Agilent EEsof EDA

Presentation on Simulation of WLAN Systems

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Simulation of WLAN System

- Motivation
- Basic System
- WLAN Design Library (DL) in ADS
- Simulation of WLAN System
- Test and Verification of WLAN Power Amplifier
- Conclusions

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Motivation

- 5-GHz WLAN systems based on IEEE 802.11a deliver higher data rates, better spectral efficiency, improved multipath performance, and less interference in low mobility wireless conditions.
- The demand for WLAN systems is rapidly growing. WLAN systems are being marketed all over the world.
- To design WLAN system with non-linear components under multipath channel environment, simulation tools must be used. ADS WLAN DL serves this purpose.
- ADS T&V templates using key measurements, such as EVM, CCDF, and ORFS are very useful to test and verify key components such as Power Amplifiers (PA).

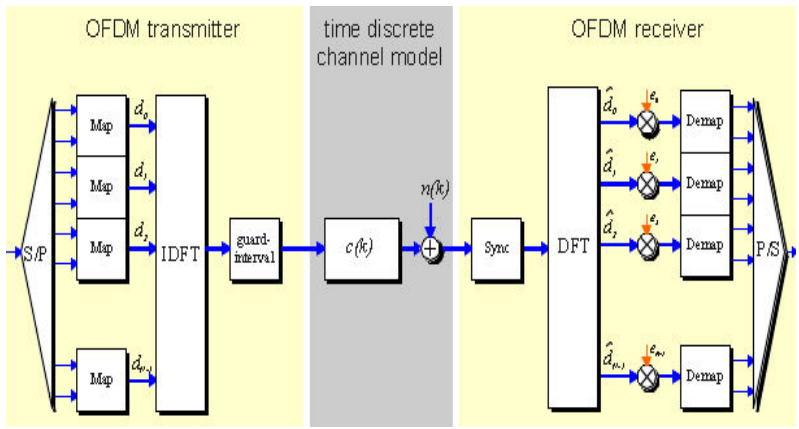
Basic System

- **OFDM Signal**
- **Burst Structure**
- **Synchronization**
- **Measurements**

For supporting 5-GHz WLAN systems with high-rate data transmission, multi-carrier modulation, orthogonal frequency division multiplex (OFDM) is proposed. The basic principle of OFDM is to split a high data rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. Because the symbol duration increases for the lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Intersymbol interference (ISI) is eliminated almost completely because the OFDM allows us to insert adequate guard interval between successive OFDM symbols.

In order to use OFDM for WLAN system, frequency synchronization and timing synchronization is very important. The proposed frequency synchronization is based on detecting and compensation of the carrier frequency offset between the transmitter and the receiver by using two preambles. Also, a channel estimation model is used to detect and remove the delay spread.

OFDM Transmission and Receiving



In the Figure, a simplified block diagram of OFDM transmitter and receiver is shown. The information data are serial-parallel converted then modulated by the allocated subcarrier using linear modulation such as BPSK, QPSK,16-QAM, and 64- QAM. The OFDM signal is generated as the IFFT of modulated subsymbols. To combat ISI adequate guard interval between successive OFDM symbols is inserted by using the 'guard Interval' block.

The time discrete channel model provides multipath channel environments as well as channel noise to simulate practical WLAN systems.

In the OFDM receiver block, the 'Sync' block is for timing, frequency synchronization as well as phase compensation. Through DFT and demodulation and parallel to serial conversion the information data will be detected.

WLAN Burst Structure

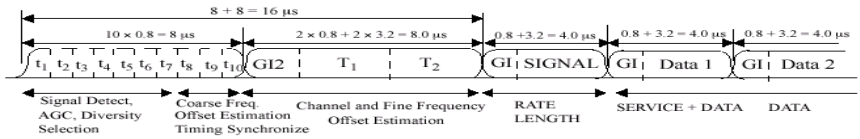


Table 79—Timing-related parameters

Parameter	Value
N_{SD}: Number of data subcarriers	48
N_{SP}: Number of pilot subcarriers	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)
T_{FFT}: IFFT/FFT period	3.2 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)
T_{SHORT}: Short training sequence duration	8 µs ($10 \times T_{FFT}/4$)
T_{LONG}: Long training sequence duration	8 µs ($T_{GI2} + 2 \times T_{FFT}$)

