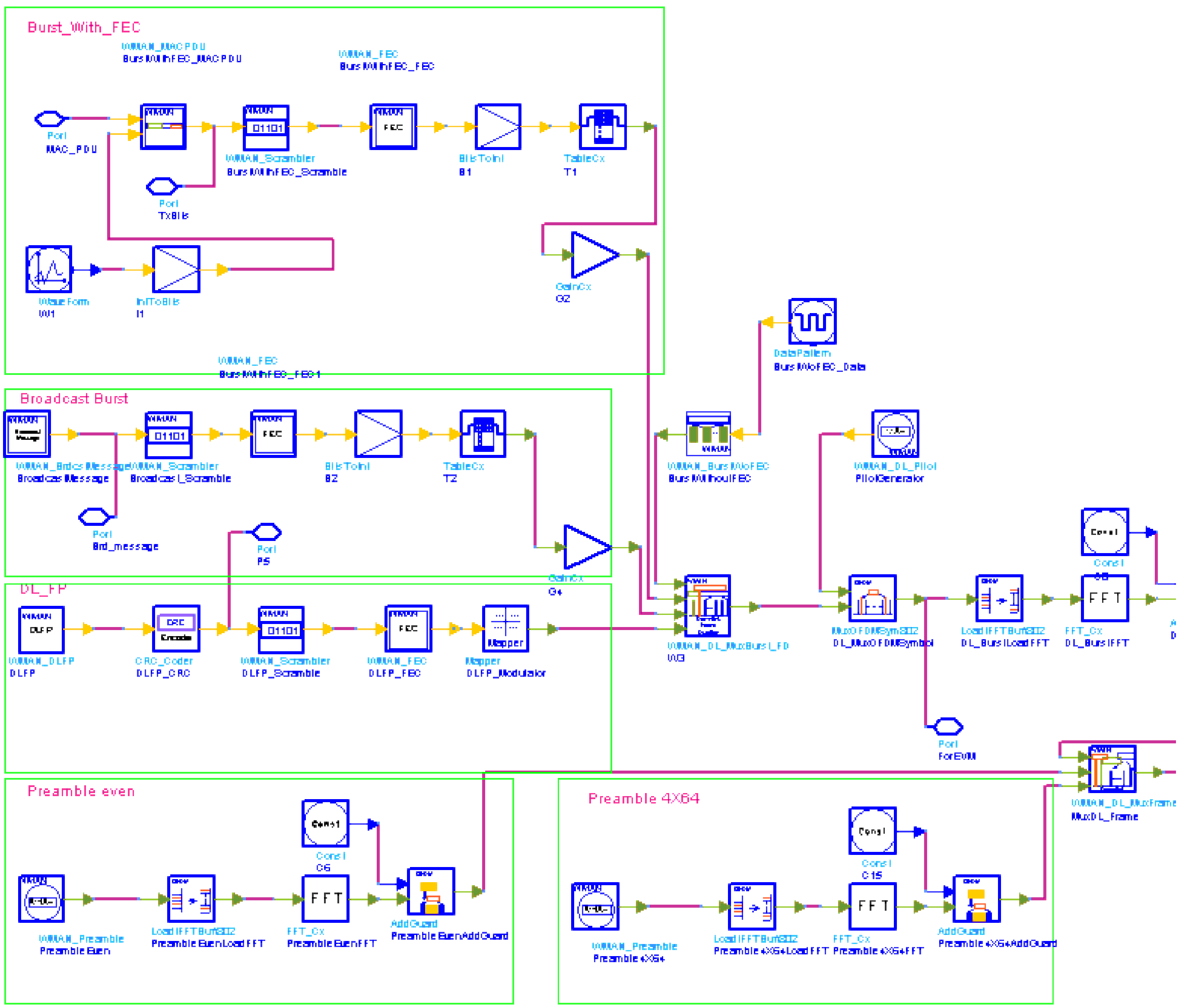
Pin	Name	Description	Signal Type
1	MAC_Data	input of raw data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	FrameData	output of DL Subframe	complex
3	ForEVM	output of DL multiplexed data for EVM test	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int
5	DLFP	output of DLFP bits	int
6	Brd_message	output of broadcast message	int

Notes/Equations

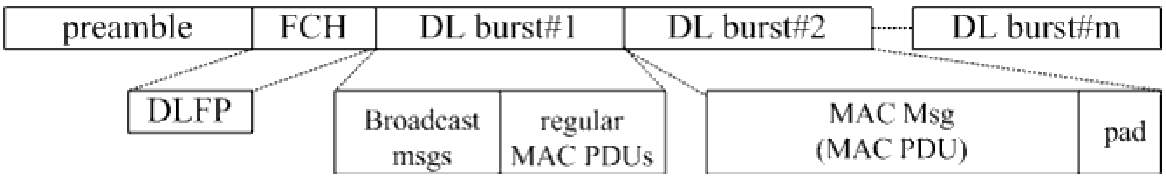
1. This subnetwork generates a WMAN Downlink subsystem baseband signal. The schematic for this subnetwork is shown in WMAN_DL_Src_FD Schematic.



WMAN_DL_Src_FD Schematic

2. The input of this subnetwork is MAC PDU data of the FEC-encoded burst; MAC header data is specified by MAC_Header.

3. WMAN_DL_Src_FD is implemented according to the specification.
WMAN DL Subframe Structure shows the downlink subframe format. It includes the long preamble, FCH, broadcast burst and one or several downlink bursts carrying MAC PDUs. The duplexing method shall be either FDD or TDD. In TDD mode, the downlink subframe occupies the first part of the frame, and the uplink subframe is in the last (second) part of the frame. If the transmission time for all the bursts does not fit the time of the downlink subframe allocated, gaps will be padded at the end of subframe. The broadcast burst always immediately follows the FCH if exist consisting of 21 consecutive OFDM symbols. One downlink subframe contains maximum 16 bursts except FCH and each burst contains only one MAC PDU. Among these bursts, only one FEC-encoded bursted is supported which is randomized, RS-CC coded and interleaved. Other bursts will be provided PN sequences as their coded source respectively.



WMAN DL Subframe Structure

The downlink long preamble consists of two consecutive OFDM symbols. The first OFDM symbol uses only subcarriers the indices of which are a multiple of 4 identified as $P_{4\times64}$ and the second OFDM symbol utilizes only even subcarriers identified as P_{EVEN}. The basic sequence for one OFDM symbol time domain packet is implemented by WMAN_Preamble.
The FCH is coded in the following manner:

- WMAN_DLFP generates the DLFP, then an 8 bit Header Check Sequence is padded.
- Randomized by WMAN_Scramble with initial state 100101010000000.
- Convolutional encoded and interleaved by WMAN_FEC.
The FEC-encoded burst is coded in the following manner:
- Add MAC header with parameter MAC_Header.
- Randomized by WMAN_Scramble.
- RS-CC encoded, punctured (by WMAN_Puncture) and interleaved by WMAN_FEC.
After encoding, the FCH and coded burst will be mapped to the constellation respectively. Other bursts without FEC, will be provided PN sequence as their coded bits and mapped to the constellation according to their Rate_ID by WMAN_BurstWoFEC.
The FCH , FEC-encoded burst are concatenated with non-coded bursts by WMAN_DL_MuxBurst.
WMAN_DL_Pilot generates modulated pilot for downlink bursts. After IFFT and cyclic prefix insertion, the $P_{4\times64}$ and P_{EVEN} are combined with downlink payload (including FCH and downlink bursts) in WMAN_DL_MuxFrame.
At last, oversampling is implemented by a transmitter filter.

4. Parameter Details
- NumberOfBurst specifies the number of active downlink bursts.
- BurstWithFEC specifies the downlink burst FEC.
- DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to the values listed in the following tagble, which is based on the specification.

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1", preamble is placed before the burst, otherwise preamble is not placed before the burst.
- PrmlTimeShift is an array parameter. Its size should be the same as NumberOfBurst, which determines the number of samples of cyclic shift delay in time for the preamble symbols.
- DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
- OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this source. For example, if OversamplingOption = Ratio 2, it means the IFFT size is 512.
- Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor (!wman-8-09-086.gif!) as follows,

  $$F_s = floor((N_{factor} \times Bandwidth)/8000) \times 8000$$

  The sampling factors are listed in the following table.

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from 0 to 1.
- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the downlink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the downlink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
- Brd_Message specifies whether the broadcast burst is inserted or not. The broadcast burst is transmitted with BPSK 1/2 after FCH burst and before the data bursts. The number of OFDM symbols in the broadcast burst is 21.
- IdleInterval specifies the time of idle interval between two consecutive frames.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.

- AutoMACHeaderSetting specifies whether the MAC_Header is generated automatically or not.
- MAC_Header specifies the MAC header of FEC-encoded burst. This parameter is only active when AutoMACHeaderSetting is set to NO.
- UL_ChannelID specifies the uplink channel ID. This parameter is used in UL-MAP.
- UCD_Count specifies the UCD count. This parameter is used in UCD.
- UL_NumberOfSS specifies the number of the uplink subscribers. This parameter is used in UL-MAP.
- UL_CID specifies the CID for the uplink subscribers. This parameter is used in UL-MAP.
- UL_DataLength specifies the data length for the uplink subscribers. This parameter is used in UL-MAP.
- UL_Rate_ID specifies the rate ID for the uplink subscribers. This parameter is used in UL-MAP.
- UL_Subchannelization specifies whether subchannelization is used or not. This parameter is used in UL-MAP.
- UL_SubchannelIndex specifies the index of subchannels for the uplink subscribers. This parameter is used in UL-MAP.
- UL_MidambleRepetition specifies the repetition of midambles for the uplink subscribers. This parameter is used in UL-MAP.

5. Samples per frame
   One WMAN downlink frame consists of Idle, long preamble, FCH, broadcast burst and multiple downlink bursts.
   The downlink long preamble consists of two consecutive OFDM symbols.
   FCH is transmitted in one OFDM symbol. The number of OFDM symbols of the ith downlink burst(!wman-8-09-088.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

   PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$ represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$ otherwise, $Prml[i] = 0$.
   So the total number of OFDM symbols $N_{totalSymbol}$ for the downlink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

   N_{Brdcst} is the number of OFDM symbols of the broadcast burst where it is equal to 21 when Brd_Message is YES and is equal to 0 when Brd_Message is NO.
   The number of samples per one OFDM symbol (!wman-8-09-096.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

   The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

   If FrameDuration is Continuous, the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

   Otherwise, if FrameDuration is set to other values (2.5 ms, 4 ms, 5 ms, 8 ms, 10 ms, 12.5 ms or 20 ms), the total samples of one downlink frame $Samples_{Frame}$

is $Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$

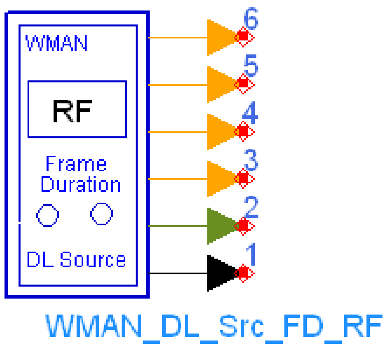
This model work on frame by frame. Each firing, $8 \times DataLength$ tokens are consumed at pin MAC_PDU, $Samples_{Frame}$ tokens are produced at pin FrameData, $200 \times \left(1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} N_{Symbol}[i]\right)$ tokens are produced at pin ForEVM, $8 \times DataLength + 80$ tokens are produced at pin PSDUFCS, and 11 tokens are produced at pin DLFP.

6. Output delay
   $30 \times 2^{oversamplingOption}$ delay is introduced by TransmitterFilter in the design WMAN_DL_SignalSrc, where the delay are equal to $(Length - 1)/2$. Length is the parameter in TransmitterFilter.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_DL_Src_FD_RF (WMAN DL Source RF with FrameDuration)



Description Downlink RF signal source with broadcast message and frame duration
Library WMAN, Signal Source
Class TSDFWMAN_DL_Src_FD_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	Source resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	3407 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	(−∞, ∞)
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
Brd_Message	Broadcast message enabled or not: NO, YES	NO		enum	
IdleInterval	Idle interval	0.0 usec	sec	real	[0, 1000)
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
DL_ChannelID	Downlink channel ID	0		int	[0, 255]
DCD_Count	DCD count	1		int	[0, 255]

