Advanced Design System 2011.01

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WLAN 11n Design Library

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About WLAN 11n Design Library

The Agilent EEsof WLAN 11n wireless design library is developed based on Enhanced Wireless Consortium (EWC) HT PHY specification v1.13, which was released in Nov. 2005. This library intends 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.

WLAN 11n System Overview

In response to the growing demand for higher-performance wireless local area networks (WLANs), the Institute of Electrical and Electronics Engineers - Standards Association (IEEE-SA) approved the creation of the IEEE 802.11 Task Group n (802.11 TGn) in 2003. The objective of TGn is to define both the 802.11 physical layers (PHY) and the Medium Access Control Layer (MAC) specifications so that a maximum throughput of at least 100 Mbps can be achieved.

The WLAN 11n evolutionary philosophy is reusing existing technologies, while introducing new technologies to provide effective performance improvements.

The reused technologies include Orthogonal Frequency Division Multiplexing (OFDM), forward error correction (FEC) coding, interleaving and quadrature amplitude modulation (QAM) mapping. By applying these 11a legacy technologies, backward compatibility is easily realized and the costs are kept down.

To achieve a much higher throughput, both the PHY and MAC layer must be improved. These improvements include applying multiple-input multiple-output (MIMO) technology, enabling a short guard interval (GI), optional 40 MHz channel bandwidth, optional low density parity check(LDPC) coding scheme, aggregated MAC protocol data unit and etc. With all of these improvements, the ultimate throughput will be increased as much as 600 Mbps.

MIMO is one of the most important technologies introduced to 11n PHY specification. Traditionally, the multipath is perceived as interference degrading a receiver's ability to recover the information. But MIMO technology enables the opportunity to spatially resolve multipath signals, providing antenna diversity and spatial multiplexing ability to enhance the receiver performance.

To accelerate the IEEE 802.11n development process, Enhanced Wireless Consortium was formed by Wi-Fi industry key players in September 2005. The consortium published its PHY and MAC specifications which have been adopted by the IEEE 802.11 TGn as the draft joint proposal for approval.

The major specifications for the WLAN 11n physical layer are listed in the following table.

WLAN 11n Physical Layer Major Specifications

Specification	Settings
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Error correcting code	CC, LDPC (optional)
Coding rate	1/2, 2/3, 3/4,5/6
N_{FFT} :FFT Size	64 in 20 MHz channel 128 in 40 MHz channel
Number of data subcarriers	48 in legacy 20 MHz channel 52 in HT 20 MHz channel 108 in HT 40 MHz channel
Number of pilot subcarriers	4 in legacy and HT 20 MHz channel 6 in 40 MHz HT channel
Number of total subcarriers used	52 in legacy 20 MHz channel 56 in HT 20 MHz channel 114 in HT 40 MHz channel
Δf : Subcarrier frequency spacing	312.5 kHz
T_{FFT}: FFT/IFFT period	3.2 µsec
T_{GI}: Guard interval period	0.8 µsec for normal guard interval 0.4 µsec for short guard interval
T_{SYM}: OFDM symbol interval	$T_{FFT} + T_{GI}$

Some frequently used parameters in this document are listed in the following table.

Frequently Used Parameters

Parameter	Description
NCBPS	Number of coded bits per symbol
NCBPSS	Number of coded bits per symbol per spatial stream
NDBPS	Number of data bits per symbol
NCBPSC	Number of coded bits per single carrier
NSTS	Number of space time streams
NSS	Number of spatial streams
NESS	Number of extension spatial streams
NTx	Number of transmit chains
NES	Number of FEC encoders
NSYM	Number of OFDM symbols in the data field
NHTLTF	Number of HT long training fields

WLAN 11n Design Library Key Features

WLAN 11n wireless design library follows EWC HT PHY specification v1.13. The key features include:

- 20/40 MHz channel bandwidth
- Up to 4x4 antenna arrays
- Short GI enabled
- Convolutional coding
- Operating mode: Mixed mode and Green field mode

- Antenna mapping scheme: Direct mapping and spatial spreading
- 11n MIMO channel with userdefined option

Component Libraries Overview

The components in WLAN 11n wireless design library are organized in five categories: Channel, Measurements, Source Components, Source, Receiver components and Receiver.

Channel

The 11n MIMO channel model is provided in this category.

- WLAN_11n_Channel: 11n MIMO channel

Measurements

The 11n measurement models are provided in this category.

- WLAN_11n_EVM_: EVM measurement
- WLAN_11n_RF_CCDF: RF CCDF measurement

Source Components

The components that can be used to construct 11n signals sources are provided in this category.

- WLAN_11n_BurstMux: Burst mulitplexer
- WLAN_11n_BusFork2: Bus fork 2
- WLAN_11n_DataWrap: Data wrapper
- WLAN_11n_Interleaver: Interleaver
- WLAN_11n_LLTF: Legacy long training field generator
- WLAN_11n_PilotGen: Pilot generator
- WLAN_11n_PreambleMux: preamble multiplexer
- WLAN_11n_Scrambler: Scrambler
- WLAN_11n_RF_Modulator: RF modulator
- WLAN_11n_ChCoder: Channel coder
- WLAN_11n_HTLTF_GF: Green Field HT long training field generator
- WLAN_11n_HTLTF_MM: Mixed Mode HT long training field generator
- WLAN_11n_HTSIG: HT signal field generator
- WLAN_11n_HTSTF: HT short training field generator
- WLAN_11n_LSIG: Legacy signal field generator
- WLAN_11n_LSTF: Legacy short training field generator
- WLAN_11n_Mapper: Constellation mapper
- WLAN_11n_MuxOFDMSym: OFDM symbol multiplexer
- WLAN_11n_OFDMMod: OFDM modulator
- WLAN_11n_Preamble: Preamble generator
- WLAN_11n_SpatialMapper: Spatial mapper

- WLAN_11n_SpatialParser: Spatial parser

Source

The 11n top-level signal sources are provided in this category.

- WLAN_11n_Source: Baseband signal source
- WLAN_11n_Source_RF: RF signal source

Receiver Components

The components that can be used to construct 11n receivers are provides in this category.

- WLAN_11n_Sync: time and frequency synchronizer
- WLAN_11n_RF_Demodulator: RF demodulator
- WLAN_11n_ChDecoder: Channel decoder
- WLAN_11n_ChEstimator:Channel estimator
- WLAN_11n_Demapper: Constellation demapper
- WLAN_11n_OFDMDeMod: OFDM demodulator
- WLAN_11n_PhaseTracker: Phase tracker
- WLAN_11n_SpatialCommutator: Spatial commutator
- WLAN_11n_AntDemapper: Antenna demapper
- WLAN_11n_DataUnwrap: Data unwrapper
- WLAN_11n_BurstDemux: Burst demultiplexer

Receiver

The 11n top-level receivers are provided in this category.

- WLAN_11n_Receiver
- WLAN_11n_Receiver_RF

Design Examples

WLAN 11n wireless design library provides design examples for both transmitter and receiver measurements. These design examples can help test and verify RF and baseband performance with standard references.

WLAN_11n_Tx_wrk

The transmitter measurements in this workspace include EVM, spectrum mask and CCDF.

- WLAN_11n_CCDF: 11n signal CCDF measurement test bench
- WLAN_11n_TxEVM: EVM measurement test bench
- WLAN_11n_Spectrum: transmit spectrum measurement test bench with spectrum mask

WLAN_11n_Rx_wrk

THe WLAN 11n full-link BER/PER tests are provided in WLAN_11n_RX_wrk.

- WLAN_11n_AWGN_System_2SS: BER/PER measurement for two spatial streams case under AWGN channel.
- WLAN_11n_Fading_System_1SS: BER/PER measurement for one spatial stream case under MIMO fading channel.
- WLAN_11n_Fading_System_2SS: BER/PER measurement for two spatial streams case under MIMO fading channel.

Acronyms

Acronym	Description
AWGN	addition white Gaussian noise
CCDF	complementary cumulative distribution function
EVM	error vector magnitude
FEC	forward error correction
FFT	fast fourier transform
GF	green field
GI	guard interval
HT	high throughput
LDPC	low density parity check
IEEE	Institute of Electrical and Electronic Engineering
IFFT	inverse fast fourier transform
LTF	long training field
MAC	medium access control
MCS	modulation and coding scheme
MIMO	multiple input and multiple output
MM	mixed mode
OFDM	orthogonal frequency division multiplexing
PA	power amplifier
PER	packet error rate
PHY	physical layer
QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
RCE	relative constellation error
RF	radio frequency
RX	receive or receiver
SDU	service data unit
STF	short training field
TX	transmit or transmitter
WLAN	wireless local area networks

References

- EWC HT PHY Specification v1.13 November 5th, 2005. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n Channel

The 11n MIMO channel model is provided in this category.

- *WLAN 11n Channel (WLAN 11n MIMO channel)* (wlan11n)

WLAN_11n_Channel (WLAN 11n MIMO channel)
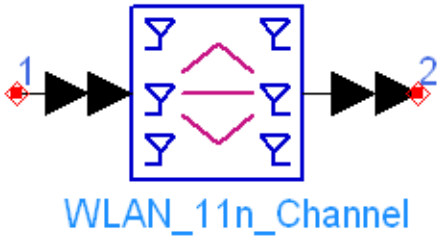
Description MIMO 802.11n channel model
Library WLAN 11n, Channel
Class TSDFWLAN_11n_Channel

Parameters

Name	Description	Default	Unit	Type	Range
ModelType	802.11n channel model case: A, B, C, D, E, F, User Defined	A		enum	
CorrelationCoefType	type of spatial correlation coefficient: Complex Correlation, Power Correlation	Complex Correlation		enum	
IncludePathloss	pathloss included in channel coefficients: Yes, No	Yes		enum	
TxRxDistance	separation between transmitter and receiver (for pathloss computation)	3 meter	m	real	(0, ∞)
CarrierFrequency	carrier frequency	2.44 GHz	Hz	real	(0, ∞)
PowerLineFrequency	frequency of electrical power	60 Hz	Hz	real	(0, ∞)
Seed	seed for random number generator (set to 0 for random seed)	0		int	[0, ∞)
NumTxAntennas	number of transmit antennas	1		int	[1, ∞)
TxArrayType	type of transmit array: Uniform Linear Tx, Uniform Circular Tx, User Defined Tx	Uniform Linear Tx		enum	
TxArrayDimension	total length of linear array or diameter of circular array at transmitter in wavelengths	0.5		real	(0, ∞)
TxArrayFileName	name of file containing transmit array element positions (only for user-defined array)			filename	
NumRxAntennas	number of receive antennas	1		int	[1, ∞)
RxArrayType	type of receive array: Uniform Linear Rx, Uniform Circular Rx, User Defined Rx	Uniform Linear Rx		enum	
RxArrayDimension	total length of linear array or diameter of circular array at receiver in wavelengths	0.5		real	(0, ∞)
RxArrayFileName	name of file containing receive array element positions (only for user-defined array)			filename	
PASType	shape of power azimuth spectrum (only for user-defined model): Laplacian, Gaussian, Uniform	Laplacian		enum	
RiceanFactor	Ricean K factor for line of sight component (only for user-defined model)	0	dB	real	(-∞, 0]
EnvironmentSpeed	max speed of environment creating channel Doppler effect (km/h, only for user-defined model)	1.2		real	(0, 40]
PathLoss	bulk path loss (only for user-defined model)	0	dB	real	(-∞, 0]
MPathFileName	name of file containing multipath description (only for user-defined model)			filename	

Pin Inputs

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

Pin Outputs

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

Notes/Equations

1. This model is used to generate time-varying channel models for multiple transmit and

receive antennas in a multipath propagation environment.

2. Options A-F of ModelType correspond to channel models defined in IEEE 802.11-03/940r (802.11n channel models). The multipath fading is modeled as a tapped-delay line with the number of taps and the delay and gain of each tap specified by parameters specified for each ModelType. For each tap, the method of filtered noise is used to generate a matrix time-varying channel coefficients with the correct distribution and spectrum.
   For each tap at a specified time instant, the matrix of channel coefficients is

$$H = \sqrt{P}\left[\sqrt{\frac{K}{K+1}}H_F + \sqrt{\frac{1}{K+1}}H_V\right]$$

where P is the sum of the powers in all taps, H_F is a fixed matrix for a line-of-sight contribution whose angles of departure and arrival are 45 degrees, H_V is a variable matrix whose elements are complex Gaussian random variables (Rayleigh magnitude), and K is the Ricean K-factor.
   Characteristics of each model are summarized in the following table.

Model Characteristics

Model	Number of Taps	Max Delay Spread (ns)	K: First Tap (dB)	K: Remaining Taps (dB)
A	1	-	0	$-\infty$
B	2	80	0	$-\infty$
C	2	200	0	$-\infty$
D	3	390	3	$-\infty$
E	4	730	6	$-\infty$
F	6	1050	6	$-\infty$

3. Antenna correlation is represented according to the Kronecker model

$$H_V = R_{rx}^{0.5}H_{iid}R_{tx}^{0.5}$$

where R_{tx} and R_{rx} represent the correlation matrices at transmit and receive, respectively, and H_{iid} is a matrix of independent, zero-mean, unit-variance complex Gaussian random variables. It is assumed that the multipath propagation for each tap may be characterized by an angle of departure and angle spread at the transmitter, and an angle of arrival and angle spread at the receiver. The angular power distribution of these "clusters" follows a truncated Laplacian shape in angle. These parameters, coupled with the antenna array geometries, allow computation of the correlation matrices.
   CorrelationCoefficientType determines whether the antenna correlations are computed from the complex signal voltages or signal power.

4. IncludePathLoss determines whether or not bulk path loss is included in the computation. Path loss depends on the distance between the transmitter and receiver (TxRxDistance). If TxRxDistance is below the breakpoint, it meets the LOS condition and $PathLoss = 20\log(4\pi fd/c)$, where f is the carrier frequency, d is the TxRxDistance, and c is the speed of light. If TxRxDistance is above the breakpoint, it meets the NLOS condition and $PathLoss = 20\log(4\pi fd_{BP}/c) + 35\log(d/d_{BP})$, where d_{BP} is the breakpoint distance shown in the following table.

Breakpoint Distance

Breakpoint Distance

Model	$d_{BP(m)}$
A	5
B	5
C	5
D	10
E	20
F	30

5. For channel models A-E, the scatterer in the environment are assumed to be moving at a velocity of 1.2 km/hour. The Doppler spectrum is given as $S(f) = [1 + 9(f/f_d)^2]^{-1}$ where f_d is the Doppler frequency. For channel model F, it is assumed that the 3rd tap also sees a vehicle moving at 40 km/hour which places a spike at the corresponding Doppler frequency. The power in this spike is chosen so that the ripple on narrowband channel responses is approximately 3 dB. Filters are used to ensure that the time-varying channel coefficients have these Doppler spectra.

6. Because fluorescent lights operating by creating a plasma (ionized gas), the scattering behavior of these lights changes as the power line goes from a high voltage (ionized gas appears as a scatterer) to zero voltage (gas is not ionized). This can create a Doppler component that appears at twice the power line frequency whose spectral width is determined by the harmonics. Models D (taps 2, 4, 6 in cluster 2) and E (taps 3, 5, 7 in cluster 1) include the impact of this interference. The interferer-to-carrier ratio is generated as a realization of a Gaussian random variable with mean 0.0203 and standard deviation 0.0107.

7. If the transmit and receive antenna are either uniform linear or uniform circular arrays, they can be specified using the TxArrayType and TxArrayDimension (or RxArrayType and RxArrayDimension) parameters. Custom transmit array designs can be specified by selecting TxArrayType as "User Defined Tx" and specifying the name of an input file for TxArrayFileName. This file must be an ASCII file, with one line of the file for each antenna element in the array. Each line contains three tab or space-delineated numbers representing the *x*, *y*, and *z* coordinate of the antenna element in the array. Each element is assumed to have an omnidirectional radiation pattern in the horizontal (*x* - *y*) plane. A similar discussion applies to custom receive array designs (using RxArrayType and RxArrayFileName). The same file can be used to specify both transmit and receive arrays.

8. If the predefined models A-F are unsuitable for the application, ModelType can be specified to be a User Defined Model, and the channel characteristics must be specified. In this case, multipath characteristics are defined in an ASCII file specified in the MPathFileName parameter. Each line of this file represents a single multipath cluster, with six tab or space-delimited numbers specifying the multipath characteristics with the order shown in the table. The following table is an example file for 6 taps.

Example File, 6 Taps

Delay (first multipath starts at 0)	Power gain in dB	Angle of departure in degrees	Departure angle spread in degrees	Angle of arrival in degrees	Arrival angle spread in degrees
0	0	13.5	24.7	-65.7	22.0
10e-9	-2.1	13.5	24.7	-65.7	22.0
20e-9	-4.3	162.3	18.0	5.8	17.5
40e-9	-13.0	28.6	10.8	-143.8	25.0
45e-9	-5.8	13.5	24.7	-65.7	22.0
60e-9	-18.2	-85.2	18.0	43.4	18.0

For user-defined models, the power angular distribution in each cluster can be a truncated Laplacian (as in the predefined models), a truncated Gaussian, or uniform in angle (this is used only to compute the antenna correlation matrices). RiceanFactor, EnvironmentSpeed, and PathLoss parameters specify the Ricean K-factor for the first tap (dB), velocity of the scatterers creating the Doppler spectrum (km/hour), and bulk path loss (dB) for the channel, respectively.

9. Output Delay: A delay of 32 tokens is introduced by this model.

References

1. IEEE 802.11-04/940r2, IEEE P802.11 Wireless LAN TGn Channel Models, January 9, 2004.

WLAN 11n Design Examples

This section includes the WLAN 11n transmitter and receiver design examples.

WLAN 11n Tx Workspace Examples

WLAN_11N_Tx_wrk provides design examples for the WLAN 11n transmitter test and measurement, which are based on the EWC HT PHY Specification:

- WLAN_11n_CCDF: measures Complementary Cumulative Distribution Function of the transmitted signal
- WLAN_11n_TxEVM_2Tx: measures error vector magnitude for two transmit antennas
- WLAN_11n_Spectrum: measures the transmit PSD and compare it with specified mask.

Complementary Cumulative Distribution Function Measurement

WLAN_11n_CCDF

Features

- Configurable WLAN 11n signal source
- Two transmit antennas
- CCDF measurement

Description

This design is used to measure CCDF for WLAN 11n RF signal source with two transmit antennas. The design schematic is shown in the following figure.
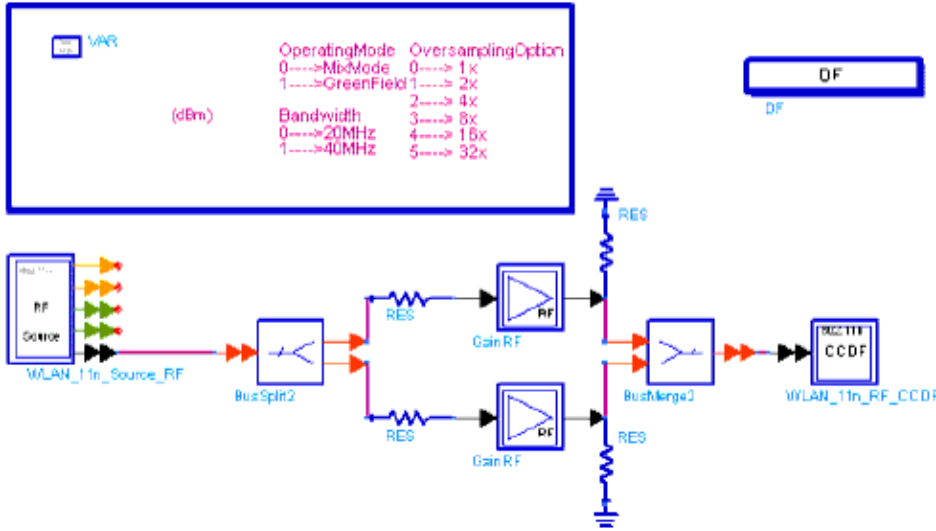
WLAN_11n_CCDF Schematic

The VAR incorporates parameters to configure the WLAN_11n_Source_RF.

Simulation Results

Simulation results displayed in WLAN_11n_CCDF.dds is shown on the following figure.

WLAN 11n CCDF Measurement Results

Benchmark

- Hardware Platform: Pentium IV 2.0 GHz, 1.5GB memory
- Software Platform: Windows XP, ADS 2005A
- Simulation Time: approximately 30 seconds

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN 11n Transmitter EVM Measurement

WLAN_11n_TxEVM_2Tx

Features

- Configurable WLAN 11n signal source
- Two transmit antennas
- EVM measurement
- Consistent measurement results with Agilent 89600 software

Description

This design measures EVM (Error Vector Magnitude) or RCE (Relative Constellation Error) of a WLAN 11n RF signal source (transmitter). EVM is the difference between the measured waveform and the theoretical modulated waveform and shows modulation accuracy. In mathematics, EVM here is defined as the ratio of Root-Mean-Square (RMS) error to RMS value of the theoretical modulated waveform. When Signal to Noise Ratio (SNR) is high, the EVM value shall be similar with SNR in absolute value.
The schematic for this design is shown in the following figure.

WLAN_11n_TxEVM_2Tx.dsn

WLAN 11n Transmitter EVM Measurement
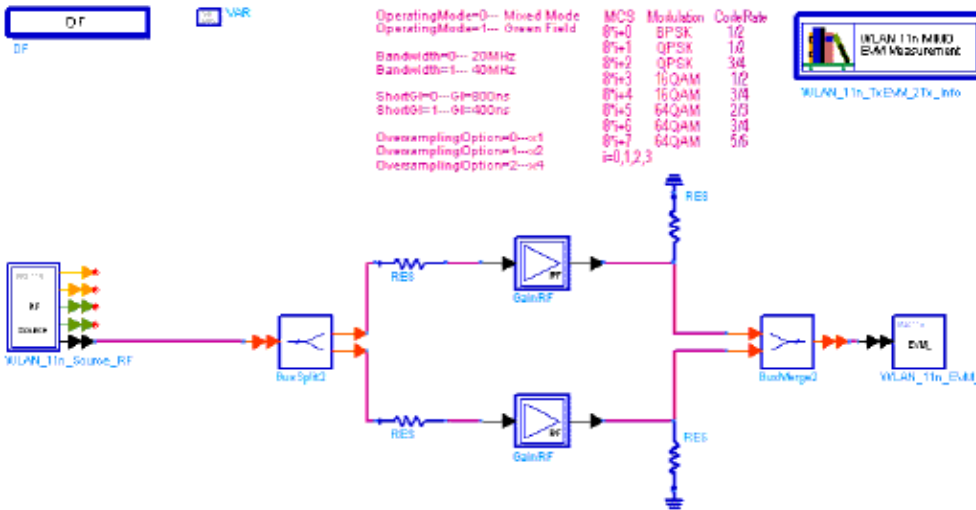
WLAN_11n_TxEVM_2Tx Schematic

WLAN_11n_Source_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 WLAN_11n_EVM_, which uses the same algorithm as that in Agilent 89600 software, will measure EVM, carrier frequency offset as well as other aspects of the measured signal.

> **ⓘ Note**
> Input and output resistors are put outside the corresponding source and measurement models because resistor pairs on two ends of a bus are transparent to each other. For obtaining reasonable measurement results, parameters of model WLAN_11n_EVM_ should be consistent with the corresponding input signal. For more details on UWB_MBOFDM_EVM, see document of this model.

Simulation Results

Simulation results in the Data Display System are shown in the following figure, which includes the average EVM measurement result in dB and percentage, EVM results of each successfully analyzed frame. Synchronization correlation coefficient, carrier frequency offset and some other auxiliary informations are provided in simulation status window.

EVM (Preambles and Data)

Frame	RCE_dB		RCE_rms_percent	
	RCE_dB(1)	RCE_dB(2)	RCE_rms_percent(1)	RCE_rms_percent(2)
1	-60.232	-60.955	0.097	0.089
2	-60.844	-61.275	0.093	0.086
3	-60.766	-59.807	0.092	0.102
4	-60.744	-61.057	0.092	0.088
5	-61.108	-61.337	0.087	0.086
6	-60.253	-60.742	0.097	0.092
7	-60.889	-60.807	0.090	0.091
8	-60.087	-61.000	0.092	0.089
Average 0	-60.830	-60.882	0.091	0.090

EVM (Data)

Frame	DataRCE_dB		DataRCE_rms_percent	
	DataRCE_dB(1)	DataRCE_dB(2)	DataRCE_rms_percent(1)	DataRCE_rms_percent(2)
1	-60.101	-60.866	0.098	0.091
2	-60.553	-61.188	0.094	0.087
3	-60.690	-59.743	0.092	0.103
4	-60.673	-60.976	0.093	0.089
5	-61.098	-61.265	0.089	0.086
6	-60.185	-60.657	0.098	0.093
7	-60.814	-60.721	0.091	0.092
Average 0	-60.751	-60.804	0.092	0.091

EVM (Pilot)

Frame	PilotRCE_dB		PilotRCE_rms_percent	
	PilotRCE_dB(1)	PilotRCE_dB(2)	PilotRCE_rms_percent(1)	PilotRCE_rms_percent(2)
1	-61.285	-62.509	0.088	0.075
2	-61.495	-62.421	0.084	0.076
3	-61.878	-60.728	0.081	0.092
4	-61.776	-62.466	0.082	0.075
5	-62.375	-62.400	0.076	0.076
6	-61.249	-62.044	0.087	0.079
7	-61.555	-62.108	0.083	0.078
Average 0	-62.015	-62.048	0.079	0.079

Measurement Results

Benchmark

- Hardware platform: Pentium IV 2.26 GHz, 1024 MB memory
- Software platform: Windows 2000 Professional, ADS 2005A
- Simulation time: about 20 seconds

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

Transmit Spectrum Measurement for WLAN 11n

WLAN_11n_Spectrum

Features

- Configurable WLAN 11n signal source
- Two transmit antennas
- Spectrum analysis

Description

This example demonstrates the WLAN 11n signal power spectrum density with two transmit antennas and compare the results with specified spectrum mask. It is easy to customize this example to measure the spectrum for up to 4 transmit antennas.

Schematics
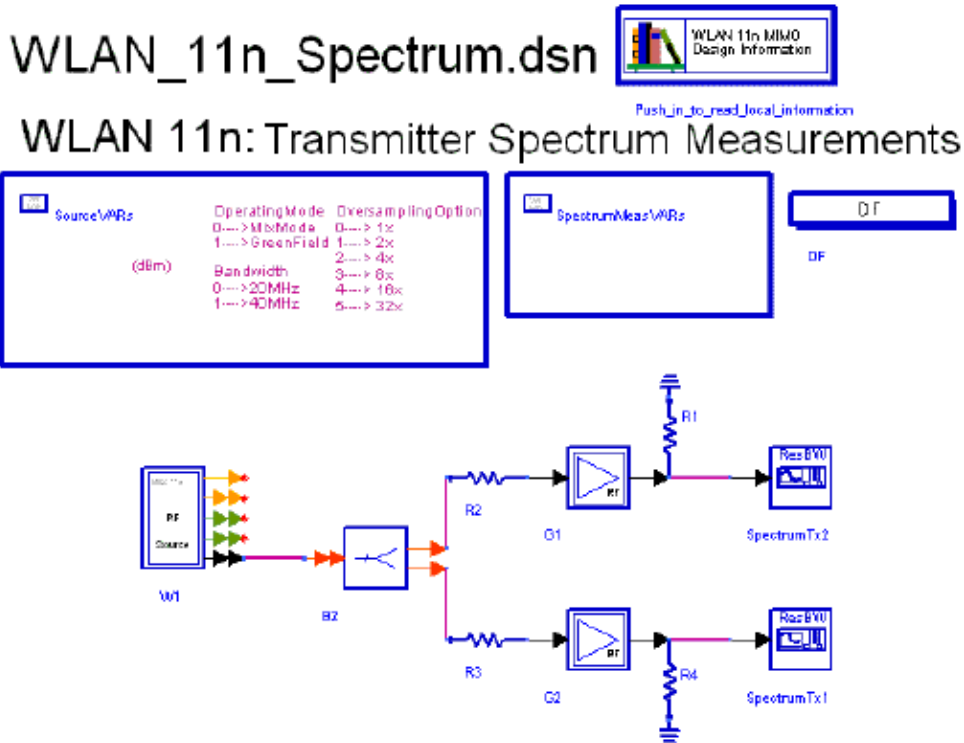
WLAN_11n_Spectrum Schematic

Simulation Results

Simulation results are displayed in WLAN_11n_Spectrum.dds. The following figure shows the power spectrum density of two transmit antennas with the spectrum mask, left for antenna one and right for antenna two. According to the specification, for 20MHz bandwidth, the signal spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset and -45 dBr at 30 MHz frequency offset and above. For 40MHz bandwidth, the signal spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 38 MHz, -20 dBr at 21 MHz frequency offset, -28 dBr at 40 MHz frequency offset and -45 dBr at 60 MHz

frequency offset and above.
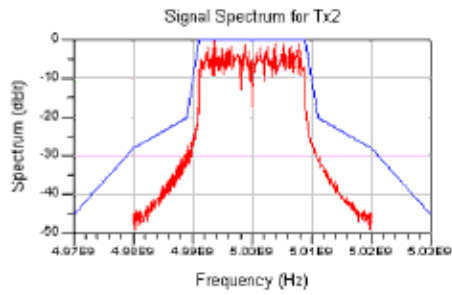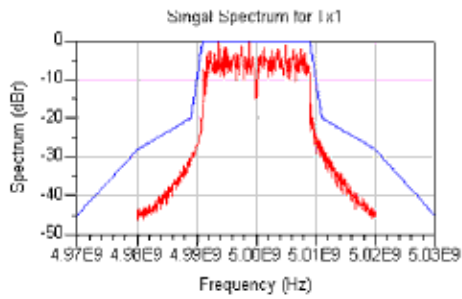
WLAN 11n Spectrum Measurement Results

Benchmark

- Hardware Platform: Pentium IV 2.0 GHz, 1.5GB memory
- Software Platform: Windows XP, ADS 2005A
- Simulation Time: approximately 4 seconds

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN 11n Rx Workspace Examples

WLAN_11N_Rx_wrk provides design examples for the WLAN 11n receiver test and measurement, which are based on the EWC HT PHY Specification:

- WLAN_11n_AWGN_System_2SS: measures WLAN 11n system performance with two spatial streams under AWGN channel.
- WLAN_11n_Fading_System_1SS: WLAN 11n system performance with one spatial stream under fading channel.
- WLAN_11n_Fading_System_2SS: WLAN 11n system performance with two spatial streams under fading channel.

