Testing New-generation Wireless LAN

Application Note

Introduction

The first popular standards for wireless LAN (IEEE 802.11a and b) were designed primarily to serve the needs of a laptop PC in the home and office, and later to allow connectivity "on the road" in airports, hotels, Internet cafes, and shopping malls. Their main function was to provide a link to a wired broadband connection for Web browsing and email. Since the speed of the broadband connection was the limiting factor, a relatively low-speed wireless connection was sufficient – 802.11a provided up to 54 Mb/s at 5 GHz, and 802.11b up to 11 Mb/s at 2.4 GHz, both in unlicensed spectrum bands. To minimize interference from other equipment, both used forms of spread-spectrum transmission and were heavily encoded. A later revision of the standard, 802.11g in 2003, consolidated use in the 2.4 GHz band but maintained the maximum data rate at 54 Mb/s. However, by the same time, new usage models with the need for higher throughput had been recognized: data sharing amongst connected devices in the home or small office and wireless printing as examples. A study project was set up which produced 802.11n in 2009. As well as improving the maximum single-channel data rate to over 100 Mb/s, this new standard introduced MIMO (multiple input, multiple output) sometimes referred to as spatial streaming, where up to 4 separate physical transmit and receive antennas carry independent data that is aggregated in the modulation/demodulation process.

Today, there are further usage models, summarized in Table 1, that require even higher data throughput to support today's "unwired office".

Table 1. New WLAN usage models.

Category	Usage Model
Wireless Display	• Desktop storage and display • Projection to TV or projector in conference room or auditorium • In-room gaming • Streaming from camcorder to display • Professional HDTV outside broadcast pickup
Distribution of HDTV	• Video streaming around the home • Intra-large-vehicle applications (e.g. airplane, ferry) • Wireless networking for office • Remote medical assistance
Rapid upload/download	• Rapid file transfer / sync • Picture-by-picture viewing • Airplane docking (manifests, fuel, catering, . .) • Downloading movie content to mobile device • Police surveillance data transfer
Backhaul	• Multi-media mesh backhaul • Point-to-point backhaul
Outdoor campus / auditorium	• Video demo /tele-presence in auditorium • Public safety mesh (incident presence)
Manufacturing floor	• Automation

To cater for these, two new IEEE project groups aimed at providing "Very High Throughput" (VHT) have been set up. Working Group TGac aims to specify 802.11ac as an extension of 802.11n, providing a minimum of 500 Mb/s single link and 1 Gb/s overall throughput, running in the 5 GHz band. Working Group TGad in partnership with the Wireless Gigabit Alliance (WiGig) have jointly proposed 802.11ad, providing up to 7 Gbs throughput using approximately 2 GHz of spectrum at 60 GHz over a short range. (60 GHz transmission suffers from large attenuation through physical barriers.) Bearing in mind the number of existing devices, backward compatibility with existing standards using the same frequency range is a "must". The goal is for all the 802.11 series of standards to be backward compatible, and for 802.11ac and ad to be compatible at the Medium Access Control (MAC) or Data Link layer, and differ only in physical layer characteristics (see Figure 1). Devices could then have three radios: 2.4 GHz for general use which may suffer from interference, 5 GHz for more robust and higher speed applications, and 60 GHz for ultra-high-speed within a room – and support session switching amongst them. Both new standards are currently in draft form. 802.11ad is scheduled to be finalized by the end of 2012, while 802.11ac is scheduled to be finalized by the end of 2013. However, devices complying with draft versions of the standards may appear before this.

Because of the differences in physical layer attributes of the two Very High Throughput standards at 5 and 60 GHz, for the remainder of this application note, we will focus on 802.11ac.

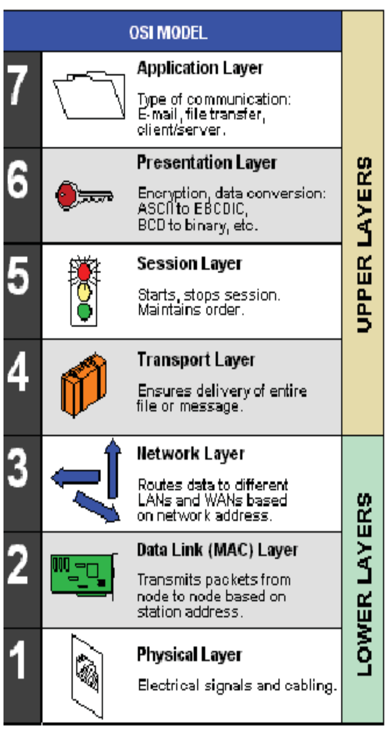


Figure 1. OSI 7-layer model.