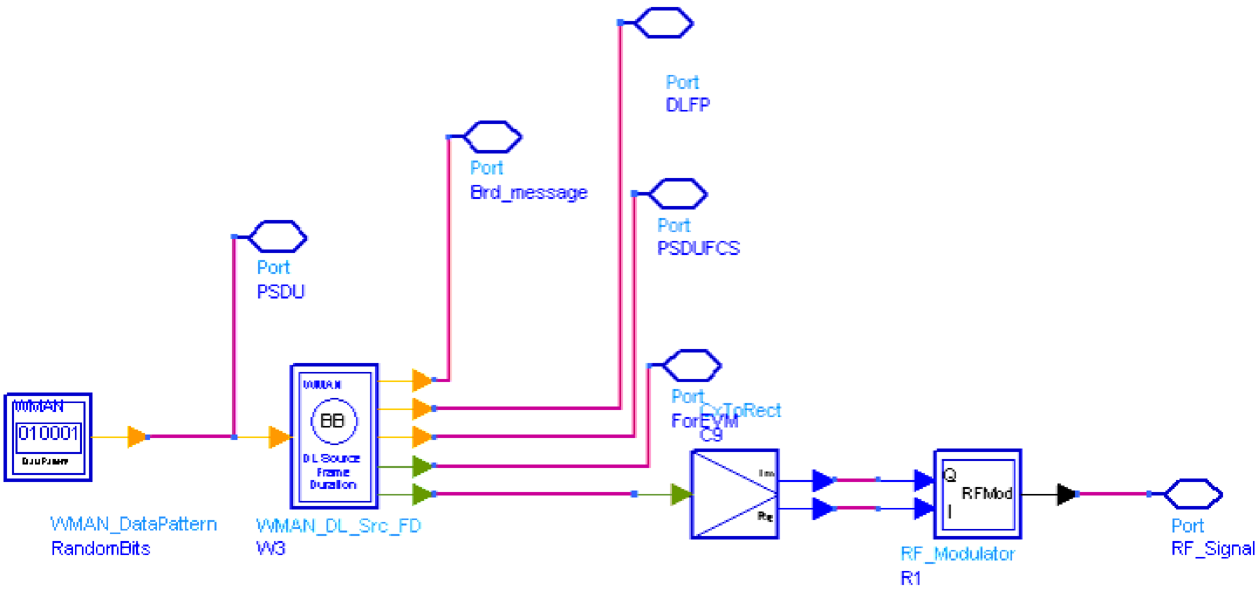
DataPattern	WMAN Data Pattern: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0, S_BPSK, S_QPSK, S_16-QAM, S_64-QAM	PN9		enum	
NumberOfBurst	Number of Burst	1		int	[1, 16]
BurstWithFEC	The number of burst with FEC	1		int	[1, 16]
CID	CID of each burst	{1}		int array	[0, 65535]
DataLength	MAC PDU payload byte length of each burst	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each burst	{1}		int array	[0, 6]
PreamblePresent	Preamble present or not	{0}		int array	{0, 1}
PrmlTimeShift	Preamble time shift of each burst	{0}		int array	[0, 255]
UL_ChannelID	Uplink channel ID	0		int	[0, 255]
UCD_Count	UCD count	1		int	[0, 255]
UL_NumberOfSS	Uplink number of subscribers	1		int	[1, 16]
UL_CID	Uplink CID	{0}		int array	[0, 65535]
UL_DataLength	Uplink MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
UL_Rate_ID	Uplink Rate ID of each subscriber	{1}		int array	[0, 6]
UL_Subchannelization	Uplink Subchannelization or not: NO, YES	NO		enum	
UL_SubchannelIndex	Uplink list of each subchannel index	{8}		int array	[1, 15] or [17, 31]
UL_MidambleRepetition	Uplink Midamble repetition of each subscriber	{0}		int array	[0, 3]

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Signal	output of RF signal	timed
2	ForEVM	output of DL multiplexed data for EVM test	complex
3	PDUFCS	output of MAC PDU data of burst with FEC	int
4	PSDU	output of PSDU bits	int
5	DLFP	output of DLFP bits	int
6	Brd_message	output of broadcast message	int

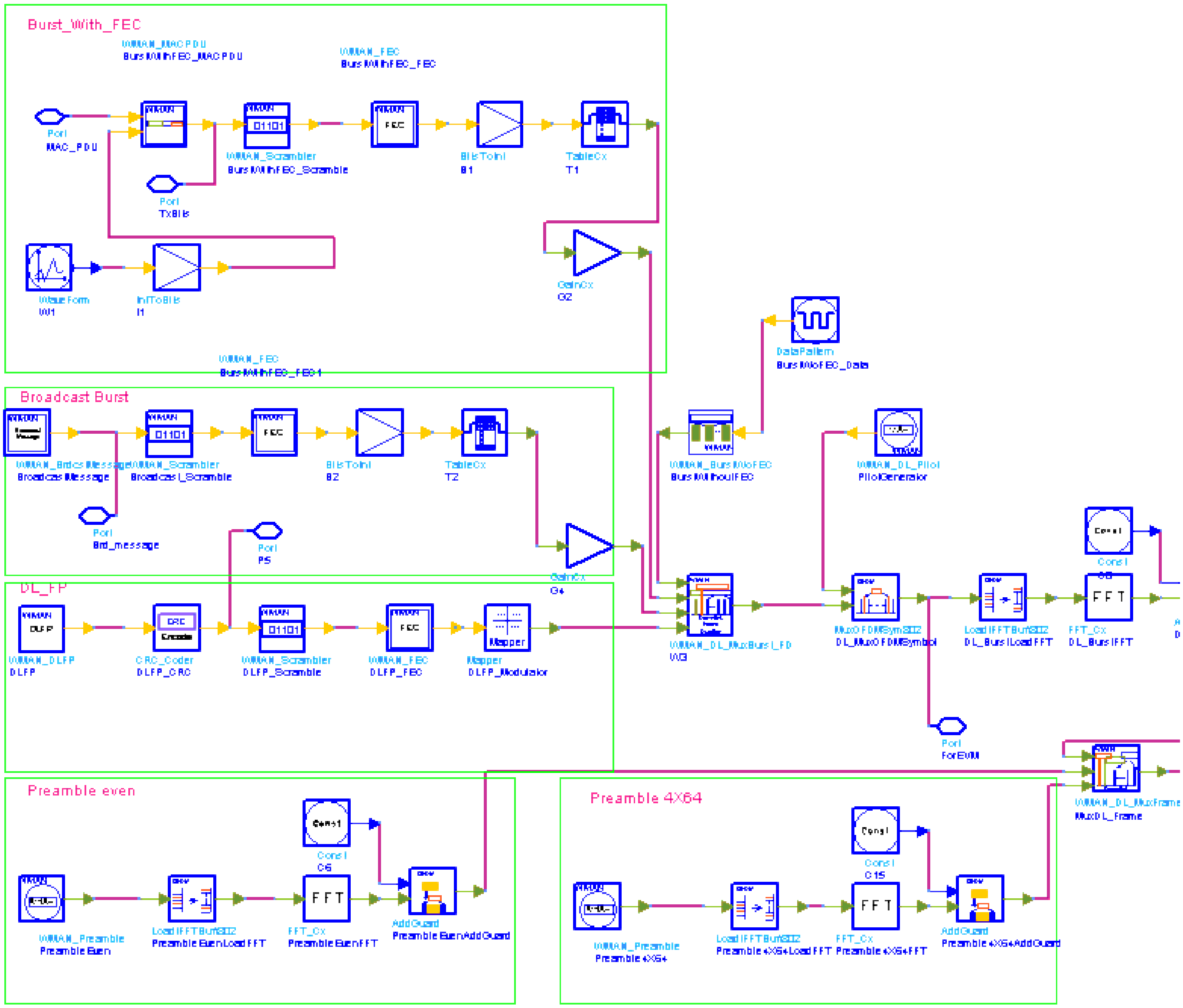
Notes/Equations

1. This subnetwork generates a WMAN Downlink subsystem RF signal. The subnetwork includes WMAN_DL_Src_FD, which generates the downlink baseband signal of WMAN Downlink subsystem, and the RF_Modulator.
   The schematic for this subnetwork is shown in WMAN_DL_Src_FD_RF Schematic.



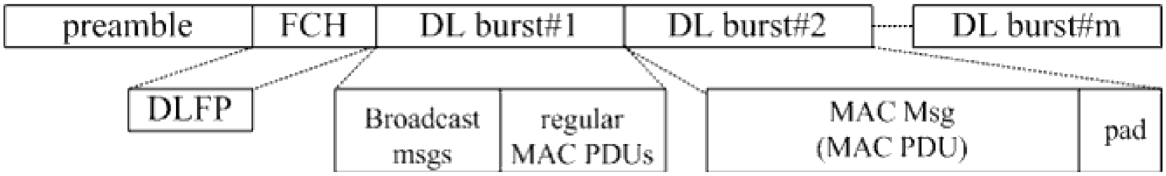
WMAN_DL_Src_FD_RF Schematic

2. The WMAN OFDM downlink baseband signal source format follows the specification. The schematic is shown in WMAN_DL_Src_FD Schematic.



WMAN_DL_Src_FD Schematic

3. Source functions are implemented as follows:
   The input of this subnetwork is MAC PDU data of the FEC-encoded burst; MAC header data is specified by MAC_Header.
   WMAN DL Frame Structure shows the downlink subframe format. It includes the long preamble, FCH, broadcast burst and one or several downlink bursts carrying MAC PDUs. The duplexing method shall be either FDD or TDD. In TDD mode, the downlink subframe occupies the first part of the frame, and the uplink subframe is in the last (second) part of the frame. If the transmission time for all the bursts does not fit the time of the downlink subframe allocated, gaps will be padded at the end of subframe. The broadcast burst always immediately follows the FCH if exist consisting of 21 consecutive OFDM symbols. One downlink subframe contains maximum 16 bursts except FCH and each burst contains only one MAC PDU. Among these bursts, only one FEC-encoded bursted is supported which is randomized, RS-CC coded and interleaved. Other bursts will be provided PN sequences as their coded source respectively.



WMAN DL Frame Structure

The downlink long preamble consists of two consecutive OFDM symbols. The first OFDM symbol uses only subcarriers the indices of which are a multiple of 4 identified as $P_{4\times64}$ and the second OFDM symbol utilizes only even subcarriers identified as P_{EVEN}. The basic sequence for one OFDM symbol time domain packet is implemented by WMAN_Preamble.
The FCH is coded in the following manner:

- WMAN_DLFP generates the DLFP, then an 8 bit Header Check Sequence is padded.
- Randomized by WMAN_Scramble with initial state 100101010000000.
- Convolutional encoded and interleaved by WMAN_FEC.
  The FEC-encoded burst is coded in the following manner:
- Add MAC header with parameter MAC_Header.
- Randomized by WMAN_Scramble.
- RS-CC encoded, punctured (by WMAN_Puncture) and interleaved by WMAN_FEC.
  After encoding, the FCH and coded burst will be mapped to the constellation respectively.
  Other bursts without FEC, will be provided PN sequence as their coded bits and mapped to the constellation according to their Rate_ID by WMAN_BurstWoFEC.
  The FCH, FEC-encoded burst are concatenated with non-coded bursts by WMAN_DL_MuxBurst.
  WMAN_DL_Pilot generates modulated pilot for downlink bursts. After IFFT and cyclic prefix insertion, the $P_{4\times64}$ and P_{EVEN}
  are combined with downlink payload (including FCH and downlink bursts) in WMAN_DL_MuxFrame.
  At last, oversampling is implemented by a transmitter filter.

4. 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. The output rms voltage is given by sqrt(2×ROut×Power).

- NumberOfBurst specifies the number of active downlink bursts.
- BurstWithFEC specifies the downlink burst FEC.
- DataLength is the array of each DL burst's MAC PDU payload byte length. Rate_ID is the array of each DL burst's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID (R) determine the number of data symbols per DL burst. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) are set according to *Mandatory Channel Coding per Modulation*, which is based on the specification.

Rate_ID	**Modulation**	**Uncoded block size(bytes)**	**Coded block size(bytes)**	**Overall coding rate**	**RS code**	**CC code rate**
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- PreamblePresent is the array of each DL burst's preamble present. It determines whether preamble is placed before the burst or not. If "1", preamble is placed before the burst, otherwise preamble is not placed before the burst.
- PrmlTimeShift is an array parameter. Its size should be the same as NumberOfBurst, which determines the number of samples of cyclic shift delay in time for the preamble symbols.
- DIUC, FrameNumber, BSID are used to generate the scrambler DL initialization vector.
- OversamplingOption indicates the oversampling ratio of transmission signal. There are six oversampling ratios (1, 2, 4, 8, 16, 32) to support in this source. For example, if OversamplingOption = Ratio 2, it means the IFFT size is 512.
- Bandwidth determines the nominal channel bandwidth. The sampling frequency (Fs) implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor(!wman-8-10-121.gif!) as follows:

$$F_s = floor((N_{factor} \times Bandwidth)/8000) \times 8000$$

The sampling factors are listed in *Sampling Factor Requirement*.

sampling factor n	**bandwidth**
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix (G) specifies the ratio of cyclic prefix time to "useful" time, whose range is from 0 to 1.
- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the

DL_Ratio parameter in one frame.

- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the downlink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the downlink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
- Brd_Message specifies whether the broadcast burst is inserted or not. The broadcast burst is transmitted with BPSK 1/2 after FCH burst and before the data bursts. The number of OFDM symbols in the broadcast burst is 21.
- IdleInterval specifies the time of idle interval between two consecutive frames.
- UL_ChannelID specifies the uplink channel ID. This parameter is used in UL-MAP.
- UCD_Count specifies the UCD count. This parameter is used in UCD.
- UL_NumberOfSS specifies the number of the uplink subscribers. This parameter is used in UL-MAP.
- UL_CID specifies the CID for the uplink subscribers. This parameter is used in UL-MAP.
- UL_DataLength specifies the data length for the uplink subscribers. This parameter is used in UL-MAP.
- UL_Rate_ID specifies the rate ID for the uplink subscribers. This parameter is used in UL-MAP.
- UL_Subchannelization specifies whether subchannelization is used or not. This parameter is used in UL-MAP.
- UL_SubchannelIndex specifies the index of subchannels for the uplink subscribers. This parameter is used in UL-MAP.
- UL_MidambleRepetition specifies the repetition of midambles for the uplink subscribers. This parameter is used in UL-MAP.