BER and PER of WLAN 11n under AWGN Channel

WLAN_11n_AWGN_System_2SS

Features

- 2 transmit antennas
- Mixed Mode
- 20MHz
- Normal GI

Description

The performance of a WLAN 11n receiver in AWGN channel is evaluated by this example. The simulation link incorporates implementation losses due to packet acquisition error, carrier offset recovery error, channel estimation error and etc.
The schematic for this example is shown in the following figure.

WLAN 11n: BER and PER of WLAN 11n under AWGN Channel
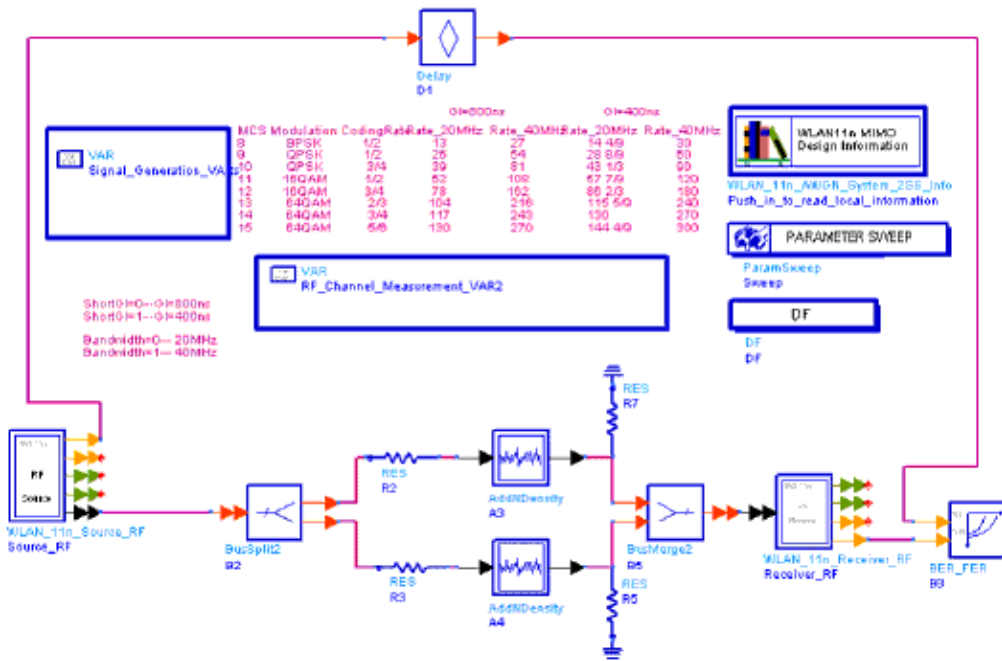
WLAN_11n_AWGN_System_2SS Schematic

WLAN_11n_Source_RF generates the ideal signal waveform which is distorted by AWGN channel. Then WLAN_11n_Receiver_RF performs frame acquisition, frequency offset compensation, channel equalization and demodulates the information bits out. BER_FER model compares the demodulated bits with the delayed raw information bits and output the BER/FER results with the predefined relative estimation variance.

> **Note** Input and output resistors are put outside the corresponding source and receiver models because resistor pairs on two ends of a bus are transparent to each other. For obtaining reasonable measurement results, parameters of the receiver should be consistent with that of the input signal.

Simulation Results

BER/FER results for different Modulation Coding Schemes (MCS) from the Data Display System are shown in the following figure.

2 Spatial Streams BER and PER under AWGN channel
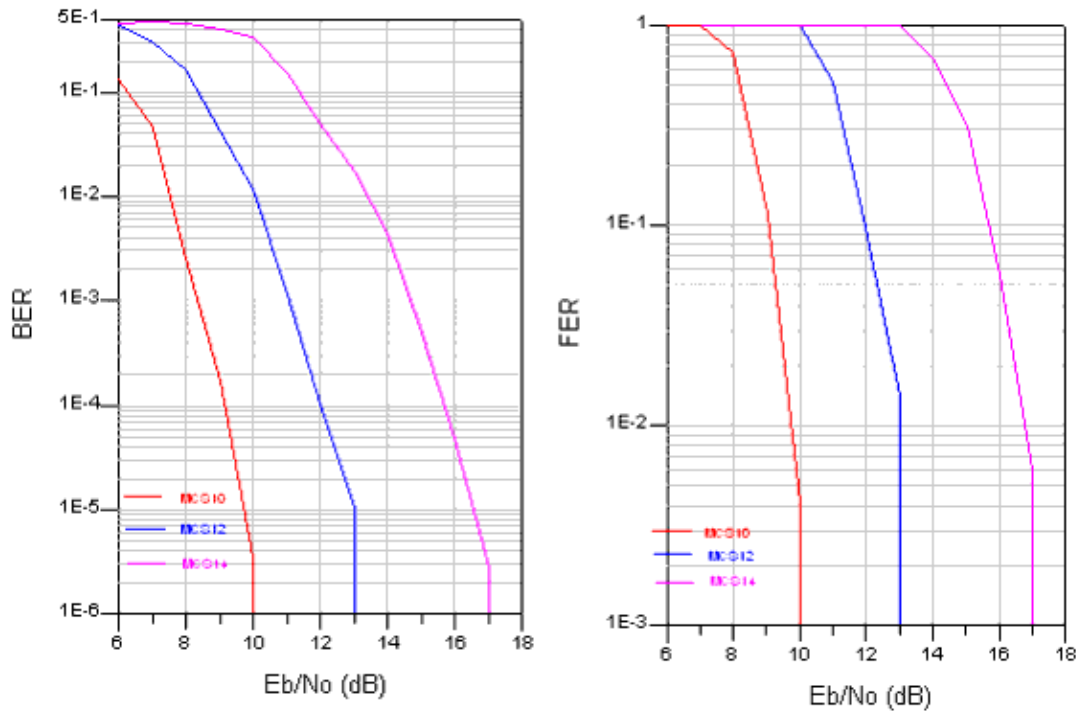
Measurement Results

Benchmark

- Hardware platform: Pentium IV 2.26 GHz, 1024 MB memory
- Software platform: Windows 2000 Professional, ADS 2005A
- Simulation time: about 10 minutes for MCS10

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

BER and PER of WLAN 11n under Fading Channel

WLAN_11n_Fading_System_1SS
WLAN_11n_Fading_System_2SS

Features

- 1 transmit antenna and 2 antennas
- Mixed Mode
- 20MHz
- Normal GI

Description

The performance of a WLAN 11n receiver under fading channels are evaluated by these examples. The simulation link incorporates implementation losses due to packet acquisition error, carrier offset recovery error, channel estimation error and etc. The schematics for these examples are shown in the following figures.

WLAN_11n_Fading_System_1SS Schematic

WLAN_11n_Fading_System_1SS Schematic

WLAN_11n_Source_RF generates the ideal signal waveform which is distorted by fading channel. Sub-network model WLAN_PowerControl and WLAN_PowerControl2 are used to adjust output power of the channel model frame by frame. Because signal power under fading channel fluctuates within several tens of dBs, power control, which is also used in close loop in the real world, makes the simulation results more sense. WLAN_11n_Receiver_RF performs frame acquisition, frequency offset compensation, channel equalization and demodulates the information bits out. BER_FER model compares the demodulated bits with the delayed raw information bits and output the BER/FER results with the predefined relative estimation variance.

> **ℹ Note** Input and output resistors are put outside the corresponding source and receiver models because resistor pairs on two ends of a bus are transparent to each other. For obtaining reasonable measurement results, parameters of the receiver should be consistent with that of the input signal.

Simulation Results

BER/FER results for different Modulation Coding Scheme (MCS) from the Data Display System are shown in the following figures.

1 Spatial Stream BER and PER under Fading channel
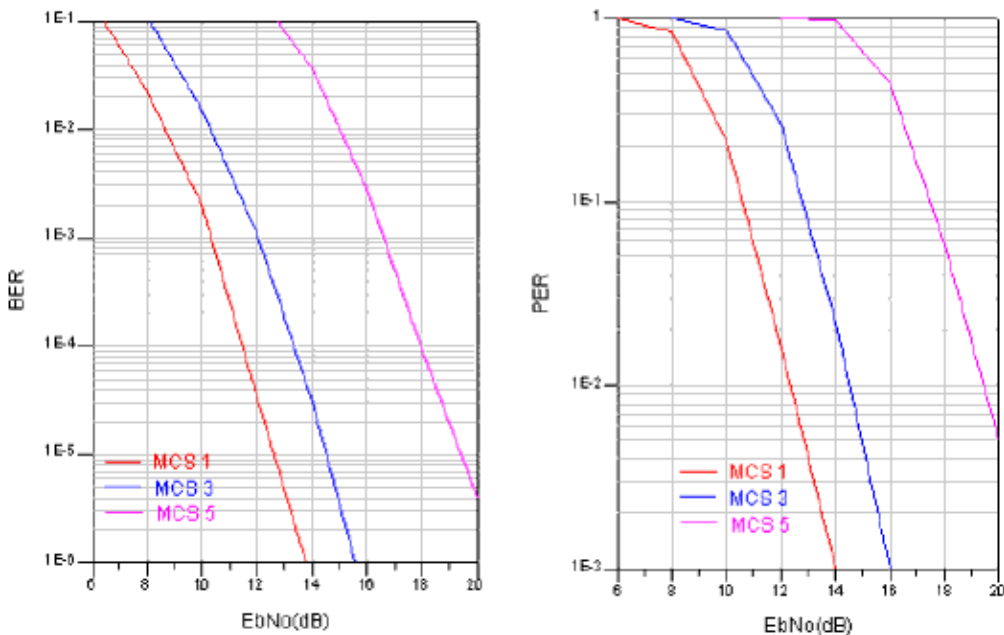
Measurement Results for 1SS

2 Spatial Streams BER and PER under Fading channel
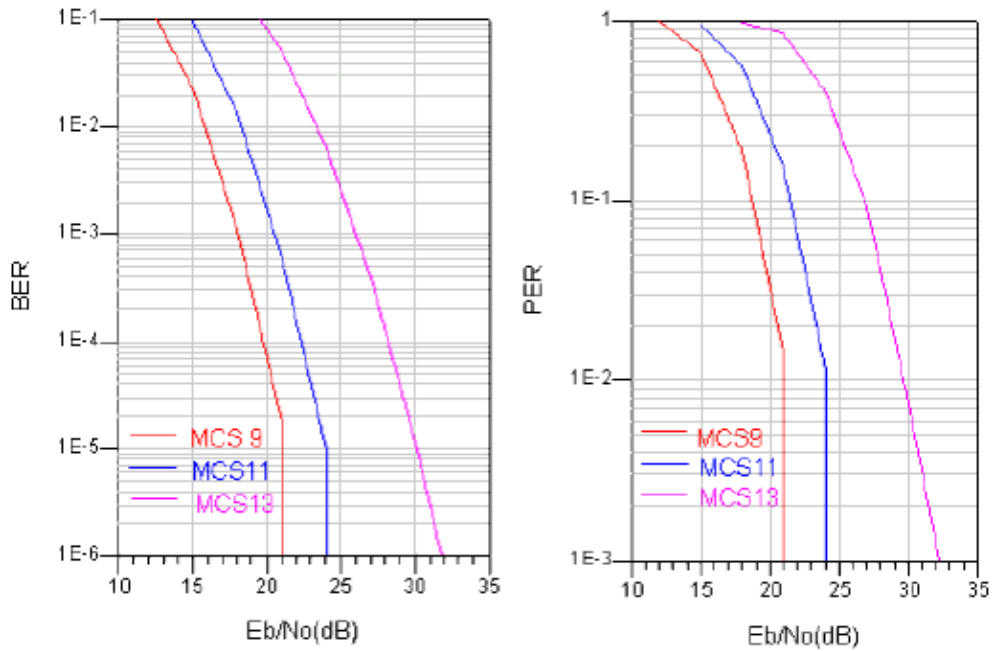
Measurement Results for 2SS

Benchmark

- Hardware platform: Pentium IV 2.26 GHz, 1024 MB memory
- Software platform: Windows 2000 Professional, ADS 2005A
- Simulation time: about 10 hours for MCS1

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n Measurements

The WLAN 11n measurement models are provided in this category.

- *WLAN 11n EVM (WLAN 11n EVM measurement)* (wlan11n)
- *WLAN 11n RF CCDF (WLAN 11n RF CCDF)* (wlan11n)

WLAN_11n_EVM_ (WLAN 11n EVM measurement)
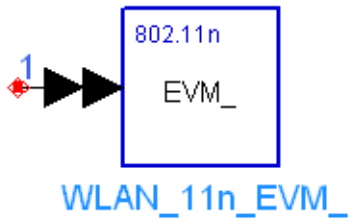
Description WLAN 11n EVM measurement star
Library WLAN 11n, Measurements
Class TSDFWLAN_11n_EVM_

Parameters

Name	Description	Default	Unit	Type	Range
FCarrier	carrier frequency	5.0e9	Hz	real	(0, ∞)
MirrorSpectrum	Mirror frequency spectrum? NO, YES	NO		enum	
Start	start time for data recording. DefaultTimeStart will inherit from the DF Controller.	DefaultTimeStart	sec	real	[0, ∞)
AverageType	average type: Off, RMS (Video)	RMS (Video)		enum	
FramesToAverage	number of frames that will be averaged if AverageType is RMS (Video)	20		int	[1, ∞)
GuardIntervalSel	Auto Detect Gurad, ManuOverride Guard	Auto Detect Gurad		enum	
GuardInterval	guard interval time of data symbol, expressed as a fraction of the FFT time length	0.25		real	[0, 1]
SearchLength	search length, should include more than 2 full frames	1.0e-3	sec	real	(0, ∞)
MeasurementOffset	measurement offset (the first MeasurementOffset number of data symbols shall be excluded for EVM)	0		int	[0, 21848]
MeasurementInterval	measurement interval of data symbols (0~21848, if 21848 all data symbols from MeasurementOffset to the end shall be used)	21848		int	[0, 21848]
SubcarrierSpacing	spacing between subcarriers in Hz	312.5e3	Hz	real	(0, ∞)
SymbolTimingAdjust	amount of time (expressed as a percent of the FFT time length) to back away from the end of the symbol time when deciding the part of the symbol that the FFT will be performed on	-3.125		real	[-100*GuardInterval, 0]
TrackAmplitude	pilot amplitude tracking: NO, YES	NO		enum	
TrackPhase	pilot phase tracking: NO, YES	YES		enum	
TrackTiming	pilot timing tracking: NO, YES	YES		enum	
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz		enum	
NumTx	number of transmit chains (antennas)	1		int	[1, 2]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	multiple timed

Notes/Equations

1. This model is used to perform EVM (Error Vector Magnitude or Relative Constellation Error) measurement for WLAN 11n signal. The input signal format should be compatible with EWC specification (References #1). Signals of one transmit channel and two transmit channels are supported.
2. The input signal should be a timed RF (complex envelope) signal or this model will error out. This measurement provides results in Data Display for RCE_dB (Relative Constellation Error in dB of all non-zero subcarriers of analyzed

data OFDM symbols),

> RCE_rms_percent (Relative Constellation Error in root mean square percent of all non-zero subcarriers of analyzed data OFDM symbols),
> DataRCE_dB (RCE_dB of data subcarriers of analyzed data OFDM symbols),
> DataRCE_rms_percent (RCE_rms_percent of data subcarriers of analyzed data OFDM symbols),
> PilotRCE_dB (RCE_dB of pilot subcarriers of analyzed data OFDM symbols), and
> PilotRCE_rms_percent (RCE_rms_percent of pilot subcarriers of analyzed data OFDM symbols).

Additionally, synchronization correlation coefficient, carrier frequency offset as well as some other auxiliary information are provided in Simulation/Synthesis Messages box.

3. The algorithm used here is the same as the one used in the Agilent 89600 VSA software. Following is a brief description of the algorithm.
Starting at the time instant specified by the *Start* parameter, a signal segment of length *SearchLength* is acquired. This signal segment is searched in order for a complete burst to be detected.

> The burst search algorithm looks for both a burst on and a burst off transition. In order for the burst search algorithm to detect a burst, an idle part must exist between consecutive bursts and the bursts must be at least 15 dB above the noise floor.
> If the acquired signal segment does not contain a complete burst, the algorithm will not detect any burst and the analysis that follows will most likely produce incorrect results. Therefore, *SearchLength* must be long enough to acquire at least one complete burst. Because the time instant specified by the *Start* parameter can be soon after the beginning of a burst, it is recommended that *SearchLength* be set to a value approximately equal to 2 burstLength + 3 idle, where burstLength is the duration of a burst in seconds and idle is the duration of the idle part in seconds. If the duration of the burst or the idle part is unknown, then a TimedSink component can be used to record the signal and the signal can be plotted in the Data Display. By observing the magnitude of the signal's envelope versus time one can determine the duration of the burst and the idle interval.

After a burst is detected, synchronization is performed. The burst is then demodulated (the *FCarrier* parameter sets the frequency of the internal local oscillator signal). The burst is then analyzed to get the EVM measurement results.

> The EVM results is that of each input channel, each of which could contain a mix of data from several different data streams. To compute the EVM of the input channel, the measured and reference data from the data streams is mapped back through the measured channel response matrix, to produce measured and reference vectors for each input channel. EVM is computed from these measured and reference vectors for the input channel. The measured and reference vectors for the input channel are currently kept internal to the model, so can't be examined by the user.
> If *AverageType* is set to Off, only one burst is detected, demodulated, and analyzed.
> If *AverageType* is set to RMS (Video), after the first burst 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 *SearchLength*. When the buffer is full again a new burst search is performed and when a burst is detected it is demodulated and analyzed. These steps repeat until *FramesToAverage* bursts are processed or *SearchLength* × *FramesToAverage* long signals are analyzed.

If for any reason a burst is misdetected the results from its analysis are discarded. The EVM results obtained from all the successfully detected, demodulated, and analyzed bursts are averaged to give the average result.

4. Parameter details.

FCarrier is the internal local oscillator frequency used by demodulator.

MirrorSpectrum is used to mirror the spectrum (invert the Q envelope) of input signal.

Start indicates the time instant from which the input signal is collected for measurement.

AverageType is used to select average type of measurement. If it is set to Off, only one burst is detected, demodulated, and analyzed. If it is set to RMS (Video), measurement shall be repeated until *FramesToAverage* bursts are detected or *SearchLength* × *FramesToAverage* long signals are analyzed.

FramesToAverage is the number of frames that will be averaged if *AverageType* is RMS (Video).

GuardIntervalSel is used to select guard interval of data symbols. If it's set Auto Detect Guard, the demodulator will get guard interval of data symbols automatically. If it's set ManuOverride Guard, the demodulator will regard guard interval of data symbols as *GuardInterval* whatever the real one is.

GuardInterval sets the guard interval of data symbols for the demodulator, as a fraction of the FFT time period, only 0.25 (full guard interval) and 0.125 (half guard interval or ShortGI) is allowed. It is valid only when *GuardIntervalSel* is set to ManuOverride Guard.

SearchLength indicates how long a signal is used each measurement. It's recommended that *SearchLength* be set a value of a little more than 2 times of the duration of a valid burst plus idle part.

MeasurementOffset indicates the number of data symbols at the beginning of data payload that shall be discarded in EVM calculation. If the number of data symbols detected in a burst is less than the sum of *MeasurementOffset* and *MeasurementInterval*, the real "MeasurementOffset" shall be reduced till 0.

MeasurementInterval indicates the number of data symbols used for EVM calculation. If it is set to 21848, all data symbols except the first *MeasurementOffset* data symbols shall be used. If the number of data symbols detected in a burst is less than the sum of *MeasurementOffset* and *MeasurementInterval*, the real "MeasurementOffset" shall be reduced till 0. If the number of data symbols detected is less than *MeasurementInterval*, the real "MeasurementInterval" shall be reduced and all data symbols shall be used for EVM calculation. See the following figure for the relationship of *SearchLength*, *MeasurementOffset*, and *MeasurementInterval*.
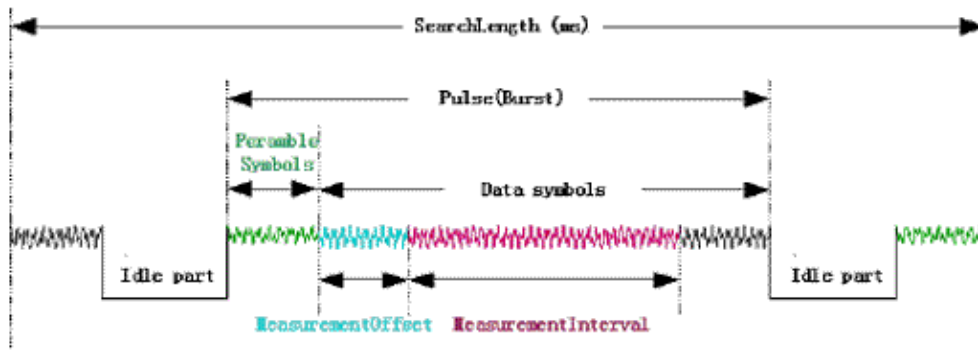
Relationship of *SearchLength*, MeasurementOffset and MeasurementInterval

SubCarrierSpacing specifies the subcarrier spacing of the OFDM signal. The subcarrier spacing must match the actual subcarrier spacing in the input signal in order for the demodulation and analysis to be successful.

SymbolTimingAdjust is used for optimal demodulation. Normally, when demodulating an OFDM symbol, the guard interval is skipped and an FFT is performed on the last portion of the symbol time. However, this means that the FFT will include the transition region between this symbol and the following symbol. To avoid this, it is generally beneficial to back away from the end of the symbol time and use part of the guard interval. The *SymbolTimingAdjust* parameter controls how far the FFT part of the symbol is adjusted away from the end of the symbol time. The value is in terms of percent of the used (FFT) part of the symbol time. Note that this parameter value is negative, because the FFT start time is moved back by this parameter. The following figure explains this concept. When setting this parameter, be careful to not back away from the end of the symbol time too much because this may make the FFT include corrupt data from the transition region at the beginning of the symbol time. Values belongs to [-3.125%, (GuardInterval/2)%] is recommended.
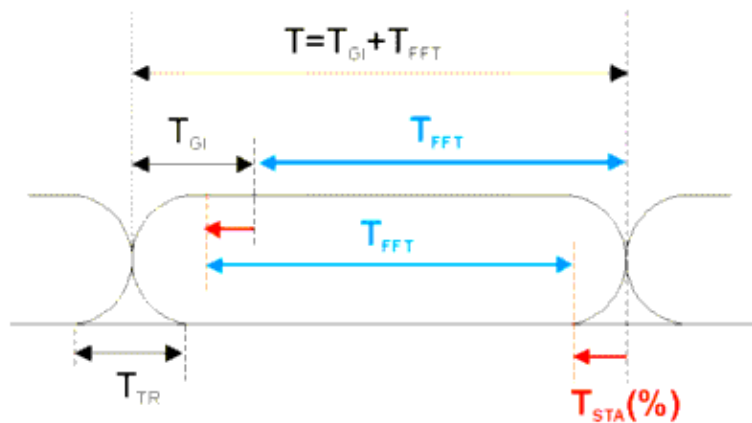
T = Symbol Time
T_{GI} = Guard Interval
T_{FFT} = FFT/IFFT Time Period
T_{TR} = Symbol Transition Time
T_{STA} = Symbol Timing Adjust (%)

TrackAmplitude is used to decide whether amplitude tracking which is derived from pilots in data symbols shall be used in demodulation process.

TrackPhase is used to decide whether phase tracking which is derived from pilots in data symbols shall be used in demodulation process.

TrackTiming is used to decide whether timing tracking which is derived from pilots in data symbols shall be used in demodulation process.

Bandwidth is the bandwidth of the input signal, 20 MHz or 40 MHz.

NumTx is the number of input channels, only 1-channel and 2-channel signals are supported by this model.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_RF_CCDF (WLAN 11n RF CCDF)

WLAN_11n_RF_CCDF

Description Complementive cumulative distribute function of signal
Library WLAN 11n, Measurements
Class TSDFWLAN_11n_RF_CCDF

Parameters

Name	Description	Default	Unit	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode		enum	
MCS	modulation Coding Scheme ([0,31])	0		int	[0, 31]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz		enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256		int	[1, 2^16-1]
ShortGI	400ns guard interval in data symbols: NO, YES	NO		enum	
NumHTLTF	number of HT long training fields	1		int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1		enum	
IdleInterval	Idle Interval	100 nsec	sec	real	[0, 1000usec]
NumTx	number of transmit chains (antennas)	1		int	[1, 4]
OutputPoint	Indicate output precision	100		int	[1, ∞)
RefR	Reference resistance	50.0		real	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	multiple timed

Notes/Equations

1. This subnetwork is used to measure the CCDF (complementary cumulative distribution function) for WLAN 11n RF signals. The subnetworks schematic is shown in the following figure.

WLAN_11n_CCDF Schematic

2. The input RF signal is down-converted to baseband signals first and then the time and frequency offset have been compensated. The CCDF of data field and whole packet are measured on each transmit chain and saved to the dataset. The distribution range from the peak power to the minimum power is divided into measurement bins based on the parameter *OutputPoint*.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n Receiver Components

The components that can be used to construct 11n receivers are provides in this category.

- *WLAN 11n AntDemapper (WLAN 11n Antenna)* (wlan11n)
- *WLAN 11n BurstDemux (WLAN 11n Burst Demultiplexer)* (wlan11n)
- *WLAN 11n ChDecoder (WLAN 11n FEC decoder)* (wlan11n)
- *WLAN 11n ChEstimator (WLAN 11n Channel Estimator)* (wlan11n)
- *WLAN 11n DataUnwrap (WLAN 11n Data Unwrap)* (wlan11n)
- *WLAN 11n Demapper (WLAN 11n constellation demapper)* (wlan11n)
- *WLAN 11n OFDMDeMod (WLAN 11n OFDM demodulation)* (wlan11n)
- *WLAN 11n PhaseTracker (WLAN 11n Phase Tracker)* (wlan11n)
- *WLAN 11n RF Demodulator (WLAN 11n RF Demodulator)* (wlan11n)
- *WLAN 11n SpatialCommutator (WLAN 11n Spatial Commutator)* (wlan11n)
- *WLAN 11n Sync (WLAN 11n Synchronizer)* (wlan11n)

WLAN_11n_AntDemapper (WLAN 11n Antenna)
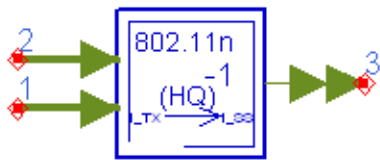
WLAN_11n_AntDemapper

Description high throuhput long training field for mixed mode
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_AntDemapper

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]
NumRx	number of receiver antennas	1	int	[1, 4]

Pin Inputs

Pin	Name	Description	Signal Type
1	HQ_D	channel coefficient in data subcarriers	complex matrix
2	Data_PT	data part after phase tracker in data subcarriers	complex matrix

Pin Outputs

Pin	Name	Description	Signal Type
3	DataAftChC	data part after channel compensation and antenna demapper in data subcarriers	multiple complex

Notes/Equations

1. This subnetwork model is used to demap the received signal chains to spatial streams and remove the effect of cyclic shift as well as the channel.

2. The input HQ_D is $NumRx \times N_{SS}$ matrix pin which input the estimated channel impulse response matrix of the data subcarriers. The input Data_PT is $NumRx \times 1$ matrix pin which input the values of the data subcarriers after phase offset compensation. The output DataAftChC is multi-port pin which should be expanded to the number of spatial streams (NSS) and used to output the values of the data subcarriers after channel compensation.
The schematic of this subnetwork is shown in the following figure.

WLAN_11n_AntDemapper Schematic

Each firing,
In the case of 20 MHz transmission,

- 52 tokens (!wlan11n-7-02-005.gif! matrix) are consumed at pin HQ_D;
- 52 × NSYM (!wlan11n-7-02-006.gif! matrix) tokens are consumed at pin Data_PT;
- 52 × NSYM tokens are produced at each port of the pin DataAftChC.
  In the case of 40 MHz transmission,
- 108 tokens (!wlan11n-7-02-007.gif! matrix) are consumed at pin HQ_D;
- 108 × NSYM (!wlan11n-7-02-008.gif! matrix) tokens are consumed at pin Data_PT;
- 108 × NSYM tokens are produced at each port of the pin DataAftChC.
  where,

$$N_{SYM} = m_{STBC} \times ceil((8 \times HTLength + 16 + 6 \times N_{ES})/(m_{STBC} \times N_{DBPS}))$$

  where,
  mSTBC is 1 (STBC is not used.) HTLength is the PSDU length in byte. NES is the number of FEC encoders used which is decided by the parameter MCS.
  NDBPS is the number of data bits per symbol which is decided by parameters MCS and Bandwidth.

3. The antenna demap and channel compensations in all data subcarriers are expressed as follows:

$$\tilde{D}^n(k) = (H\Phi Q(k))^{\dagger} \cdot R^n(k)$$

where,

$$R^n(k) = \left[R^n{}_1(k) , \dots , R^n{}_{NumRx}(k) \right]^T$$ is the $NumRx \times 1$ received signal vector of the k'th data subcarrier of the n'th data symbol.

$$\tilde{D}^n(k) = \left[\tilde{D}^n{}_1(k) , \dots , \tilde{D}^n{}_{N_{ss}}(k) \right]^T$$ is the recovered spatial stream vector of the k'th data subcarrier of the n'th data symbol.

$$(H\Phi Q(k))^{\dagger} = ((H\Phi Q(k))^H \cdot H\Phi Q(k))^{-1} \cdot (H\Phi Q(k))^H$$ is the pseudo-inverse of the estimated channel impulse response matrix of the k'th data subcarriers $H\Phi Q(k)$.