In the WLAN system, packetized burst signals are transmitted without scheduling. Therefore, synchronization must be established burst by burst. The proposed burst structure based on IEEE 802.11A is shown in Figure 2. The OFDM burst actually has four distinct regions shown in Figure 2. The first is the Short preamble (training sequence). This is followed by a Long preamble (training sequence) and finally by the Signal and Data symbols. Between each burst section, there are some guard intervals

Algorithms Applied in WLAN receiver

- **Symbol Synchronization**
- **Frequency Synchronization**
- **Channel Estimation and Delay Spread compensation**

For frequency synchronization, the first step is estimate the received burst symbol delay, then synchronize it.

To estimate frequency offset, two short preambles are used to compute the phase offset between transmitted signal and receiving signal based on the maximum likelihood algorithm.

After computing correlation between the 9th and 10th short preambles, the phase offset $\Delta\theta$ can be determined.

The frequency offset Δf can be found by using the following equation:

$\Delta f = \Delta\theta / 2pi\ T$

where T is duration of one short preamble (0.8 usec).

A channel estimation model is used to detect and remove the delay spread after FFT

WLAN Library in ADS
System Models

- **Channel coding**
  - **convolutional coder/decoder, Puncture coder/decoder, interleaver/deinterleaver, Scrambler.**
- **Modulation**
  - **BPSK, QPSK, 16-QAM, 64-QAM modulation/demodulation.**
- **Framing**
  - **Burst framing, OFDM symbol multiplex/demultiplex, Guard interval inserter.**
- **Receiver**
  - **Symbol synchronization, Frequency synchronization, Phase Estimate, Phase tracking, channel estimator, OFDM Equalizer.**

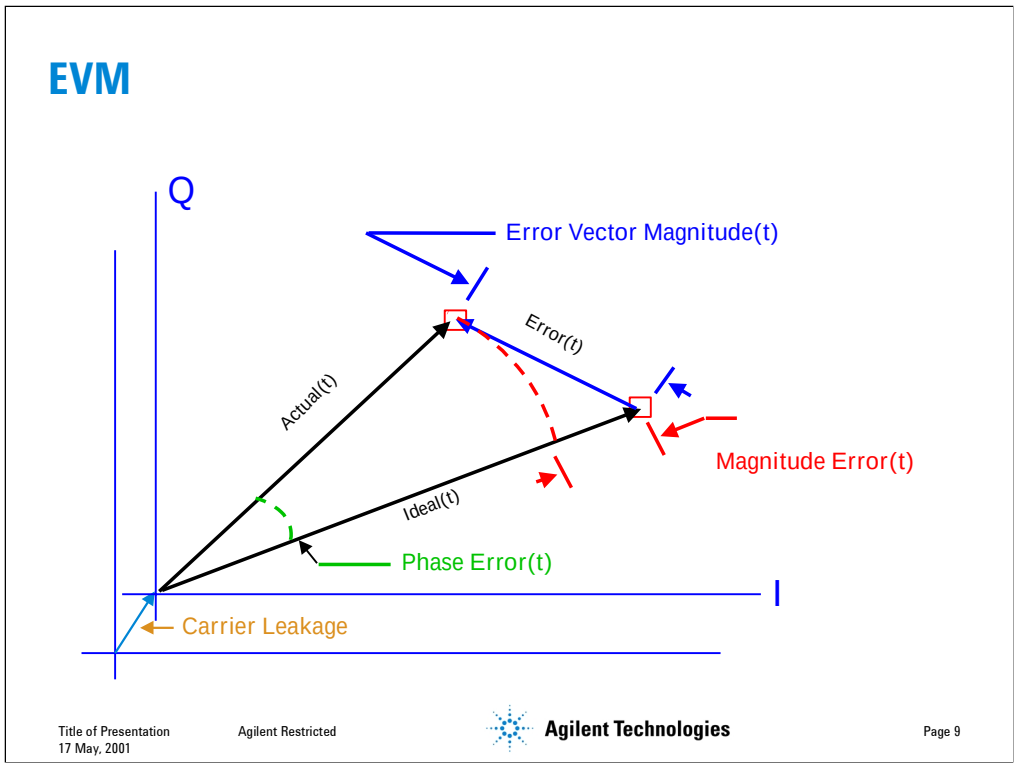
To simulate WLAN system the WLAN library provides simulation models for data and signal generation, channel coding, modulation, Burst framing, Receiving, as well as measurements.