Technical Differences From 802.11n

The 802.11ac physical layer is an extension of the existing 802.11n standard, and as already discussed, maintains backward compatibility with it. The following discussion highlights the changes. Table 2 shows the physical layer features of 802.11n, and Table 3 shows how this is extended for 802.11ac. The theoretical maximum data rate for 802.11n is 600 Mb/s using 40 MHz bandwidth with 4 spatial streams, though most consumer devices are limited to 2 streams. The theoretical 802.11ac maximum data rate is 6.93 Gb/s, using 160 MHz bandwidth, 8 spatial streams, MCS9 with 256QAM modulation, and short guard interval. A more practical maximum data rate for consumer devices might be 1.56 Gb/s which would require an 80 MHz channel with 4 spatial streams, MCS9, and normal guard interval.

Table 2. IEEE 802.11n key specifications

Feature	Mandatory	Optional
Transmission method	OFDM	
Channel bandwidth	20 MHz	40 MHz
FFT size	64	128
Data subcarriers/ pilots	52/4	108/6
Subcarrier spacing	312.5 kHz	
OFDM symbol duration	4 µs (800 ns guard interval)	3.6 µs with short guard interval
Modulation types	BPSK, QPSK, 16QAM, 64QAM	
Forward error correction	Binary convolutional coding (BCC)	Low density parity check (LDPC)
Coding rates	1/2, 2/3, 3/4, 5/6	
MCS supported	0 to 7, 0 to 15 for access points	8 to 76, 16 to 76 for access points
Spatial streams and MIMO	1, 2 for access points direct mapping	3 or 4 streams Tx beamforming, STBC
Operating mode/ PPDU format	Legacy/non-HT (802.11a/b/g) Mixed/HT-mixed (802.11a/b/g/n)	Greenfield/HT-Greenfield (802.11n only)

Table 3. IEEE 802.11ac key specifications

Feature	Mandatory	Optional
Channel bandwidth	20 MHz, **40 MHz, 80 MHz**	**160 MHz, 80+80 MHz**
FFT size	64, **128, 256**	**512**
Data subcarriers/ pilots	52/4, **108/6, 234/8**	**468/16**
Modulation types	BPSK, QPSK, 16QAM, 64QAM	**256QAM**
MCS supported	**0 to 7**	**8 and 9**
Spatial streams and MIMO	**1**	**2 to 8** Tx beamforming, STBC BPSK, QPSK, 16QAM, 64QAM **Multi-user MIMO (MU-MIMO)**
Operating mode/ PPDU format	**Very high throughput/VHT**	

Technical Differences From 802.11n

The new wider mandatory channel bandwidths are shown in Figure 2 for the U.S. region, along with possible placements of the non-contiguous 80+80 MHz channels specified in the standard. Note that due to the need to avoid operation in channels that may interfere with weather radars, in certain locations there may only be one available 160 MHz channel. While 160 MHz and 80+80 MHz modes are both included as optional features in the 802.11ac standard, it is likely that first devices will have a maximum of 80 MHz bandwidth, and no more than the maximum 4 spatial streams specified in 802.11n.

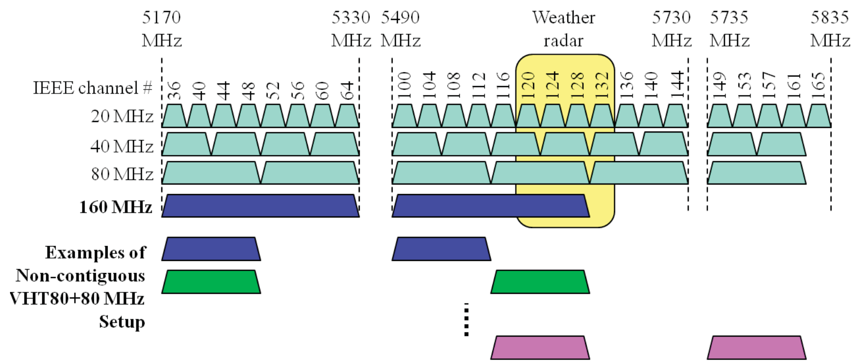


Figure 2. IEEE 802.11ac frequency allocation for the US region.