The matrix inversion of $(H\Phi Q(k))^H \cdot H\Phi Q(k)$ is performed by the WLAN_11n_InverseCx_M. If this matrix is singular, the output is a zeros matrix with the same size.

The recovered spatial stream vectors are unpacked and output at Pin DataAftChC.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_BurstDemux (WLAN 11n Burst Demultiplexer)

WLAN_11n_BurstDemux
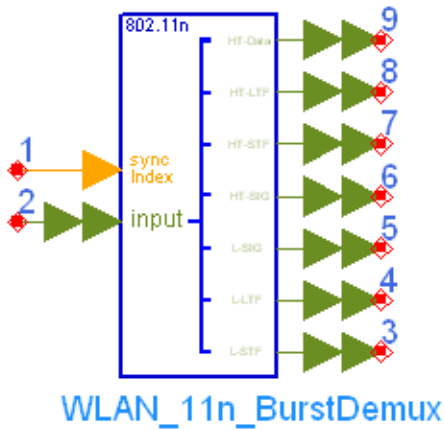
Description 802.11n burst de-multiplexing
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_BurstDemux

Parameters

Name	Description	Default	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode	enum	
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]
ShortGI	400ns guard interval in data symbols: NO, YES	NO	enum	
NumHTLTF	number of HT long training fields	1	int	[1, 4]
NumRx	number of transmit chains (antennas)	1	int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	syncIndex	index of optimal start point L-STF	int
2	input	frequency offset compensated signal (without idle interval)	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	LSTF	legacy short training field without guard interval	multiple complex
4	LLTF	legacy long training field(HT-LTF1 in Green Field Mode) without guard interval)	multiple complex
5	LSIG	L-SIG Mixed Mode or zeros in Green Field Mode without guard interval	multiple complex
6	HTSIG	high throughtput signal field without guard interval	multiple complex
7	HTSTF	high throughput short training field without guard interval	multiple complex
8	HTLTF	high throughput long training field (of one OFDM symbol length each) without guard interval	multiple complex
9	Data	data symbols without guard interval	multiple complex

Notes/Equations

1. This model is used to de-multiplex the received bursts (frames) for WLAN 11n RF receiver.
2. Its input (and each output) pin is a multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is NumRx, for instance, the Bus model with parameter "BusWidth" set to NumRx.
3. The input signal should be a cluster of pure frames (without idle interval) with same duration and preamble format.
   Input "SyncIndex" is used to determine the start of L-STF in the input frame. If this pin is left unconnected, default value 0 shall be used. If "SyncIndex" is connected and its value is not 0, value SyncIndex - FrameLength shall be used as the optimal start of the burst which means signal of the preceding frame shall be used.
4. Each fire, $N_{inSample}$ tokens in each transmit channel shall be consumed at the "input" pin, $N_{outSample}$ tokens shall be generated at each output pin, where

$$N_{inSample} = [(8 + NumHTLTF) \cdot 80 + 80 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$ in Mixed
Mode and full guard interval in data symbols,

$$N_{inSample} = [(8 + NumHTLTF) \cdot 80 + 64 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$ in Mixed
Mode and half guard interval in data symbols,

$$N_{inSample} = [(5 + NumHTLTF) \cdot 80 + 80 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$ in Green
Field and full guard interval in data symbols,

$$N_{inSample} = [(5 + NumHTLTF) \cdot 80 + 64 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$ in Green
Field and half guard interval in data symbols,

$$N_{outSample} = N_{Field} \cdot 64 \cdot 2^{Bandwidth + OversamplingOption}$$,

NumDataSym is determined by parameter HTLength and MCS, see section 4 in References #1 for more details. NField is the output symbol number of each signal field. For Mixed Mode,

$$N_{L-STF} = 2$$,

$$N_{L-LTF} = 2,$$
$$N_{L-SIG} = 1,$$
$$N_{HT-SIG} = 2,$$
$$N_{HT-STF} = 1,$$
$$N_{HT-LTF} = NumHTLTF,$$
$$N_{Data} = NumDataSym;$$

and for Green Field,

$N_{L-LTF} = 2$ which is in fact the signal field of HT-LTF1 for demodulating HT-SIG,

$$N_{HT-SIG} = 2,$$
$$N_{HT-LTF} = NumHTLTF,$$
$$N_{Data} = NumDataSym.$$

5. The outputs of each field, including L-STF, L-LTF, L-SIG, HT-SIG, HT-STF, HT-LTF and Data, are all OFDM symbols without guard interval. The following figure shows the relationship of input and outputs.
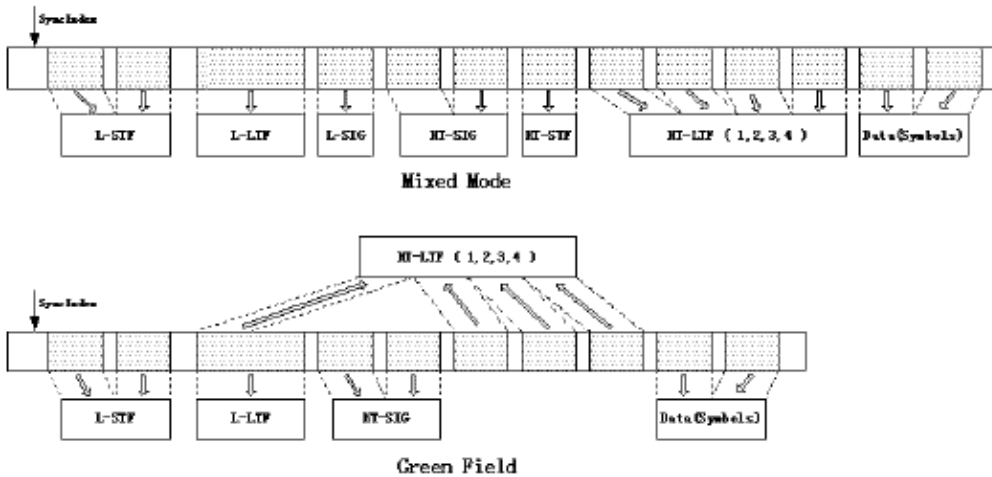
Relationship of Input and Outputs

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_ChDecoder (WLAN 11n FEC decoder)
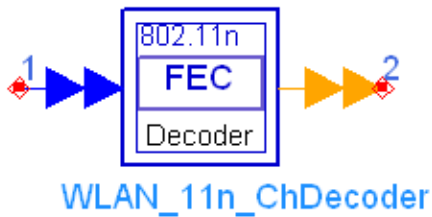
WLAN_11n_ChDecoder

Description Channel decoding of PSDU
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_ChDecoder

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	encoded bit stream	multiple real

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	un-Coded bits	multiple int

Notes/Equations

1. This subnetwork is used to implement the Viterbi decoder.
2. The input and output pins are multiport pins, the buswidth of which is N_{ES}. Each firing, $N_{SYM} \times N_{CBPS}$ tokens are consumed and $N_{SYM} \times N_{DBPS}$ tokens are produced, where N_{SYM} is the number of data symbols per frame, N_{DBPS} is number of data bits per OFDM symbol and N_{CBPS} is the number of coded bits per OFDM symbol. The schematic of this subnetwork is shown in the following figure.
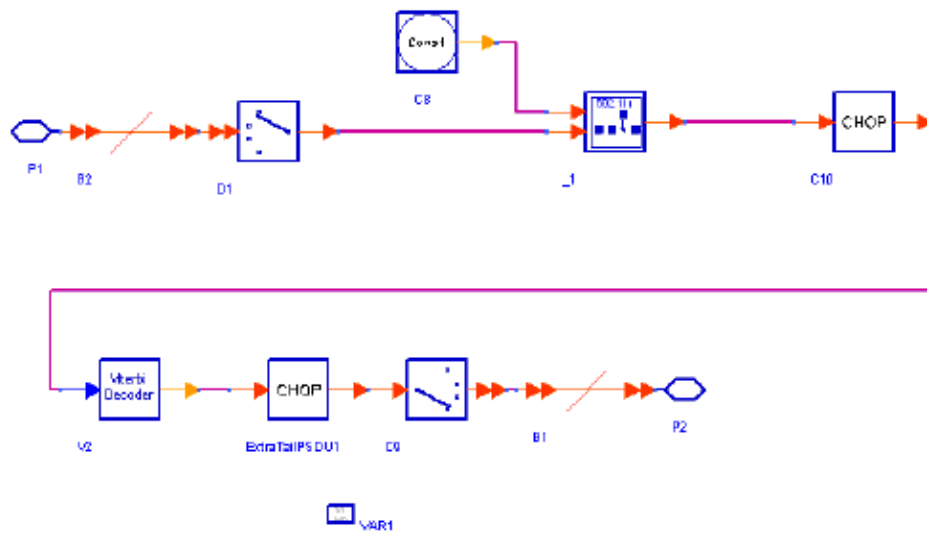
WLAN_11n_ChDeoder Schematic

3. The input data are padded with zeros first, which is the reverse process of puncture. Then a Viterbi decoder is applied to achieve maximum likelihood decoding.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_ChEstimator (WLAN 11n Channel Estimator)
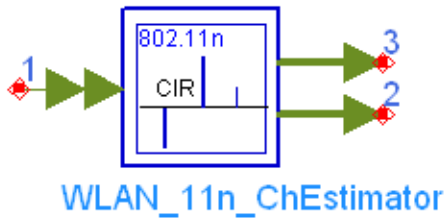
Description high througput long training field for mixed mode
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_ChEstimator

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
NumHTLTF	number of HT long training fields	1	int	[1, 4]
NumRx	number of receiver antennas	1	int	[1, 4]

Pin Inputs

Pin	Name	Description	Signal Type
1	Signal_F	output signals from FFT	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	HQ_D	channel coefficient in data subcarriers	complex matrix
3	HQ_P	channel coefficient in pilot subcarriers	complex matrix

Notes/Equations

1. This subnetwork is used to estimate the WLAN MIMO channel based on the High Throughput Long Training Fields (HT-LTFs) and output estimated channel impulse response (CIR) matrixes of the active subcarriers which include the data subcarriers part and the pilot subcarriers part.
2. The input is multi-port pin which should be expanded to the number of receiver antennas (NumRx). The two outputs are $NumRx \times N_{SS}$ matrix pins which are used to output estimated channel impulse response matrix of the data subcarriers part and the pilot subcarriers part respectively.
   The schematic of this subnetwork is shown in the following figure.
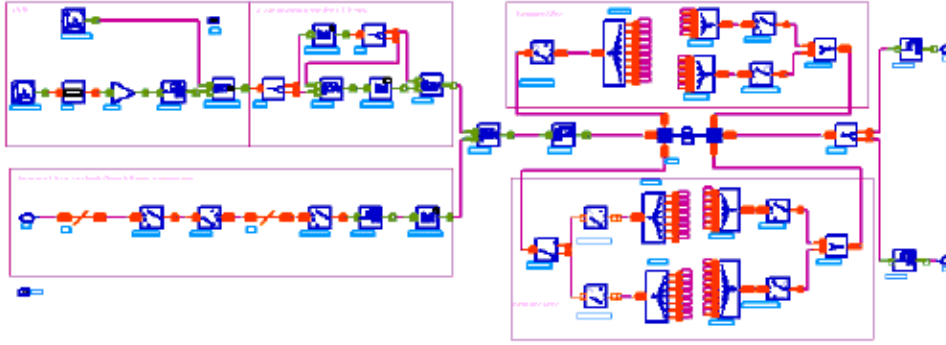
WLAN_11n_ChEstimator Schematic

Each firing,
In the case of 20 MHz transmission, 56 tokens are consumed at each input port; 52 tokens (!wlan11n-7-05-040.gif! matrix) are produced at the output port HQ_D and 4 tokens (!wlan11n-7-05-041.gif! matrix) are produced at the output port HQ_P.
In the case of 40 MHz transmission, 114 tokens are consumed at each input port; 108 tokens (!wlan11n-7-05-042.gif! matrix) are produced at the output port HQ_D and 6 tokens (!wlan11n-7-05-043.gif! matrix) are produced at the output port HQ_P.

3. This subnetwork model uses the HTLTF(s) to estimate the overall channel matrix $H\Phi Q$, which includes the applied Spatial Mapping Matrix Q and the effect of cyclic shift Φ.

4. The sequence used to construct the HT training sequence is defined as follows:
   If Bandwidth=20 MHz,

   $HTLTF1_{-28:28}$ = {1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1,

   1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 0, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1,
   1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1}

   If Bandwidth=40 MHz,

   $HTLTF1_{-58:58}$ = {1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -

   1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -
   1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, 0, 0, 0, -1, 1, 1, -1, 1, 1, -1, -1,
   1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -
   1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1}

The transmitted sequence in the iSMI'th spatial mapper input in the n'th HT training symbol is multiplied by the polarity PHTLTF(iSMI,n). The 4×4 polarity pattern matrix PHTLTF is defined as follows:

$$P_{HTLTF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix}$$

For the kth subcarrier, the $NumRx \times NumHTLTF$ matrix of the received signal R(k) is expressed as follows:

$$R(k) = H\Phi Q(k) \cdot HTLTF(k)$$

where,

$$HTLTF(k) = P_{HTLTF}^{N_{ss} \times NumHTLTF} \cdot HTLTF1(k)$$

$P_{HTLTF}^{N_{ss} \times NumHTLTF}$ is a $N_{SS} \times NumHTLTF$ submatrix of P $_{HTLTF}$ with the first N $_{SS}$ raws and the first NumHTLTF columns of P $_{HTLTF}$.

For this subcarrier, the estimated CIR $H\Phi Q$ is a $NumRx \times N_{SS}$ matrix which can be calculated as follows:

$$H\Phi Q(k) = R(k) \cdot (HTLTF(k))^{\dagger}$$

where,

$$(HTLTF)^{\dagger} = HTLTF^{H} \cdot (HTLTF \cdot HTLTF^{H})^{-1}$$ is the pseudo-inverse of HTLTF.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_DataUnwrap (WLAN 11n Data Unwrap)
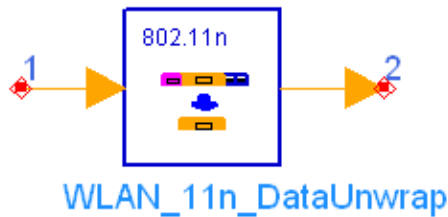
WLAN_11n_DataUnwrap

Description Tailling and padding of PSDU bit stream
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_DataUnwrap

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^{16-1}])	256	int	[1, 2^{16-1}]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	PSDU in bit	int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	bits after tail and pad bits are removed	int

Notes/Equations

1. This model is used to extract PSDU bits stream from the received data field and delete the service field, the tail and the pad bits.
2. Each firing,

    $N_{SYM} \times N_{DBPS}$ tokens are consumed at pin In which are the received data field including service field, tail and pad bits.

   where

    N_{SYM} is the number of symbols in the data field which is computed using the formula:

$$N_{SYM} = m_{STBC} \times ceil((8 \times HTLength + 16 + 6 \times N_{ES})/(m_{STBC} \times N_{DBPS}))$$

   where

m_{STBC} is 1 (STBC is not used.)

HTLength is the PSDU length in byte.
16 is the number of service field bits which have been scrambled by the scrambler.

N_{ES} is the number of FEC encoders used which is decided by the parameter MCS and $6 \times N_{ES}$ is the number of tail bits.

N_{DBPS} is the number of data bits per symbol which is decided by parameters MCS and Bandwidth.

$8 \times$ *HTLength* tokens are produced at pin Out which are the extracted PSDU bits stream.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_Demapper (WLAN 11n constellation demapper)
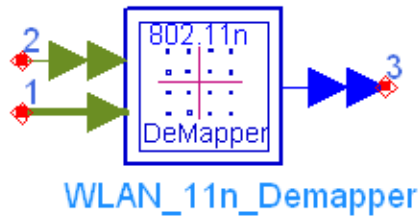
WLAN_11n_Demapper

Description Demapping of BPSK, QPSK 16-QAM or 64-QAM for each spacial stream
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_Demapper

Parameters

Name	Description	Default	Type	Range
MCS	Modulation Coding Scheme ([0~32])	0	int	[0~32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]
NumRx	Number of transmit antennas	1	int	[1, 4]
CSI	Channel status information usage option: OFF, ON	OFF	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	H	channel	complex matrix
2	In	input signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	Out	bit stream	multiple real

Notes/Equations

1. This subnetwork is used to implement BPSK,QPSK 16QAM and 64QAM demodulation and output the soft decision value for the Viterbi decoder.
2. The frequency-domain equalized data and the channel estimation matrix are input while the soft demapped bits are output. The buswidth of the input is the same as the buswidth of output, which is N_{Tx}. Each firing, $N_{SYM}*N_{SD}$ data tokens and one token of channel estimation matrix are consumed and $N_{SYM}*N_{DPPS}$ tokens of bits are produced, where N_{SYM} is the number of data symbols per frame, N_{DPPS} is number of data bits per OFDM symbol and N_{SD} is the number of data subcarriers per OFDM symbol. The schematic of this subnetwork is shown as follows
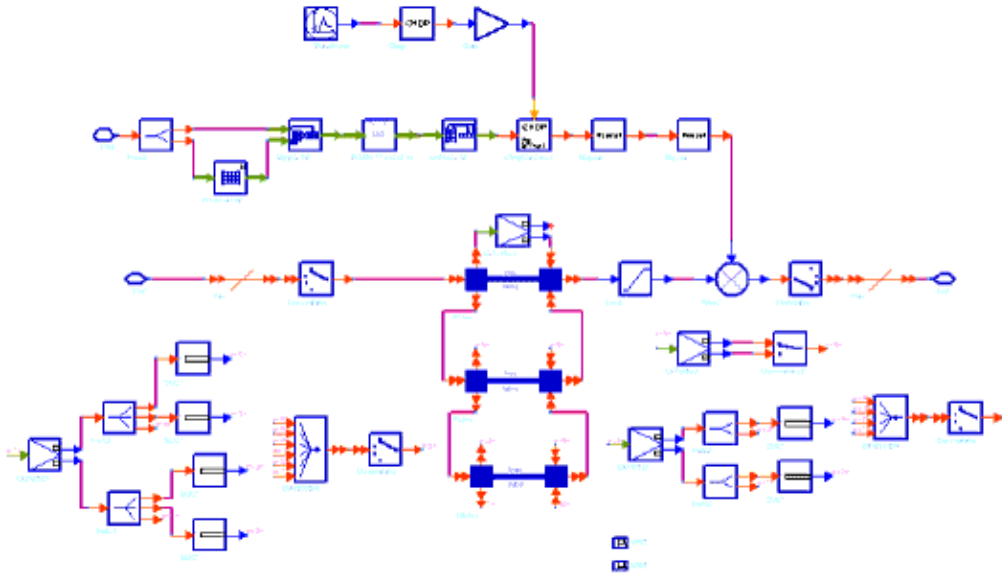
WLAN_11n_Demapper schematic

3. The soft value for each bit is determined by the Euclid distance from the constellation to the decision phase. The soft output is weighted by the channel state information, which is calculated from the received power on each N_{SS}.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_OFDMDeMod (WLAN 11n OFDM demodulation)
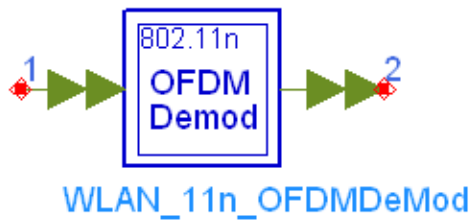
Description OFDM symbol modulation
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_OFDMDeMod

Parameters

Name	Description	Default	Type	Range
NumRx	Number of Receiver antennas	1	int	[0~4]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	OFDM symbol stream	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output subcarrier stream	multiple complex

Notes/Equations

1. This subnetwork is used to convert the 11n time domain signals to frequency domain by applying FFT.
2. The input and output pins are multi-port pins. Both of them has a buswidth of N_{SS}.

   The subnetworks schematic is shown in the following figure.
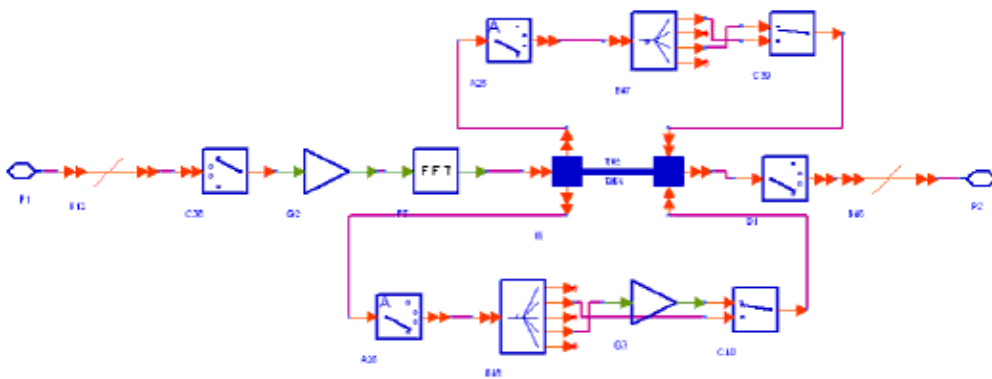
WLAN_11n_OFDMDeMod Schematic

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_PhaseTracker (WLAN 11n Phase Tracker)

WLAN_11n_PhaseTracker
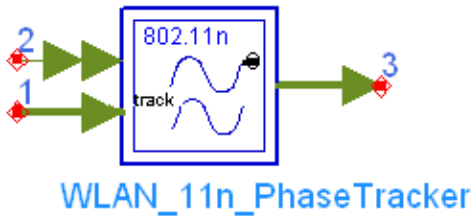
Description phase tracker
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_PhaseTracker

Parameters

Name	Description	Default	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode	enum	
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]
NumRx	number of receiver antennas	1	int	[1, 4]
Phase	initial phase of pilots	0	int	[0, 126]

Pin Inputs

Pin	Name	Description	Signal Type
1	HQ_P	channel coefficient in pilot subcarriers	complex matrix
2	Data_R	data part received including pilot subcarriers	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	DataAftPT	data part after phase tracker in data subcarriers	complex matrix

Notes/Equations

1. This subnetwork model is used to track and compensate the phase drift on data subcarriers caused by the remaining frequency offset.

2. The input HQ_P is $NumRx \times N_{SS}$ matrix pin which input the estimated channel impulse response matrixes of the pilot subcarriers. The input Data_R is a multi-port pin which should be expanded to the number of receiver antennas (NumRx). The received signal of the active subcarriers (including data subcarriers and pilot subcarriers) are input from this port. The output DataAftPT is $NumRx \times 1$ matrix pin. The updated values of the data subcarriers are output from this port.
The schematic of this subnetwork is shown in the following figure.
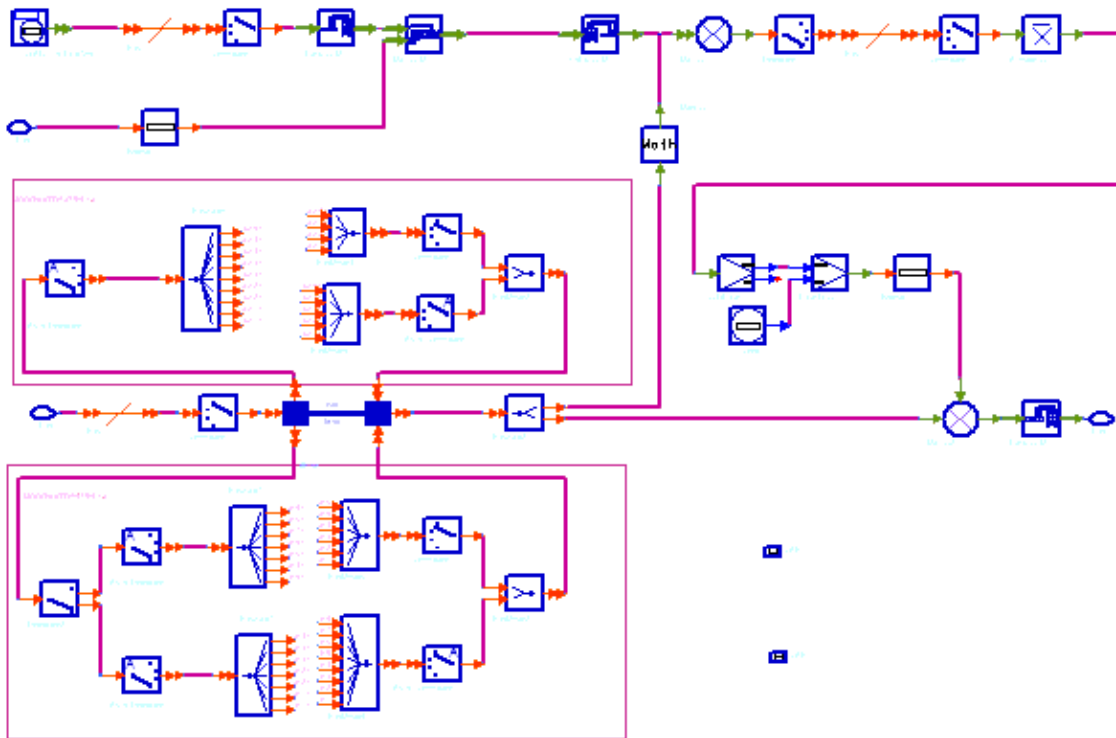
WLAN_11n_PhaseTracker Schematic

Each firing,
in the case of 20 MHz transmission,

> 4 tokens (!wlan11n-7-09-067.gif! matrix) are consumed at pin HQ_P;
> $56 \times N_{SYM}$ tokens are consumed at each port of the pin Data_R;
>
> $52 \times N_{SYM}$ tokens (!wlan11n-7-09-068.gif! matrix) are produced at the
>
> output port;

in the case of 40 MHz transmission,

> 6 tokens (!wlan11n-7-09-069.gif! matrix) are consumed at pin HQ_P;
> $114 \times N_{SYM}$ tokens are consumed at each port of the pin Data_R;
>
> $108 \times N_{SYM}$ tokens (!wlan11n-7-09-070.gif! matrix) are produced at the
>
> output port.

where,

$$N_{SYM} = m_{STBC} \times ceil((8 \times HTLength + 16 + 6 \times N_{ES})/(m_{STBC} \times N_{DBPS}))$$

> where,
> m_{STBC} is 1 (STBC is not used.) *HTLength* is the PSDU length in byte. N_{ES}
>
> is the number of FEC encoders used which is decided by the parameter
> MCS.
> *N*   is the number of data bits per symbol which is decided by

DBPS

parameters MCS and Bandwidth.

3. The phase offset of each received signals chain are detected and compensated respectively.

The phase offset of i'th received signal chain θ_i is calculated as follows:

$$\theta_i = \arg\left(\frac{1}{N_{SP}} \cdot \sum_k^{N_{SP}} conj(\hat{P}_i(k)) \cdot P'_i(k)\right)$$

where,

$\hat{P}_i(k)$ is the current received value of the k'th pilot subcarrier of the i'th received signal chain.

$P'_i(k)$ is the value of the k'th pilot subcarrier of the i'th received signal chain, which is calculated according the estimated CIR matrix of this subcarrier and the pilot value transmitted.

N_{SP} is the number of Pilot Subcarriers.

In the case of 20 MHz transmission, 4 pilots subcarriers inserted in -21, -7, 7 and 21 and the estimated CIRs matrixes of these pilot subcarriers are used.
In the case of 40 MHz transmission, 6 pilots subcarriers inserted in -53, -25, -11, 11, 25 and 53 and the estimated CIRs matrixes of these pilot subcarriers are used.

The estimated phase offset θ_i are used to compensate the data subcarriers of this received signal chain.

Set $d_i(k)$ and $d'_i(k)$ are the received value and the compensated value of the k'th data subcarrier from the i'th received signal chain respectively. Then

$$d_i'(k) = d_i(k) \cdot e^{j\theta_i} \qquad i = 1, ..., NumRx \qquad k = 1, ..., N_{SD}$$

The updated values of the same subcarrier are packed to a $NumRx \times 1$ matrix and all these matrixes of the data subcarriers are output at Pin DataAftPT.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_RF_Demodulator (WLAN 11n RF Demodulator)
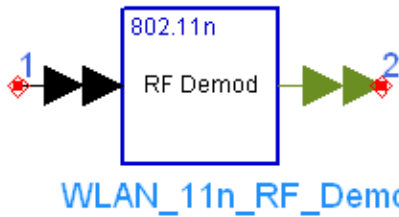
Description RF demodulator with complex output for 802.11n
Library WLAN 11n, Receiver Components
Class TSDFWLAN_11n_RF_Demodulator

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	DefaultRIn	Ohm	real	(0, ∞)
FCarrier	internal (local) reference frequency(-1 for ideal FCarrier lock)	-1	Hz	real	{-1} or (0, ∞)
Phase	reference phase in degrees	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)
VRef	modulator voltage reference level	1	V	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO		enum	
NumTx	number of transmit antennas	1		int	[1, 32)
AntGainImbalance	gain imbalance in dB, relative to average power (Power/NumTx)	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
IQGainImbalance	gain imbalance in dB, Q channel relative to I channel	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
PhaseImbalance	phase imbalance in degrees, Q channel relative to I channel	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input baseband signal	multiple timed

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output RF signal	multiple complex

Notes/Equations

1. This model is used to convert timed RF signals into baseband signals for WLAN 11n RF receiver.
   Its input (output) pin is a multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.

Its input are timed RF signals and outputs are baseband (complex envelope) signals. WLAN_11n_RF_Demodulator does not downsample or filter the down converted signals.

For each input sample consumed, one output sample is produced.

2. Each port (transmit channel) of the input bus should be connected in series to a resistor with impedance of *RIn*. This resistor connects this model with the preceding model.

3. Parameter details:

   - *FCarrier* is used to set the internal oscillator frequency used for demodulation. Local carriers of all transmit channels are from the same oscillator without phase noise. Setting *FCarrier* to -1 means that this model shall use the input signal characterization frequency as the internal oscillator frequency.
   - *Phase* is the reference phase array of each transmit channel in degree, which will result in constellation rotation.
   - The *VRef* parameter is used to calibrate the demodulator. Output values shall be the same as the values at the input of WLAN_11n_RF_Modulator when the following conditions are satisfied:

     power at the demodulator input is 10 mW = 10 dBm;
     VRef is set to the same value for WLAN_11n_RF_Modulator and this model.