Main functions of WLAN models can meet the system requirements by IEEE 802.11a standard.

The detailed information can be found in WLAN library manual.

WLAN DL in ADS
Measurements

- Error Vector Magnitude (EVM)
- Output RF Spectral With Mask (ORFS- Spectral Mask)
- Complementary Cumulative Distribution Function (CCDF)
- Power Vs Time

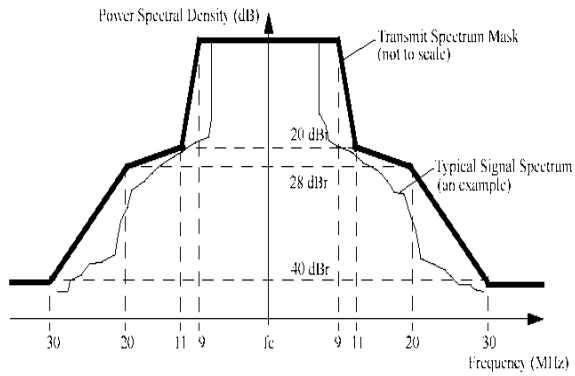


EVM represents the distance between the measured and expected carrier magnitude and phase at some point in time after it has been compensated in timing, amplitude, frequency, phase and DC offset.

For IEEE 802.11a, the error vector between the vector representing the transmitted signal and the vector representing the error-free modulated signal defines modulation accuracy. The magnitude of the error vector is called error vector magnitude (EVM).

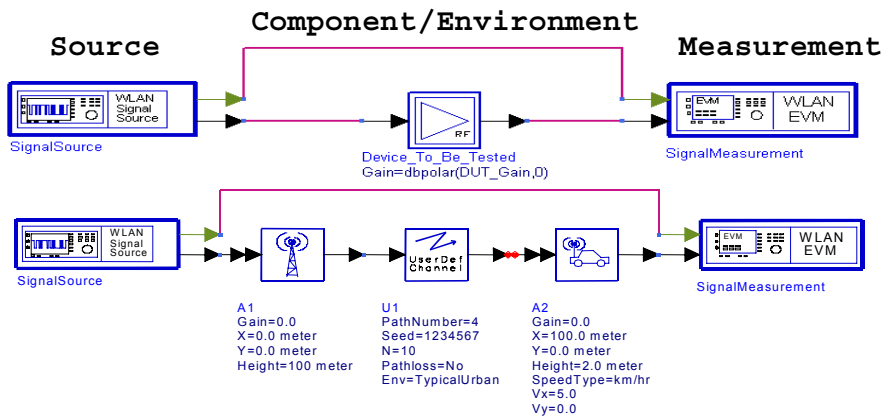
The purpose of this test is to verify that the RMS EVM measured on the specific part of the burst meets the conformance requirement. (does not exceed the conformance requirement.)

Spectral Mask



The output RF spectrum due to modulation is the relationship between the frequency offset from the carrier and the power measured in a specified bandwidth. The measurement provides information about distribution of the transmitter's channel spectral energy due to modulation.

Simulation of WLAN System Configuration



Hierarchical structures and simulation templates are used for easy usage.