5. Key parameter calculation:
One WMAN downlink frame consists of Idle, long preamble, broadcast burst, FCH, broadcast burst and multiple downlink bursts.
The downlink long preamble consists of two consecutive OFDM symbols.
FCH is transmitted in one OFDM symbol. The number of OFDM symbols of ith downlink burst (!wman-8-10-123.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

PreamblePresent indicates whether the downlink burst starts with a short preamble or not. Let $Prml[i]$
represent the number of OFDM symbol per each preamble present. If preamblePresent is set to 1 in the ith burst, then $Prml[i] = 1$, otherwise, $Prml[i] = 0$.
So the total number of OFDM symbols $N_{totalSymbol}$
for the downlink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 1 + N_{Brdcst} + \sum_{i=1}^{NumberOfBurst} (N_{Symbol}[i] + Prml[i])$$

N_{Brdcst}
is the number of OFDM symbols of the broadcast burst where it is equal to 21 when Brd_Message is YES and is equal to 0 when Brd_Message is NO.
The number of samples per one OFDM symbol (!wman-8-10-131.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times 2^{OversamplingOption} \times F_s$$

If FrameDuration is Continuous, the total samples of one downlink frame $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

Otherwise, if FrameDuration is set to other values (2.5 ms, 4 ms, 5 ms, 8 ms, 10 ms, 12.5 ms or 20 ms), the total samples of one downlink frame $Samples_{Frame}$ is

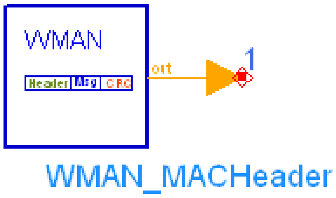
$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

6. Output delay
   $30 \times 2^{oversamplingOption}$ delay is introduced by TransmitterFilter in the design WMAN_DL_SignalSrc, where the delay are equal to $(Length - 1)/2$. Length is the parameter in TransmitterFilter.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_MACHeader (WMAN MAC Header)



Description MAC header generator
Library WMAN, Signal Source
Class SDFWMAN_MACHeader

Parameters

Name	Description	Default	Type	Range
DataLength	MAC PDU payload byte length	100	int	[1, 16383]
CID	CID	0	int	[0, 65535]

Pin Outputs

Pin	Name	Description	Signal Type
1	out	MACHeader	int

Notes/Equations

1. This subnetwork is used to generate MAC Header.
2. Each firing 6 × 8 bit tokens are produced at Pin MACHeader.
3. Two MAC Header formats are defined. The first is the generic MAC header that begins each MAC PDU containing either MAC management messages or CS data. The second is the bandwidth request header used to request additional bandwidth. The single-bit Header Type (HT) field distinguishes the generic MAC header and bandwidth request header formats. The HT field shall be set to zero for the Generic Header and to one for a bandwidth request header. In this module, HT is set to zero (*Generic MAC Header*).

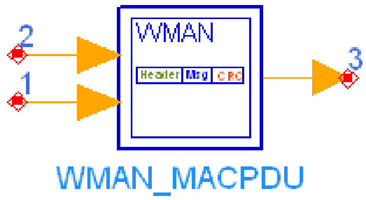
Generic MAC Header

Syntax	Size	Notes
HT	1 bit	Header Type. Shall be set to zero in Generic MAC header.
EC	1 bit	Encryption Control
Type	6 bit	This field indicates the subheaders and special payload types present in the message payload. Set zero here.
reserved	1 bit	0
CI	1 bit	CRC Indicator
EKS	2 bit	Encryption Key Sequence
reserved	1 bit	0
LEN	11 bit	Length. The length in bytes of the MAC PDU including the MAC header and the CRC if present. The length in bytes of payload is DataLength+10.
CID	16 bit	Connection identifier
HCS	8 bit	Header Check Sequence

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_MACPDU (WMAN MAC PDU)



Description MAC PDU generator
Library WMAN, Signal Source
Class SDFWMAN_MACPDU

Parameters

Name	Description	Default	Type	Range
DataLength	MAC message payload byte length	100	int	[1, 4095]
CID	connection identifier	0	int	[0, 65535]
AutoMACHeaderSetting	: NO, YES	NO	enum	

Pin Inputs

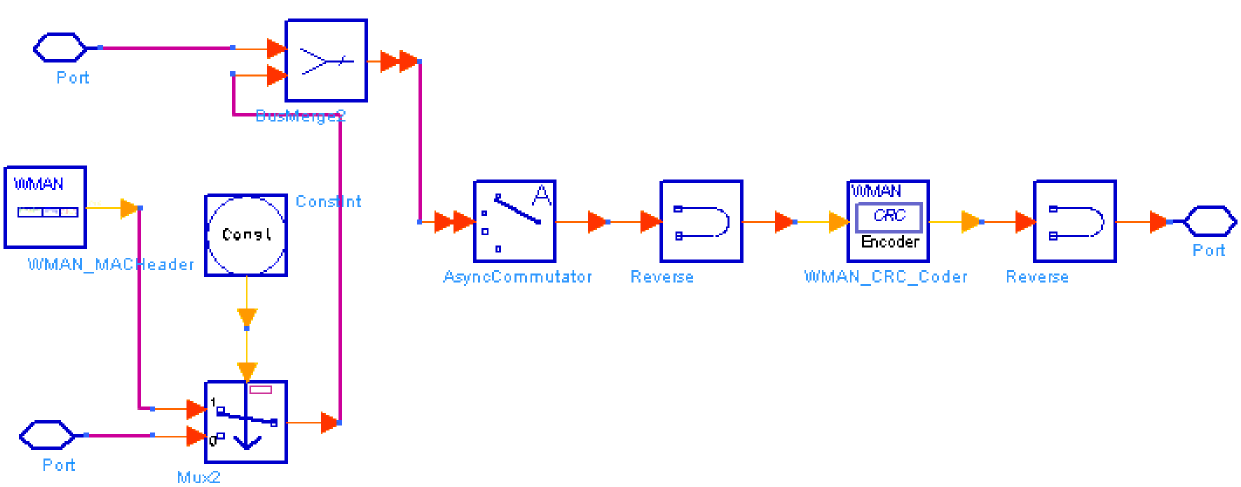
Pin	Name	Description	Signal Type
1	header	MAC header	int
2	message	MAC message payload	int

Pin Outputs

Pin	Name	Description	Signal Type
3	MACPDU	MAC PDU	int

Notes/Equations

1. This subnetwork is used to generate MAC PDU.
2. Each firing 6×8 bit tokens are consumed at Pin header; DataLength×8 bit tokens are consumed at Pin data; (DataLength+10)×8 bit tokens are produced at Pin out.
3. The schematic of this subnetwork is shown in WMAN_MACPDU Schematic.



WMAN_MACPDU Schematic

4. The structure of MAC PDU is shown in MAC PDU. Each MAC PDU contains 6 bytes MAC Header, DataLength[SSWithFEC] bytes MAC PDU payload and 4 bytes CRC.
   The parameter AutoMACHeaderSetting controls to generate 6 bytes MAC header. If AutoMACHeaderSetting=YES, the 6 bytes MAC header is generated by WMAN_MACHeader, otherwise, the 6 bytes MAC header is input from pin header.

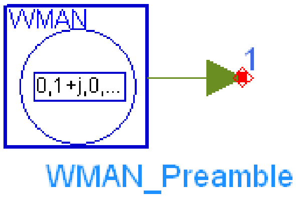
MAC Header 6 bytes	MAC msg payload (optional)	CRC (optional)

MAC PDU

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_Preamble (WMAN Preamble Generator)



Description Preamble generator
Library WMAN, Signal Source
Class SDFWMAN_Preamble

Parameters

Name	Description	Default	Type	Range
PreambleType	Preamble type option: P_Even, P_Odd, P_4X64	P_Even	enum	
Subchannelization	Indication of subchannelization: NO, YES	NO	enum	
SubchannelIndex	list of each subchannel index	{8}	int array	[1, 15] or [17, 31]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	Preamble sequences	complex

Notes/Equations

1. This model is used to generate the frequency domain training sequence in order to obtain one OFDM symbol defined for preamble.
   If $Subchannelization = NO$, each firing, 200 output tokens are produced. The parameter SubchannelIndex is unused and the output sequence is decided by the parameter PreambleType.
   If $PreambleType = P\_Even$, the frequency sequence for the 2 times 128 sequence PEVEN is defined by:
   $$P_{EVEN}(k) = \begin{cases} \sqrt{2} \times P_{ALL}(k) & k_{mod2} = 0 \\ 0 & k_{mod2} \neq 0 \end{cases}$$
   If $PreambleType = P\_4 \times 64$, the frequency sequence for the 4 times 64 sequence $P_{4 \times 64}$ is defined by:
   $$P_{4 \times 64}(k) = \begin{cases} \sqrt{2} \times \sqrt{2} \times conj(P_{ALL}(k)) & k_{mod4} = 0 \\ 0 & k_{mod4} \neq 0 \end{cases}$$
   If $PreambleType = P\_Odd$, the frequency sequence for the 2 times 128 sequence PODDis defined by:
   $$P_{ODD}(k) = \begin{cases} 0 & k_{mod2} = 0 \\ \sqrt{2} \times P_{ALL}(k) & k_{mod2} \neq 0 \end{cases}$$
   The sequence PALL is defined as follows:
   PALL(-100:100) = {1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j,-1-j, 1-j, -1+j, 1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j, -1-j, 1-j, -1+j, 1-j, 1-j, -1-j, 1+j, 1-j, 1-j, -1+j, 1-j, 1-j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, 1+j, -1-j,

-1-j, 1-j, -1+j, 1+j, 1+j, 1-j, -1+j, 1+j, 1+j, -1-j, 1+j, 1+j, 1+j, -1+j, 1-j, -1+j, -1+j, 1-j, -1+j, 1-j, 1-j,1+j, -1-j, -1-j, -1-j, -1+j, 1-j, -1-j, -1-j, 1+j, -1-j, -1-j, -1-j, 1-j, -1+j, 1-j, 1-j, -1+j, 1-j, -1+j,-1+j, -1-j, 1+j, 0, -1-j, 1+j, -1+j, -1+j, -1-j, 1+j, 1+j, 1+j, -1-j, 1+j, 1-j, 1-j, 1-j, -1+j, -1+j, -1+j, -1+j, 1-j, -1-j, -1-j, -1+j, 1-j, 1+j, 1+j, -1+j, 1-j, 1-j, 1-j, -1+j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, -1+j, -1+j, 1+j, -1-j, 1-j, 1-j, 1+j, -1-j, -1-j, -1-j, 1+j, -1-j, -1+j, -1+j, -1+j, 1-j, 1-j, 1-j, 1-j, -1+j, 1+j, 1+j, -1-j, 1+j, -1+j, -1+j, -1-j, 1+j, 1+j, 1+j, -1-j, 1+j, 1-j, 1-j, 1-j, -1+j, -1+j, -1+j, -1+j, 1-j, -1-j, -1-j, 1-j, -1+j, -1-j, -1-j, 1-j, -1+j, -1+j, -1+j, 1-j, -1+j,1+j, 1+j, 1+j, -1-j, -1-j, -1-j, -1-j, 1+j, 1-j, 1-j}

If $Subchannelization = YES$, each firing, $N_{Subchannel} \times 200$ output tokens are produced, corresponding to the NSubchannel subchannels indexed by the parameter SubchannelIndex orderly, where the NSubchannel is the number of subchannels, i.e. the size of the parameter SubchannelIndex. Every 200 output tokens corresponding to one Subchannel is defined by PSUB. Preamble subcarriers that do not fall within the allocated subchannel shall be set to zero.

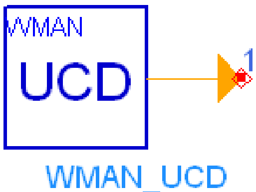
The sequence PSUB is defined as follows:

PSUB(-100:100) = {1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, 1+j, 1-j, 1+j,1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, -1-j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, 0,1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, 1-j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, -1-j, -1-j, 1+j, -1-j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, -1+j, 1+j, 1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j, -1-j, -1-j, 1+j, -1-j, 1-j, -1-j, -1-j, -1-j, 1+j, 1+j, -1+j, 1+j, -1+j, 1+j, 1-j, 1+j, 1+j, -1-j, -1-j, 1+j, 1-j, 1+j, -1-j, 1+j, 1+j, 1+j, 1+j, -1-j, 1+j, -1+j, 1+j, 1+j, 1+j, -1-j, -1-j, 1-j, -1-j, -1-j, -1-j, -1+j, -1-j, -1-j, 1+j, 1+j, -1-j, -1+j, -1-j, 1+j, -1-j, -1-j}

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UCD (WMAN UCD)



Description UCD generator
Library WMAN, Signal Source
Class SDFWMAN_UCD

Parameters

Name	Description	Default	Type	Range
UCD_Count	UCD count	0	int	[0, 255]
RangingBackoffStart	Ranging backoff start	1	int	[0, 255]
RangingBackoffEnd	Ranging backoff end	7	int	[0, 255]
RequestBackoffStart	Request backoff start	1	int	[0, 255]
RequestBackoffEnd	Request backoff end	7	int	[0, 255]
AutoMACHeaderSetting	Auto MAC Header Setting or not: NO, YES	NO	enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}	int array	[0, 255]

Pin Outputs

Pin	Name	Description	Signal Type
1	out	UCD	int

Notes/Equations

1. This model is used to generate Uplink Channel Descriptor (UCD) message for WMAN OFDM system. An UCD shall be transmitted by the BS to define the characteristics of a uplink physical channel. In this UCD message format, UIUC from 5 to 11 are defined with different burst profiles (Rate ID), shown in *OFDM UIUC Values*.

   OFDM UIUC Values

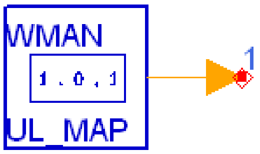
UIUC	Rate ID
5	0 (BPSK 1/2)
6	1 (QPSK 1/2)
7	2 (QPSK 3/4)
8	3 (16-QAM 1/2)
9	4 (16-QAM 3/4)
10	5 (64-QAM 2/3)
11	6 (64-QAM 3/4)

2. Each firing, $(MACHeader + UCDHeaderLength + UCDIELength \times UCDIENumber) \cdot 8$ tokens are produced. MACHeader is 6. UCDHeaderLength is 6. UCDIELength is 6. UCDIENumber is 7.
3. Note that UCD of the model generated does not include HCS, which will be added later.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_UL_MAP (WMAN Uplink MAP)



WMAN_UL_MAP

Description Uplink MAP generator
Library WMAN, Signal Source
Class SDFWMAN_UL_MAP
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}	int array	[0, 3]
UL_ChannelID	Uplink channel ID	0	int	[0, 255]
UCD_Count	UCD count	0	int	[0, 255]
Allocation_StartTime	Allocation of start time	0	int	[0, ∞]
CID	CID	{0}	int array	[0, 65535]
UIUC	UIUC	{0}	int array	[0, 15]
AutoMACHeaderSetting	Auto MAC deader setting or not: NO, YES	NO	enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}	int array	[0, 255]

Pin Outputs

Pin	Name	Description	Signal Type
1	out	UL_MAP	int

Notes/Equations

1. This model is used to generate UL-MAP IE for WMAN OFDM system. UL-MAP is a MAC Layer Message that tells a subscriber station (SS) about the construction of the uplink OFDM signal. UL-MAP defines the entire access for a scheduling interval.
2. Each firing, $(MACHeader + ULMAPHeaderLength + ULMAPIELength \times ULMAPIENumber) \cdot 8$ tokens are produced.
   MACHeader is 6.
   ULMAPHeaderLength is 7.
   ULMAPIELength is 6.