     The *MirrorSpectrum* parameter can be used to mirror the spectrum (invert the Q envelope) at the output of the demodulator of each transmit channel.
   - *NumTx* is the number of transmit channels or bus width of input and output signals.
   - *AntGainImbalance* is the gain imbalance array of each transmit channel in dB, relative to 0 dB (default gain) of this channel.
   - *IQGainImbalance* is the gain imbalance array of each transmit channel in dB, Q channel relative I channel.
     PhaseImbalance is the phase imbalance array of each transmit channel in degree, Q channel relative to I channel.

4. Brief description of implementation algorithms.

   Assuming that the input signal of the *i*'th transmit channel is

   $$V(t) = Real\{(inRe[i] + inIm[i]) \cdot e^{j \cdot 2\pi \cdot FCarrier_{Input} \cdot t}\}$$, the output signal on the *i*'th

   transmit channel is generated as follows:

   Step 1:

   $$outRe[i] = Real\{(inRe[i] + inIm[i]) \cdot e^{j \cdot 2\pi \cdot (FCarrier_{Input} - FCarrier) \cdot t}\} \ ;$$

   $$outIm[i] = Imag\{(inRe[i] + inIm[i]) \cdot e^{j \cdot 2\pi \cdot (FCarrier_{Input} - FCarrier) \cdot t}\} \ ;$$

   Step 2: phase rotation and phase imbalance

   $$temp = outRe[i] \ ;$$

   $$outRe[i] = outRe[i] \cos\left(\frac{Phase[i] \cdot \pi}{180}\right) - outIm[i] \sin\left(\frac{Phase[i] \cdot \pi}{180}\right) \ ;$$

$$outIm[i] = temp \cdot \sin\left(\frac{(Phase[i] + PhaseImbalance[i]) \cdot \pi}{180}\right)$$
$$+ outIm[i]\cos\left(\frac{(Phase[i] + PhaseImbalance[i]) \cdot \pi}{180}\right) \quad ;$$

Step 3: IQ gain imbalance

$$outIm[i] = outIm[i] \cdot 10^{\frac{IQGainImbalance[i]}{20}} \quad ;$$

Step 4: inter-antenna gain imbalance

$$outRe[i] = outRe[i] \cdot 10^{\frac{AntGainImbalance[i]}{20}} \quad ;$$

$$outIm[i] = outIm[i] \cdot 10^{\frac{AntGainImbalance[i]}{20}} \quad ;$$

Step 5: gain scaling.

$$outRe[i] = outRe[i] \cdot \frac{VRef}{\sqrt{(RIn)/50}} \quad ;$$

$$outIm[i] = outIm[i] \cdot \frac{VRef}{\sqrt{(RIn)/50}} \quad ;$$

Step 6: mirror spectrum

if (MirrorSpectrum = = YES)
$$outIm[i] = -outIm[i] \quad .$$

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n _SpatialCommutator (WLAN 11n Spatial Commutator)
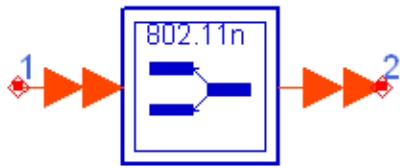
WLAN_11n_SpatialCommutator

Description 11n spatial commutator
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_SpatialCommutator

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,31])	0	int	[0, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	multiple anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output signal	multiple anytype

Notes/Equations

1. This subnetwork is used to map signal on spatial streams to encoder streams.
2. The input and output pins are multi-port pins. The buswidth of input pin is N_{SS}, while the output buswidth is N_{ES}. Each firing, $s \times N_{ES}$ tokens from each input port will be consumed, $s = \max(1, N_{BPSC}/2)$, and $s \times N_{SS}$ tokens are produced to each output port. The subnetworks schematic is shown in the following figure.
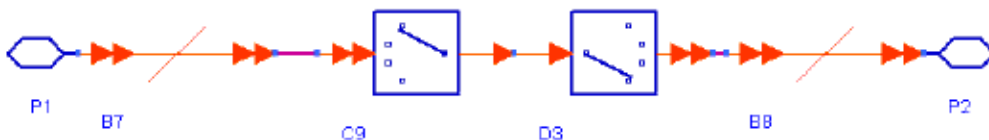
References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_Sync (WLAN 11n Synchronizer)
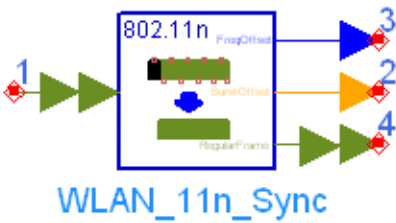
Description 802.11n frequency and timing synchronization
Library WLAN 11n, Receiver Components
Class SDFWLAN_11n_Sync

Parameters

Name	Description	Default	Unit	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode		enum	
MCS	modulation Coding Scheme ([0,32])	0		int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz		enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256		int	[1, 2^16-1]
ShortGI	400ns guard interval in data symbols: NO, YES	NO		enum	
NumHTLTF	number of HT long training fields	1		int	[1, 4]
NumRx	number of transmit chains (antennas)	1		int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1		enum	
IdleInterval	Idle Interval	100 nsec	sec	real	[0, 1000usec]
OutType	character of output signal: FreqCompensate, NoFreqCompensate	FreqCompensate		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	baseband signal for synchronization	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	SyncIndex	index of optimal start point of L-STF (reference of input signal)	int
3	FreqOffset	frequency offset scaled in subcarrier interval	real
4	output	frequency offset compensated signal	multiple complex

Notes/Equations

1. This model is used to synchronize the input signal for WLAN 11n baseband receiver, including frame synchronization and carrier frequency synchronization.
2. Its "input" and "output" are multi-port pins, each sub-port corresponds to a receiver channel/chain. The two pins should be connected with pins whose bus width are

NumRx, for instance, the Bus model with parameter "BusWidth" set to *NumRx*. The input signal should be a cluster of baseband frames (with or without idle interval) with the same duration and preamble format.

"output" outputs the time synchronized frame without idle duration, which is abstracted from the input signal by a "optimal" window. If FreqCompensate is selected for parameter *OutType*, carrier frequency compensation shall be applied to the output signal, otherwise no carrier frequency compensation shall be applied.

"SyncIndex" outputs the index of start point of the "optimal" time synchronization window for the input signal vector. The index is an offset of input samples index [0, 1, ..., $N_{inSample}$ -1]. $N_{inSample}$ is defined below.

"FreqOffset" outputs the carrier frequency difference between RF demodulator and RF modulator, it's the ratio of measured carrier frequency difference in Hz to subcarrier interval ΔF which is 312.5 kHz for 11n.

Each fire, $N_{inSample}$ tokens in each receiver channel shall be consumed at the "input"

pin, $N_{outSample}$ tokens in each receiver channel shall be generated at the "output"

pin, 1 token shall be generated at pin "SyncIndex" and "FreqOffset", where

$$N_{inSample} = [\lfloor idleInterval \cdot 20e6 \rfloor + (8 + NumHTLTF) \cdot 80 + 80 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$

in Mixed Mode and full guard interval in data symbols,

$$N_{inSample} = [\lfloor idleInterval \cdot 20e6 \rfloor + (8 + NumHTLTF) \cdot 80 + 64 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$

in Mixed Mode and half guard interval in data symbols,

$$N_{inSample} = [\lfloor idleInterval \cdot 20e6 \rfloor + (5 + NumHTLTF) \cdot 80 + 80 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$

in Green Field and full guard interval in data symbols,

$$N_{inSample} = [\lfloor idleInterval \cdot 20e6 \rfloor + (5 + NumHTLTF) \cdot 80 + 64 \cdot NumDataSym] \cdot 2^{Bandwidth + OversamplingOption}$$

in Green Field and half guard interval in data symbols,

$$N_{outSample} = N_{inSample} - (\lfloor idleInterval \cdot 20e6 \rfloor \cdot 2^{Bandwidth + OversamplingOption})$$
,

NumDataSym is determined by parameter HTLength and MCS, see section 4 in Reference #1 below for more details.

3. Brief description of synchronization algorithm.
   In this model, only L-STF is used for synchronization.
   Assuming

   N_{L-STS} is the sample number of the period of L-STF, i.e. 1/10 of L-STF,

   $N_{corrWin}$=9 × N_{L-STS} is the moving window (gate) width for accumulating

   the correlated samples,
   {s[m][n]} denotes the vector of input samples, m = 0, 1, ..., *NumTx*-1, n = -N_{L-STS}-$N_{corrWin}$+1, 0, 1, ..., $N_{inSample}$-1, where n<0 refers to samples

   of the preceding frame.

Correlate input samples of each receiver channel and sum them up, we get the correlation function

$$Corr(l) = \frac{\sum\limits_{n=l}^{l+N_{corrWin}-1}\left(\sum\limits_{m=0}^{NumTx-1}(s[m][n])^* \cdot s[m][n+N_{L-STS}]\right)}{\sum\limits_{n=l}^{l+N_{corrWin}-1}\left|\sum\limits_{m=0}^{NumTx-1}(s[m][n])^* \cdot s[m][n+N_{L-STS}]\right|}$$

if $\quad l = 0, 1, ..., N_{inSample} - N_{L-STS} - N_{corrWin}$

$$Corr(l) = \frac{\sum\limits_{n=l-N_{inSample}}^{l+N_{corrWin}-1-N_{inSample}}\left(\sum\limits_{m=0}^{NumTx-1}(s[m][n])^* \cdot s[m][n+N_{L-STS}]\right)}{\sum\limits_{n=l-N_{inSample}}^{l+N_{corrWin}-1-N_{inSample}}\left|\sum\limits_{m=0}^{NumTx-1}(s[m][n])^* \cdot s[m][n+N_{L-STS}]\right|}$$

if
$l = N_{inSample} - N_{L-STS} - N_{corrWin} + 1, N_{inSample} - N_{L-STS} - N_{corrWin} + 2, ..., N_{inSample} - 1$

and obtain the maximum correlation coefficient

$$Corr_{max} = |Corr(l_{max})| = max\{|Corr(l)|\}$$.

If correlation coefficient *Corr* $_{max}$ is less than 0.5, this model shall regard the present frame as an incompatible one and report synchronization failure information. Once synchronization search fails in a frame, input signal are processed using synchronization information of the preceding frame. If *Corr* $_{max}$ is greater than 0.5, then output "SyncIndex" and "FreqOffset" shall be obtained,

$$SyncIndex = [l_{max} - N_{DataGI}/4 + N_{inSample}]_{mod\,N_{inSample}}$$,

$$FreqOffset = [\angle Corr(l_{max})] \cdot 2/\pi$$,

where the estimated start point of synchronization window is $N_{DataGI}/4$ samples ahead of the index of correlation peak. This offset is used to prevent the output signal being abstracted from the duration that is distorted by potential transition between OFDM symbols or inter-OFDM symbol interference resulted from multi-path propagation.
The first sample of "output" shall be the $-[(N_{inSample}-SyncIndex)_{mod\,N_{inSample}}]$ 'th sample of "input", here negative index refers to samples of the preceding frame. In most cases, the signal of "output" starts from the preceding frame.
The estimated residual carrier frequency in Hz Δf shall be "FreqOffset" multiplied by sub-carrier interval ΔF, i.e. $\Delta f = FreqOffset \cdot \Delta F$.
Residual carrier frequency of input signal should be within $(-2 \cdot \Delta F, 2 \cdot \Delta F)$. If the input signal has a residual carrier frequency of $\Delta f \geq 2 \cdot \Delta F$ or $\Delta f \leq -2 \cdot \Delta F$, the estimated result shall has a error of $k \cdot \Delta F$, where k is an integer.

References

1. EWC HT PHY Specification v1.13, November 5th, 2005.

WLAN_11n Receivers

The 11n top-level receivers are provided in this category.

- *WLAN 11n Receiver (WLAN 11n Baseband Receiver)* (wlan11n)
- *WLAN 11n Receiver RF (WLAN 11n RF Receiver)* (wlan11n)

WLAN_11n_Receiver (WLAN 11n Baseband Receiver)
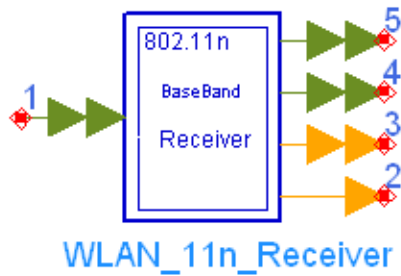
Description 11n signal receiver
Library WLAN 11n, Receiver
Class SDFWLAN_11n_Receiver

Parameters

Name	Description	Default	Unit	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode		enum	
MCS	modulation Coding Scheme ([0,31])	0		int	[0, 31]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz		enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256		int	[1, 2^16-1]
ShortGI	400ns guard interval in data symbols: NO, YES	NO		enum	
NumHTLTF	number of HT long training fields	1		int	[1, 4]
NumRx	number of transmit chains (antennas)	1		int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1		enum	
IdleInterval	Idle Interval	100 nsec	sec	real	[0, 1000µsec]
ScrambleSeed	initial state of scrambler(should not be all 0)	1 1 1 1 1 1 1		int array	[0 1]
ScrambleReinit	reset initial state of the scrambler each burst (by ScrambleSeed) or not: NO, YES	YES		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	BaseBand	802.11n baseband signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	PSDU	PSDU in bit	int
3	BitsChCoded	convolutional eccoded bit stream	multiple int
4	SigAftMatrix	signal after spatial mapping and after IFFT	multiple complex
5	Constellation	constellation after OFDM symbol mux and before spatial mapping	multiple complex

Notes/Equations

1. This subnetwork model is used to detect, demodulate and decode the baseband

signal. The baseband receiver schematic is shown in the following figure.
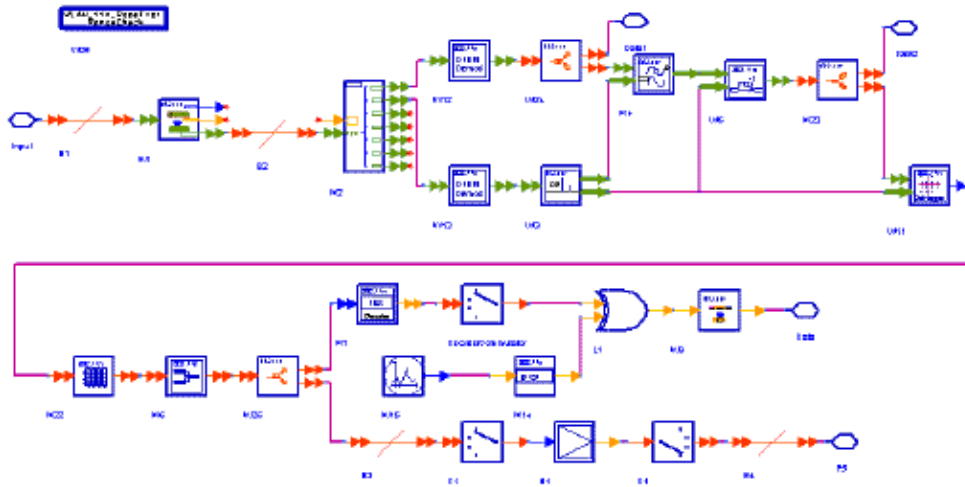
WLAN_11n_Receiver Schematic

2. Receiver functions are implemented as follows:

- Start of frame is detected and frequency offset is estimated. WLAN_11n_Sync performs frame synchronization and carrier frequency synchronization using the Legacy Short Training Field (L-STF) and the IdleInterval is removed in this model. The output signal of this model is time synchronized frame without idle duration, with "optimal" frame window. If OutType=FreqCompensate, the estimated frequency offset is compensated on the output signal, otherwise, no carrier frequency compensation shall be applied. This model will introduce one-frame delay in most cases.

- According to the start of the frame, this frame is de-multiplexed into several parts in WLAN_11n_BurstDemux. WLAN_11n_BurstDemux outputs all parts of preamble and the data part and the guard intervals are removed for all parts.

- The OFDM demodulations are performed in WLAN_11n_OFDMDeMod for the data part and the HT Long Training Fields (HT-LTFs) which are used for channel estimation. The null subcarriers are removed in this model.

- Complex channel impulse response (CIR) matrixes are estimated for each active subcarrier in WLAN_11n_ChEstimator. The estimated CIR matrixes of pilot subcarriers are used in WLAN_11n_PhaseTracker. The estimated CIR matrixes of data subcarriers are used in WLAN_11n_AntDemapper and WLAN_11n_Demapper.

- Phase offset of the active subcarriers are estimated, then all data subcarrier values are de-rotated according to the estimated phase offset. WLAN_11n_PhaseTracker implements these functions.

- The effect of spatial mapping, cyclic shift and the transmit channel is equalized in the model WLAN_11n_AntDemapper. After equalization, the output signal is for constellation of each spatial stream.

- The signal of each spatial stream after WLAN_11n_AntDemapper are then demapped by WLAN_11n_Demapper. The Soft demapper type is supported and the CSI (channel state information) can be set to ON or OFF in this model.

- After de-interleaving, de-scrambling and the spatial commutator, there are two branches, one is for PSDU bits stream which including FEC Decoding, Descrambling and DataUnwrap; the other is for the bits before decoded.

- The WLAN_11n_Receiver_RangeCheck model is used to check parameters for WLAN_11n_Receiver. If illegal parameters are evaluated on

WLAN_11n_Receiver, error or warning messages shall be displayed on the Simulation/Synthesis Message box and simulation may be forcibly terminated at the beginning of simulation.

3. Parameter Details
   - *OperatingMode* is an enumerate parameter specifying the receiver operating mode, MixedMode or GreenField.
   - *MCS* specifies the modulation and coding scheme.Currently MCS0 to MCS31 are supported.
   - *Bandwidth* is an enumerate parameter specifying the signal bandwidth. Both 20 MHz transmission and 40 MHz transmission are supported in this library.
   - *HTLength* specifies the number of information bytes per packet, so the total information bits per packet is HTLength × 8.
   - *ShortGI* is an query parameter specifying short GI is used after the HT training or not. If ShortGI is set to YES, then the guard interval will be 0.4μsec; *ShortGI* is set to NO, the guard interval will be 0.8μsec.
   - *NumHTLTF* specifies the number of HT long training field. *NumHTLTF* must not be less than the number of spatial streams (N_{SS}) which is decided by the parameter *MCS*. And if the N_{SS} is 3, *NumHTLTF* must be 4.
   - *NumRx* specifies the number of receiver antennas. The number of receiver antennas must not be less than N_{SS} and must be equal or larger than *NumHTLTF*.
   - *OversamplingOption* determined the oversampling ratio of the input signal. Total six oversampling ratios (1x, 2x, 4x, 8x, 16x and 32x) are supported.
   - *IdleInterval* specifies the idle interval time between two consecutive packets. The default value is 100nsec.
   - *ScrambleSeed* specifies the initial state of the scrambler. ScrambleReinit is an enumerate parameter specifying whether the scrambler feedback register will be re-initialized on each packet or not.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_Receiver_RF (WLAN 11n RF Receiver)
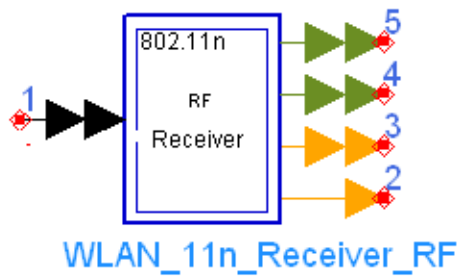
Description 11n signal receiver
Library WLAN 11n, Receiver
Class TSDFWLAN_11n_Receiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	DefaultRIn	Ohm	real	(0, ∞)
FCarrier	internal (local) reference frequency(-1 for ideal FCarrier lock)	-1	Hz	real	{-1} or (0, ∞)
Phase	reference phase in degrees	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)
AntGainImbalance	gain imbalance in dB, relative to average power (Power/NumTx)	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
IQGainImbalance	gain imbalance in dB, Q channel relative to I channel	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
PhaseImbalance	phase imbalance in degrees, Q channel relative to I channel	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO		enum	
OperatingMode	operating mode: MixedMode, GreenField	MixedMode		enum	
MCS	modulation Coding Scheme ([0,31])	0		int	[0, 31]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz		enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256		int	[1, 2^16-1]
ShortGI	400ns guard interval in data symbols: NO, YES	NO		enum	
NumHTLTF	number of HT long training fields	1		int	[1, 4]
NumRx	number of transmit chains (antennas)	1		int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1		enum	
IdleInterval	Idle Interval	100 nsec	sec	real	[0, 1000µsec]
ScrambleSeed	initial state of scrambler(should not be all 0)	1 1 1 1 1 1 1		int array	[0 1]
ScrambleReinit	reset initial state of the scrambler each burst (by ScrambleSeed) or not: NO, YES	YES		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	RF_Sig	802.11n RF signal	multiple timed

Pin Outputs

Pin	Name	Description	Signal Type
2	PSDU	PSDU in bit	int
3	BitsChCoded	convolutional eccoded bit stream	multiple int
4	SigAftMatrix	signal after spatial mapping and after IFFT	multiple complex
5	Constellation	constellation after OFDM symbol mux and before spatial mapping	multiple complex

Notes/Equations

1. This subnetwork is used to demodulate and decode the WLAN 11n RF signals. The schematic for this subnetwork is shown in the following figure.
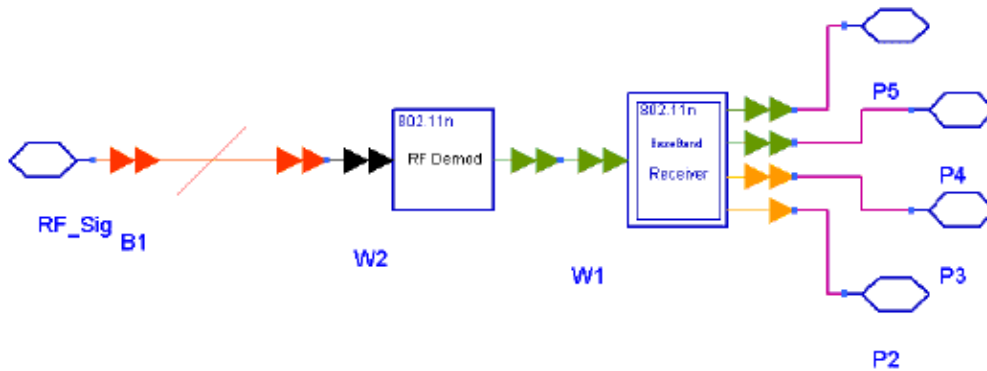
WLAN_11n_Receiver_RF Schematic

The received RF signal from each antenna is demodulated by WLAN_11n_Demodulator, and then the demodulated signal is sent to the baseband receiver for baseband processing.

2. The schematic of WLAN_11n baseband receiver is shown in the following figure.
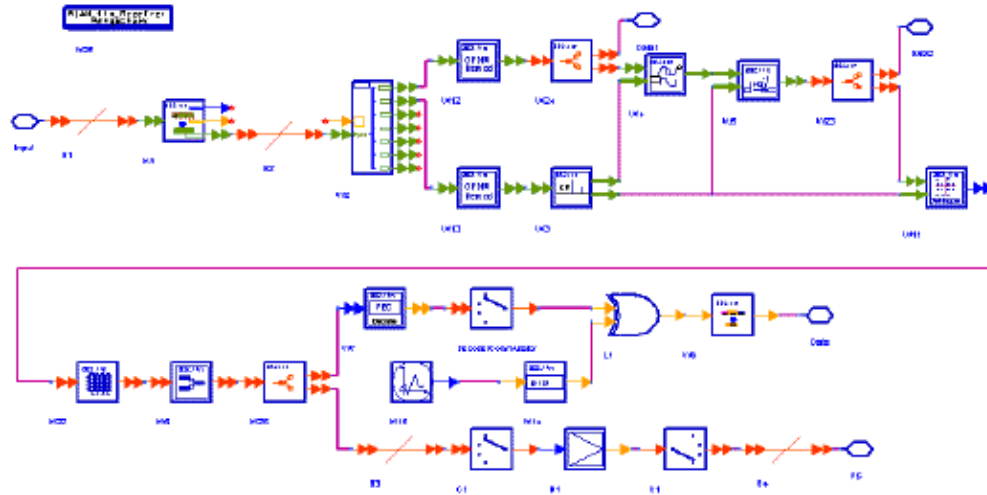
WLAN_11n_Receiver Schematic

3. Receiver functions are implemented as follows:
   - Start of frame is detected and frequency offset is estimated. WLAN_11n_Sync performs frame synchronization and carrier frequency synchronization using the Legacy Short Training Field (L-STF) and the IdleInterval is removed in this model. The output signal of this model is time synchronized frame without idle duration, with "optimal" frame window. If OutType=FreqCompensate, the estimated frequency offset is compensated on the output signal, otherwise, no carrier frequency compensation shall be applied. This model will introduce one frame delay.
   - According to the start of the frame, the frame is de-multiplex into several parts in WLAN_11n_BurstDemux. WLAN_11n_BurstDemux outputs all parts of preamble and the data part and the guard intervals are removed for all parts.
   - The OFDM demodulations are performed in WLAN_11n_OFDMDeMod for the data part and the HT Long Training Fields (HT-LTFs) which are used for channel estimation. The null subcarriers are removed in this model.
   - Complex channel impulse response (CIR) matrixes are estimated for each active subcarrier in WLAN_11n_ChEstimator. The estimated CIR matrixes of the pilot subcarriers are used in WLAN_11n_PhaseTracker. The estimated CIR matrixes of the data subcarriers are used in WLAN_11n_AntDemapper and WLAN_11n_Demapper.
   - Phase offset of the active subcarriers are estimated, then all data subcarrier values are de-rotated according to the estimated phase offset. WLAN_11n_PhaseTracker implements these functions.
   - The effect of spatial mapping, cyclic shift and the transmit channel is equalized in the model WLAN_11n_AntDemapper. After equalization, the output signal is for constellation of each spatial stream.
   - The signal of each stream after WLAN_11n_AntDemapper are then demapped by WLAN_11n_Demapper. The Soft demapper type is supported and the CSI (channel state information) can be set to ON or OFF in this model.
   - After de-interleaving, de-scrambling and the spatial commutator, there are two branches, one is for PSDU bits stream which including FEC Decoding, Descrambling and DataUnwrap; the other is for the bits before decoded.
   - The WLAN_11n_Receiver_RangeCheck model is used to check parameters for WLAN_11n_Receiver. If illegal parameters are evaluated on WLAN_11n_Receiver, error or warning messages shall be displayed on the Simulation/Synthesis Message box and simulation may be forcibly terminated at the beginning of simulation.
4. Parameter Details
   - *RIn* is the impedance value of the resistor which shall be connected to the preceding model for impedance matching.
   - *FCarrier* is used to set the internal oscillator frequency used for demodulation. Local carriers of all transmit channels are from the same oscillator without phase noise. When FCarrier is set to -1, internal oscillator frequency synchronization to the input signal is performed.
   - *Phase* is the reference phase array of received signal from each antenna in degree, which will result in constellation rotation.
   - *MirrorSpectrum* can be used to mirror the spectrum (invert the Q envelope) at the output of the demodulator for the received signal from each antenna.
   - *AntGainImbalance* is gain imbalance array of the received signal from each antenna in dB.
   - *IQGainImbalance* is the gain imbalance array of the received signal from each

antenna in dB.Q channel relative to I channel.

- *PhaseImbalance* is the phase imbalance array of the received signal from each antenna in degree, Q channel relative to I channel.
- *OperatingMode* is an enumerate parameter specifying the receiver operating mode, MixedMode or GreenField.
- *MCS* specifies the modulation and coding scheme.Currently MCS0 to MCS31 are supported.
- *Bandwidth* is an enumerate parameter specifying the signal bandwidth. Both 20 MHz transmission and 40 MHz transmission are supported in this library.
- *HTLength* specifies the number of information bytes per packet, so the total information bits per packet is HTLength × 8.
- *ShortGI* is an query parameter specifying short GI is used or not after the HT training. If ShortGI is set to YES, then the guard interval will be 0.4μsec; ShortGI is set to NO, the guard interval will be 0.8μsec.
- *NumHTLTF* specifies the number of HT long training field. *NumHTLTF* must not be less than the number of spatial streams (N_{SS}) which is decided by the parameter *MCS*. And if the N_{SS} is 3, *NumHTLTF* must be 4.
- *NumRx* specifies the number of receiver antennas. The number of receiver antennas must not be less than N_{SS} and must be equal or larger than *NumHTLTF*.
- *OversamplingOption* determined the oversampling ratio of the input signal. Total six oversampling ratios (1x, 2x, 4x, 8x, 16x and 32x) are supported.
- *IdleInterval* specifies the idle interval time between two consecutive packets. The default value is 100nsec.
- *ScrambleSeed* specifies the initial state of the scrambler.
- *ScrambleReinit* is an enumerate parameter specifying whether the scrambler feedback register will be re-initialized on each packet or not.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n Source Components

The components that can be used to construct 11n signals sources are provided in this category.