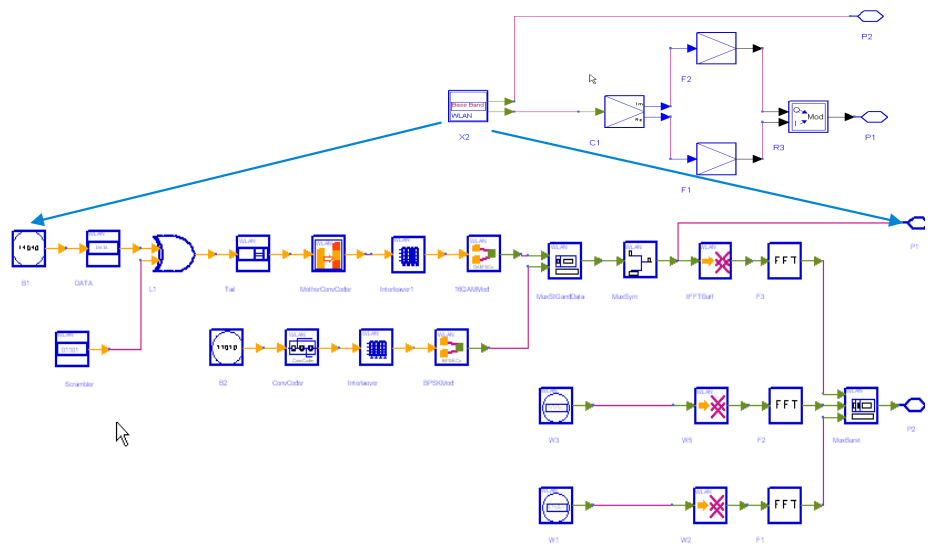
1. Test and verify the designed power amplifier (or other RF device) to see if this component can meet the WLAN standard.

2. Simulation of WLAN systems under multipath channel environments.

3. Combine 1 and 2.

Simulation of WLAN System: Source Configuration:

Source Example: A 36 Mbps Signal Source



For the hierarchical structured source, users can push into the block and see the lower level structure. The second level of the hierarchy includes a baseband source and a RF modulator. Push into the baseband source, the third level of the hierarchy is shown how to generate WLAN signals based on IEEE 802 11a standard.

Generating the short training sequence section of the preamble by using W1, W2 and F1 in the lowest branch.

Generating the long preamble sequence section of the preamble by using W3, W5 and F2 in the third branch.

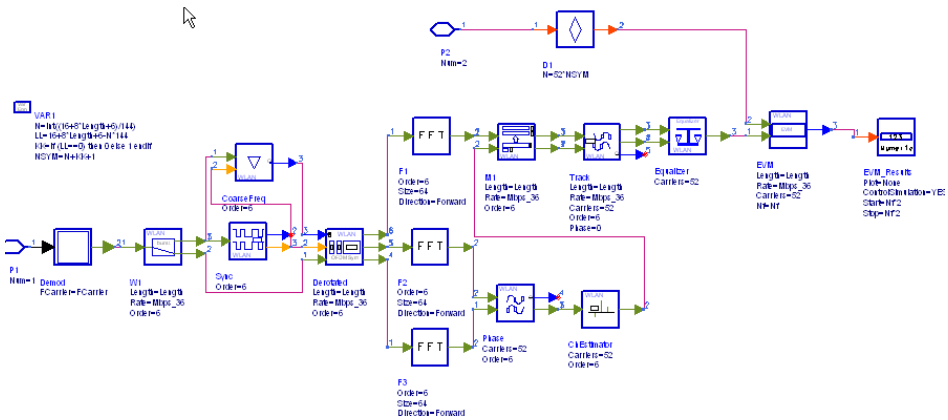
Generating the SIGNAL field bits, Coding, interleaving, modulating, multiplexing with Data section by using B2, ConvCoder, Interleaver, BSKmod in the lower branch.

Forming the Data, Scrambling, Convolutional coding, interleaving, 16 QAM modulation and multiplexing with signal section data by using B1, Data, Scrambler, L1, Tail, PuncCoder, Interleaver, 16 QAM, MuxSigandData in the upper branch.

Mapping the SIGNAL and Data into frequency domain, then transformation from frequency to time by using MuxSym and IFFTBuffer, F3 in the upper branch.

Forming the PPDU frame by multiplexing short preamble, long preamble, signal and Data to the OFDM burst by using MuxBurst model.

Simulation of WLAN System Measurement Configuration: EVM



To estimate the EVM the following steps are performed

Start of frame is detected by using W1 (WLAN_BurstSync)..

Using the short preambles to synchronize the in WLAN_BurstSync.

Frequency offsets are estimated by using the WLAN_FreqSync model.