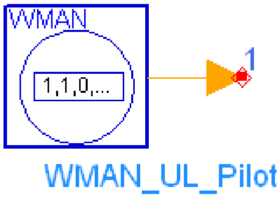
ULMAPIENumber is $NumberOfSS + 1$ which are the End MAP IE and the data bursts.

3. When AutoMACHeaderSetting is set to YES, the MAC header is calculated automatically. Otherwise the values in the parameter MAC_Header are used.
4. Note that UL-MAP of the model generated does not include HCS, which will be added later.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_UL_Pilot (WMAN Uplink Pilot Generator)



Description Uplink pilot generator
Library WMAN, Signal Source
Class SDFWMAN_UL_Pilot
Derived From WMAN_UL_Base

Parameters

Name	Description	Default	Type	Range
NumberOfSS	Number of subscribers	1	int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}	int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}	int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO	enum	
SubchannelIndex	List of each subchannel index	{8}	int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}	int array	[0, 3]
PilotPN_Phase	the Pilot PN phase	0	int	[0, 2047]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	a sequence for the uplink pilot modulation	int

Notes/Equations

1. This model is used to generate the sequences used for pilot modulation in OFDM uplink symbols following the preamble.
2. Each firing,
   - For non-subchannelization mode, $\sum_{i=1}^{NumberOfSS} N_{Symbol}[i]$ tokens are produced,
     where, NSymbol[i] is the number of OFDM symbols of the ith SS and is calculated as follows:
     $N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$
     the UncodedBlockSize[R[i]] is decided by Rata_ID(i), as defined in *Data-Rate-Dependent Parameters*.

Data-Rate-Dependent Parameters

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- For subchannelization mode, NMaxDataSym tokens are produced, where NMaxDataSym is the maximum of NSymbol[i]. NSymbol[i] can be calculated as follows:

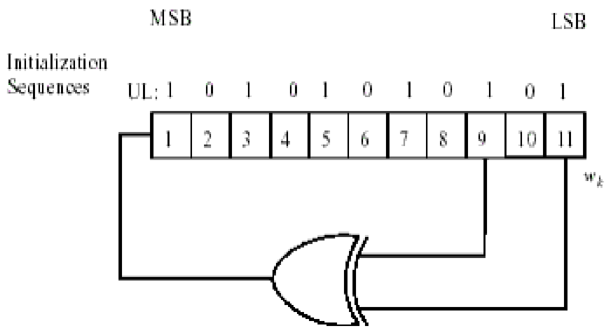
$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

  Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in *Number of Subchannels*.

  Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

3. The pseudo-random binary sequence (PRBS) generator is shown in PRBS for Pilot Modulation, for which the polynomial is $X^{11} + X^9 + 1$. The output value used for the pilot modulation for OFDM symbol k is derived by $1 - 2w_k$. The index k represents the symbol index relative to the beginning of the burst and the first symbol of the preamble is denoted by k=0.



PRBS for Pilot Modulation

MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation.
Midamble Repetition Interval shows the meaning each MidambleRepetition value corresponds to.

Midamble Repetition Interval

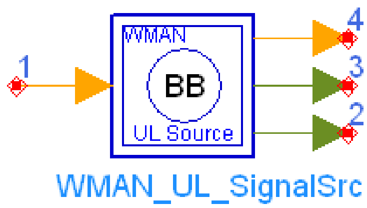
Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

If one value in the array of MidamblePresent is set to nonzero, then the present midambles in this burst should be counted when the data symbols is indexed.
PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_SignalSrc (WMAN Uplink Signal Source)



Description Uplink baseband signal source
Library WMAN, Signal Source
Class SDFWMAN_UL_SignalSrc

Parameters

Name	Description	Default	Unit	Type	Range
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
TimeOffset	Time offset of each subscriber	{0 usec}	sec	real array	[0, IdleInterval]
UIUC	UIUC of each subscriber	{1}		int	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
PilotPN_Phase	Pilot phase	0		int	[0, 4095]
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}		int array	[0, 255]
Power	Power of each subscriber	{ 0.01 W }	W	real array	(0, ∞)

Pin Inputs

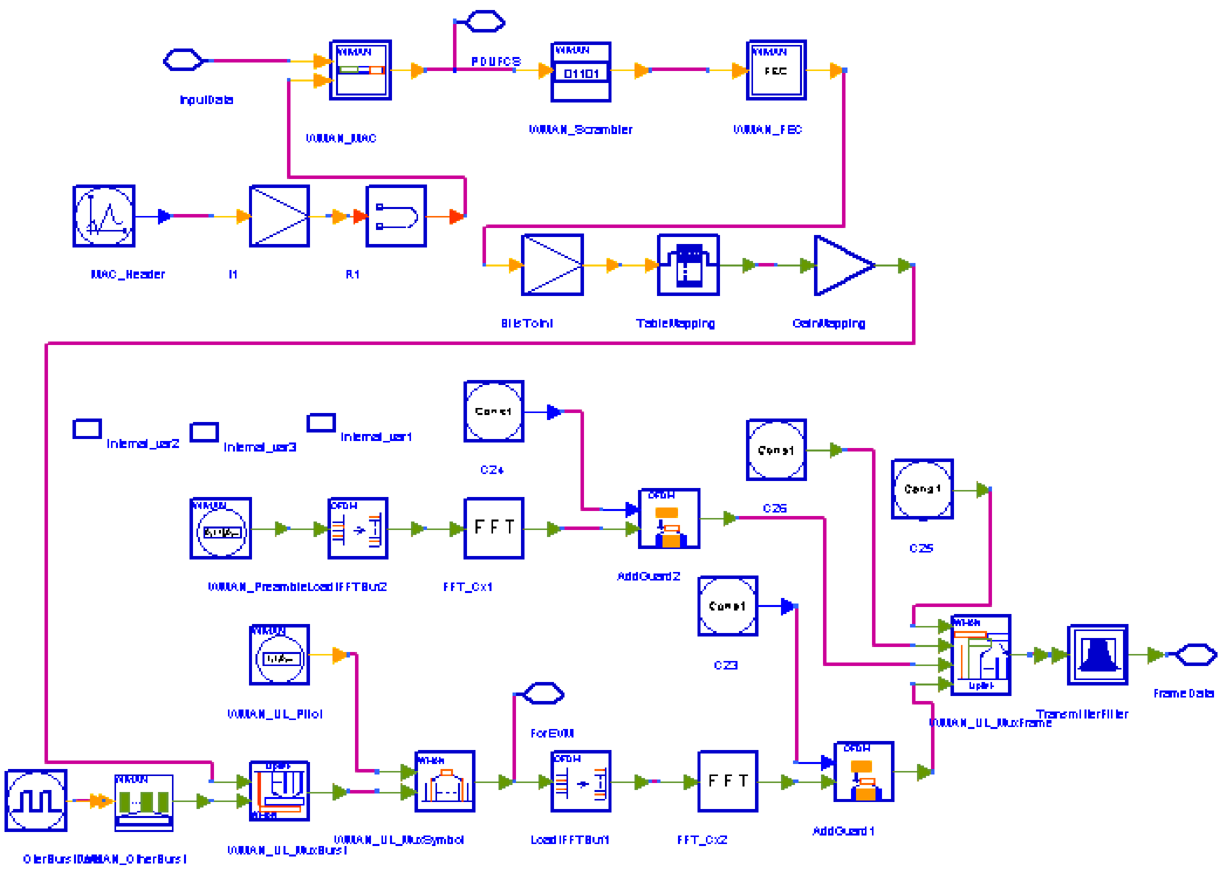
Pin	Name	Description	Signal Type
1	InputData	input of raw data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	FrameData	output of uplink Subframe	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int

Notes/Equations

1. This subnetwork is used to generate a WMAN OFDM Uplink baseband signal. The schematic for this subnetwork is shown in WMAN_UL_SignalSrc Schematic.



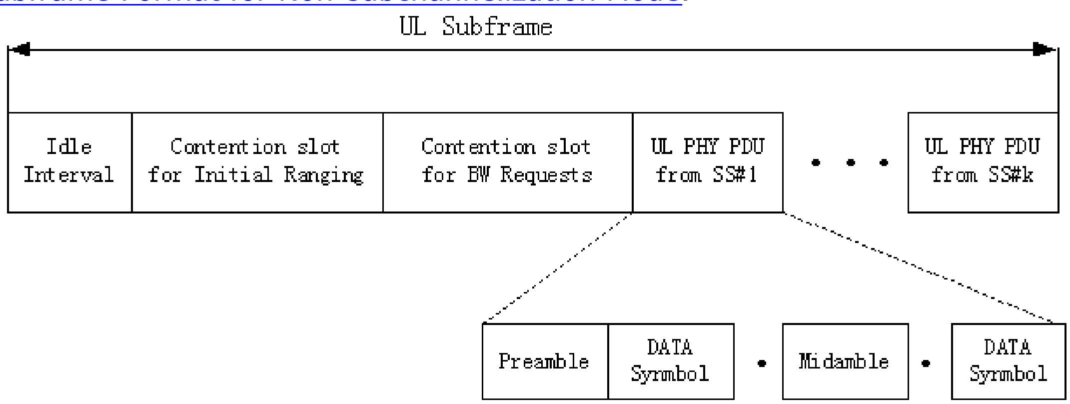
WMAN_UL_SignalSrc Schematic

1. WMAN OFDM Uplink baseband signal source is implemented according to the specification. Non-subchannelization and subchannelization modes are supported. The maximum number of SSs supported is 16. For non-subchannelization mode, the maximum number of bursts supported is 16. For subchannelization mode, only one burst is supported, where maximum 16 SSs can be allocated, while each SS uses one different subchannel.
   For the SS with FEC-encoded, one PHY MAC PDU is contained. The MAC PDU payload data of the SS with FEC-encoded are input at pin InputData. The MAC PDU format is shown in MAC PDU Format. Each MAC PDU contains 6 bytes MAC Header, DataLength[SSWithFEC] bytes MAC PDU payload, and 4 bytes CRC. The total byte length of MAC PUD is DataLength[SSWithFEC]+10. The MAC Header and CRC are padded in WMAN_MACPDU.

MAC Header (6 Bytes)	MAC PDU Payload (DataLength bytes)	CRC (4 Bytes)

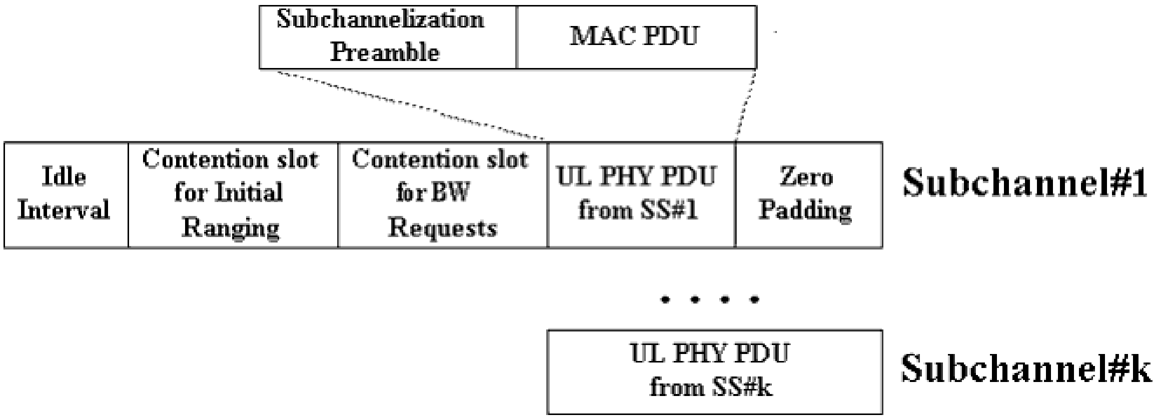
MAC PDU Format

After MAC Header and CRC are padded, the MAC PDU is put into the randomizer (WMAN_Scrambler). Then a 0x00 tail byte is added to the end of the randomized block, which is reserved by RS-CC and CC. To form an integer number of OFDM symbols, unused bytes in the burst payload may be padded by the bytes 0xFF.
The data after padded will be encoded by RS-CC or CC with a specified rate corresponding to the Rate_ID[SSWithFEC] which is done in WMAN_FEC. Then the signal after passing through the puncturer, intelever and mapper will be combined with other SS's signal in WMAN_UL_MuxBurst. The puncturer and intelever are also in WMAN_FEC. The other SS's signal data are generated in WMAN_BurstWoFEC. WMAN_UL_MuxOFDMSym is used to multiplex data subcarriers and pilot subcarriers, while the pilot subcarriers are produced in WMAN_UL_Pilot. Then after IFFT transfer, the complete uplink subframe is produced in WMAN_UL_MuxFrame.
For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-subchannelization Mode.



Uplink Subframe Format for Non-subchannelization Mode

A complete Uplink subframe is started with an idle interval, followed by contention slot for Initial Ranging and contention slot for BW Requests. Then comes each SS's UL PHY PDU in order, which includes the short preamble, data OFDM symbols and midambles. Each SS holds a time slot.
For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Subchannelization Mode.



Uplink Subframe Format for Subchannelization Mode

For subchannelization mode, each SS transmits signals simultaneously, using different subchannels. The SSs shall be time-aligned. The time duration of uplink subframe is determined by the longest time duration among all the SSs. consequently for other SSs having less time duration, zeros will be padded at the end.