- *WLAN 11n BurstMux (WLAN 11n Burst Multiplex)* (wlan11n)
- *WLAN 11n BusFork2 (WLAN 11n Bus Fork 2)* (wlan11n)
- *WLAN 11n ChCoder (WLAN 11n FEC encoder)* (wlan11n)
- *WLAN 11n DataWrap (WLAN 11n Data Wrap)* (wlan11n)
- *WLAN 11n HTLTF GF (WLAN 11n High Throughput Long Training Field for Green Field)* (wlan11n)
- *WLAN 11n HTLTF MM (WLAN 11n High Throughput Long Training Field for Mixed Mode)* (wlan11n)
- *WLAN 11n HTSIG (WLAN 11n High Throughput SIGNAL Field)* (wlan11n)
- *WLAN 11n HTSTF (WLAN 11n High Throughput Short Training Field)* (wlan11n)
- *WLAN 11n Interleaver (WLAN 11n Interleaver)* (wlan11n)
- *WLAN 11n LLTF (WLAN 11n Legacy Long Training Field)* (wlan11n)
- *WLAN 11n LSIG (WLAN 11n Legacy SIGNAL Field)* (wlan11n)
- *WLAN 11n LSTF (WLAN 11n Legacy Short Training Field)* (wlan11n)
- *WLAN 11n Mapper (WLAN 11n Mapper)* (wlan11n)
- *WLAN 11n MuxOFDMSym (Mux Pilot Subcarriers with the Data Subcarriers To Generate OFDM Symbol)* (wlan11n)
- *WLAN 11n OFDMMod (WLAN 11n OFDM Modulation)* (wlan11n)
- *WLAN 11n PilotGen (WLAN 11n Pilot Generation)* (wlan11n)
- *WLAN 11n Preamble (WLAN 11n Preamble)* (wlan11n)
- *WLAN 11n PreambleMux (WLAN 11n Preamble Multiplexer)* (wlan11n)
- *WLAN 11n RF Modulator (WLAN 11n RF Modulator)* (wlan11n)
- *WLAN 11n Scrambler (WLAN 11n Scrambler)* (wlan11n)
- *WLAN 11n SpatialMapper (WLAN 11n Spatial mapper)* (wlan11n)
- *WLAN 11n SpatialParser (WLAN 11n spatial parser)* (wlan11n)

WLAN_11n_BurstMux (WLAN 11n Burst Multiplex)
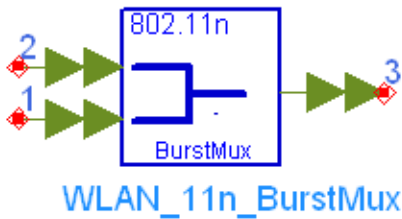
Description Burst multiplexer
Library WLAN 11n, Source Components
Class SDFWLAN_11n_BurstMux

Parameters

Name	Description	Default	Unit	Type	Range
OperatingMode	the PHY operating mode: MixedMode, GreenField	MixedMode		enum	
MCS	Modulation Coding Scheme ([0~31])	0		int	[0~31]
Bandwidth	Band width: BW20M, BW40M	BW20M		enum	
HTLength	octet number of PSDU	256		int	[1, 65535]
ShortGI	ShortGI or not: NO, YES	NO		enum	
NumHTLTF	number of HT_LTF	1		int	[1, 4]
NumTx	number of transmit chains	1		int	[1, 4]
OversamplingOption	Oversampling ratio option: x1, x2, x4, x8, x16, x32	x1		enum	
Window	use time domain window or not: NO, YES	NO		enum	
TransitionTime	the transition time of window function	100 nsec	sec	real	(0, 800 nsec]
IdleInterval	Idle Interval	10 usec	sec	real	[0, 1000 usec]

Pin Inputs

Pin	Name	Description	Signal Type
1	Prmbl	preamble	multiple complex
2	Data	SIGNAL and DATA OFDM symbols	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	Output	burst signal	multiple complex

Notes/Equations

1. This model is used to multiplex the preamble and the data field into one complete frame. The Idle interval insertion is implemented and the window is added if the parameter Window is set to YES.
2. This model has 2 multiport input pins (Prmbl and Data) and 1 multiport output pin which should be expanded to the number of transmit chains (N_{Tx}).

Each firing,

- $N_{PrmblPoint}$ tokens are consumed at each port of the Prmbl pin.
- $N_{DataPoint}$ tokens are consumed at each port of the Data pin.
- $N_{IdlePoint}+N_{PrmblPoint}+N_{DataPoint}$ tokens are produced at each port of the output pin.

  where

  $N_{IdlePoint}$ is the number of samples of the Idler interval.

  $N_{PrmblPoint}$ is the number of samples of the preamble part and is defined as follows:

  $$N_{PrmblPoint} = N_{P-SYM} \times (N_{SC} + N_{SC}/4) \times 2^{OversamplingOption}$$

  N_{SC} is the number of sub-carriers which is 64 for 20 MHz transmission or 128 for 40 MHz.

  N_{P_SYM} is the number of symbols of the preamble part.

  For Mixed Mode, $\quad N_{P-SYM} = 2+2+1+2+1+NumHTLTF$

  For Green Field, $\quad N_{P-SYM} = 2+2+2+(NumHTLTF-1)$

  $N_{DataPoint}$ is the number of samples of the data field and is calculated as follows:

  $$N_{DataPoint} = N_{SYM} \times (N_{SC} + N_{GI}) \times 2^{OversamplingOption}$$

  If ShortGI=NO, $N_{GI} = N_{SC}/4$, otherwise, $N_{GI} = N_{SC}/8$.

  N_{SYM} is the number of symbols in the data field which is calculated using the formula:

  $$N_{SYM} = m_{STBC} \times ceil((8 \times HTLength + 16 + 6 \times N_{ES})/(m_{STBC} \times N_{DBPS}))$$

  m_{STBC} is 1 (STBC is not used.) HTLength is the PSDU length in byte. N_{ES} is the number of FEC encoders used which is decided by the parameter MCS. N_{DBPS} is the number of data bits per symbol which is decided by parameters MCS and Bandwidth.

1. If Window=YES, a window function is added to the burst signals. The definition of the window function $w_{TField}(t)$ is given in 802.11a specification:

$$w_{TField}(t) = \begin{cases} Sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \leq t < T-(T_{TR}/2)) \\ Sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T-(T_{TR}/2) \leq t < T+(T_{TR}/2)) \end{cases}$$

T_{TR} is Transition Time, which is usually set to 100nsec. $w_{TField}(t)$ represents the time-windowing function, depending on the value of the duration parameter T, may extend over more than one period T_{FFT}.

The windowing function $w_{TField}(t)$ is applied to all fields, which are L-STF, L-LTF, L-

SIG, HT-SIG, HT-STF, HT-LTFs and Data symbols for MixedMode and L-STF, HT-LTF1, HT-SIG, HT-LTFs and Data symbols for GreenField.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_BusFork2 (WLAN 11n Bus Fork 2)
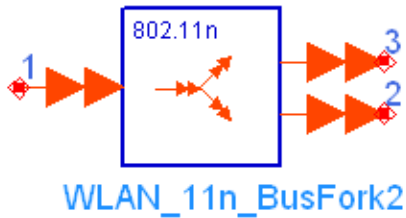
Description Copy particles from an input bus to each output bus
Library WLAN 11n, Source Components
Class SDFWLAN_11n_BusFork2

Parameters

Pin	Name	Description	Signal Type
1	input		multiple anytype

Pin Outputs

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

Notes/Equations

1. This model is used to explicitly connect a multi-port output pin of a component to 2 multi-port input pins of other components.
2. The bus width of input pin and output pins should be same in order for the model to work properly.
3. WLAN_11n_BusFork2 is typically used with numeric signals.
4. When forced to connect with timed signals, it assumes infinite equivalent input resistances and zero equivalent output resistances.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_ChCoder (WLAN 11n FEC encoder)
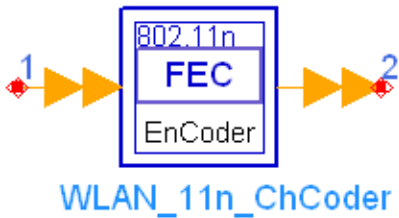
**Description Channel coding of PSDU
Library WLAN 11n, Source Components
Class SDFWLAN_11n_ChCoder**

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	Un-coded bit stream	multiple int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	Coded bits	multiple int

Notes/Equations

1. This subnetwork is used to encode the input date to enable forward error correction.
2. The input and output pins are multiport pins. The buswidth for both input and output pins is N_{ES}. Each firing, $N_{SYM} \times N_{DBPS}$ tokens are consumed and $N_{SYM} \times N_{CBPS}$ tokens are produced, where N_{SYM} is the number of data symbols per frame, N_{DBPS} is number of data bits per OFDM symbol and N_{CBPS} is the number of coded bits per OFDM symbol. The schematic of this subnetwork is shown in the following figure.

3. The input data is encoded using the convolutional encoder defined in References #2.

   The generator polynomials for A output is $G_1 = 133_{oct}$ and $G_2 = 171_{oct}$ for B output according to the following figure.

Convolutional Code of Rate 1/2 (Constraint Length=7)

4. After encoding, the encoded data will be punctured. If the coding rate is 2/3 or 3/4, the puncture pattern will be the same as the pattern in 802.11a, which is shown in the following figure.
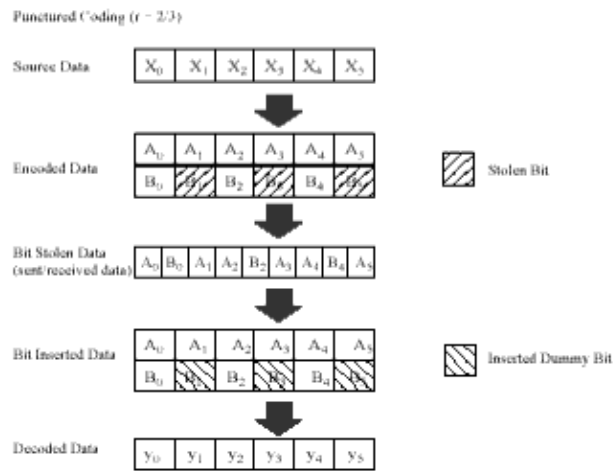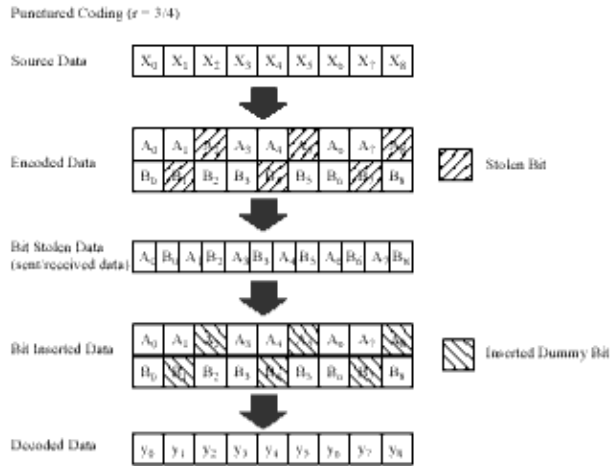
WLAN 11n Puncture Pattern for Code Rate 3/4 and 2/3

If the coding rate is 5/6, which is new in 11n, the puncture scheme is shown as in the following figure.
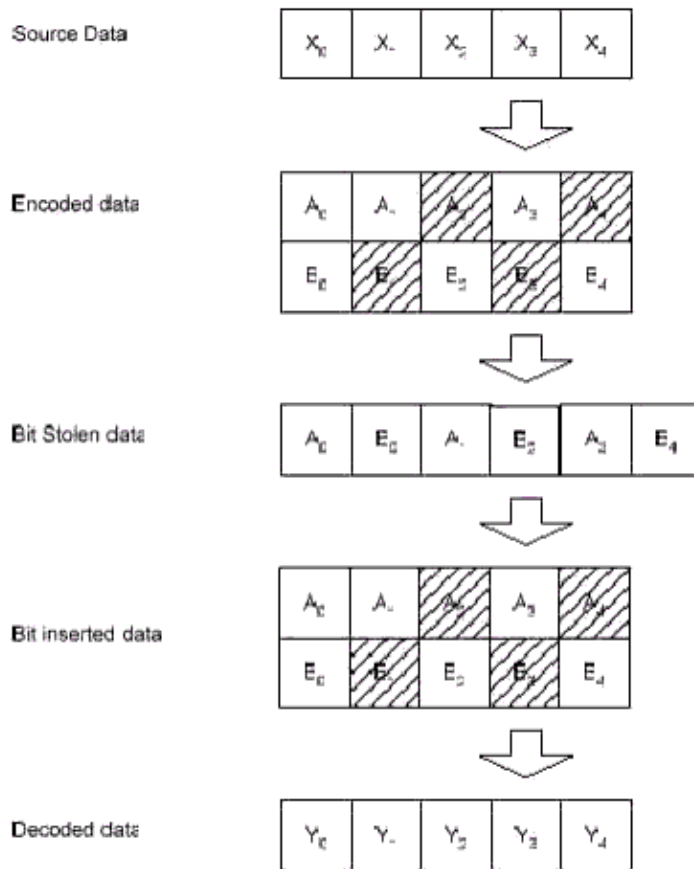
Figure 8 - Puncturing at rate 5/6

WLAN 11n Puncture Pattern for Code Rate 5/6

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_DataWrap (WLAN 11n Data Wrap)
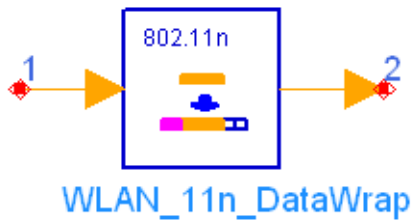
Description Tailling and padding of PSDU bit stream
Library WLAN 11n, Source Components
Class SDFWLAN_11n_DataWrap

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	PSDU in bit	int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	bits after tailing and padding	int

Notes/Equations

1. This model is used to tail and pad the PSDU bits stream to generate data field of the PPDU. The data field contains the service field, the PSDU, the tail bits and the pad bits if needed.
2. Each firing,
   - $8 \times HTLength$ tokens are consumed at pin In which are the PSDU bits stream.
   - $N_{SYM} \times N_{DBPS}$ tokens are produced at pin Out which are the bits after padding and tailing.

     where

     N_{SYM} is the number of symbols in the data field which is computed using the

     formula:

     $$N_{SYM} = m_{STBC} \times ceil((8 \times HTLength + 16 + 6 \times N_{ES})/(m_{STBC} \times N_{DBPS}))$$

     where

     m_{STBC} is 1 (STBC is not used.)

HTLength is the PSDU length in byte.

16 is the number of "zero" service field bits which will be used for scrambler initialization, scrambled by the scrambler.

N_{ES} is the number of FEC encoders used which is decided by the parameter MCS and $6 \times N_{ES}$ is the number of "zero" tail bits.

N_{DBPS} is the number of data bits per symbol which is decided by parameters MCS and Bandwidth.

The number of "zero" pad bits is thus $N_{SYM} \times N_{DBPS} - 8 \times HTLength - 16 - 6 \times N_{ES}$.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_HTLTF_GF (WLAN 11n High Throughput Long Training Field for Green Field)

Description high througput long training field for green field
Library WLAN 11n, Source Components
Class SDFWLAN_11n_HTLTF_GF

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
NumHTLTF	number of HT long training fields	1	int	[1, 4]
NumTx	number of transmit antennas	1	int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping	enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1	complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
GuardInterval	Guard interval (cyclic prefix) length	1/4	real	[0, 1/4]

Pin Outputs

Pin	Name	Description	Signal Type
1	HTLTF1	high throughput long training field signal HT-LTF1	multiple complex
2	HTLTF234	high throughput long training field signal HT-LTF234	multiple complex

Notes/Equations

1. This subnetwork is used to generate the high throughput long training field signal for Green Field operation.
   Its output pins are multi-port pins, each sub-port corresponds to a transmit channel/chain. These pins should be connected with pins whose bus width are NumTx, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.
   Its outputs are time domain signals with total mean square value (power) on each pin of 1, covering 1 transmit chain to 4 transmit chains, 20 MHz and 40 MHz.
2. The schematic of this subnetwork is shown in the following figure.
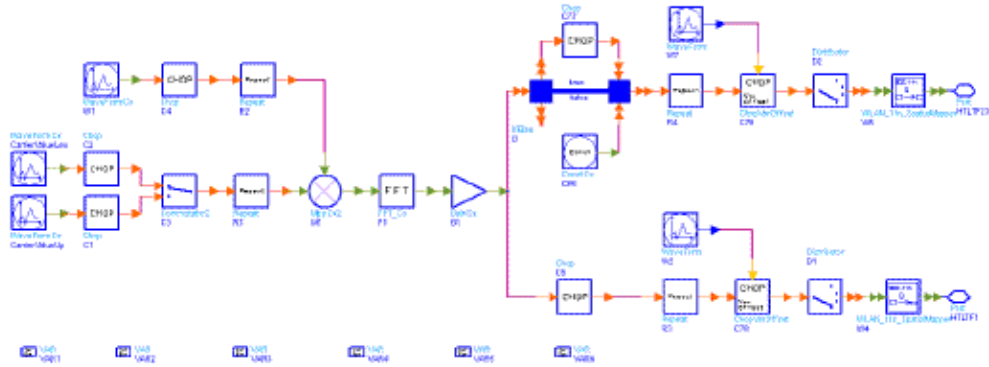
WLAN_11n_HTLTFGF Schematic

3. The data sequence in frequency domain for 20 MHz is:

$HTLTF_{-28,28}$ = {1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 0, ...
1, −1, −1, 1, 1, −1, 1, −1, 1, −1, −1, −1, −1, −1, 1, 1, −1, −1, 1, −1, 1, −1, 1, 1, 1, 1, −1, −1}

The data sequence in frequency domain for 40 MHz is:

$HTLTF_{-58,58}$ = {1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, ...
1, −1, −1, 1, 1, −1, 1, −1, 1, −1, −1, −1, −1, −1, 1, 1, −1, −1, 1, −1, 1, −1, 1, 1, 1, 1, −1, −1, −1, 1, 0, ...
0, 0, −1, 1, 1, −1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, ...
1, −1, −1, 1, 1, −1, 1, −1, 1, −1, −1, −1, −1, −1, 1, 1, −1, −1, 1, −1, 1, −1, 1, 1, 1, 1}

Cyclic shift is applied on transmit chains, and the time domain representation of the waveform transmitted in the i $_{TX}$'th transmit chain during the n'th data HT-LTF

(!wlan11n-5-06-042.gif!) is:

$$r_{HT-LTF}^{n,\,i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-HTF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX},i_{STS}} P_{HTLTF}(i_{STS}, n) \cdot HTLTF(k) \cdot \exp(j2\pi k\Delta F(t - \alpha T_{GI} - T_{CS}^{i_{STS}})) + \right.$$

$$\left. \gamma \sum_{k=1}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX},i_{STS}} P_{HTLTF}(i_{STS}, n) \cdot HTLTF(k) \cdot \exp(j2\pi k\Delta F(t - \alpha T_{GI} - T_{CS}^{i_{STS}})) \right)$$

and it is

$$r_{HT-LTF}^{n,\,i_{TX}}(t) = \frac{1}{\sqrt{N_{ESS} \cdot N_{HT-HTF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} \sum_{i_{ESS}=1}^{N_{ESS}} [Q_k]_{i_{TX},\,i_{STS}+i_{ESS}} P_{HTLTF}(i_{ESS}, n - N_{DLTF}) \cdot HTLTF(k) \cdot \exp(j2\pi k\Delta F(t - T_{GI} - T_{CS}^{i_{STS}})) + \right.$$

$$\left. \gamma \sum_{k=1}^{N_{SR}} \sum_{i_{ESS}=1}^{N_{ESS}} [Q_k]_{i_{TX},\,i_{STS}+i_{ESS}} P_{HTLTF}(i_{ESS}, n - N_{DLTF}) \cdot HTLTF(k) \cdot \exp(j2\pi k\Delta F(t - T_{GI} - T_{CS}^{i_{STS}})) \right)$$

for the extension HT-LTFs (!wlan11n-5-06-045.gif!).
Where

n=1 refers to HT-LTF1 and is exported from pin HT-LTF1, n>1 refers to the additional HT-LTFs and is exported from pin HT-LTF234;
N_{STS} is the number of data space time streams;

N_{ESS} is the number of extension space time streams;

N_{HT-LTF}^{Tone} is the number of subcarriers used, which is 56 for 20 MHz and 114 for 40 MHz respectively;

N_{DLTF} is the number of data LTFs;

N_{ELTF} is the number of extension LTFs;

N_{LTF} is the number of total LTFs;

α equals to 2 if $n=1$, and equals to 1 if n>1;

The definition of $\omega_T(t)$ is given in section 17.3.2.4 of References #1. In this model $\omega_T(t)$ is the rectangular impulse function of 4us (HT-LTF234) or 8us (HT-LTF1);

N_{SR} is the number of subcarriers occupying half of the overall bandwidth, which is 28 for 20 MHz and 58 for 40 MHz respectively;

$T_{CS}^{i_{STS}}$ is used in Green Field and takes values from the following table;

γ is 1 for 20 MHz and j for 40 MHz;

Q_k is the spatial mapping matrix for subcarrier k (in this subnetwork we use the same matrix for all subcarriers);

P_{HTLTF} is the HT-LTF mapping matrix:

$$P_{HTLTF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix};$$

$T_{CS}^{i_{STS}}$ **Values for the HT Portion of the Packet**

Number of space time streams	Cyclic shift for STS 1	Cyclic shift for STS 2	Cyclic shift for STS 3	Cyclic shift for STS 4
1	0 ns	-	-	-
2	0 ns	-400 ns	-	-
3	0 ns	-400 ns	-200 ns	-
4	0 ns	-400 ns	-200 ns	-600 ns

This model only supports cases of $N_{STS}=NumHTLTF$.

4. Parameter details:

SpatialMappingScheme: DirectMapping, SpatialExpansion and UserDefined.
If DirectMapping is selected, only signal on the i_{SS}'th space time stream is mapped onto the i_{TX}'th ($i_{TX} = i_{STS}$) transmit chain.

If SpatialExpansion is selected, signal on different spatial streams are mapped onto each transmit chain by a predetermined matrix.
If UserDefined is selected, signal on different spatial streams are mapped onto each transmit chain by a user defined matrix **SpatialMappingMatrix**.
SpatialMappingMatrix: User defined matrix for spatial expansion, it should be an array of $N_{TX} \times N_{TX}$ elements which are abstracted from a N_{TX}

$\times\ N_{TX}$ matrix line by line (from the first line to the last line, and from left to right each line).

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_HTLTF_MM (WLAN 11n High Throughput Long Training Field for Mixed Mode)

WLAN_11n_HTLTF_MM

Description high througput long training field for mixed mode
Library WLAN 11n, Source Components
Class SDFWLAN_11n_HTLTF_MM

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
NumHTLTF	number of HT long training fields	1	int	[1, 4]
NumTx	number of transmit antennas	1	int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping	enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1	complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
GuardInterval	Guard interval (cyclic prefix) length	1/4	real	[0, 1/4]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	high throughput long training field signal	multiple complex

Notes/Equations

1. This subnetwork is used to generate the high throughput long training field signal for Mixed Mode operation.
   Its output pin is multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.
   Its output is time domain signal with total mean square value (power) of 1, covering 1 transmit chain to 4 transmit chains, 20 MHz and 40 MHz.
2. The schematic of this subnetwork is shown in the following figure.
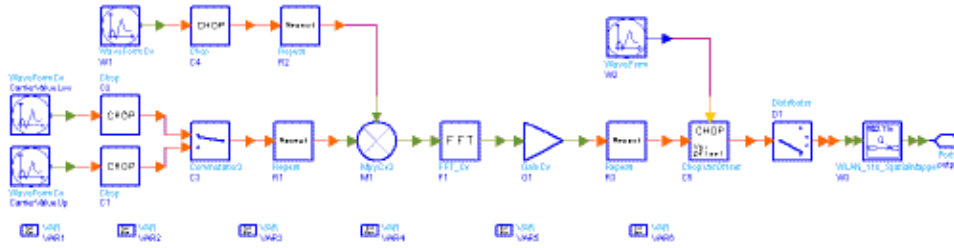
WLAN_11n_HTLTFMM Schematic

3. The data sequence in frequency domain for 20 MHz is:

$HTLTF_{-28,28}$ = {1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 0, ...
1, −1, −1, 1, 1, −1, 1, −1, 1, −1, −1, −1, −1, −1, 1, 1, −1, −1, 1, −1, 1, −1, 1, 1, 1, 1, −1, −1}

The data sequence in frequency domain for 40 MHz is:

$HTLTF_{-58,58}$ = {1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, ...
1, −1, −1, 1, 1, −1, 1, −1, 1, −1, −1, −1, −1, −1, 1, 1, −1, −1, 1, −1, 1, −1, 1, 1, 1, 1, −1, −1, −1, 1, 0, ...
0, 0, −1, 1, 1, −1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, 1, 1, −1, −1, 1, 1, −1, 1, −1, 1, 1, 1, 1, ...
1, −1, −1, 1, 1, −1, 1, −1, 1, −1, −1, −1, −1, −1, 1, 1, −1, −1, 1, −1, 1, −1, 1, 1, 1, 1}

Cyclic shift is applied on transmit chains, and the time domain representation of the waveform transmitted in the i_{TX}'th transmit chain during the n'th data HT-LTF (!wlan11n-5-07-057.gif!) is:

$$r_{HT-LTF}^{n, i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-HTF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} P_{HTLTF}(i_{STS}, n) \cdot HTLTF(k) \cdot \exp(j2\pi k \Delta F(t - \alpha T_{GI} - T_{CS}^{i_{STS}})) + \right.$$

$$\left. \gamma \sum_{k=1}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} P_{HTLTF}(i_{STS}, n) \cdot HTLTF(k) \cdot \exp(j2\pi k \Delta F(t - \alpha T_{GI} - T_{CS}^{i_{STS}})) \right)$$

and it is

$$r_{HT-LTF}^{n, i_{TX}}(t) = \frac{1}{\sqrt{N_{ESS} \cdot N_{HT-HTF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} \sum_{i_{ESS}=1}^{N_{ESS}} [Q_k]_{i_{TX}, i_{STS}+i_{ESS}} P_{HTLTF}(i_{ESS}, n - N_{DLTF}) \cdot HTLTF(k) \cdot \exp(j2\pi k \Delta F(t - T_{GI} - T_{CS}^{i_{STS}})) + \right.$$

$$\left. \gamma \sum_{k=1}^{N_{SR}} \sum_{i_{ESS}=1}^{N_{ESS}} [Q_k]_{i_{TX}, i_{STS}+i_{ESS}} P_{HTLTF}(i_{ESS}, n - N_{DLTF}) \cdot HTLTF(k) \cdot \exp(j2\pi k \Delta F(t - T_{GI} - T_{CS}^{i_{STS}})) \right)$$

for the extension HT-LTFs (!wlan11n-5-07-060.gif!).
Where

N_{STS} is the number of data space time streams;

N_{ESS} is the number of extension space time streams;

N_{HT-LTF}^{Tone} is the number of subcarriers used, which is 56 for 20 MHz and 114 for 40 MHz respectively;

N_{DLTF} is the number of data LTFs;

N_{ELTF} is the number of extension LTFs;

N_{LTF} is the number of total LTFs;

α equals to 1;

The definition of $\omega_T(t)$ is given in section 17.3.2.4 of References #1. In this model $\omega_T(t)$ is the rectangular impulse function of 4us;

N_{SR} is the number of subcarriers occupying half of the overall bandwidth, which is 28 for 20 MHz and 58 for 40 MHz respectively;

$T_{CS}^{i_{STS}}$ is used in Green Field and takes values from the following table;

γ is 1 for 20 MHz and j for 40 MHz;

Q_k is the spatial mapping matrix for subcarrier k (in this subnetwork we use the same matrix for all subcarriers);

P_{HTLTF} is the HT-LTF mapping matrix:

$$P_{HTLTF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix};$$

$T_{CS}^{i_{STS}}$ **Values for the HT Portion of the Packet**

Number of space time streams	Cyclic shift for STS 1	Cyclic shift for STS 2	Cyclic shift for STS 3	Cyclic shift for STS 4
1	0 ns	-	-	-
2	0 ns	-400 ns	-	-
3	0 ns	-400 ns	-200 ns	-
4	0 ns	-400 ns	-200 ns	-600 ns

This model only supports cases of N_{STS}=NumHTLTF.

4. Parameter details:
   SpatialMappingScheme: DirectMapping, SpatialExpansion and UserDefined.
   If DirectMapping is selected, only signal on the i_{SS}'th space time stream is mapped onto the i_{TX}'th ($i_{TX} = i_{STS}$) transmit chain.

   If SpatialExpansion is selected, signal on different spatial streams are mapped onto each transmit chain by a predetermined matrix.
   If UserDefined is selected, signal on different spatial streams are mapped onto each transmit chain by a user defined matrix **SpatialMappingMatrix**.
   SpatialMappingMatrix: User defined matrix for spatial expansion, it should be an array of $N_{TX} \times N_{TX}$ elements which are abstracted from a $N_{TX} \times N_{TX}$ matrix line by line (from the first line to the last line, and from left to right each line).

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC)

and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band,
June 12th, 2003.