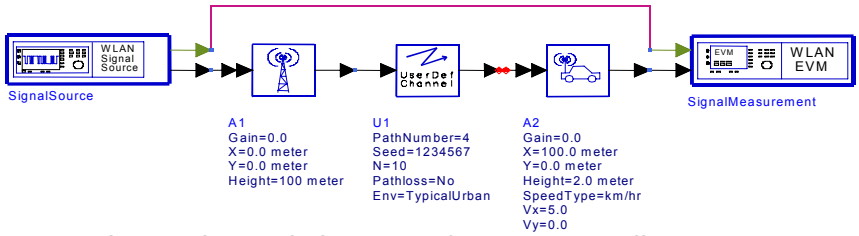
The packet is derotated according to estimated frequency offset by using the WLAN_DemuxBurst.

The complex channel response coefficients are estimated for each subcarrier by using the WLAN_PhaseEst and the WLAN_ChannelEst.

Each data OFDM symbol is transformed into subcarrier received values; the phase from the pilot subcarriers is estimated; subcarrier values are rotated according to the estimated phase; and, each subcarrier value is divided with a complex estimated channel response coefficient by using the WLAN_MuxDataChEst, WLAN_PhaseTrack and WLAN_Equalizer.

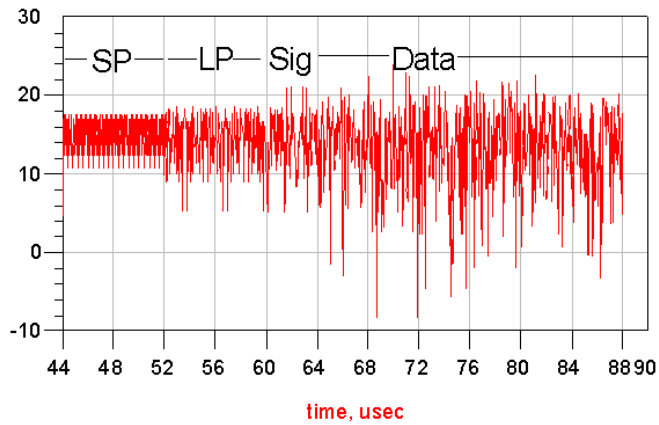
For each data-carrying subcarrier the closest constellation point is determined and the Euclidean distance from it is calculated. For the EVM, the RMS average of all errors in a packet is calculated.

Simulaton of WLAN System Under Multipath Channel



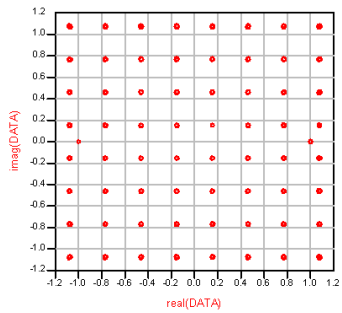
- **Source: 48 Mbps, 64 QAM Data, 50 KHz Frequency offset**
- **Antenna & Indoor Propagaton Model: Four Fading Paths, 0-5 Km/hr Vx considered**
- **Measurements**
  - **Waveform**
  - **IQ with & without frequency synchronization**
  - **EVM**

Basic Test: WLAN Waveform

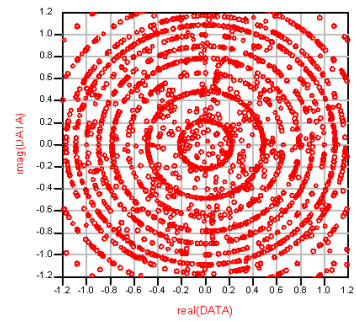


The system output waveforms can be captured from the simulation data shown in the slide. As can be seen, the 10 short preambles (SP) can be viewed during the first 8 us, then two long preambles can be found in the second 8 us. The WLAN SIGNAL (Sig) can be observed in the next 4 us. The rest of waveforms are the WLAN DATA (Data).