2. Parameter Details
   - NumberOfSS specifies the number of active subscribers (SS).
   - SSWithFEC specifies the SS which goes through FEC encoding and decoding.
   - DataLength is the array of each SS's MAC PDU payload byte length.Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to *Mandatory Channel Coding per Modulation*, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

   - Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
   - SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
   - MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. *Midamble repetition interval* shows the meaning each MidambleRepetition value corresponds to,

Midamble repetition interval

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

- UIUC, FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- MAC_Header specifies the 6 byte data inserted in MAC Header.
- OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
- Bandwidth is the nominal channel bandwidth. The sampling frequency implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows:
  $$F_s = floor((n \times Bandwidth)/8000) \times 8000$$
  The sampling factors are listed in *Sampling Factor Requirements*.

Sampling Factor Requirements

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.
- PrmlTimeShift indicates the number of samples of cyclic shift which are delayed in time in the preamble and midamble symbols.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- TimeOffset is the array of each SS's time offset arrived at BS. 0 means the SS's signal arrives at BS exactly when scheduled. Other values can be used to introduce a time offset to simulate arrival differences between different SS transmissions. Note that the actual time offset delay of each SS is the value in TimeOffset minus the last SS's time offset.
- Power is the array of each SS's transmitting power. In non-subchannelization mode, the first SS's output voltage is adjusted to be 1, by multiplying signal amplitude with Gain, where Gain is defined as:
  $$Gain = 256 \times 2^{OversamplingOption} / (\sqrt{200})$$
  For other SS, the ith SS's output voltage is adjusted aligned with the first SS's by multiplying signal amplitude with Gain[i] respectively, where Gain[i] is defined as:
  $$Gain[i] = Gain[1] \times \sqrt{(Power[i])/(Power[1])}$$
  Here Power[1] is the first SS's Power.
  In subchannelization mode, the first SS's output voltage is adjusted to be 1, while other SSs' output voltages are adjusted according to the ratio of the number of subcarriers the SSs contain to the number of subcarriers the first SS contains. Note that only the first value in the array of Power is used to adjust the first SS's output voltage, and other values in the array of Power are ignored.

3. Output Pin Delay Adjustment
   Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
   The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink.
   For non-subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for

Initial Ranging and contention slot for BW, and multiple uplink bursts. Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively. Each uplink burst consists of one short preamble, data symbols and midambles. The short preamble consists of one OFDM symbols.
The number of OFDM data symbols of ith uplink SS(!wman-8-18-179.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst,
if $MidambleRepetition[i]$ is not zero $Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$
else
$Midamble[i] = 0$

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol (!wman-8-18-187.gif!) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where, G is the CyclicPrefix.
The samples of IdleInterval(!wman-8-18-189.gif!) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s$$

So, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

For subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS(!wman-8-18-193.gif!) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$

Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in *Number of Subchannels*.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

So, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

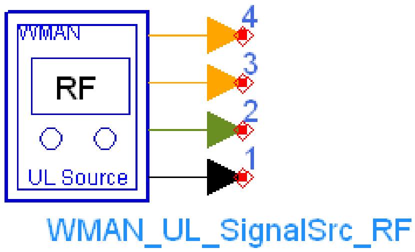
In the source, $30 \times 2^{oversamplingOption}$ delay is introduced by the transmitter filter in the design WMAN_UL_SignalSrc, where the delay is equal to $(Length - 1)/2$. Length is the parameter in the transmitter filter.

References

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_SignalSrc_RF (WMAN Uplink Signal Source RF)



Description Uplink RF signal source
Library WMAN, Signal Source
Class TSDFWMAN_UL_SignalSrc_RF

Parameters

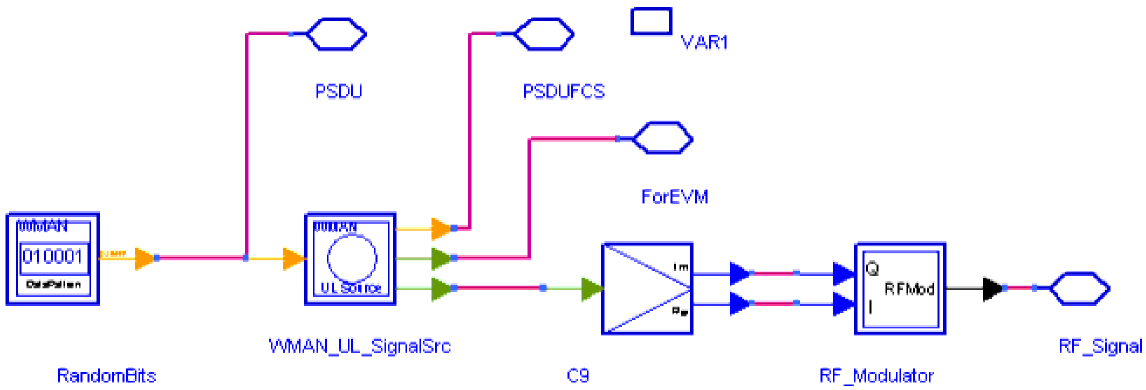
Name	Description	Default	Unit	Type	Range
ROut	Source resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	3407 MHz	Hz	real	(0, ∞)
Power	Power of each subscriber	{ 0.01 W }	W	real array	(0, ∞)
MirrorSpectrum	Indication of mirror spectrum about 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	(−∞, ∞)
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 4095]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
TimeOffset	Time offset of each subscriber	{0 usec}	sec	real array	[0, IdleInterval]
UIUC	UIUC of each subscriber	{1}		int	[0, 15]
FrameNumber	Frame Number	0		int	[0, 15]
BSID	BS ID	0		int	[0, 15]
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000]
PilotPN_Phase	Pilot phase	0		int	[0, 4095]
DataPattern	WMAN Data Pattern: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0, S_BPSK, S_QPSK, S_16-QAM, S_64-QAM	PN9		enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}		int array	[0, 255]

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Signal	output of RF signal	timed
2	ForEVM	output of Modulated data of all bursts for EVM	complex
3	PDUFCS	output of MAC PDU data of burst with FEC	int
4	PSDU	output of PSDU bits	int

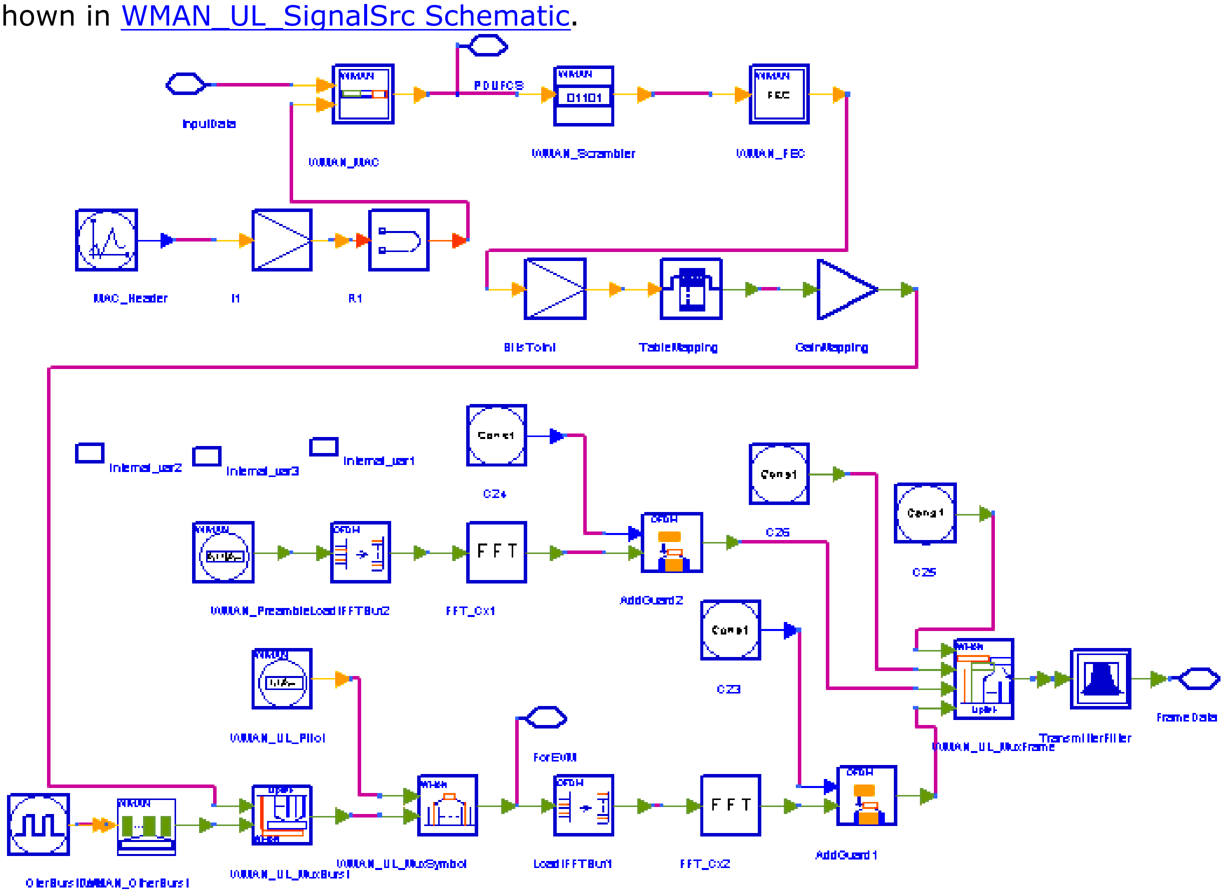
Notes/Equations

1. This subnetwork is used to integrates an RF modulator with the baseband signal source. The WMAN OFDM uplink baseband signal is fed into the RF modulator. The RF signal is timed signal after RF modulation.
   The schematic for this subnetwork is shown in WMAN_UL_SignalSrc_RF Schematic.



WMAN_UL_SignalSrc_RF Schematic

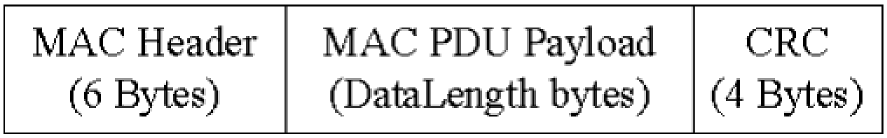
2. The WMAN OFDM uplink baseband signal source format follows the specification. The schematic is shown in WMAN_UL_SignalSrc Schematic.



WMAN_UL_SignalSrc Schematic

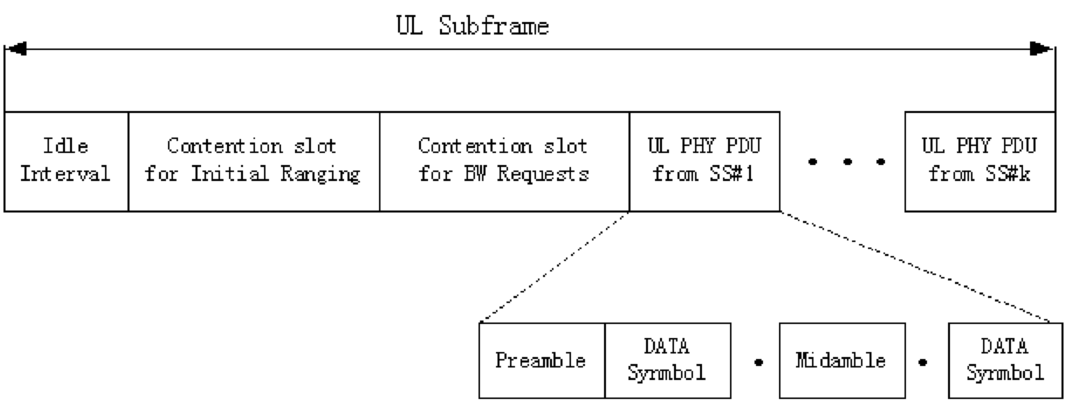
3. WMAN OFDM Uplink baseband signal source is implemented according to the specification. Non-

subchannelization and subchannelization modes are supported. The maximum number of SSs supported is 16. For non-subchannelization mode, the maximum number of bursts supported is 16. For subchannelization mode, only one burst is supported, where maximum 16 SSs can be allocated, while each SS uses one different subchannel.
For the SS with FEC-encoded, one PHY MAC PDU is contained. The MAC PDU payload data of the SS with FEC-encoded are generated in WMAN_DataPattern. The MAC PDU format is shown in MAC PDU Format. Each MAC PDU contains 6 bytes MAC Header, DataLength[SSWithFEC] bytes MAC PDU payload, and 4 bytes CRC. The total byte length of MAC PUD is DataLength[SSWithFEC]+10. The MAC Header and CRC are padded in WMAN_MACPDU.