WLAN_11n_HTSIG (WLAN 11n High Throughput SIGNAL Field)

WLAN_11n_HTSIG

Description high throught signal field
Library WLAN 11n, Source Components
Class SDFWLAN_11n_HTSIG

Parameters

Name	Description	Default	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode	enum	
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]
Reserved	reserved bits in HT SIGNAL field, defaulted by all "1"s: Reserved0, Reserved1, Reserved2, Reserved3, Reserved4, Reserved5, Reserved6, Reserved7	Reserved7	enum	
Aggregation	Aggregate-MPDU in data portion of the packet: Otherwise, A-MPDU	A-MPDU	enum	
STBC	difference between N_STS and N_SS ([0,3], 0-> No STBC)	0	int	[0, 3]
AdvCoding	block convolutional coding or advanced coding: BCC, Advanced	BCC	enum	
ShortGI	400ns guard interval in data symbols: NO, YES	NO	enum	
NumHTLTF	number of HT long training fields	1	int	[1, 4]
NumTx	number of transmit chains (antennas)	1	int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping	enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1	complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
GuardInterval	Guard interval (cyclic prefix) length	1/4	real	[0, 1/4]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	HT SIGNAL field	multiple complex

Notes/Equations

1. This subnetwork is used to generate the 8us-long high throughput SIGNAL field signal for both Mixed Mode and Green Field.
   Its output pin is multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.
   Its output is time domain signal with total mean square value (power) of 1 (a little smaller than 1 in Green Field), covering 1 transmit chain to 4 transmit chains, 20 MHz and 40 MHz.
2. The schematic of this subnetwork is shown in the following figure.
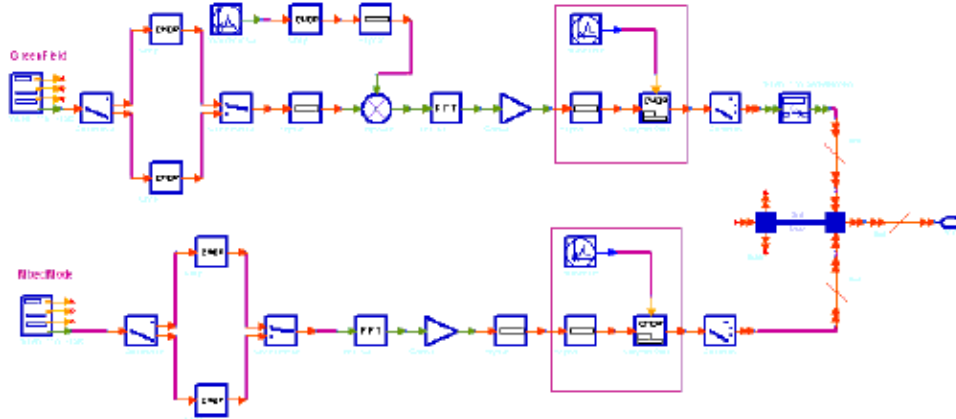
WLAN_11n_HTSIG Schematic

3. The HT-SIG is composed of two parts HTSIG1 and HTSIG2, each containing 24 SIGNAL bits. The data sequence in frequency domain used for IFFT is generated by model WLAN_11n_HTSIG_ as follows.
   Step 1: filling in 48 information bits for HTSIG1 and HTSIG2 as shown in the following figure.
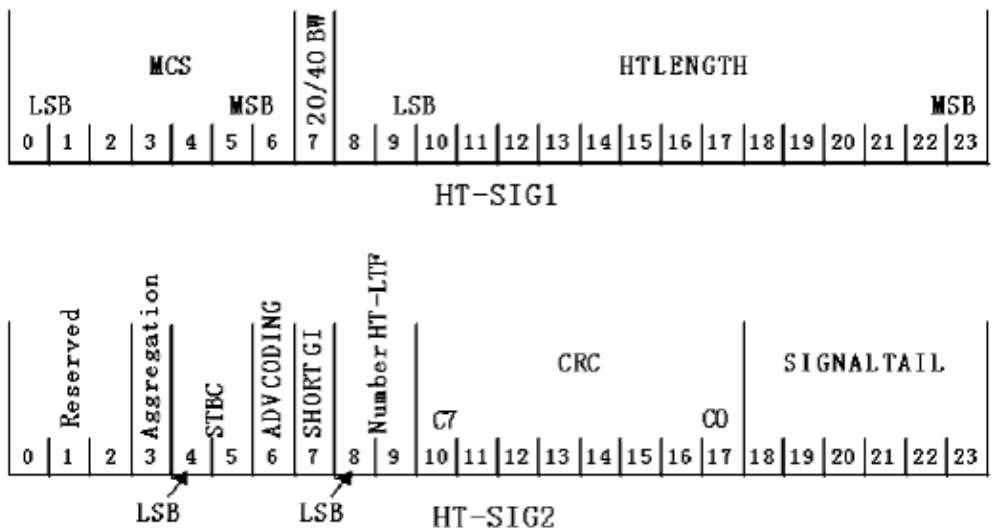
The High Throughput SIGNAL Bits

The transmission of each field is LSB first, their meanings are shown in the following table:

Fields of High Throughput Signal Field

Field Name	Number of Bits	Explanation and coding
Modulation and Coding Scheme	7	Index into Modulation and Coding Schemes
BW 20/40	1	0 if 20 MHz or 40 MHz upper/lower; 1 if 40 MHz
Length	16	The number of bytes of data in the PSDU (0-65535)
Reserved ones	3	Set to ones by transmitter, shall be ignored by receiver.
Aggregation	1	Set to 1 to indicate that the PPDU in the data portion of the packet contains an A_MPDU. Set to 0 otherwise.
STBC	2	Indicates the difference between either the number of space time streams N_{STS} and the number of spatial streams N_{SS} indicated by the MCS, 00 - No STBC (NSTS=NSS)
Advanced Coding	1	1- advanced coding, 0-BCC
Short GI	1	indicate that the short GI is used after the HT training
Number of HT-LTF	2	Number of HT-LTF. -b'00-not a sounding frame LTF, b'01-2LTF's, b'10-3LTF's, b'11 4 LTF's.
CRC	8	CRC of bits 0-23 in HT-SIG1 and bits 0-9 in HT-SIG2. The first bit to be transmitted is bit C7.
Tail Bits	6	Used to terminate the trellis of the convolution coder. Set to 0.

The CRC bits protects bits 0-33 of the HT-SIG. The value of the CRC field is the ones complement of

$$crc(D) = M(D)D^8_{mod\,G(D)}\,,$$

where the shift register is initialized to all ones,

$$M(D) = m_0 D^{k-1} + m_1 D^{k-2} + \ldots + m_{k-2} D + m_{k-1}$$ is the HT-SIG represented as

polynomial, $G(D) = D^8 + D^2 + D + 1$ is the CRC generating polynomial, and

$$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D + c_7$$.

The CRC field is transmitted with c_7 first. The following figure shows the operation of the CRC. First the shift register is reset to all ones. The bits are then passed through the XOR at the input. When the last bit have entered, the bits are outputted, c_7 first, through an inverter.
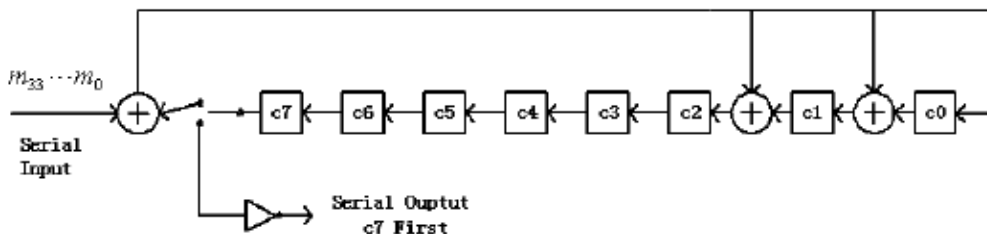
HT-SIG CRC Calculation

Step 2: The HT-SIG parts will be encoded, interleaved, mapped, and have pilots inserted following the steps described in sections 17.3.5.5, 17.3.5.6, 17.3.5.8 of the IEEE802.11a standard References #2. The stream of 96, complex numbers generated by these steps will be divided into two groups of 48 complex numbers: $\{d_{k,n}\}$, $k=0...47$, $n=0,1$.

4. Timed domain signal on the i_{TX}'th transmit chain is as follows.

In Mixed Mode, cyclic shift is applied on transmit chains, for 20 MHz transmission,

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N^{Tones}}} \sum_{n=0}^{1} \omega_T(t - nT_{SYM}) \cdot$$

$$\left(\sum_{k=0}^{47} d_{k,n} \exp(j2\pi M(k)\Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \right.$$

$$\left. + p_{n+z} \sum_{k=-N_{SR}}^{N_{SR}} P_k \exp(j2\pi k \Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \right)$$

for 40 MHz transmission,

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N^{Tones}}} \sum_{n=0}^{1} \omega_T(t - nT_{SYM}) \cdot$$

$$\left(j \sum_{k=0}^{47} d_{k,n} \exp(j2\pi(M(k) - 32)\Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \right.$$

$$- \sum_{k=0}^{47} d_{k,n} \exp(j2\pi(M(k) + 32)\Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}}))$$

$$+ p_{n+z} \sum_{k=-N_{SR}}^{N_{SR}} P_k \exp(j2\pi(k - 32)\Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}}))$$

$$\left. + jP_{n+z} \sum_{k=-N_{SR}}^{N_{SR}} P_k \exp(j2\pi(k + 32)\Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \right)$$

In Green Field, cyclic shift is applied on space time streams, for 20 MHz transmission,

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N^{Tones}}} \sum_{n=0}^{1} \omega_T(t - nT_{SYM}) \cdot$$

$$\left(\sum_{k=0}^{47} \sum_{i_{STS}=1}^{N_{STS}} [Q_{M(k)}]_{i_{TX}, i_{STS}} [P_{HTLTF}]_{i_{STS}, 1} d_{k,n} \exp(j2\pi M(k)\Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})) \right.$$

$$\left. + p_{n+z} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_{M(k)}]_{i_{TX}, i_{STS}} [P_{HTLTF}]_{i_{STS}, 1} P_k \exp(j2\pi k \Delta F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{STS}})) \right)$$

for 40 MHz transmission,

$$
r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N^{Tones}}} \sum_{n=0}^{1} \omega_T(t - nT_{SYM}) \cdot
$$

$$
\left(j \sum_{k=0}^{47} \sum_{i_{STS}=1}^{N_{STS}} [Q_{M(k)-32}]_{i_{TX}, i_{STS}} [P_{HTLTF}]_{i_{STS}, 1} d_{k,n} \exp(j2\pi(M(k)-32)\Delta F(t-nT_{SYM}-T_{GI}-T_{CS}^{i_{STS}}))
\right.
$$

$$
- \sum_{k=0}^{47} \sum_{i_{STS}=1}^{N_{STS}} [Q_{M(k)+32}]_{i_{TX}, i_{STS}} [P_{HTLTF}]_{i_{STS}, 1} d_{k,n} \exp(j2\pi(M(k)+32)\Delta F(t-nT_{SYM}-T_{GI}-T_{CS}^{i_{STS}}))
$$

$$
+ P_{n+z} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_{M(k)-32}]_{i_{TX}, i_{STS}} [P_{HTLTF}]_{i_{STS}, 1} P_k \exp(j2\pi(k-32)\Delta F(t-nT_{SYM}-T_{GI}-T_{CS}^{i_{STS}}))
$$

$$
\left.
+ jP_{n+z} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_{M(k)+32}]_{i_{TX}, i_{STS}} [P_{HTLTF}]_{i_{STS}, 1} P_k \exp(j2\pi(k+32)\Delta F(t-nT_{SYM}-T_{GI}-T_{CS}^{i_{STS}}))
\right)
$$

Where

N_{TX} is the number of transmit chains;

N_{STS} is the number of space time streams;

N^{Tone} is the number of subcarriers used (in training OFDM symbols). In Mixed Mode, HT-SIG shall be equalized before decoding by L-LTF, so N^{Tone} is 52 for 20 MHz and 104 for 40 MHz; In Green Field, HT-SIG shall be equalized before decoding by HT-LTF1, so N^{Tone} is 56 for 20 MHz and 114 for 40 MHz, which means the power of HT-SIG field shall be a little lower than the other preamble fields;

The definition of $\omega_T(t)$ is given in section 17.3.2.4 of References #2. In this model $\omega_T(t)$ is the rectangular impulse function of 4us;

N_{SR} is the number of subcarriers occupying half of the overall bandwidth, which is 26 for 20 MHz and 58 for 40 MHz respectively;

$T_{CS}^{i_{TX}}$ is used in Mixed Mode and takes value from the following table;

$T_{CS}^{i_{STS}}$ is used in Green Field and takes values from the second table;

γ is 1 for 20 MHz and j for 40 MHz;

Q_k is the spatial mapping matrix for subcarrier k (in this subnetwork we use the same matrix for all subcarriers), used only in Green Field;

$M(k)$, p_n, P_k are defined in section 17.3.5.9 of the 802.11a standard References #2.

The value of z is zero in a GF packet and 1 in a mixed mode packets.

P_0 is the first pilot value in the sequence defined in section 17.3.5.9 of the 802.11a standard References #2.

$T_{CS}^{i_{TX}}$ **Values for the Legacy Portion of the Packet**

Number of Tx Chains	cyclic shift for Tx chain 1	cyclic shift for Tx chain 2	cyclic shift for Tx chain 3	cyclic shift for Tx chain 4
1	0 ns	-	-	-
2	0 ns	-200 ns	-	-
3	0 ns	-100 ns	-200 ns	-
4	0 ns	-50 ns	-100 ns	-150 ns

$T_{CS}^{i_{STS}}$ **Values for the HT Portion of the Packet**

Number of space time streams	cyclic shift for STS 1	cyclic shift for STS 2	cyclic shift for STS 3	cyclic shift for STS 4
1	0 ns	-	-	-
2	0 ns	-400 ns	-	-
3	0 ns	-400 ns	-200 ns	-
4	0 ns	-400 ns	-200 ns	-600 ns

PHTLTF is the HT-LTF mapping matrix:

$$P_{HTLTF} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix}.$$

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_HTSTF (WLAN 11n High Throughput Short Training Field)
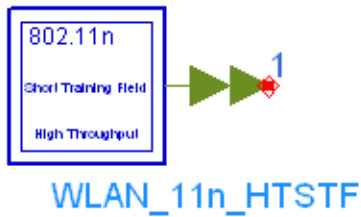
WLAN_11n_HTSTF

Description high throughput short training field
Library WLAN 11n, Source Components
Class SDFWLAN_11n_HTSTF

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
NumTx	number of transmit antennas	1	int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping	enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1	complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
GuardInterval	Guard interval (cyclic prefix) length	1/4	real	[0, 1/4]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	HT short training field signal	multiple complex

Notes/Equations

1. This subnetwork is used to generate the 4us-long high throughput short training field signal for Mixed Mode operation.
   Its output pin is multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.
   Its output is time domain signal with total mean square value (power) of 1, covering 1 transmit chain to 4 transmit chains, 20 MHz and 40 MHz.
2. The schematic of this subnetwork is shown in the following figure.
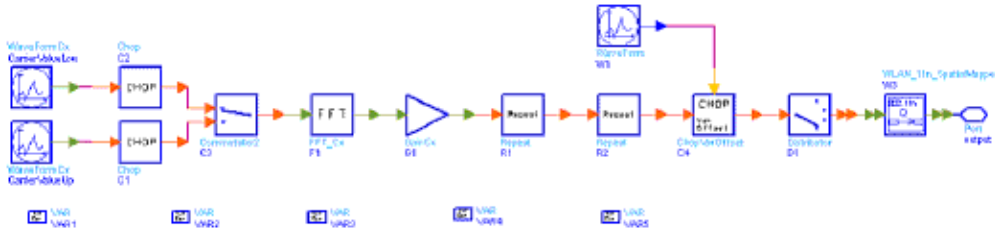
WLAN_11n_HTSTF Schematic

3. The data sequence in frequency domain for 20 MHz is:

$$HTS_{-28,28} = \sqrt{1/2}\{0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \ldots$$
$$0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0\}$$

The data sequence in frequency domain for 40 MHz is:

$$HTS_{-58,58} = \sqrt{1/2}\{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \ldots$$
$$0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, \ldots$$
$$0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \ldots$$
$$0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\}$$

Cyclic shift is applied on space time streams, signal on the i_{TX}'th transmit chain is:

$$r_{HT-STF}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{HT-STF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} HTS_k \exp(j2\pi k \Delta F(t - T_{CS}^{i_{STS}})) + \right.$$

$$\left. \gamma \sum_{k=1}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} HTS_k \exp(j2\pi k \Delta F(t - T_{CS}^{i_{STS}})) \right)$$

Where

N_{STS} is the number of space time streams;

N_{HT-STF}^{Tone} is the number of subcarriers used, which is 12 for 20 MHz and 24 for 40 MHz respectively;

The definition of $\omega_T(t)$ is given in section 17.3.2.4 of References #1. In this model $\omega_T(t)$ is the rectangular impulse function of 4us;

N_{SR} is the number of subcarriers occupying half of the overall bandwidth, which is 28 for 20 MHz and 58 for 40 MHz respectively;

$T_{CS}^{i_{STS}}$ takes values from the following table;

γ is 1 for 20 MHz and j for 40 MHz;

Q_k is the spatial mapping matrix for subcarrier k (in this subnetwork we use the same matrix for all subcarriers);

$T_{CS}^{i_{STS}}$ **Values for the HT Portion of the Packet**

Number of space time streams	cyclic shift for STS 1	cyclic shift for STS 2	cyclic shift for STS 3	cyclic shift for STS 4
1	0 ns	-	-	-
2	0 ns	-400 ns	-	-
3	0 ns	-400 ns	-200 ns	-
4	0 ns	-400 ns	-200 ns	-600 ns

4. Parameter details:

> **SpatialMappingScheme**: DirectMapping, SpatialExpansion and UserDefined. It's used for Green Field.
> If DirectMapping is selected, only signal on the i_{SS}'th space time stream is mapped onto the i_{TX}'th ($i_{TX} = i_{STS}$) transmit chain.
>
> If SpatialExpansion is selected, signal on different spatial streams are mapped onto each transmit chain by a predetermined matrix.
> If UserDefined is selected, signal on different spatial streams are mapped onto each transmit chain by a user defined matrix **SpatialMappingMatrix**.
> **SpatialMappingMatrix**: User defined matrix for spatial expansion, it should be an array of $N_{TX} \times N_{TX}$ elements which are abstracted from a $N_{TX} \times N_{TX}$ matrix line by line (from the first line to the last line, and from left to right each line).

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_Interleaver (WLAN 11n Interleaver)

WLAN_11n_Interleaver
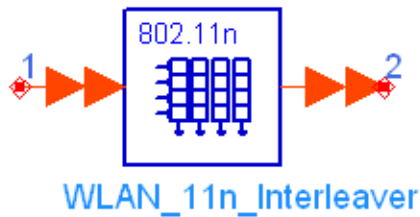
Description interleaving of bit space-time bit streams
Library WLAN 11n, Source Components
Class SDFWLAN_11n_Interleaver

Parameters

Name	Description	Default	Type	Range
MCS	Modulation Coding Scheme ([0~31])	0	int	[0~31]
Bandwidth	Band width: BW20M, BW40M	BW20M	enum	
Direction	Interleaver or Deinterleaver: Interleave, Deinterleave	Interleave	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	spacial bit stream to be interleaved or deinterleaved	multiple anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	interleaved or deinterleaved spacial bit stream	multiple anytype

Notes/Equations

1. This model is used to interleave (Direction=Interleave) the bits at the output of the stream parser in the transmitter or deinterleave (Direction=Deinterleave) the data at the output of the QAM demapping in the receiver.
2. This model has one multiport pin In and one multiport pin Out which should be expanded to the number of spatial stream (N_{SS}).

    Each firing,
    N_{CBPSS} tokens are consumed at each input port and produced at each output port.

    where
    N_{CBPSS} is the number of coded bits per symbol per spatial stream, which is
    decided by parameters MCS and Bandwidth.
3. The bits at the output of the stream parser are divided into block of N_{CBPSS}, each

    block is interleaved by an interleaver based on the 802.11a interleaver. This interleaver, which is based on entering the data in rows, and outputting it in columns, has a different number of columns and rows when a 20 MHz channel is used and when a 40 MHz channel is used. The numbers are described in the following

table:

Number of Rows and Columns in the Interleaver

	20 MHz	40 MHz
N_{COL}	13	18
N_{ROW}	$4N_{BPSC}$	$6N_{BPSC}$
N_{ROT}	11	29

4. The interleaving is defined using three permutations.
   The first permutation is defined by the rule:

$$i = N_{ROW}(k \bmod N_{COL}) + floor(k/N_{COL}) \qquad k = 0, 1, ..., N_{CBPSS} - 1$$

   The second permutation is defined by the rule:

$$j = s \times floor(i/s) + (i + N_{CBPSS} - floor(N_{COL} \times i/N_{CBPSS})) \bmod s \qquad i = 0, 1, ..., N_{CBPSS} - 1$$

   where
   the value of s is determined by the number of code bits per sub carrier:
$$s = max(N_{BPSC}/2, 1)$$

   If more than one spatial stream exists, a frequency rotation is applied to the output
   of the second permutation
$$r = (j - ((i_{ss} \times 2) \bmod 3 + 3 \times floor(i_{ss}/3)) \times N_{ROT} \times N_{BPSC}) \bmod N_{CBPSS} \quad j = 0, 1, ..., N_{CBPSS} - 1$$

   where
   $i_{ss} = 0, 1, ..., N_{ss} - 1$ is the index of spatial stream on which this interleaver
   is operating.
5. The de-interleaving uses the following operations to perform the inverse rotation.
   We denote by r the index of the bit in the received block (per spatial stream).
   The first permutation reverses the third (frequency rotation) permutation of the
   interleaver

$$j = (r + ((i_{ss} \times 2) \bmod 3 + 3 \times floor(i_{ss}/3)) \times N_{ROT} \times N_{BPSC}) \bmod N_{CBPSS} \quad r = 0, 1, ..., N_{CBPSS} - 1$$

   The second permutation reverses the second permutation in the interleaver.

$$i = s \times floor(j/s) + (j + floor(N_{COL} \times j/N_{CBPSS})) \bmod s \qquad j = 0, 1, ..., N_{CBPSS} - 1$$

   s is defined as above.
   The third permutation reversed the first permutation of the interleaver:

$$k = N_{COL} \times i - (N_{CBPSS} - 1) \times floor(i/N_{ROW}) \qquad i = 0, 1, ..., N_{CBPSS} - 1$$

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC)

and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_LLTF (WLAN 11n Legacy Long Training Field)
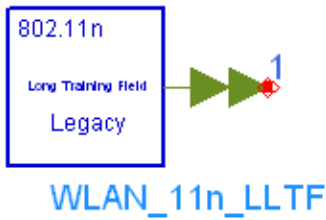
WLAN_11n_LLTF

Description legacy long training field
Library WLAN 11n, Source Components
Class SDFWLAN_11n_LLTF

Parameters

Name	Description	Default	Type	Range
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
NumTx	number of transmit antennas	1	int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
GuardInterval	Guard interval (cyclic prefix) length	1/2	real	[0, 1/2]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	legacy long training field signal	multiple complex

Notes/Equations

1. This model is used to generate the 8us-long legacy long training field signal for Mixed Mode operation.
   Its output pin is multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.
   Its output is time domain signal with total mean square value (power) of 1, covering 1 transmit chain to 4 transmit chains, 20 MHz and 40 MHz.
   Each firing, $160 \cdot 2^{(Bandwidth + OversamplingOption)}$ tokens are generated for each transmit chain.

2. The data sequence in frequency domain for 20 MHz is:
$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, \dots$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\}$$

The data sequence in frequency domain for 40 MHz is:
$$L_{-58,58} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, \dots$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, \dots$$
$$0, 0, 0, 0, 0, 0, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, \dots$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\}$$

cyclic shift is applied on transmit chains, signal on the iTX'th transmit chain is:

$$r_{L-LTF}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-LTF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} L_k \exp(j2\pi k \Delta F(t - T_{GI2} - T_{CS}^{i_{TX}})) + \gamma \sum_{k=1}^{N_{SR}} L_k \exp(j2\pi k \Delta F(t - T_{GI2} - T_{CS}^{i_{TX}})) \right)$$

Where

N_{TX} is the number of transmit chains;

N_{L-LTF}^{Tone} is the number of subcarriers used, which is 52 for 20 MHz and 104 for 40 MHz respectively;

The definition of $\omega_T(t)$ is given in section 17.3.2.4 of References #1. In this model $\omega_T(t)$ is the rectangular impulse function of 8us;

N_{SR} is the number of subcarriers occupying half of the overall bandwidth, which is 26 for 20 MHz and 58 for 40 MHz respectively;

$T_{CS}^{i_{TX}}$ takes value from the following table;

γ is 1 for 20 MHz and j for 40 MHz;

T_{GI2} = 1.6 us.

$T_{CS}^{i_{TX}}$ **Values for the Legacy Portion of the Packet**

Number of Tx Chains	cyclic shift for Tx chain 1	cyclic shift for Tx chain 2	cyclic shift for Tx chain 3	cyclic shift for Tx chain 4
1	0 ns	-	-	-
2	0 ns	-200 ns	-	-
3	0 ns	-100 ns	-200 ns	-
4	0 ns	-50 ns	-100 ns	-150 ns

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_LSIG (WLAN 11n Legacy SIGNAL Field)
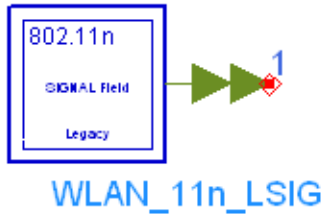
WLAN_11n_LSIG

Description legacy signal field (loaded for IFFT)
Library WLAN 11n, Source Components
Class SDFWLAN_11n_LSIG

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]
NumTx	number of transmit antennas	1	int	[1, 4]
ShortGI	400ns guard interval in data symbols: NO, YES	NO	enum	
NumHTLTF	number of transmit antennas	1	int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
GuardInterval	Guard interval (cyclic prefix) length	1/4	real	[0, 1/4]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	legacy SIGNAL field	multiple complex

Notes/Equations

1. This subnetwork is used to generate the 4us-long legacy SIGNAL field signal for Mixed Mode operation.
   Its output pin is multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.
   Its output is time domain signal with total mean square value (power) of 1, covering 1 transmit chain to 4 transmit chains, 20 MHz and 40 MHz.
2. The schematic of this subnetwork is shown in the following table.

3. The data sequence in frequency domain used for IFFT is generated by model WLAN_11n_LSIG_ as follows.
   Step 1: filling in 24 information bits as in the following figure.

Where, `Rate' is set 6Mbps in legacy representation, i.e. `1 1 0 1'. The `Length' field is $Length = 3 \cdot (\lceil N_{data}\rceil + N_{HT-LTF} + 3) - 3$ and is transmitted LSB first. N_{data} is the number of 4us symbols in the data part of the frame. While using short GI N_{data} is equal to the actual number of symbols in the data part of the frame multiplied by 9/10. The symbol $\lceil x \rceil$ denotes the lowest integer greater than or equal to x. The reserved bit is set to 0. The parity field will have the even parity of bits 0-16.

Step 2: the information bits are encoded, interleaved, mapped and have pilots inserted following the steps described in sections 17.3.5.5, 17.3.5.6, 17.3.5.8 of the IEEE 802.11a standard References #2. The stream of 48 complex numbers generated by these steps is represented by $\{d_k\}$, k=0...47.

4. Cyclic shift is applied on transmit chains, the time domain signal on the _i $_{TX}$'th transmit chain is as follows.
   for 20 MHz transmission,

$$r_{L-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-SIG}^{T_{one}}}} \omega_T(t) \cdot$$
$$\left(\sum_{k=0}^{47} d_k \exp(j2\pi M(k)\Delta F(t - T_{GI} - T_{CS}^{i_{tx}})) + p_0 \sum_{k=-N_{SR}}^{N_{SR}} P_k \exp(j2\pi k\Delta F(t - T_{GI} - T_{CS}^{i_{tx}})) \right)$$

for 40 MHz transmission,

$$r^{i_{TX}}_{L-SIG}(t) = \frac{1}{\sqrt{N_{TX} \cdot N^{Tone}_{L-SIG}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=0}^{47} d_k \exp\left(j2\pi(M(k)-32)\Delta F(t-T_{GI}-T^{i_{TX}}_{CS})\right) + j\sum_{k=0}^{47} d_k \exp\left(j2\pi(M(k)+32)\Delta F(t-T_{GI}-T^{i_{TX}}_{CS})\right) \right.$$

$$\left. + p_0 \sum_{k=-N_{SR}}^{N_{SR}} P_k \left(\exp\left(j2\pi(k-32)\Delta F(t-T_{GI}-T^{i_{TX}}_{CS})\right) + j\exp\left(j2\pi(k+32)\Delta F(t-T_{GI}-T^{i_{TX}}_{CS})\right) \right) \right)$$

Where

N_{TX} is the number of transmit chains;

N^{Tone}_{L-SIG} is the number of subcarriers used, which is 52 for 20 MHz and 104 for 40 MHz respectively;

The definition of $\omega_T(t)$ is given in section 17.3.2.4 of References #2. In this model $\omega_T(t)$ is the rectangular impulse function of 4us;

N_{SR} is the number of subcarriers occupying half of the overall bandwidth, which is 26 for 20 MHz and 58 for 40 MHz respectively;

$M(k)$, P_k are defined in section 17.3.5.9 of the 802.11a standard References #2;

P_0 is the first pilot value in the sequence defined in section 17.3.5.9 of the 802.11a standard References #2;

$T^{i_{TX}}_{CS}$ takes value from the following table;

γ is 1 for 20 MHz and j for 40 MHz;

T_{GI} = 0.8 us.

$T^{i_{TX}}_{CS}$ **Values for the Legacy Portion of the Packet**

Number of Tx Chains	Cyclic shift for Tx chain 1	Cyclic shift for Tx chain 2	Cyclic shift for Tx chain 3	Cyclic shift for Tx chain 4
1	0 ns	-	-	-
2	0 ns	-200 ns	-	-
3	0 ns	-100 ns	-200 ns	-
4	0 ns	-50 ns	-100 ns	-150 ns

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_LSTF (WLAN 11n Legacy Short Training Field)
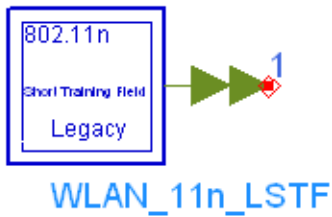
WLAN_11n_LSTF

Description legacy short training field
Library WLAN 11n, Source Components
Class SDFWLAN_11n_LSTF

Parameters

Name	Description	Default	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode	enum	
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
NumTx	number of transmit antennas	1	int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping	enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1	complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
GuardInterval	Guard interval (cyclic prefix) length	1/4	real	[0, 1/4]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	legacy short training field signal	multiple complex

Notes/Equations

1. This subnetwork is used to generate the 8us-long legacy short training field signal, both for Mixed Mode and Green Field.
   Its output pin is multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.
   Its output is time domain signal with total mean square value (power) of 1, covering 1 transmit chain to 4 transmit chains, 20 MHz and 40 MHz.
   In the case of 1 transmit chain and 20 MHz, its output is identical to the 802.11a short training sequence.
2. The schematic of this subnetwork is shown in the following figure.