Basic Test: IQ Diagrams



System with Frequency Synchronization

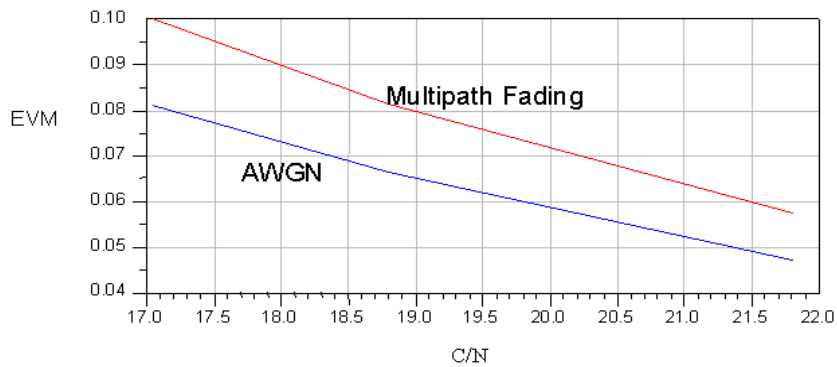


System without Frequency Synchronization

The simulation results for the system output IQ diagrams are shown in the slide. Figure a shows the IQ for system with frequency synchronization, and Figure b shows the IQ diagram for the system without frequency synchronization.

As can be shown from the two graphs the frequency synchronization model is very important for the WLAN system

EVM VS C/N for WLAN system under Multipath Channel

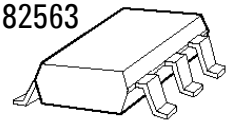


This slide shows the WLAN system EVM performance for an indoor environment. Four paths are considered based on IEEE 802.11a standard. Frequency offset of 50KHz is considered. To describe the practical environment, the slow speed of 5 km/hr for Vx is specified to include the Doppler frequency shift. To show the system performance, an EVM vs. C/N plot is provided with a reference curve of AWGN case.

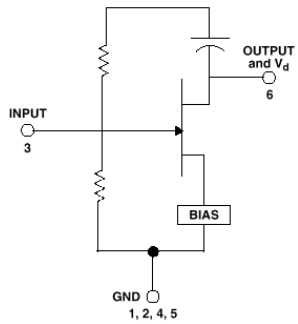
Test and Verification of WLAN Power Amplifier

- **Purpose: Test a Power Amplifier (PA) for WLAN terminals from Product list of Vendors.**
- **Candidate PA: MGA-82563 (0.1-6 GHz), low noise economic GaAs PA from Agilent.**
- **Test and Verify to see if the candidate can meet the requirement by the standard**

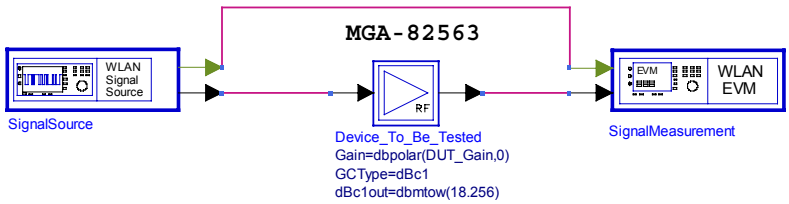
MGA-82563



Simplified Schematic

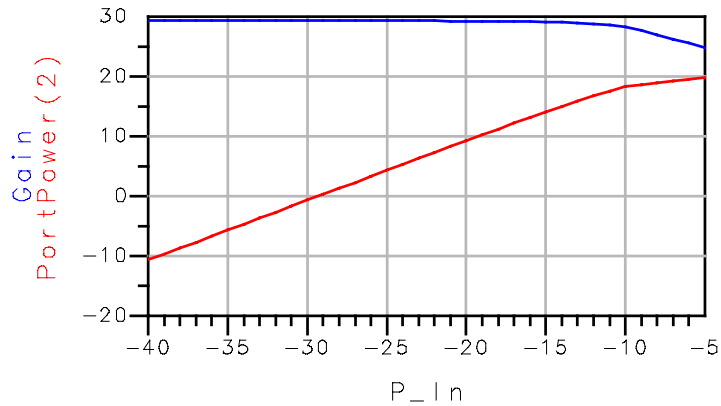


Test and Verification of WLAN Power Amplifier



- **Purpose: T&V of a candidate WLAN Amplifier, Agilent's MGA-82563**
- **Simulation configuration**
  - **Signal Source: 36 Mbps 16-QAM Data, 50 kHz frequency offset**
  - **Tested PA: Agilent's MGA-82563**
  - **Measurements: ORFS with Mask, EVM, CCDF**

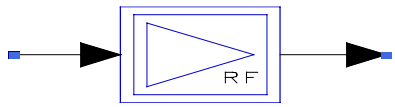
MGA-82563 Output Power / Gain Vs Input Power



This slide shows the MGA-82563 output power performance expressed by the red curve, Output power Vs Input power. The PA Gain performance also is shown.