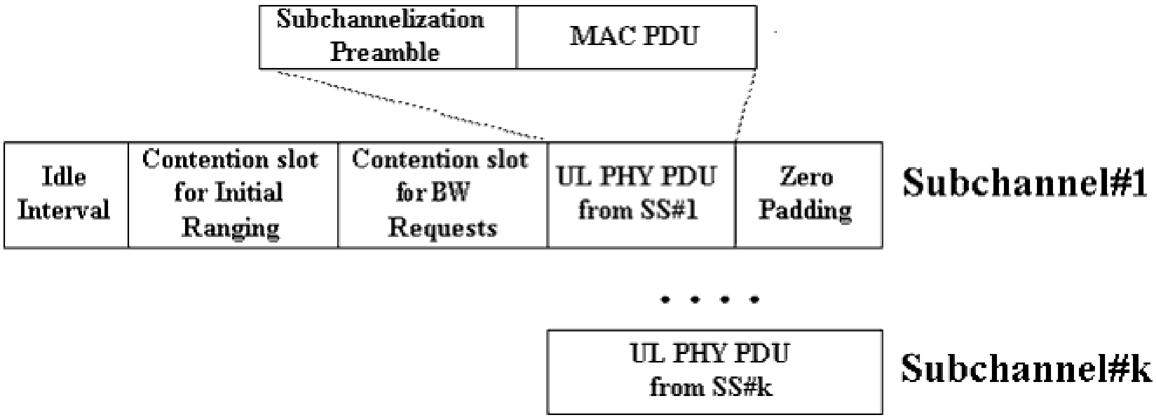
MAC PDU Format

After MAC Header and CRC are padded, the MAC PDU is put into the randomizer (WMAN_Scrambler). Then a 0x00 tail byte is added to the end of the randomized block, which is reserved by RS-CC and CC. To form an integer number of OFDM symbols, unused bytes in the burst payload may be padded by the bytes 0xFF.
The data after padded will be encoded by RS-CC or CC with a specified rate corresponding to the Rate_ID[SSWithFEC] which is done in WMAN_FEC. Then the signal after passing through the puncturer, intelever and mapper will be combined with other SS's signal in WMAN_UL_MuxBurst. The puncturer and intelever are also in WMAN_FEC. The other SS's signal data are generated in WMAN_BurstWoFEC. WMAN_UL_MuxOFDMSym is used to multiplex data subcarriers and pilot subcarriers, while the pilot subcarriers are produced in WMAN_UL_Pilot. Then after IFFT transfer, the complete uplink subframe is produced in WMAN_UL_MuxFrame.
For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-subchannelization Mode.



Uplink Subframe Format for Non-subchannelization Mode

A complete Uplink subframe is started with an idle interval, followed by contention slot for Initial Ranging and contention slot for BW Requests. Then comes each SS's UL PHY PDU in order, which includes the short preamble, data OFDM symbols and midambles. Each SS holds a time slot.
For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Subchannelization Mode.



Uplink Subframe Format for Subchannelization Mode

For subchannelization mode, each SS transmits signals simultaneously, using different subchannels. The SSs shall be time-aligned. The time duration of uplink subframe is determined by the longest time duration among all the SSs. consequently for other SSs having less time duration, zeros will be padded at the end.

4. 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 the array of each SS's RF output signal power. The Power of the signal is defined as the average SS's power excluding the idle interval time intervals.
   - 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).
   - NumberOfSS specifies the number of active subscribers (SS).
   - SSWithFEC specifies the SS which goes through FEC encoding and decoding.
   - DataLength is the array of each SS's MAC PDU payload byte length.Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to *Mandatory Channel*

Coding per Modulation, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
- SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
- MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. *Midamble Repetition Interval* shows the meaning each MidambleRepetition value corresponds to,

Midamble Repetition Interval

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

- UIUC, FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- MAC_Header specifies the 6 byte data inserted in MAC Header.
- OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
- Bandwidth is the nominal channel bandwidth. The sampling frequency implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows:

  $$F_s = floor((n \times Bandwidth)/8000) \times 8000$$

  The sampling factors are listed in *Sampling Factor Requirement*.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.

- PrmlTimeShift indicates the number of samples of cyclic shift which are delayed in time in the preamble and midamble symbols.
- IdleInterval specifies the time of idle interval between two consecutive subframes.
- TimeOffset is the array of each SS's time offset arrived at BS. 0 means the SS's signal arrives at BS exactly when scheduled. Other values can be used to introduce a time offset to simulate arrival differences between different SS transmissions.Note that the actual time offset delay of each SS is the value in TimeOffset minus the last SS's time offset.

5. Output Pin Delay Adjustment
Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts. Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively. Each uplink burst consists of one short preamble, data symbols and midambles. The short preamble consists of one OFDM symbols.
The number of OFDM data symbols of ith uplink SS(!wman-8-19-211.gif!) is calculated as follows:
$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$
MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst,
if $MidambleRepetition[i]$
is not zero
$$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$
else $Midamble[i] = 0$
So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:
$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$
The number of samples per one OFDM symbol (!wman-8-19-219.gif!) is calculated as:
$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$
where, G is the CyclicPrefix.
The samples of IdleInterval(!wman-8-19-221.gif!) is calculated as follows:
$$Samples_{idle} = IdleInterval \times F_s$$
So, the total samples of one uplink subframe $Samples_{Frame}$
is
$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$
For subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.
The number of OFDM data symbols of ith uplink SS(!wman-8-19-225.gif!) is calculated as follows:
$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels}[i])$$
Here Nsubchannels[i] is the number of subchannels of the ith SS. For non-subchannelization mode, Nsubchannels[i] is equal to 16; For subchannelization mode, Nsubchannels[i] is determined by SubchannelIndex[i], shown in *Number of Subchannels*.

Number of Subchannels

SubchannelIndex	Nsubchannels
1,3,5,7,9,11,13,15,17,19,21,23,	1
2,6,10,14,18,22,26,30	2
4,12,20,28	4
8,24	8

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

So, the total samples of one uplink subframe $Samples_{Frame}$ is

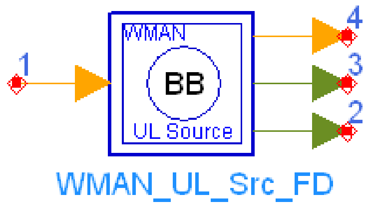
$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

In the source, $30 \times 2^{oversamplingOption}$ delay is introduced by the transmitter filter in the design WMAN_UL_SignalSrc, where the delay is equal to $(Length - 1)/2$. Length is the parameter in the transmitter filter.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D3, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, May 2005.

WMAN_UL_Src_FD (WMAN Uplink Signal Source with Frame Duration)



Description Uplink baseband signal source with broadcast message and frame duration
Library WMAN, Signal Source
Class SDFWMAN_UL_Src_FD

Parameters

Name	Description	Default	Unit	Type	Range
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
IdleInterval	Idle Interval	0.0 μsec	sec	real	[0, 1000]
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
CID	CID of each subscriber	{1}		int array	[0, 65535]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
TimeOffset	Time offset of each subscriber	{0 μsec}	sec	real array	[0, IdleInterval]
PilotPN_Phase	Pilot phase	0		int	[0, 4095]
AutoMACHeaderSetting	Auto MAC header setting or not: NO, YES	YES		enum	
MAC_Header	MAC header data	{0XA2, 0X48, 0X22, 0X4F, 0X93, 0X0E}		int array	[0, 255]
Power	Power of each subscriber	{ 0.01 W }	W	real array	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	InputData	input of raw data	int

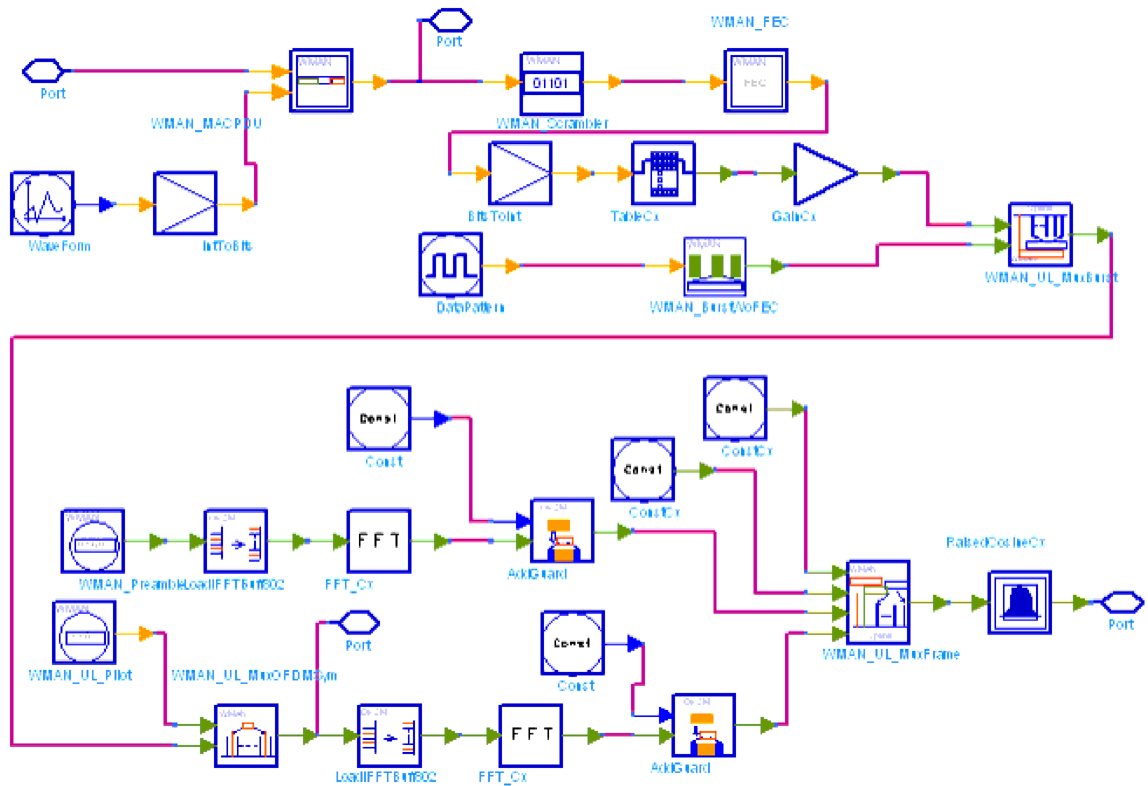
Pin Outputs

Pin	Name	Description	Signal Type
2	FrameData	output of uplink Subframe	complex
3	ForEVM	output of Modulated data of all bursts for EVM	complex
4	PDUFCS	output of MAC PDU data of burst with FEC	int

Notes/Equations

1. This subnetwork is used to generate a WMAN OFDM Uplink subframe baseband signal.

The schematic for this subnetwork is shown in WMAN_UL_Src_FD Schematic.



WMAN_UL_Src_FD Schematic

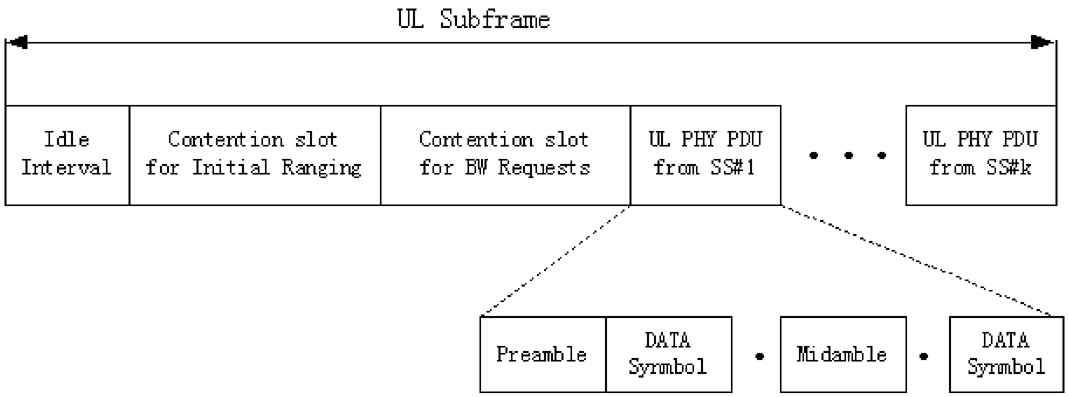
2. WMAN OFDM Uplink baseband signal source is implemented according to the specification. Non-subchannelization and subchannelization modes are supported. The maximum number of SSs supported is 16. For non-subchannelization mode, the maximum number of bursts supported is 16. For subchannelization mode, only one burst is supported, where maximum 16 SSs can be allocated, while each SS uses one different subchannel.
For the SS with FEC-encoded, one PHY MAC PDU is contained. The MAC PDU payload data of the SS with FEC-encoded are input at pin InputData. The MAC PDU format is shown in MAC PDU Format. Each MAC PDU contains 6 bytes MAC Header, DataLength[SSWithFEC] bytes MAC PDU payload, and 4 bytes CRC. The total byte length of MAC PUD is DataLength[SSWithFEC]+10. The MAC Header and CRC are padded in WMAN_MACPDU.

MAC Header (6 Bytes)	MAC PDU Payload (DataLength bytes)	CRC (4 Bytes)

MAC PDU Format

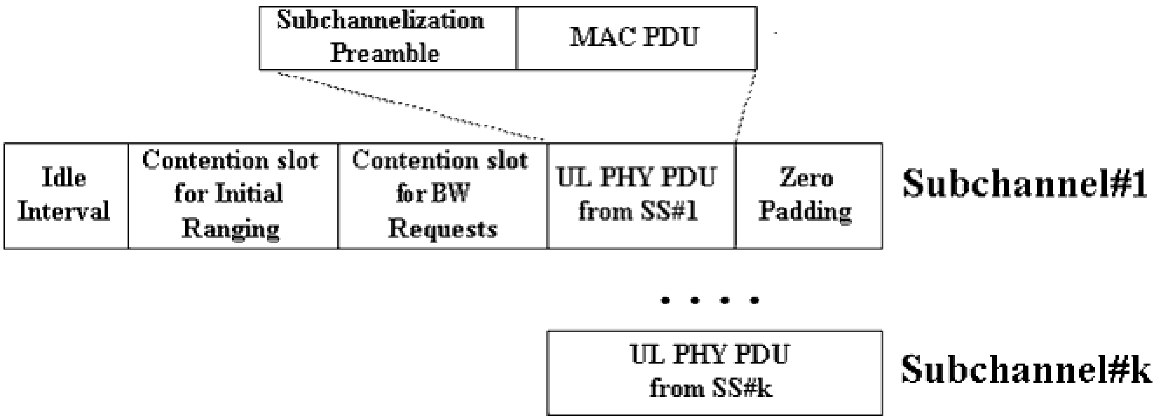
After MAC Header and CRC are padded, the MAC PDU is put into the randomizer (WMAN_Scrambler). Then a 0x00 tail byte is added to the end of the randomized block, which is reserved by RS-CC and CC. To form an integer number of OFDM symbols, unused bytes in the burst payload may be padded by the bytes 0xFF.
The data after padded will be encoded by RS-CC or CC with a specified rate corresponding to the Rate_ID[SSWithFEC] which is done in WMAN_FEC. Then the signal after passing through the puncturer, intelever and mapper will be combined with other SS's signal in WMAN_UL_MuxBurst. The puncturer and intelever are also in WMAN_FEC. The other SS's signal data are generated in

WMAN_BurstWoFEC. WMAN_UL_MuxOFDMSym is used to multiplex data subcarriers and pilot subcarriers, while the pilot subcarriers are produced in WMAN_UL_Pilot. Then after IFFT transfer, the complete uplink subframe is produced in WMAN_UL_MuxFrame.
For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-Subchannelization Mode.