WLAN_11n_LSTF Schematic

3. The data sequence in frequency domain for 20 MHz is:

$S_{-26,26} = \sqrt{1/2}\{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \ldots$
$0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\}$

The data sequence in frequency domain for 40 MHz is:

$S_{-58,58} = \sqrt{1/2}\{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \ldots$
$0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, \ldots$
$0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, \ldots$
$0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\}$

In Mixed Mode, cyclic shift is applied on transmit chains, signal on the i_{TX}'th transmit chain is:

$$r_{L-STF}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-STF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} S_k \exp(j2\pi k\Delta F(t - T_{CS}^{i_{TX}})) + \gamma \sum_{k=1}^{N_{SR}} S_k \exp(j2\pi k\Delta F(t - T_{CS}^{i_{TX}})) \right)$$

In Green Field, cyclic shift is applied on space time streams, signal on the i_{TX}'th transmit chain is:

$$r_{L-STF}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{L-STF}^{Tone}}} \omega_T(t) \cdot$$

$$\left(\sum_{k=-N_{SR}}^{0} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX},i_{STS}} S_k \exp(j2\pi k\Delta F(t - T_{CS}^{i_{STS}})) + \gamma \sum_{k=1}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX},i_{STS}} S_k \exp(j2\pi k\Delta F(t - T_{CS}^{i_{STS}})) \right)$$

Where

N_{TX} is the number of transmit chains;

N_{STS} is the number of space time streams;

N_{L-STF}^{Tone} is the number of subcarriers used, which is 12 for 20 MHz and 24 for 40 MHz respectively;

The definition of $\omega_T(t)$ is given in section 17.3.2.4 of References #1. In this model $\omega_T(t)$ is the rectangular impulse function of 8us;

N_{SR} is the number of subcarriers occupying half of the overall bandwidth, which is 26 for 20 MHz and 58 for 40 MHz respectively;

$T_{CS}^{i_{TX}}$ is used in Mixed Mode and takes value from the following table;

$T_{CS}^{i_{STS}}$ is used in Green Field and takes values from the second table;

γ is 1 for 20 MHz and j for 40 MHz;

Q_k is the spatial mapping matrix for subcarrier k (in this subnetwork we use the same matrix for all subcarriers);

$T_{CS}^{i_{TX}}$ **Values for the Legacy Portion of the Packet**

Number of Tx Chains	Cyclic shift for Tx chain 1	Cyclic shift for Tx chain 2	Cyclic shift for Tx chain 3	Cyclic shift for Tx chain 4
1	0 ns	-	-	-
2	0 ns	-200 ns	-	-
3	0 ns	-100 ns	-200 ns	-
4	0 ns	-50 ns	-100 ns	-150 ns

$T_{CS}^{i_{STS}}$ **Values for the HT Portion of the Packet**

Number of space time streams	Cyclic shift for STS 1	Cyclic shift for STS 2	Cyclic shift for STS 3	Cyclic shift for STS 4
1	0 ns	-	-	-
2	0 ns	-400 ns	-	-
3	0 ns	-400 ns	-200 ns	-
4	0 ns	-400 ns	-200 ns	-600 ns

4. Parameter details:

SpatialMappingScheme: DirectMapping, SpatialExpansion and UserDefined. It's used for Green Field.
If DirectMapping is selected, only signal on the i_{SS}'th space time stream is mapped onto the i_{TX}'th ($i_{TX} = i_{STS}$) transmit chain.

If SpatialExpansion is selected, signal on different spatial streams are mapped onto each transmit chain by a predetermined matrix.
If UserDefined is selected, signal on different spatial streams are mapped onto each transmit chain by a user defined matrix **SpatialMappingMatrix**.
SpatialMappingMatrix: User defined matrix for spatial expansion, it should be an array of $N_{TX} \times N_{TX}$ elements which are abstracted from a $N_{TX} \times N_{TX}$ matrix line by line (from the first line to the last line, and from left to right each line). It's valid only for Green Field.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_Mapper (WLAN 11n Mapper)
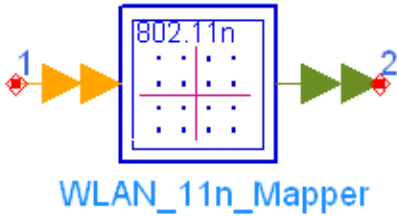
Description Mapping of BPSK, QPSK 16-QAM or 64-QAM for each spacial stream
Library WLAN 11n, Source Components
Class SDFWLAN_11n_Mapper

Parameters

Name	Description	Default	Type	Range
MCS	Modulation Coding Scheme ([0~32])	0	int	[0~32]
Bandwidth	Band width: BW20M, BW40M	BW20M	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	interleaved or deinterleaved spacial bit stream	multiple int

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	signal after constellation mapping	multiple complex

Notes/Equations

1. This subnetwork model is used to map the sequence of bits in each spatial stream to complex constellation points.
2. The input and output pins are multi-port pins which should be expanded to the number of spatial stream (N_{SS}). Each firing, N_{BPSC} tokens are consumed at each input port and 1 token is produced at each output port, where N_{BPSC} is number of coded bits per single carrier.
   The schematic of this subnetwork is shown in the following figure.
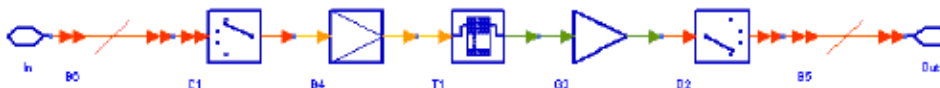
   WLAN_11n_Mapper Schematic
3. The mapping scheme is decided by the parameter MCS and the mapping pattern is defined in section 17.3.5.7 of the 802.11a standard.
   - When $MCS \bmod 8 = 0$, BPSK mapping will consume one input bit to produce

124

complex output data, as illustrated in the following figure.
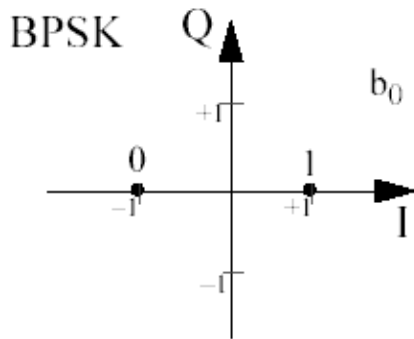
BPSK Constellation Mapping

- When $0 < MCS \bmod 8 \leq 2$, QPSK mapping will consume 2 bits to produce complex output data, as illustrated in the following figure. After mapping, the output signal is normalized by normalization factor a, where $a = \sqrt{1/2}$.
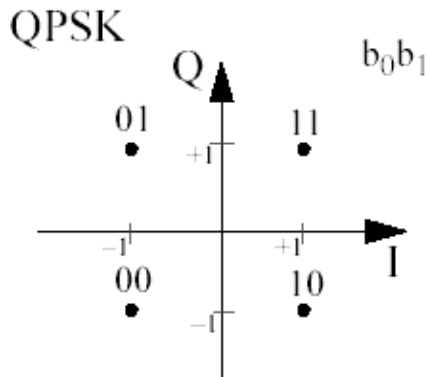
QPSK Constellation Mapping

- When $2 < MCS \bmod 8 \leq 4$, 16-QAM mapping will consume 4 bits to produce complex output data, as illustrated in the following figure. After mapping, the output signal is normalized by normalization factor a, where $a = \sqrt{1/10}$.

16-QAM constellation diagram

Q

$b_0 b_1 b_2 b_3$

00 10   01 10   11 10   10 10

00 11   01 11   11 11   10 11

00 01   01 01   11 01   10 01

00 00   01 00   11 00   10 00
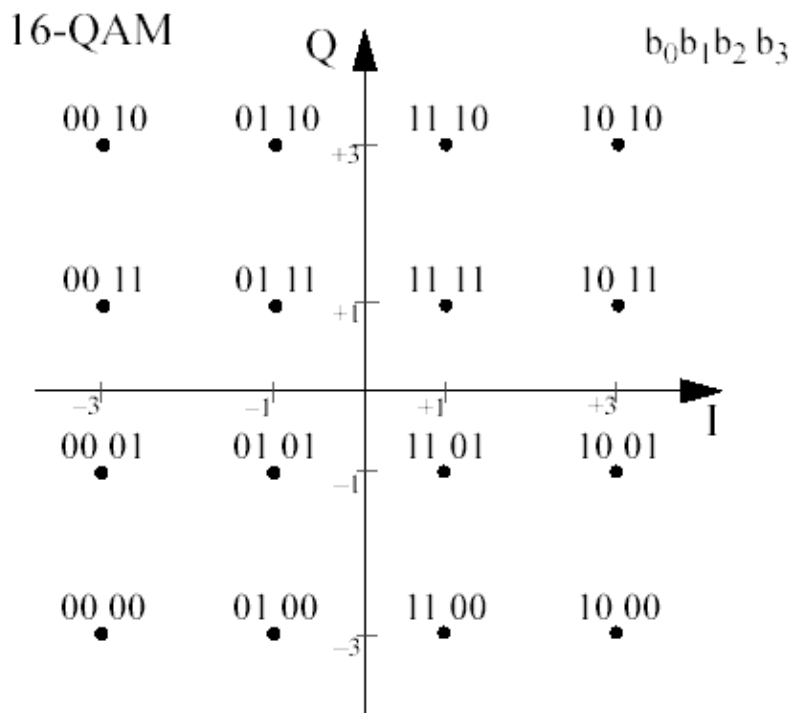
16-QAM Constellation Mapping

- When $4 < MCS \bmod 8 \leq 7$, 64-QAM mapping will consume 6 bits to produce complex output data, as illustrated in the following figure. After mapping, the output signal is normalized by normalization factor a, where $a = \sqrt{1/42}$.
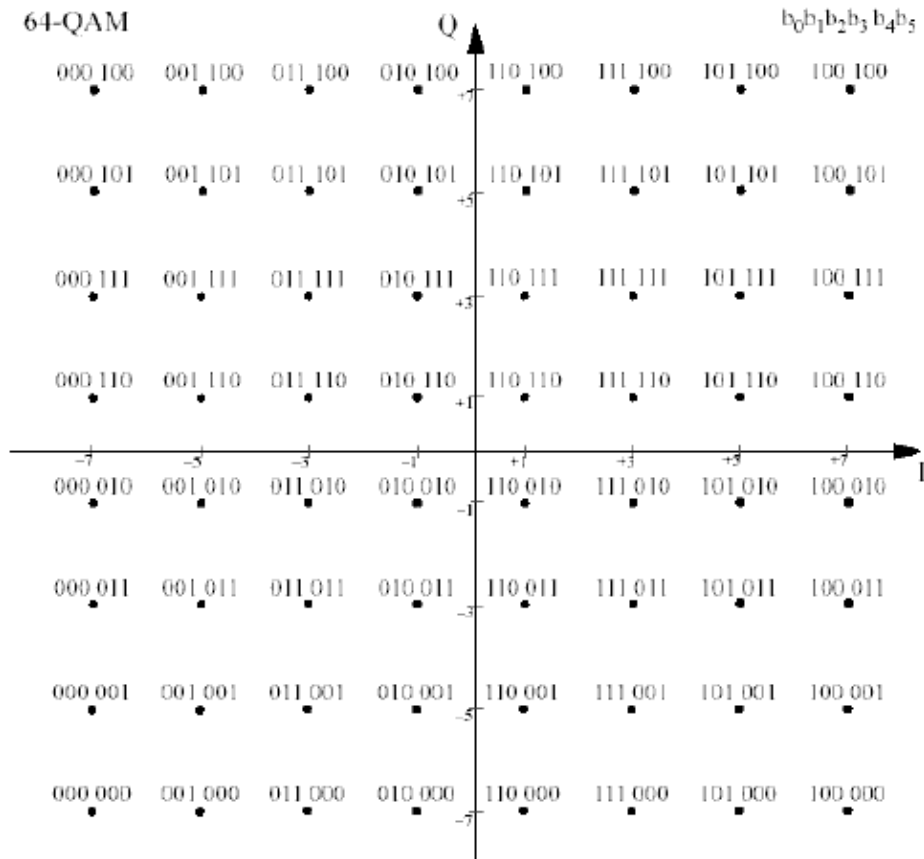
64-QAM Constellation Mapping

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_MuxOFDMSym (Mux Pilot Subcarriers with the Data Subcarriers To Generate OFDM Symbol)

WLAN_11n_MuxOFDMSym
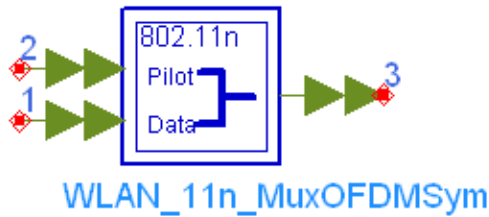
Description insert pilots to data subcarrier and gernerate OFDM symbol
Library WLAN 11n, Source Components
Class SDFWLAN_11n_MuxOFDMSym

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	data	data stream	multiple complex
2	pilot	pilot stream	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
3	output	data stream with and	multiple complex

Notes/Equations

1. This subnetwork is used to insert pilot subcarriers into the data subcarriers and generate data ODFM symbol in frequency domain.
2. Each firing, if the signal bandwidth is 20 MHz, 52 data tokens and 4 pilot tokens are consumed, while 56 output tokens are produced; if the signal bandwidth is 40 MHz, 108 data tokens and 6 pilot tokens are consumed, while 114 output tokens are produced.
3. The subnetworks schematic is shown in the following figure.
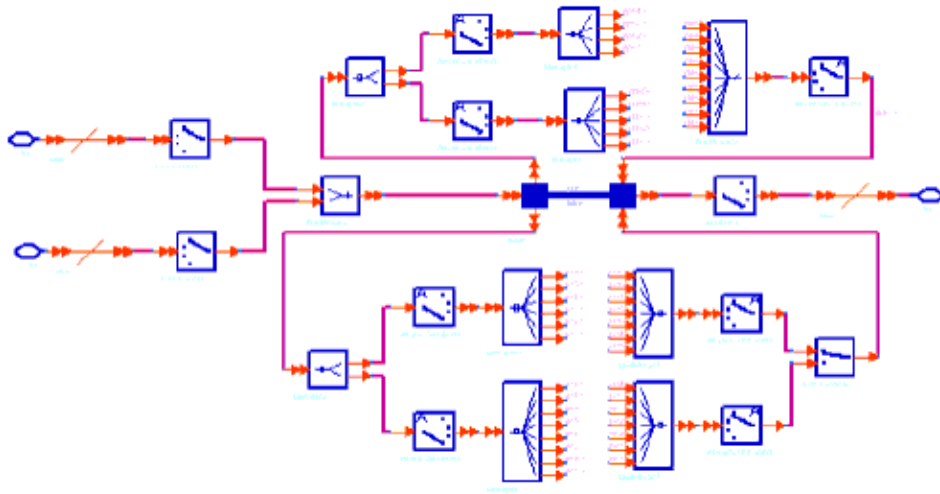
WLAN_11n_MuxOFDMSym Schematic

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_OFDMMod (WLAN 11n OFDM Modulation)

Description OFDM symbol modulation
Library WLAN 11n, Source Components
Class SDFWLAN_11n_OFDMMod

Parameters

Name	Description	Default	Type	Range
NumTx	Number of transmit antennas	1	int	[0~4]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	
ShortGI	400ns guard interval in data symbols: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	data stream	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	OFDM symbol	multiple complex

Notes/Equations

1. This subnetwork is used to convert the frequency domain signals to time domain by applying IFFT.
2. The input and output pins are multi-port pins. Both of them have a buswidth of N_{SS}.

   The subnetworks schematic is shown in the following figure.

3. On each spatial stream, the timed signal after IFFT is cyclic shifted to prevent unwanted beamforming. Guard intervals are also add to eliminate the multipath interference within the interval.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_PilotGen (WLAN 11n Pilot Generation)

WLAN_11n_PilotGen

Description Pilot generator
Library WLAN 11n, Source Components
Class SDFWLAN_11n_PilotGen

Parameters

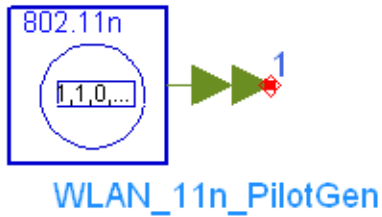| Name	Description	Default	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode	enum	
MCS	Modulation Coding Scheme ([0~31])	0	int	[0~31]
Bandwidth	Band width: BW20M, BW40M	BW20M	enum	
HTLength	octet number of PSDU	256	int	[1, 65535]
Phase	initial phase of pilots	0	int	[0, 126]

Pin Outputs

Pin	Name	Description	Signal Type
1	output	Pilot for each spatial stream	multiple complex

Notes/Equations

1. This model is used to generate the pilot sequence for all data symbols.
2. This model has a multiport pin Out which should be expanded to the number of spatial mapper inputs (N_{SMI}).

   Each firing, $N_{SP} \times N_{SYM}$ tokens are produced at each output port of the output pin where
   N_{SP} is the number of pilot subcarriers, which is 4 in the case of 20 MHz transmission and 6 in the case of 40 MHz.
   $$N_{SYM} = m_{STBC} \times ceil((8 \times HTLength + 16 + 6 \times N_{ES})/(m_{STBC} \times N_{DBPS}))$$
   m_{STBC} is 1 (STBC is not used.) *HTLength* is the PSDU length in byte. N_{ES} is the number of FEC encoders used which is decided by the parameter MCS.
   N_{DBPS} is the number of data bits per symbol which is decided by parameters MCS and Bandwidth.
3. In the case of 20 MHz transmission 4 pilot tones are inserted in the same sub-carriers used in 802.11a standard, i.e. in sub-carriers -21, -7, 7 and 21. The pilot sequence for the nth symbols and i_{SMI}^{th} spatial mapper input is defined as follows:

$$p_n + z P^{-28, 28}_{(i_{SMI}, n)}$$

where

z is 3 in a mixed mode packet and 2 in a Green Field Packet. p_n is defined in section 17.3.5.9 of the 802.11a standard. The p_n is a cyclic extension of the 127 elements sequence and is given by

$p_{0, \dots, 126}$
= {1, 1, 1, 1, -1, -1, -1, 1, -1, -1, -1, -1, 1, 1, -1, 1, -1, -1, 1, 1, -1, 1, 1, -1, 1, 1, 1, 1, 1, 1, 1, -1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, 1, 1, -1, 1, -1, -1, -1, 1, -1, 1, 1, -1, -1, 1, -1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, -1, 1, -1, -1, 1, 1, -1, -1, -1, -1, 1, -1, -1, 1, -1, 1, 1, 1, 1, -1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, -1, 1, 1, -1, 1, -1, 1, 1, 1, -1, -1, 1, -1, -1, -1, 1, 1, 1, -1, -1, -1, -1, -1, -1, -1}

$P^{-28, 28}_{(i_{SMI}, n)}$ is defined as follow:

$$P^{-28, 28}_{(i_{SMI}, n)} = \{0, 0, 0, 0, 0, 0, 0, \psi^{(n_{SMI})}_{i_{SMI}, n \oplus 4}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$$
$$\psi^{(n_{SMI})}_{i_{SMI}, (n+1) \oplus 4}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \psi^{(n_{SMI})}_{i_{SMI}, (n+2) \oplus 4}, 0, 0, 0, 0, 0,$$
$$0, 0, 0, 0, 0, 0, 0, 0, \psi^{(n_{SMI})}_{i_{SMI}, (n+3) \oplus 4}, 0, 0, 0, 0, 0, 0, 0\}$$

In the case of 40 MHz 6 pilot tones are inserted in sub-carriers -53, -25, -11, 11, 25, 53. The pilot sequence for the nth symbols and i_{SMI}^{th} spatial mapper input is defined as follows:

$$p_n + z P^{-58, 58}_{(i_{SMI}, n)}$$

where

z and p_n are defined as above. $P^{-58, 58}_{(i_{SMI}, n)}$ is defined as follow:

$$P^{-58, 58}_{(i_{SMI}, n)} = \{0, 0, 0, 0, 0, \psi^{(n_{SMI})}_{i_{SMI}, n \oplus 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$$
$$0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \psi^{(n_{SMI})}_{i_{SMI}, (n+1) \oplus 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$$
$$0, 0, \psi^{(n_{SMI})}_{i_{SMI}, (n+2) \oplus 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$$
$$\psi^{(n_{SMI})}_{i_{SMI}, (n+3) \oplus 6}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \psi^{(n_{SMI})}_{i_{SMI}, (n+4) \oplus 6}, 0, 0, 0, 0, 0,$$
$$0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \psi^{(n_{SMI})}_{i_{SMI}, (n+5) \oplus 6}, 0,$$
$$0, 0, 0, 0\}$$

where

$n \oplus 6$ indicates symbol number modulo 6;

For each spatial mapper input there is a different pilot pattern and the pilot patterns are cyclically rotated over symbols.
The basic patterns are also different according to the total number of spatial streams for the packet.

The patterns $\psi^{(n_{SMI})}_{i_{SMI}, n}$ are defined in the following tables.

**Pilot Values for 20 MHz Transmission**

Pilot Values for 20 MHz Transmission

Nss	iss	$\psi_{i_{SMI},0}^{(n_{SMI})}$	$\psi_{i_{SMI},1}^{(n_{SMI})}$	$\psi_{i_{SMI},2}^{(n_{SMI})}$	$\psi_{i_{SMI},3}^{(n_{SMI})}$
1	0	1	1	1	-1
2	0	1	1	-1	-1
2	1	1	-1	-1	1
3	0	1	1	-1	-1
3	1	1	-1	1	-1
3	2	-1	1	1	-1
4	0	1	1	1	-1
4	1	1	1	-1	1
4	2	1	-1	1	1
4	3	-1	1	1	1

Pilot Values for 40 MHz Transmission

Nss	iss	$\psi_{i_{SMI},0}^{(n_{SMI})}$	$\psi_{i_{SMI},1}^{(n_{SMI})}$	$\psi_{i_{SMI},2}^{(n_{SMI})}$	$\psi_{i_{SMI},3}^{(n_{SMI})}$	$\psi_{i_{SMI},4}^{(n_{SMI})}$	$\psi_{i_{SMI},5}^{(n_{SMI})}$
1	0	1	1	1	-1	-1	1
2	0	1	1	-1	-1	-1	-1
2	1	1	1	1	-1	1	1
3	0	1	1	-1	-1	-1	-1
3	1	1	1	1	-1	1	1
3	2	1	-1	1	-1	-1	1
4	0	1	1	-1	-1	-1	-1
4	1	1	1	1	-1	1	1
4	2	1	-1	1	-1	-1	1
4	3	-1	1	1	1	-1	1

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_Preamble (WLAN 11n Preamble)
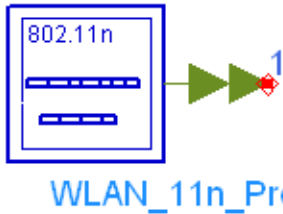
WLAN_11n_Preamble

Description preambles before data symbols
Library WLAN 11n, Source Components
Class SDFWLAN_11n_Preamble

Parameters

Name	Description	Default	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode	enum	
MCS	modulation Coding Scheme ([0,32])	0	int	[0, 32]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256	int	[1, 2^16-1]
Reserved	reserved bits in HT SIGNAL field, defaulted by all "1"s: Reserved0, Reserved1, Reserved2, Reserved3, Reserved4, Reserved5, Reserved6, Reserved7	Reserved7	enum	
Aggregation	Aggregate-MPDU in data portion of the packet: Otherwise, A-MPDU	A-MPDU	enum	
STBC	difference between N_STS and N_SS ([0,3], 0-> No STBC)	0	int	[0, 3]
AdvCoding	block convolutional coding or advanced coding: BCC, Advanced	BCC	enum	
ShortGI	400ns guard interval in data symbols: NO, YES	NO	enum	
NumHTLTF	number of HT long training fields	1	int	[1, 4]
NumTx	number of transmit chains (antennas)	1	int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping	enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1	complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	

Pin Outputs

| Pin	Name	Description	Signal Type
1	output	preamble field	multiple complex

Notes/Equations

1. This subnetwork is used to generate the preamble symbols for WLAN 11n baseband

source, both for Mixed Mode and Green Field.

Its output pin is multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.

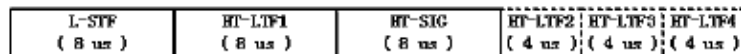2. Schematic of this subnetwork is shown in the following figure.
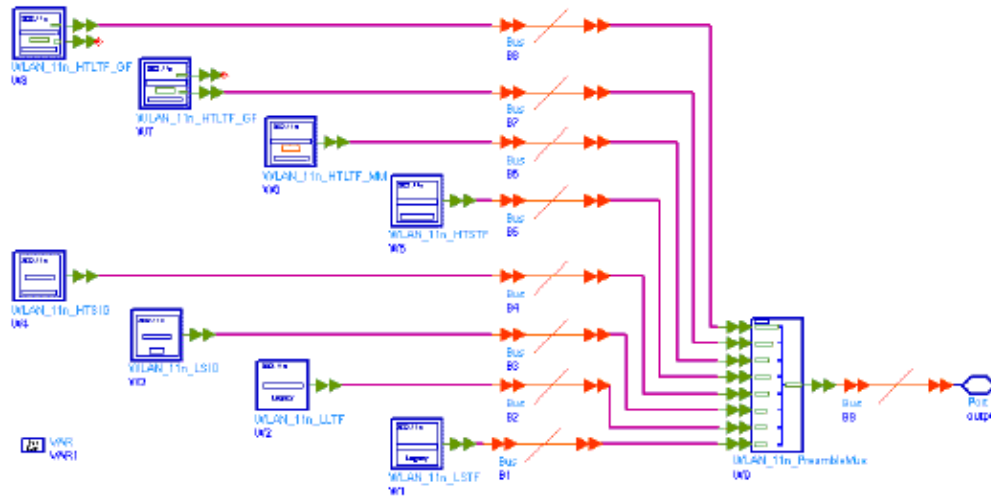
WLAN_11n_Preamble Schematic

3. The output is time domain signal with total mean square value (power) of 1 (except HT-SIG field in Green Field). Signal format is shown in the following figure.
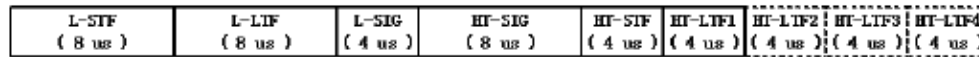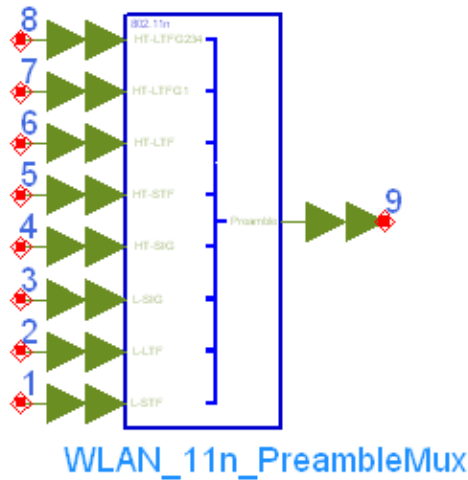

Mixed Mode

Green Field

Preamble Format

Signal fields represented by dashed rectangles are dispensable depending on parameter *NumHTLTF*.

4. Models WLAN_11n_LSTF, WLAN_11n_LLTF, WLAN_11n_LSIG, WLAN_11n_HTSIG, WLAN_11n_HTSTF, WLAN_11n_HTLTFMM and WLAN_11n_HTLTFGF are used to generate all preamble signal fields needed in Mixed Mode and Green Field. Model WLAN_11n_PreambleMux is used to multiplex each signal field needed according to given parameters.

5. For more details of each signal field, see descriptions of each model and References #1.

References

1. EWC: HT PHY Specification v1.13, November 5th, 2005.

WLAN_11n_PreambleMux (WLAN 11n Preamble Multiplexer)

Description preambles before data symbols
Library WLAN 11n, Source Components
Class SDFWLAN_11n_PreambleMux

Parameters

Name	Description	Default	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode	enum	
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz	enum	
NumHTLTF	number of HT long training fields	1	int	[1, 4]
NumTx	number of transmit chains (antennas)	1	int	[1, 4]
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	LSTF	legacy short training field	multiple complex
2	LLTF	legacy long training field	multiple complex
3	LSIG	legacy SIGNAL field	multiple complex
4	HTSIG	HT SIGNAL field	multiple complex
5	HTSTF	HT short training field	multiple complex
6	HTLTF	HT long training field (Mixed Mode)	multiple complex
7	HTLTFG1	HT long training field (Green Field HT-LTF1)	multiple complex
8	HTLTFG234	HT long training field (Green Field HT-LTF2, HTLTF3 and HTLTF4)	multiple complex

Pin Outputs

| Pin	Name	Description	Signal Type
9	output	802.11n preamble	multiple complex

Notes/Equations

1. This model is used to multiplex each signal field of the preamble part for WLAN 11n baseband source.

   Its input and output pins are multi-port pins, each sub-port corresponds to a transmit channel/chain. These pins should be connected with pins whose bus width are *NumTx* , for instance, the Bus model with parameter "BusWidth" set to *NumTx*.

   Its inputs, including L-STF, L-LTF, L-SIG, HT-SIG, HT-STF, HT-LTFMM (HT-LTF for Mixed Mode), HT-LTFG1 (HT-LTF1 for Green Field) and HT-LTFG234 (remaining HT-LTFs for Green Field), should all be time domain signals with guard interval inserted according to References #1 below.

   In Mixed Mode, HT-LTFG1 and HT-LTFG234 may be left unconnected. If the two pins are connected, tokens shall be consumed on them. The output signals of Mixed Mode are L-STF, L-LTF, L-SIG, HT-SIG, HT-STF and HT-LTFMM in order.

   In Green Field, L-LTF, L-SIG and HT-LTFMM may be left unconnected. If the three pins are connected, tokens shall be consumed on them. The output signals of Green Field are L-STF, HT-LTFG1, HT-SIG and HT-LTFG234 (if present) in order.