For 20 and 40 MHz channels, the number of subcarriers and pilots and their positions are the same as in 802.11n. New values are defined in 802.11ac for 80 MHz channels, and a 160 or 80+80 MHz channel is defined in the same way as two 80 MHz channels.

Within the frame structure, the preamble and training fields make it possible for the receiver to auto-detect the physical layer standard being used. 802.11n and 802.11ac preamble frames are shown in Figure 3. The first 4 fields in both preambles are intended to be received by non-HT and non-VHT stations for backwards compatibility. The initial Legacy Short and Long Training Fields (L-STF and L-LTF) and signal field (L-SIG) are similar to the same fields in 802.11a/b/g, while the difference in the 4th field (symbols 6 and 7) identifies the frame as either 802.11n or 802.11ac.

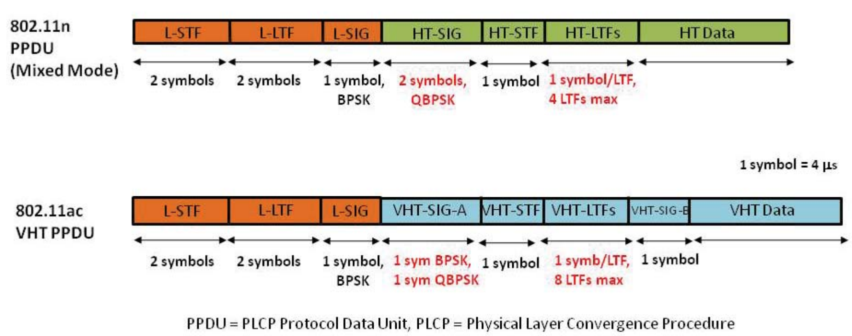


Figure 3. Comparison of 802.11n and 802.11ac frame formats.

Technical Differences From 802.11n

Examining the VHT preamble in more detail, for channels wider than 20 MHz, the legacy fields are duplicated over each 20 MHz sub-band with appropriate phase rotation. Subcarriers are rotated by 90 or 180 degrees in certain sub-bands in order to reduce the peak-to-average power ratio (PAPR). To signal VHT transmission and enable auto-detection, the first symbol of the VHT-SIG-A is BPSK, while the second symbol is BPSK with 90 degrees rotation (QBPSK). This differs from the HT-SIG for 802.11n where both symbols use QBPSK modulation. The VHT-SIG-A field contains the information required to interpret VHT packets – bandwidth, number of streams, guard interval, coding, MCS and beamforming.

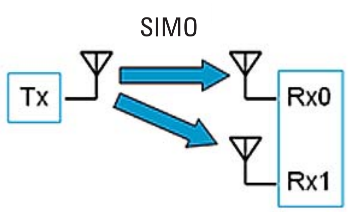
The remaining fields in the preamble are intended only for VHT devices. The VHT-STF is used to improve automatic gain control estimation in Multiple Input Multiple Output (MIMO) transmission. Next there are the long training sequences that provide a means for the receiver to estimate the MIMO channel between the transmit and receive antennas. There may be 1, 2, 4, 6 or 8 VHT-LTFs depending on the total number of space-time streams. The mapping matrix for 1, 2 or 4 VHT-LTFs is the same as in 802.11n, with new ones added for 6 or 8 VHT-LTFs. VHT-SIG-B field describes the length of the data and the modulation and coding scheme (MCS) for single or multi-user modes.

MIMO Re-visited

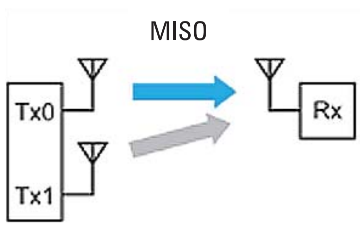
In the legacy WLAN standards, there was only one stream of data between the access point and a device. MIMO transmission was first introduced in 802.11n, and included new requirements where the access point and device communicate using two or more completely separate transmit/receive chains and take advantage of cross-coupling between them. The primary goal was to increase the data rate that a single user could expect from their wireless connection.