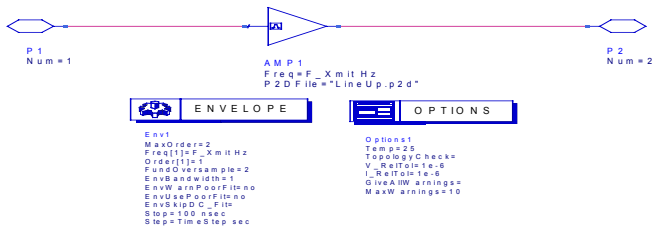
Modeling MGA-82563 for WLAN Simulation

- **As a System Behavior Model**



Device_To_Be_Tested
Gain=dbpolar(DUT_Gain,0)
GCType=dBc1
dBc1out=dbmtow(18.256)

- **As a circuit Model**



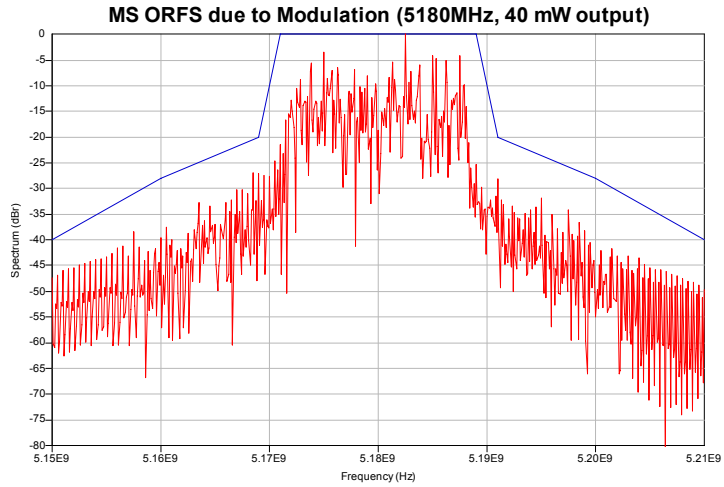
There are two approaches for modeling MGA-82563 to test and verify the performance.

1. Model it as a system model in hptolemy. A RF_Gain component is used.

2. Model it as a circuit in envelope test bench, then using co-simulation to find out the performance.

MS ORFS Due to Modulation (5180 MHz, 40mW)

T&V Result: Passed



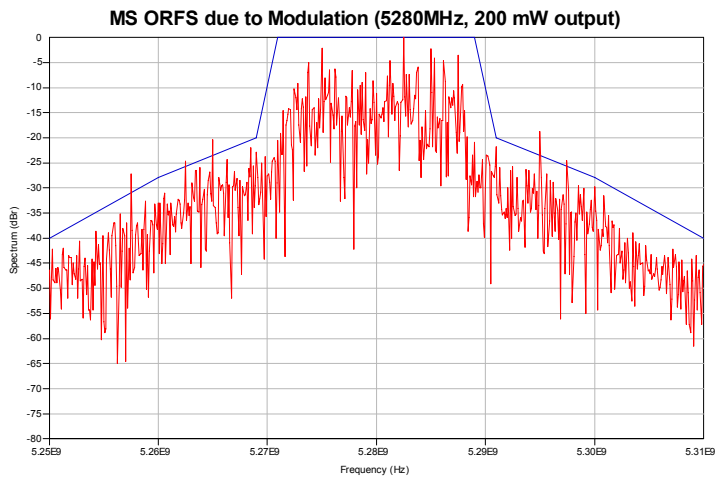
The output RF spectrum due to modulation is the relationship between the frequency offset from the carrier and the power, measured in a specified bandwidth and time, produced by the mobile station due to the effects of modulation. The measurement provides information about distribution of the transmitter's channel spectral energy due to modulation.