2. *Each fire,* N_{Field} tokens in each transmit channel shall be consumed at the input pins. N_{output} tokens in each transmit channel shall be generated at output pin, where

$$N_{Field} = 80 \cdot 2^{Bandwidth + Oversampling\ Option}$$ for L-SIG and HT-STF,

$$N_{Field} = 160 \cdot 2^{Bandwidth + Oversampling\ Option}$$ for L-STF, L-LTF, HT-SIG and HT-LTFG1,

$$N_{Field} = NumHTLTF \cdot 80 \cdot 2^{Bandwidth + Oversampling\ Option}$$ for HT-LTFMM,

$$N_{Field} = (NumHTLTF - 1) \cdot 80 \cdot 2^{Bandwidth + Oversampling\ Option}$$ for HT-LTFG234 (if *NumHTLTF* equals to 1 pin HT-LTFG234 still consume tokens),

$$N_{output} = (8 + NumHTLTF) \cdot 80 \cdot 2^{Bandwidth + Oversampling\ Option}$$ for Mixed Mode, and

$$N_{output} = (5 + NumHTLTF) \cdot 80 \cdot 2^{Bandwidth + Oversampling\ Option}$$ for Green Field.

References

1. EWC HT PHY Specification v1.13, November 5th, 2005.

WLAN_11n_RF_Modulator (WLAN 11n RF Modulator)
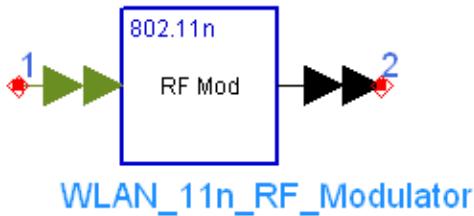
**Description RF modulator with complex input for 802.11n
Library WLAN 11n, Source Components
Class TSDFWLAN_11n_RF_Modulator**

Parameters

Name	Description	Default	Unit	Type	Range
ROut	output resistance	DefaultROut	Ohm	real	(0, ∞)
FCarrier	carrier frequency	5000 MHz	Hz	real	(0, ∞)
Power	total output power of modulator	0.01	W	real	[0, ∞)
VRef	modulator voltage reference level	1	V	real	(0, ∞)
SamplingRate	Sampling rate	20 MHz	Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO		enum	
NumTx	number of transmit antennas	1		int	[1, 32)
AntGainImbalance	gain imbalance in dB, relative to average power (Power/NumTx)	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
IQGainImbalance	gain imbalance in dB, Q channel relative to I channel	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
PhaseImbalance	phase imbalance in degrees, Q channel relative to I channel	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)
I_OriginOffset	I amplitude origin offset in percent with repect to output rms voltage	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
Q_OriginOffset	Q amplitude origin offset in percent with repect to output rms voltage	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
IQ_Rotation	IQ rotation, in degrees	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input baseband signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output RF signal	multiple timed

Notes/Equations

1. This model is used to convert baseband signals into timed RF signals for WLAN 11n

RF source.

Its input (output) pin is a multi-port pin, each sub-port corresponds to a transmit channel/chain. This pin should be connected with a pin whose bus width is *NumTx*, for instance, the Bus model with parameter "BusWidth" set to *NumTx*.

Its input are baseband (complex envelope) signals. The input signals are assumed to be filtered with multiple samples per symbol. WLAN_11n_RF_Modulator does not upsample or filter the input signals. The input signals are used to modulate the in-phase and quadrature- phase carriers of QAM modulators of different transmit channels.

For each input sample consumed, one output sample is produced.

2. Each sub-port (transmit channel) of the output bus should be connected in series to a resistor with the impedance of *ROut* for impedance matching. This resistor connects this model with the model followed.

3. Parameter details:

FCarrier is used to set the local oscillator frequency or frequency of carriers to be modulated. Carriers of all transmit channels are from the same oscillator without phase noise.

Power is the total output power of all transmit channels when:

> each output port are connected in series with a matched resistor,
> the rms (root of the sum of mean square) value of all input signals is *VRef*,
> without any impairments (*AntGainImbalance*, *IQGainImbalance*, etc. should
> be set to zeros).

The *VRef* parameter is used to calibrate the modulator. *VRef* is the rms value of all input signals that results in an instantaneous output power on matched load equal to *Power*. In order to get average output power on matched load equal to *Power*, the input rms voltage should equal to *VRef*. Therefore, in order to calibrate the modulator, *VRef* should be set to the input rms voltage. If the input rms voltage is not known, the TkIQrms component can be connected to the inputs of this model and it will report the rms value of the input IQ signal of each transmit chain.

The *SamplingRate* parameter is used to set the simulation time step at the output of the component. The simulation time step is set to 1 / SamplingRate.

The *MirrorSpectrum* parameter can be used to mirror the spectrum (invert the Q envelope) at the output of the modulator of each transmit channel. Depending on the configuration of the mixers in the upconverter, which typically follows a modulator, the signal at the upconverter's input may need to be mirrored. If such a configuration is used, then this parameter should be set to YES.

NumTx is the number of transmit channels or bus width of input and output signals.

AntGainImbalance is gain imbalance array of each transmit channel in dB, relative to 0 dB (default gain) of this channel.

IQGainImbalance is the gain imbalance array of each transmit channel in dB, Q channel relative I channel.

PhaseImbalance is the phase imbalance array of each transmit channel in degree, Q channel relative to I channel.

I_OriginOffset is the I origin offset array of each transmit channel in percent, relative to output rms voltage of this transmit channel.

Q_OriginOffset array is similar with *I_OriginOffset* array.

IQ_Rotation is IQ constellation rotation array in degree of each transmit channel.

4. Brief description of implementation algorithms.

Assuming that the input signal of the i'th transmit channel is *inRe[i]+j × inIm[i]*, output signal on the i'th transmit channel is generated as follows:

Step 1:

$$outRe[i] = inRe[i] \ ;$$
$$outIm[i] = inIm[i] \ ;$$

Step 2: mirror spectrum

if (MirrorSpectrum == YES)
$$outIm[i] = -outIm[i] \ ;$$

Step 3: IQ gain imbalance

$$outIm[i] = outIm[i] \cdot 10^{\frac{IQGainImbalance[i]}{20}} \ ;$$

Step 4: phase imbalance

$$outRe[i] = outRe[i] - outIm[i]\sin\left(\frac{PhaseImbalance[i] \cdot \pi}{180}\right) \ ;$$
$$outIm[i] = outIm[i]\cos\left(\frac{PhaseImbalance[i] \cdot \pi}{180}\right) \ ;$$

Step 5: IQ rotation

$$temp = outRe[i] \ ;$$
$$outRe[i] = outRe[i]\cos\left(\frac{IQRotation[i] \cdot \pi}{180}\right) - outIm[i]\sin\left(\frac{IQRotation[i] \cdot \pi}{180}\right) \ ;$$
$$outIm[i] = temp \cdot \sin\left(\frac{IQRotation[i] \cdot \pi}{180}\right) + outIm[i]\cos\left(\frac{IQRotation[i] \cdot \pi}{180}\right) \ ;$$

Step 6: inter-antenna gain imbalance

$$outRe[i] = outRe[i] \cdot 10^{\frac{AntGainImbalance[i]}{20}} \ ;$$
$$outIm[i] = outIm[i] \cdot 10^{\frac{AntGainImbalance[i]}{20}} \ ;$$

Step 7: origin offset

$$outRe[i] = outRe[i] + \frac{VRef}{\sqrt{NumTx}} \cdot \frac{IOriginOffset}{100} \ ;$$
$$outIm[i] = outIm[i] + \frac{VRef}{\sqrt{NumTx}} \cdot \frac{QOriginOffset}{100} \ ;$$

Step 8: gain scaling

$$outRe[i] = outRe[i] \cdot \frac{\sqrt{2 \cdot ROut \cdot Power}}{VRef} \quad ;$$

$$outIm[i] = outIm[i] \cdot \frac{\sqrt{2 \cdot ROut \cdot Power}}{VRef} \quad ;$$
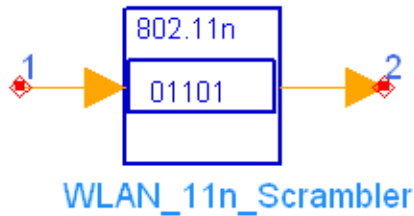
Step 9: modulation

$$V(t) = Real\{(outRe[i] + outIm[i]) \cdot e^{j \cdot 2\pi \cdot FCarrier \cdot t}\} \quad .$$

References

1. EWC HT PHY Specification v1.13, November 5th, 2005.

WLAN_11n_Scrambler (WLAN 11n Scrambler)

Description Scramble the input bits
Library WLAN 11n, Source Components
Class SDFWLAN_11n_Scrambler

Parameters

Name	Description	Default	Type	Range
MCS	Modulation Coding Scheme ([0~31])	0	int	[0~31]
Bandwidth	Band width: BW20M, BW40M	BW20M	enum	
HTLength	octet number of PSDU	256	int	[1, 65535]
ReInitialize	reset the initial state the scrambler each burst by input bits or not: NO, YES	NO	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	scrambler initial state	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	scramble sequence	int

Notes/Equations

1. This model is used to generate scramble sequence used for scrambling and descrambling.
2. Each firing:
   - 7 bit tokens are consumed at Pin In.
   - $N_{DBPS} \times N_{SYM}$ tokens are produced at Pin Out.

   where

   N_{SYM} is the number of symbols in the data field which is computed using the formula:

   $$N_{SYM} = m_{STBC} \times ceil((8 \times HTLength + 16 + 6 \times N_{ES})/(m_{STBC} \times N_{DBPS}))$$

   where

   m_{STBC} is 1 (STBC is not used.) *HTLength* is the PSDU length in byte. N_{ES} is the number of FEC encoders used which is decided by the parameter MCS.

N_{DBPS} is the number of data bits per symbol which is decided by parameters MCS and Bandwidth.

3. The length-127 frame-synchronous scrambler (see the following figure)uses the generator polynomial $S(x) = x^7 + x^4 + 1$. When the all ones initial state is used, the 127-bit sequence generated repeatedly by the scrambler (left-most used first) is:

   00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100
   11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111
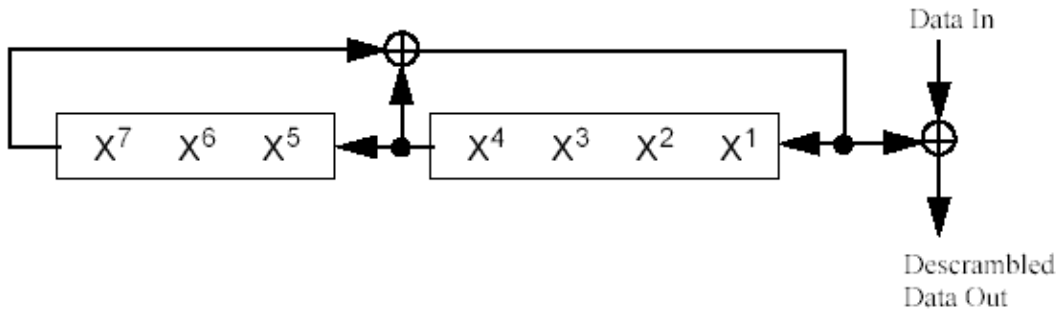
Data Scrambler

The initial state of the scrambler is set to a pseudo random non-zero state by the input pin. If the parameter ReInitialize is set to YES, the state of the scrambler is reset each frame by the input bits.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.
2. IEEE Std 802.11a-1999(R2003), Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer(PHY) specifications, High-Speed Physical Layer in the 5 GHz Band, June 12th, 2003.

WLAN_11n_SpatialMapper (WLAN 11n Spatial mapper)

Description spatial mapping for 11n
Library WLAN 11n, Source Components
Class SDFWLAN_11n_SpatialMapper

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,31])	0	int	[0, 31]
NumTx	Number of transmit antennas	1	int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping	enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1	complex array	(-∞, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	in	input signal	multiple complex

Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output signal	multiple complex

Notes/Equations

1. This subnetwork is used to map the spatial streams to different transmit chains.
2. The input and output pins are multi-port pins. The buswidth of input pin is N_{SS}, while the buswidth of the output pin is N_{ES}. The subnetworks schematic is shown in the following figure.
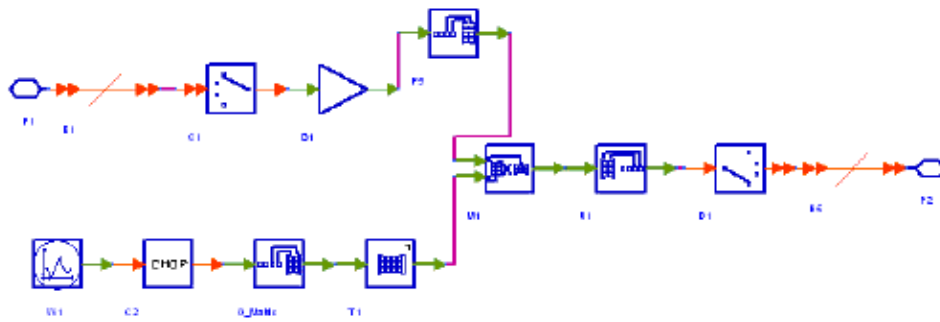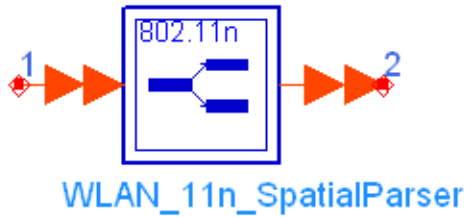
WLAN_11n_SpatialMapper Schematic

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_SpatialParser (WLAN 11n spatial parser)

WLAN_11n_SpatialParser

Description 11n spatial parser
Library WLAN 11n, Source Components
Class SDFWLAN_11n_SpatialParser

Parameters

Name	Description	Default	Type	Range
MCS	modulation Coding Scheme ([0,31])	0	int	[0, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	multiple anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output signal	multiple anytype

Notes/Equations

1. This subnetwork is used to map signal on encoder streams to spatial streams.
2. The input and output pins are multi-port pins. The buswidth of input pin is N_{SS}, while buswidth of the output is N_{ES}. The subnetworks schematic is shown in the following figure.
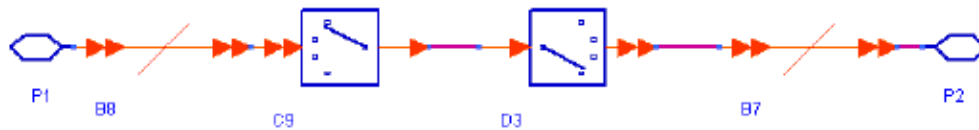
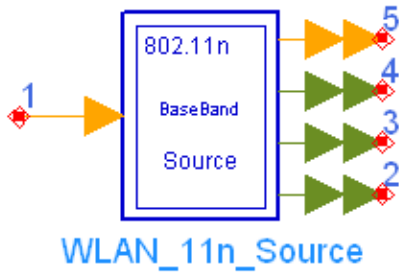**WLAN_11n_SpatialParser schematic**

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n Sources

The 11n top-level signal sources are provided in this category.

- *WLAN 11n Source (WLAN 11n baseband signal source)* (wlan11n)
- *WLAN 11n Source RF (WLAN 11n RF signal source)* (wlan11n)

WLAN_11n_Source (WLAN 11n baseband signal source)

Description 11n signal source
Library WLAN 11n, Source
Class SDFWLAN_11n_Source

Parameters

| Name	Description	Default	Unit	Type	Range
OperatingMode	operating mode: MixedMode, GreenField	MixedMode		enum	
MCS	modulation Coding Scheme ([0,31])	0		int	[0, 31]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz		enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256		int	[1, 2^16-1]
Aggregation	Aggregate-MPDU in data portion of the packet: Otherwise, A-MPDU	A-MPDU		enum	
ShortGI	400ns guard interval in data symbols: NO, YES	NO		enum	
NumHTLTF	number of HT long training fields	1		int	[1, 4]
NumTx	number of transmit chains (antennas)	1		int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping		enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1		complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1		enum	
Window	use time domain window or not: NO, YES	NO		enum	
TransitionTime	the transition time of window function	100 nsec	sec	real	(0, 800nsec]
IdleInterval	Idle Interval	100 nsec	sec	real	[0, 1000μsec]
ScrambleSeed	initial state of scrambler(should not be all 0)	1 1 1 1 1 1 1		int array	[0 1]
ScrambleReinit	reset initial state of the scrambler each burst (by ScrambleSeed) or not: NO, YES	YES		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	PSDU	PSDU in bit	int

Pin Outputs

Pin	Name	Description	Signal Type
2	BaseBand	802.11n baseband signal	multiple complex
3	SigAftMatrix	signal after spatial mapping and before IFFT	multiple complex
4	Constellation	constellation after OFDM symbol mux and before spatial mapping	multiple complex
5	BitsChCoded	convolutional eccoded bit stream	multiple int

Notes/Equations

1. This subnetwork is used to generate WLAN 11n baseband signal.
2. Each firing, HTlength × 8 information bits are consumed, while a whole WLAN 11n packet are generated. The subnetworks schematic is shown in the following figure.
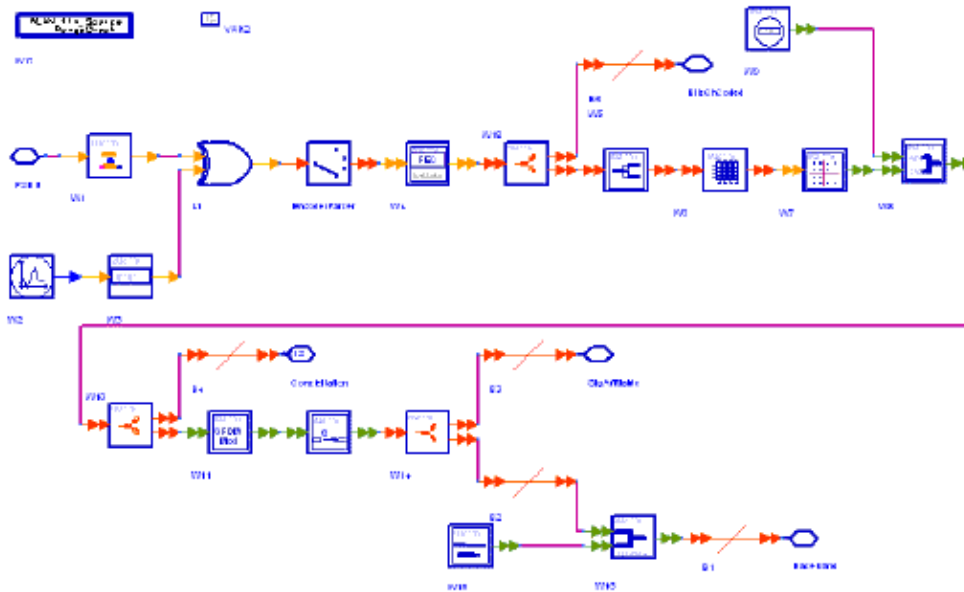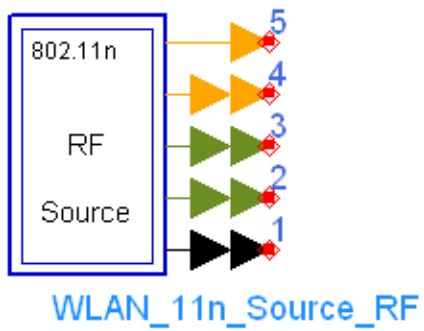

WLAN_11n_Source Schematic

3. The input information bits are padded with zero first to generate the data payload for the whole packet and then the service data is scrambled. The scrambler is the same as the scrambler in 11a. The encoder parser separates the scrambled data stream to different encoders. if N_{SS}=1 or 2, there will be one encoder; if N_{SS}=3or 4, there will be 2 encoders. Then the stream parser distributes encoded data steams to maximum 4 different spatial streams. On each spatial stream, the data are interleaved and mapped to constellations. The constellation modulation scheme includes BPSK,QPAK,16QAM and 64QAM. The pilot subcarriers are then inserted among data subcarriers to generate the OFDM symbol in frequency domain. After the OFDM modulation model, the frequency domain signal is converted to timed domain with guard interval and cyclic shift added. Then the timed signal on each spatial stream is mapped to transmit chains. Finally the whole packet is generated by concatenating the data field with the preamble field.
4. Parameter details:

- OperatingMode is an enumerate parameter specifying the transmitter operating mode. If the transmitter is working on MixedMode, although the 11a device can't decode the HT data, it still can hear the 11a legacy preambles in the packet. If the transmitter is working on GreenFieldMode, only the 11n HT device can hear and decode the transmitted signal.
- MCS specifies the modulation and coding scheme. Currently MCS0 to MCS31 are supported.
- Bandwidth is an enumerate parameter specifying the channel bandwidth, both 20 MHz and 40 MHz bandwidth are supported in this library.
- HTLength specifies the number of information bytes per packet, so the total information bits per packet is HTLength × 8.
- ShortGI is an enumerate parameter specifying the length of the guard interval. If ShortGI is Yes, then the guard interval will be 0.4 μsec; if it is No, the guard interval will be 0.8μsec
- NumHTLTF specifies the number of HT long training field. NumHTLTF must not be less than the N_{SS}. And if the N_{SS} is 3, NumHTLTF must be 4.
- NumTx specifies the number of transmit antennas. Based on References #1 below, the number of transmit antennas must not be less than N_{SS} and must be equal or larger than NumHTLTF.
- SpatialMappingScheme is an enumerate parameter specifying the scheme to map the spatial streams to the transmit chains. If SpatialMappingScheme is DirectMapping, the mapping matrix will be an identity matrix and the signal on each spatial streams will be mapped to corresponding transmit chain directly; if SpatialsMappingScheme is SpatialExpansion, the Walsh-Hadamard matrix or Fourier matrix will be used as the mapping matrix. or If SpatialMappingScheme is Userdefined, the mapping matrix will be determined by parameter SpatialMappingMatrix and any unitary matrix with $N_{TX} \times N_{TX}$ dimension can be applied.
- OversamplingOption determined the oversampling ratio of the output signal. total six oversampling ratios (1x,2x,4x,8x,16x and 32x) are supported.
- Window is an enumerate parameter to turn on/off the window function. The window function will create small overlap between consecutive OFDM symbols to reduce the spectral sidelobes of the transmitted signal.
- IdleInterval specifies the idle interval time between two consecutive packets.
- ScrambleSeed specifies the initial state of the scrambler.
- ScrambleReinit is an enumerate parameter specifying whether the scrambler feedback register will be re-initialized on each packet or not.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.

WLAN_11n_Source_RF (WLAN 11n RF signal source)

Description 11n RF signal source
Library WLAN 11n, Source
Class TSDFWLAN_11n_Source_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	output resistance	DefaultROut	Ohm	real	(0, ∞)
FCarrier	carrier frequency	5000 MHz	Hz	real	(0, ∞)
Power	total output power of modulator	0.01	W	real	[0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO		enum	
AntGainImbalance	gain imbalance in dB, relative to average power (Power/NumTx)	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
IQGainImbalance	gain imbalance in dB, Q channel relative to I channel	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
PhaseImbalance	phase imbalance in degrees, Q channel relative to I channel	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)
I_OriginOffset	I amplitude origin offset in percent with repect to output rms voltage	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
Q_OriginOffset	Q amplitude origin offset in percent with repect to output rms voltage	0.0 0.0 0.0 0.0		real array	(-∞, ∞)
IQ_Rotation	IQ rotation, in degrees	0.0 0.0 0.0 0.0	deg	real array	(-∞, ∞)
OperatingMode	operating mode: MixedMode, GreenField	MixedMode		enum	
MCS	modulation Coding Scheme ([0,31])	0		int	[0, 31]
Bandwidth	band width: BW20MHz, BW40MHz	BW20MHz		enum	
HTLength	PSDU length in byte ([1, 2^16-1])	256		int	[1, 2^16-1]
Aggregation	Aggregate-MPDU in data portion of the packet: Otherwise, A-MPDU	A-MPDU		enum	
ShortGI	400ns guard interval in data symbols: NO, YES	NO		enum	
NumHTLTF	number of HT long training fields	1		int	[1, 4]
NumTx	number of transmit chains (antennas)	1		int	[1, 4]
SpatialMappingScheme	spatial mapping scheme: DirectMapping, SpatialExpansion, UserDefined	DirectMapping		enum	
SpatialMappingMatrix	User definned spatial mapping matrix	1		complex array	(-∞, ∞)
OversamplingOption	over sampling ratio: x1, x2, x4, x8, x16, x32	x1		enum	
Window	use time domain window or not: NO, YES	NO		enum	
TransitionTime	the transition time of window function	100 nsec	sec	real	(0, 800nsec]
IdleInterval	Idle Interval	100 nsec	sec	real	[0, 1000μsec]
ScrambleSeed	initial state of scrambler(should not be all 0)	1 1 1 1 1 1 1		int array	[0 1]
ScrambleReinit	reset initial state of the scrambler each burst (by ScrambleSeed) or not: NO, YES	YES		enum	
DataPattern	WLAN 11n 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	PN9		enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	PSDU	PSDU in bit	int
2	RF_Sig	802.11n RF signal	multiple timed
3	SigAftMatrix	signal after spatial mapping and before IFFT	multiple complex
4	Constellation	constellation after OFDM symbol mux and before spatial mapping	multiple complex
5	BitsChCoded	convolutional eccoded bit stream	multiple int

Notes/Equations

1. This toplevel subnetwork is used to generate WLAN 11n RF signal.
2. Each firing, a whole WLAN 11n packet RF signals are generated and output together with intermediate results. The data pattern model produce the original information bits first and then 11n baseband signals are generated. Finally the baseband signals are upconverted to the carrier frequency by the 11n RF modulator. The subnetworks schematic is shown in the following figure.
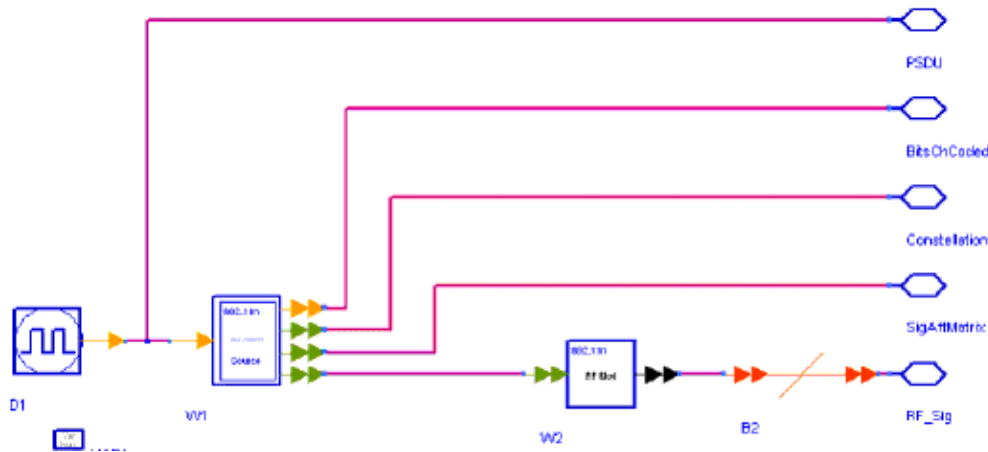
WLAN_11n_SourceRF Schematic
3. Parameter details:

- *RIn* is used to specify the input resistor.
- *FCarrier* is used to specify the carrier frequency. If the FCarrier is set to -1, the input signal characterization frequency will be used as carrier frequency.
- *Phase* is the reference phase array of each transmit channel in degree, which will result in constellation rotation.
- *MirrorSpectrum* can be used to mirror (invert the Q envelope) the spectrum of received signal from each antenna at the output of the modulator. Depending on the configuration of the mixers in the upconverter, which typically follows a modulator, the signal at the upconverter's input may need to be mirrored. If such a configuration is used, then this parameter should be set to YES.
- *AntGainImbalance* is gain imbalance array of the received signal from each antenna in dB.
- *IQGainImbalance* is the gain imbalance array of the received signal from each antenna in dB.Q channel relative to I channel.
- *PhaseImbalance* is the phase imbalance array of the received signal from each antenna in degree, Q channel relative to I channel.
- *OperatingMode* is an enumerate parameter specifying the transmitter operating

mode. If the transmitter is working on MixedMode, although the 11a device can't decode the HT data, it still can hear the 11a legacy preambles in the packet. If the transmitter is working on GreenFieldMode, only the 11n HT device can hear and decode the transmitted signal.

- *MCS* specifies the modulation and coding scheme.Currently MCS0 to MCS31 are supported.
- *Bandwidth* is an enumerate parameter specifying the signal bandwidth, both 20 MHz and 40 MHz bandwidth are support in this library.
- *HTLength* specifies the number of information bytes per packet, so the total information bits per packet is *HTLength* × 8.
- *ShortGI* is an enumerate parameter specifying the length of the guard interval. If *ShortGI* is Yes, then the guard interval will be 0.4 µsec; if it is No, the guard interval will be 0.8µsec
- *NumHTLTF* specifies the number of HT long training field. *NumHTLTF* must not be less than the N_{SS}. And if the N_{SS} is 3, *NumHTLTF* must be 4 References #1 below.
- *NumTx* specifies the number of transmit antennas. Based on References #1 below, the number of transmit antennas must not be less than N_{SS} and must be equal or larger than *NumHTLTF*.
- *SpatialMappingScheme* is an enumerate parameter specifying the scheme to map the spatial streams to the transmit chains. If *SpatialMappingScheme* is DirectMapping, the mapping matrix will be an identity matrix and the signal on each spatial streams will be mapped to corresponding transmit chain directly; if *SpatialsMappingScheme* is SpatialExpansion, the Walsh-Hadamard matrix or Fourier matrix will be used as the mapping matrix. or If *SpatialMappingScheme* is Userdefined, the mapping matrix will be determined by parameter *SpatialMappingMatrix* and any unitary matrix with N_{TX} × N_{TX} dimension can be applied.
- *OversamplingOption* determined the oversampling ratio of the output signal. Total six oversampling ratios (1x,2x,4x,8x,16x and 32x)are supported.
- *Window* is an enumerate parameter to turn on/off the window function. The window function will create small overlap between consecutive OFDM symbols to reduce the spectral sidelobes of the transmitted signal.
- *IdleInterval* specifies the idle interval time between two consecutive packets.
- *ScrambleSeed* specifies the initial state of the scrambler.
- *ScrambleReinit* is an enumerate parameter specifying whether the scrambler feedback register will be re-initialized on each packet or not.

References

1. EWC HT PHY Specification v1.13 November 5th, 2005.