Uplink Subframe Format for Non-Subchannelization Mode

A complete Uplink subframe is started with an idle interval, followed by contention slot for Initial Ranging and contention slot for BW Requests. Then comes each SS's UL PHY PDU in order, which includes the short preamble, data OFDM symbols and midambles. Each SS holds a time slot.
For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Sub-Channelization Mode.



Uplink Subframe Format for Sub-Channelization Mode

For subchannelization mode, each SS transmits signals simultaneously, using different subchannels. The SSs shall be time-aligned. The time duration of uplink subframe is determined by the longest time duration among all the SSs. consequently for other SSs having less time duration, zeros will be padded at the end.

3. Parameter Details
    - OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
    - Bandwidth defines the nominal bandwidth. According to the specification, the supported nominal bandwidths are 1.25MHz, 1.5MHz, 1.75 MHz, 2.5 MHz, 3 MHz, 3.5 MHz, 5 MHz, 5.5 MHz, 6 MHz, 7 MHz, 10 MHz, 11 MHz, 12 MHz, 14 MHz, 15 MHz, 20 MHz, 24 MHz and 28 MHz. This parameter type is floating. Other bandwidth except the above is also supported. The sampling frequency implemented in the design is decided by Bandwidth,

OversamplingOption and related sampling factor as follows:

$$F_s = floor((n \times Bandwidth)/8000) \times 8000$$

The sampling factors are listed in *Sampling Factor Requirement*.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.
- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms). When FrameDuration =Continuous, the uplink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the uplink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.
- IdleInterval specifies the time of idle interval between two consecutive subframes. The default value is 0.0 μsec.
- FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- NumberOfSS specifies the number of active subscribes (SS).
- SSWithFEC specifies the SS which goes through FEC encoding and decoding.
- CID specifies CID of each subscriber. Its type is integer array.
- Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
- SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
- DataLength is the array of each SS's MAC PDU payload byte length.
- Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to *Mandatory Channel Coding per Modulation*, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. *Midamble Repetition Interval* shows the meaning each MidambleRepetition value corresponds to.

Midamble Repetition Interval

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

- PrmlTimeShift indicates the number of samples of cyclic shift are delayed in time in the preamble and midamble symbols.
- TimeOffset is the array of each SS's time offset arrived at BS. 0 means the SS's signal arrives at BS exactly when scheduled. Other values can be used to introduce a time offset to simulate arrival differences between different SS transmissions. Note that the actual time offset delay of each SS is the value in TimeOffset minus the last SS's time offset.
- PilotPN_Phase specifies the start phase of pilots (PRBS). The specification requires PilotPN_Phase = 0.
- AutoMACHeaderSetting specifies how to get the 6 bytes MAC header. If AutoMACHeaderSetting=YES, these 6 bytes MAC header is generated by WMAN_MACHeader directly. If AutoMACHeaderSetting=NO, these 6 bytes MAC header is input by MAC_Header parameter.
- MAC_Header specifies the 6 byte data inserted in MAC Header. It is active just when AutoMACHeaderSetting=NO.
- Power is the array of each SS's transmitting power. In non-subchannelization mode, the first SS's output voltage is adjusted to be 1, by multiplying signal amplitude with Gain, where Gain is defined as: $Gain = 256 \times 2^{OversamplingOption} / (\sqrt{200})$
  For other SS, the ith SS's output voltage is adjusted aligned with the first SS's by multiplying signal amplitude with Gain[i] respectively, where Gain[i] is defined as:

  $$Gain[i] = Gain[1] \times \sqrt{(Power[i])/(Power[1])}$$

  Here Power[1] is the first SS's Power.
  In subchannelization mode, the first SS's output voltage is adjusted to be 1, while other SSs' output voltages are adjusted according to the ratio of the number of subcarriers the SSs contain to the number of subcarriers the first SS contains. Note that only the first value in the array of Power is used to adjust the first SS's output voltage, and other values in the array of Power are ignored.

4. Output Pin Delay Adjustment
   Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.
   The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for

Initial Ranging and contention slot for BW, and multiple uplink bursts. Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively. Each uplink burst consists of one short preamble, data symbols and midambles. The short preamble consists of one OFDM symbols.

The number of OFDM data symbols of ith uplink SS($N_{Symbol}[i]$) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$
represent the number of midamble symbols in ith uplink burst,

$$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

if $MidambleRepetition[i]$
is not zero

$$Midamble[i] = 0$$

else

So the total number of OFDM symbols $N_{totalSymbol}$
for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol ($Samples_{OFDM}$) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where, G is the CyclicPrefix.

The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

When FrameDuration<>Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

For subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.

The number of OFDM data symbols of ith uplink SS($N_{Symbol}[i]$) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels})$$

Here Nsubchannels is the number of subchannels. Nsubchannels is determined by SubchannelIndex, shown in *Number of Subchannels*.

Number of Subchannels

Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

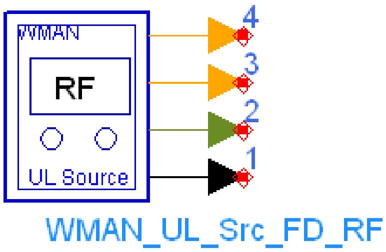
$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

In the source, $30 \times 2^{oversamplingOption}$ delay is introduced by TransmitterFilter in the design WMAN_UL_SignalSrc, where the delay is equal to $(Length - 1)/2$. Length is the parameter in TransmitterFilter.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.

WMAN_UL_Src_FD_RF (WMAN UL Source RF with Frame Duration)



Description Uplink RF signal source with broadcast message and frame duration
Library WMAN, Signal Source
Class TSDFWMAN_UL_Src_FD_RF

Parameters

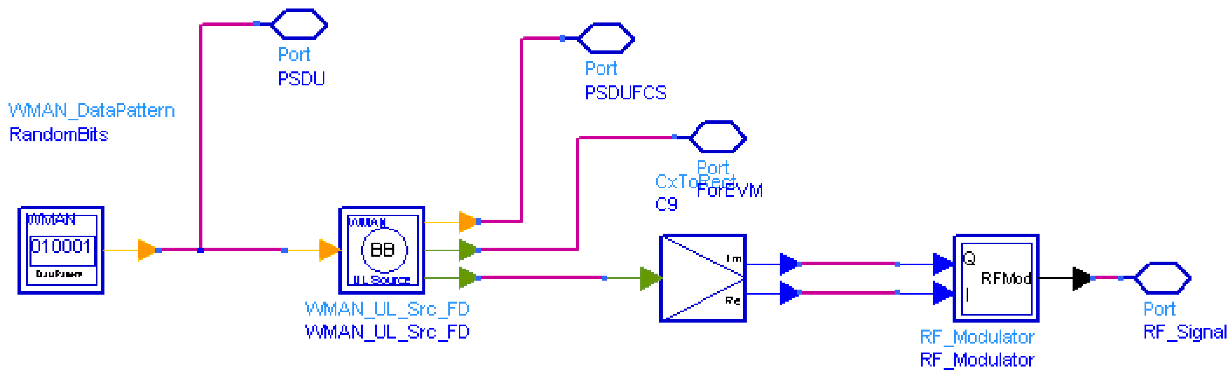
Name	Description	Default	Unit	Type	Range
ROut	Source resistance	50 Ohm	Ohm	int	(0, ∞)
RTemp	TEMPERATURE	−273.15	Celsius	real	[−273.15, ∞]
FCarrier	Carrier frequency	3407 MHz	Hz	real	(0, ∞)
Power	Power of each subscriber	{ 0.01 W }	W	real array	(0, ∞)
MirrorSpectrum	Indication of mirror spectrum about 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	(−∞, ∞)
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
Bandwidth	Bandwidth	1.75 MHz	Hz	real	(0, 1e9]
CyclicPrefix	Cyclic prefix	0.25		real	[0, 1]
FrameMode	Frame mode: FDD, TDD	FDD		enum	
DL_Ratio	Downlink ratio	0.5		real	[0.01, 0.99]
FrameDuration	Frame duration: Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms, time 20 ms	time 5 ms		enum	
IdleInterval	Idle Interval	0.0 μsec	sec	real	[0, 1000]
BSID	BSID	{0X00, 0X00, 0X00, 0X00, 0X00, 0X01}		int array	[0, 255]
FrameNumber	Frame Number	0		int	[0, 15]
DataPattern	WMAN Data Pattern: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0, S_BPSK, S_QPSK, S_16-QAM, S_64-QAM	PN9		enum	
NumberOfSS	Number of subscribers	1		int	[1, 16]
SSWithFEC	The number of subscriber with FEC	1		int	[1, 16]
CID	CID of each subscriber	{1}		int array	[0, 65535]
Subchannelization	Subchannelization or not: NO, YES	NO		enum	
SubchannelIndex	List of each subchannel index	{8}		int array	[1, 15] or [17, 31]
DataLength	MAC PDU payload byte length of each subscriber	{100}		int array	[1, 16383]
Rate_ID	Rate ID of each subscriber	{1}		int array	[0, 6]
MidambleRepetition	Midamble repetition of each subscriber	{0}		int array	[0, 3]
PrmlTimeShift	Preamble time shift of each subscriber	{0}		int array	[0, 255]
TimeOffset	Time offset of each subscriber	{0 μsec}	sec	real array	[0, IdleInterval]

Pin Outputs

Pin	Name	Description	Signal Type
1	RF_Signal	output of RF signal	timed
2	ForEVM	output of Modulated data of all bursts for EVM	complex
3	PDUFCS	output of MAC PDU data of burst with FEC	int
4	PSDU	output of PSDU bits	int

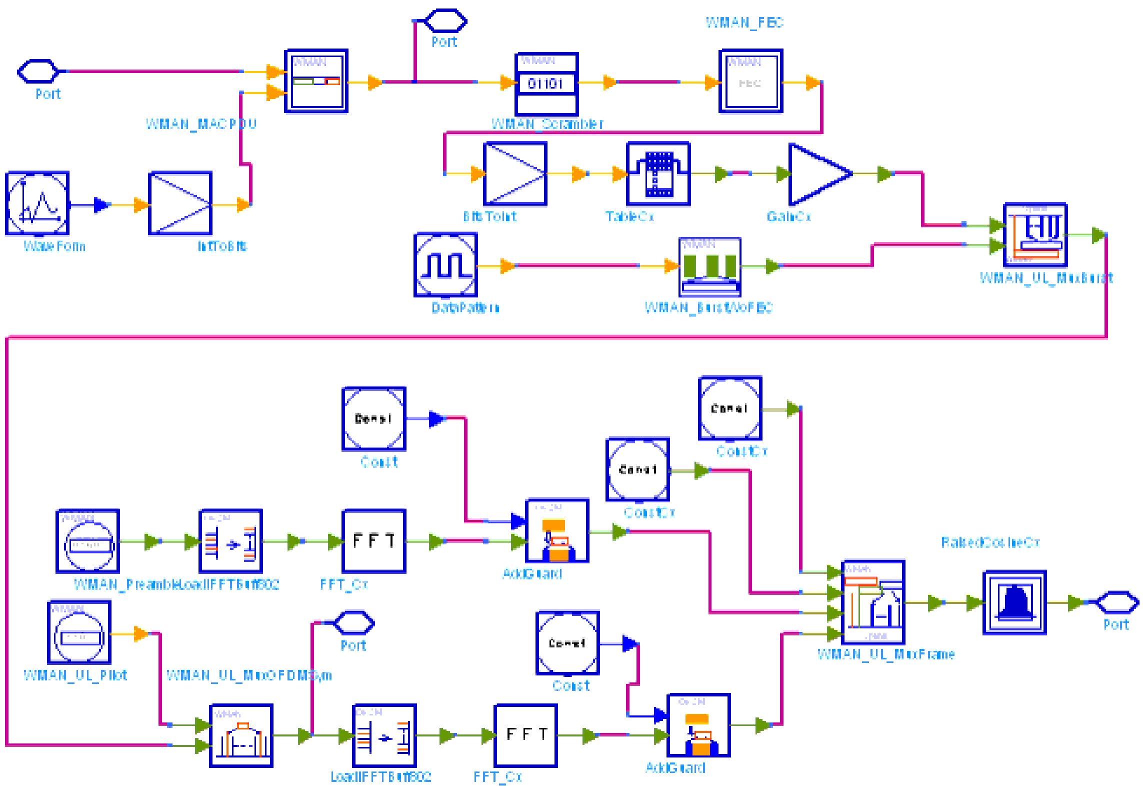
Notes/Equations

1. This subnetwork is used to integrates an RF modulator with the baseband signal source. The WMAN OFDM uplink baseband signal is fed into the RF modulator. The RF signal is timed signal after RF modulation.
   The schematic for this subnetwork is shown in WMAN_UL_SignalSrc_RF Schematic.



WMAN_UL_SignalSrc_RF Schematic

2. The WMAN OFDM uplink baseband signal source format follows the specification. The schematic is shown in WMAN_UL_Src_FD Schematic.