In the ORFS test, channel 36 corresponding to a channel center frequency 5180 MHz is used.

This test is shows that the RF spectrum (red line) does not exceed the Mask (blue line), indicating a successful test result.

MS ORFS Due to Modulation (5280 MHz, 200mW)

T&V Result: Marginal

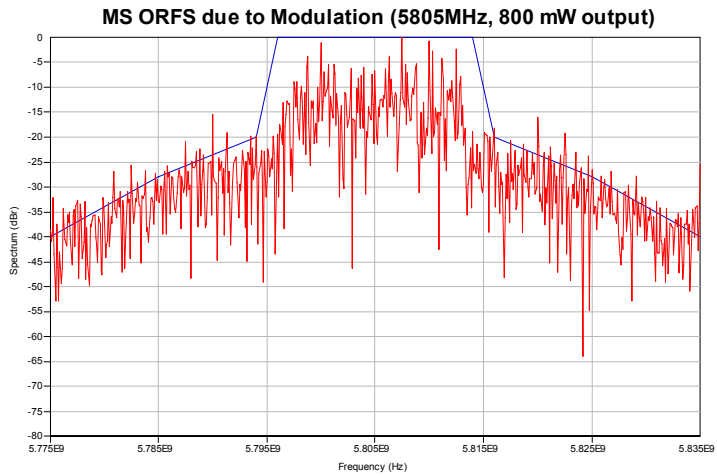


In this case the configuration for channel 56 corresponds to a channel center frequency of 5280 MHz.

Test results are marginal because a few spectrum lines (red lines) exceed the Mask (blue line).

MS ORFS Due to Modulation (5805 MHz, 800mW)

T&V Result: Failed



In this test, the configuration for channel 161 corresponds to a channel center frequency of 5805 MHz.

The test failed because the RF spectrum (red line) exceeds the Mask (blue line).

EVM Test results for MGA-82563

WLAN Error Vector Magnitude (EVM)

WLAN Specification: IEEE Std 802.11a-1999

	Channel Number 36	Channel Number 56	Channel Number 161
Carrier Offset is zero EVM (%)	7.492	28.253	56.448
Carrier Offset is 50KHz EVM (%)	7.492	28.253	56.448
Carrier Offset is 100KHz EVM (%)	7.492	28.253	56.448
	Passed	Failed	Failed

Specification requirements (under normal conditions)

The RMS EVM shall not exceed 11.2%.

Test Results

The EVM is very important for measuring the modulation accuracy.

The 802.11a standard lists rates of 6,12 and 24 Mbit/sec as mandatory. In a production environment, it should be necessary to measure the EVM only at the highest rate supported. This would be 15.8% for all modems. 54Mbit/sec modems will need to achieve 5.6% EVM. 36Mbit/sec modems will need to achieve 11.2% EVM. Outside of slightly different power statistics, there are very few error inducing mechanisms that would cause a transmitter to have a significantly different measured EVM for each rate (given the normalized constellations).

In this example, the EVM template shown in page 19 is used. EVM test results are listed in this slide. The EVM values are compared to the required EVM by the IEEE 802.11a standard automatically and the most important final result is shown. The EVM values are bounded by the 11.2% which is the requirement by IEEE 802.11A for Channel 36 with a center frequency 5180 MHz, which means the EVM results are satisfactory.

However, for channel 56 and 161, the EVM values exceed the requirements, which means they fail the test.

Agilent WSD will release new PA for WLAN system to cover channel 56 and 161.

Conclusions

- 5-GHz WLAN is one of the fastest growing systems for low mobility wireless standard.
- OFDM is the standard modulation for 5 GHz WLAN systems. Symbol and Frequency synchronization are very important for OFDM.
- The ADS WLAN DL provides simulation capabilities for WLAN system, and gives some key measurements such as EVM, CCDF, ORFS to test and verify designed components.
- ADS WLAN DL was used for test and verification of a WLAN PA to see if the PA can meet the IEEE802.11a spec. The tested PA was MGA-82563 from Agilent.

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Revised: March 27, 2008

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Printed in USA, May 17, 2001
5989-9002EN

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