WMAN_UL_Src_FD Schematic

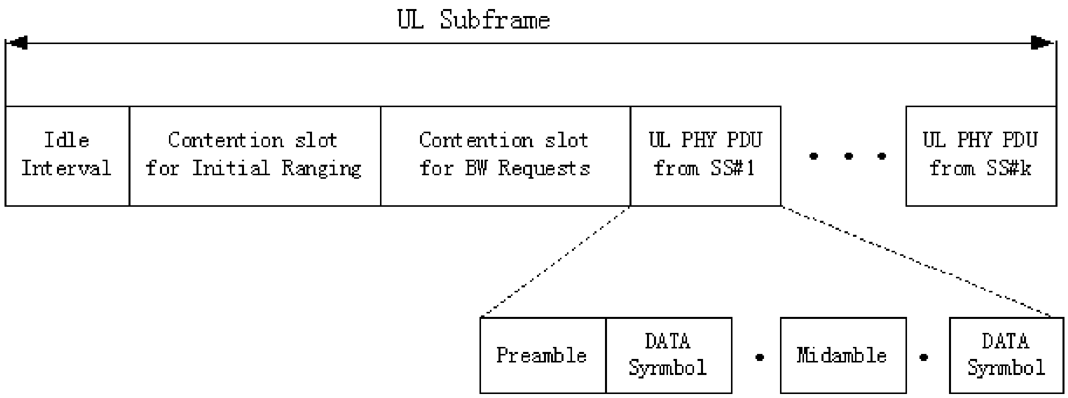
3. WMAN OFDM Uplink baseband signal source is implemented according to the specification. Non-subchannelization and subchannelization modes are supported. The maximum number of SSs supported is 16. For non-subchannelization mode, the maximum number of bursts supported is 16. For subchannelization mode, only one burst is supported, where maximum 16 SSs can be allocated, while each SS uses one different subchannel.
For the SS with FEC-encoded, one PHY MAC PDU is contained. The MAC PDU payload data of the SS with FEC-encoded are generated in WMAN_DataPattern. The MAC PDU format is shown in MAC PDU Format. Each MAC PDU contains 6 bytes MAC Header, DataLength[SSWithFEC] bytes MAC PDU payload, and 4 bytes CRC. The total byte length of MAC PUD is DataLength[SSWithFEC]+10. The MAC Header and CRC are padded in WMAN_MACPDU.

MAC Header (6 Bytes)	MAC PDU Payload (DataLength bytes)	CRC (4 Bytes)

MAC PDU Format

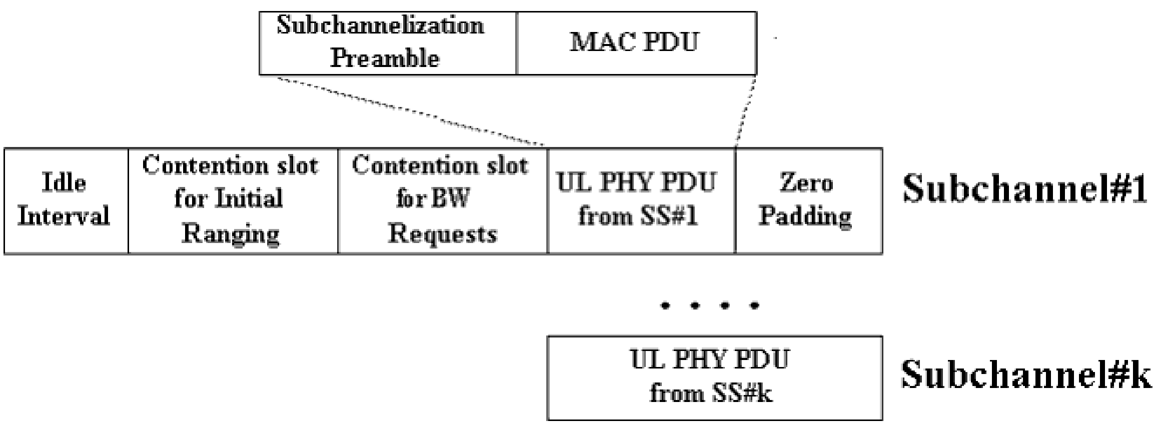
After MAC Header and CRC are padded, the MAC PDU is put into the randomizer (WMAN_Scrambler). Then a 0x00 tail byte is added to the end of the randomized block, which is reserved by RS-CC and CC. To form an integer number of OFDM symbols, unused bytes in the burst payload may be padded by the bytes 0xFF.
The data after padded will be encoded by RS-CC or CC with a specified rate corresponding to the Rate_ID[SSWithFEC] which is done in WMAN_FEC. Then the signal after passing through the puncturer, intelever and mapper will be combined with other SS's signal in WMAN_UL_MuxBurst. The puncturer and intelever are also in WMAN_FEC. The other SS's signal data are generated in WMAN_BurstWoFEC. WMAN_UL_MuxOFDMSym is used to multiplex data subcarriers and pilot

subcarriers, while the pilot subcarriers are produced in WMAN_UL_Pilot. Then after IFFT transfer, the complete uplink subframe is produced in WMAN_UL_MuxFrame.
For non-subchannelization mode, WMAN OFDM uplink subframe structure is shown in Uplink Subframe Format for Non-Subchannelization Mode.



Uplink Subframe Format for Non-Subchannelization Mode

A complete Uplink subframe is started with an idle interval, followed by contention slot for Initial Ranging and contention slot for BW Requests. Then comes each SS's UL PHY PDU in order, which includes the short preamble, data OFDM symbols and midambles. Each SS holds a time slot.
For subchannelization mode, WMAN OFDM Uplink subframe structure is shown in Uplink Subframe Format for Subchannelization Mode.



Uplink Subframe Format for Subchannelization Mode

For subchannelization mode, each SS transmits signals simultaneously, using different subchannels. The SSs shall be time-aligned. The time duration of uplink subframe is determined by the longest time duration among all the SSs. consequently for other SSs having less time duration, zeros will be padded at the end.

4. 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 the array of each SS`s RF output signal power. The Power of the signal is defined as the average SS`s power excluding the idle interval time intervals.
    - 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).
- OversamplingOption specifies the oversampling ratio of the transmission signal. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
- Bandwidth defines the nominal bandwidth. According to the specification, the supported nominal bandwidths are 1.25MHz, 1.5MHz, 1.75 MHz, 2.5 MHz, 3 MHz, 3.5 MHz, 5 MHz, 5.5 MHz, 6 MHz, 7 MHz, 10 MHz, 11 MHz, 12 MHz, 14 MHz, 15 MHz, 20 MHz, 24 MHz and 28 MHz. This parameter type is floating. Other bandwidth except the above is also supported. The sampling frequency implemented in the design is decided by Bandwidth, OversamplingOption and related sampling factor as follows:
  $$F_s = floor((n \times Bandwidth)/8000) \times 8000$$
  The sampling factors are listed in *Sampling Factor Requirement*.

Sampling Factor Requirement

sampling factor n	bandwidth
8/7	For channel bandwidths that are a multiple of 1.75 MHz
86/75	else for channel bandwidths that are a multiple of 1.5 MHz
144/125	else for channel bandwidths that are a multiple of 1.25 MHz
316/275	else for channel bandwidths that are a multiple of 2.75 MHz
57/50	else for channel bandwidths that are a multiple of 2.0 MHz
8/7	else for channel bandwidths not otherwise specified

- CyclicPrefix specifies the ratio of guard time (cyclic prefix) to useful symbol period, whose range is from 0 to 1.
- FrameMode is determines the generated frame is FDD mode or TDD mode. If FDD mode, the full frame is used to transmit this uplink signal source. If TDD mode, the frame is used to transmit both downlink and uplink signal source, the first part is for downlink transmission and the second part is for uplink transmission. These two parts are controlled by the DL_Ratio parameter in one frame.
- DL_Ratio is used to split one frame into two parts. When FrameMode=TDD and FrameDuration<>Continuous, it is active. The first part (duration is FrameDuration*DL_Ratio) is to transmit downlink (filled by zeros) and the rest part (second part) is to transmit uplink source.
- FrameDuration specifies the frame type. It's type is enum. There are 8 cases (Continuous, time 2.5 ms, time 4 ms, time 5 ms, time 8 ms, time 10 ms, time 12.5 ms and time 20 ms).

When FrameDuration =Continuous, the uplink source is transmitted continuously (without frame structure) and both FrameMode and DL_Ratio parameters are inactive. When FrameDuration <>Continuous, the uplink source is transmitted frame by frame (with frame structure) and both FrameMode and DL_Ratio parameters are active.

- IdleInterval specifies the time of idle interval between two consecutive subframes. The default value is 0.0 µsec.
- FrameNumber, BSID are used to generate the scrambler UL initialization vector.
- NumberOfSS specifies the number of active subscribes (SS).
- SSWithFEC specifies the SS which goes through FEC encoding and decoding.
- CID specifies CID of each subscriber. Its type is integer array.
- Subchannelization is the boolean value to indicate whether subchannelization is employed or not.
- SubchannelIndex is the array of each SS's subchannel index allocated. This parameter is valid only when Subchannelization is set to YES. Note that the values in SubchannelIndex should be in ascending order.
- DataLength is the array of each SS's MAC PDU payload byte length.
- Rate_ID is the array of each SS's Rate ID, whose range is from 0 to 6. DataLength and Rate_ID determine the number of data symbols per SS. Data-rate-dependent parameters (modulation, coding rate, coded bytes/uncoded bytes per OFDM symbol) will be set according to *Mandatory Channel Coding per Modulation*, which is based on the specification.

Mandatory Channel Coding per Modulation

Rate_ID	Modulation	Uncoded block size(bytes)	Coded block size(bytes)	Overall coding rate	RS code	CC code rate
0	BPSK	12	24	1/2	(12,12,0)	1/2
1	QPSK	24	48	1/2	(32,24,4)	2/3
2	QPSK	36	48	3/4	(40,36,2)	5/6
3	16-QAM	48	96	1/2	(64,48,8)	2/3
4	16-QAM	72	96	3/4	(80,72,4)	5/6
5	64-QAM	96	144	2/3	(108,96,6)	3/4
6	64-QAM	108	144	3/4	(120,108,6)	5/6

- MidambleRepetition is the array of each SS's midamble repetition interval in OFDM symbols. When the last section of symbol after the last midamble is higher than half the midamble repetition interval, a postamble shall be added at the end of the allocation. *Midamble Repetition Interval* shows the meaning each MidambleRepetition value corresponds to.

Midamble Repetition Interval

Value	Meaning
0b00	Preamble only
0b01	Midamble after every 8 data symbols
0b10	Midamble after every 16 data symbols
0b11	Midamble after every 32 data symbols

- PrmlTimeShift indicates the number of samples of cyclic shift are delayed in time in the preamble and midamble symbols.
- TimeOffset is the array of each SS's time offset arrived at BS. 0 means the SS's signal arrives at BS exactly when scheduled. Other values can be used to introduce a time offset to simulate arrival differences between different SS transmissions. Note that the actual time offset delay of each SS is the value in TimeOffset minus the last SS's time offset.
- Power is the array of each SS's transmitting power.

5. Output Pin Delay Adjustment
Before introducing delays for each output pins, the number of OFDM symbols per frame is deduced in this section.

The non-subchannelization and subchannelization modes are supported in WMAN OFDM uplink. For non-subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and multiple uplink bursts. Contention slot for Initial Ranging and contention slot for BW Requests consist of two OFDM symbols respectively. Each uplink burst consists of one short preamble, data symbols and midambles. The short preamble consists of one OFDM symbols.

The number of OFDM data symbols of ith uplink SS ($N_{Symbol}[i]$) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]))$$

MidambleRepetition indicates each SS's midamble repetition interval in OFDM symbols. Let $Midamble[i]$ represent the number of midamble symbols in ith uplink burst, if $MidambleRepetition[i]$ is not zero

$$Midamble[i] = round((N_{Symbol}[i])/2^{MidambleRepetition[i]+1})$$

$$Midamble[i] = 0$$

else

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + \sum_{i=1}^{NumberOfSS} (N_{Symbol}[i] + 1 + Midamble[i])$$

The number of samples per one OFDM symbol ($Samples_{OFDM}$) is calculated as:

$$Samples_{OFDM} = 2^{OversamplingOption} \times 256 \times (1 + G)$$

where, G is the CyclicPrefix.

The samples of IdleInterval($Samples_{idle}$) is calculated as follows:

$$Samples_{idle} = IdleInterval \times F_s$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

When FrameDuration<>Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + FrameDuration \times F_s \times 2^{OversamplingOption}$$

For subchannelization mode, one WMAN uplink subframe consists of Idle, contention slot for Initial Ranging and contention slot for BW, and one uplink burst which contains all SSs.

The number of OFDM data symbols of ith uplink SS($N_{Symbol}[i]$) is calculated as follows:

$$N_{Symbol}[i] = ceil((DataLength[i] + 11)/(uncodedBlockSize[R[i]]) \times 16/N_{subchannels})$$

Here Nsubchannels is the number of subchannels. Nsubchannels is determined by SubchannelIndex, shown in *Number of Subchannels*.

Number of Subchannels

Nsubchannels	SubchannelIndex
1	1,3,5,7,9,11,13,15,17,19,21,23,25,27,29,31
2	2,6,10,14,18,22,26,30
4	4,12,20,28
8	8,24

So the total number of OFDM symbols $N_{totalSymbol}$ for the uplink frame is calculated as follows:

$$N_{totalSymbol} = 2 + 2 + max(N_{Symbol}[i] + 1 + Midamble[i])$$

When FrameDuration=Continuous, the total samples of one uplink subframe $Samples_{Frame}$ is

$$Samples_{Frame} = Samples_{idle} + N_{totalSymbol} \times Samples_{OFDM}$$

In the source, $30 \times 2^{oversamplingOption}$ delay is introduced by TransmitterFilter in the design WMAN_UL_SignalSrc, where the delay is equal to $(Length - 1)/2$. Length is the parameter in TransmitterFilter.

References

1. IEEE Std 802.16-2004, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Section 8.3 WirelessMAN-OFDM PHY, October 1, 2004.
2. IEEE P802.16-2004/Cor1/D5, Corrigendum to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Sept. 2005.