In the specifications, the terms “input” and “output” refer to the medium between the transmitters and receivers, including the RF components of both – known as the “channel”. Thus an access point with two transmitters provides two inputs to the channel – the “MI” part, and a device with two receive chains takes two outputs from the channel – the “MO” part. This is true only if the data transmitted and received is independent, and is not just a copy of the same data, as explained below and shown in Figure 4.

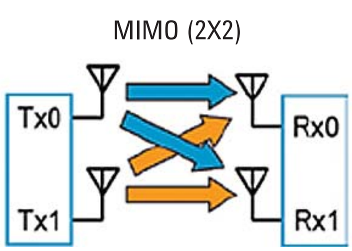
Single Input Single Output (SISO) is the standard transmission mode in most systems, and the objective of any more complex system is capacity or data rate gain measured with respect to SISO.



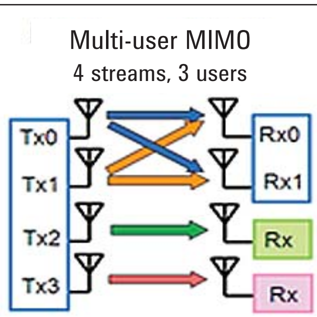
Single Input Multiple Output or Receive Diversity – a single transmitter, and therefore a single data stream, feeds two receiver chains. Aids received data integrity, especially where signal to noise ratio is poor. There is no gain in data capacity except any benefit that comes from better error ratio and consequent reduced retransmission.



Multiple Input Single Output is a transmit diversity technique. Space Time Block Coding, where the transmitters send the same data but at different times, may be used to improve signal robustness.



True Multiple Input Multiple Output, shown here with two transmitters and two receivers with independent data content, is also known as spatial multiplexing. Each receiver sees the output of the channel, which is a combination of the outputs from the transmitters. Using channel estimation techniques, the receivers use matrix mathematics to separate the two data streams and demodulate the data. In ideal conditions, with maximum de-correlation between the streams, data capacity is doubled, though there is a premium to be paid in a better signal to noise ratio requirement than for SISO.



Typical 802.11n consumer devices support up to two spatial streams rather than the maximum four specified in the standard. 802.11ac extends this to a maximum of eight streams, with likely first implementations supporting up to four. New in 802.11ac is the concept of multi-user MIMO (MU-MIMO). As opposed to “normal” (i.e. single-user) MIMO, which improves data throughput to an individual device, MU-MIMO is designed to re-use resources to improve network efficiency, though the data rate to any individual device is unchanged. MU-MIMO in 802.11ac allows transmission to up to 4 users simultaneously, with up to 4 streams per user, with a maximum of 8 streams combined, in each timeslot.

Figure 4. Transmission modes

Test Requirements

The high volumes for WLAN devices call for strict attention to manufacturing costs, and the use of innovative design techniques to maximize repeatability and minimize cost of test. This leads to the need for exhaustive testing during the design and pre-production stages of development.

The 802.11ac standard includes the transmitter and receiver tests shown in Table 4. These are similar to the tests for 802.11n, with some new definitions and specification limits added to cover the new features in 802.11ac. Since the specifications are still in draft form, the actual specifications will not be quoted here. Instead, download the latest version of the 802.11ac specification from www.ieee802.org, and see section 22.3.19 for transmitter specifications and section 22.3.20 for receiver specifications. In addition to these tests, designs will need to pass conformance tests and additional functional tests to verify performance and prove interoperability.

Table 4. Transmitter and Receiver Tests.

Transmitter Tests	Receiver Tests
Transmit spectrum mask	Minimum input level sensitivity
Spectral Flatness	Adjacent channel rejection
Transmit center frequency tolerance	Non-adjacent channel rejection
Packet alignment	Receiver maximum input level
Symbol clock frequency tolerance	Clear channel assessment (CCA) sensitivity
Modulation accuracy • Transmit center frequency leakage • Transmitter constellation error (EVM)	

Design and Test Challenges

Some of the new features in the 802.11ac standard result in new challenges in design and test. One of these is the use of 256QAM modulation, which requires better error vector magnitude (EVM) or constellation error in the transmitter and receiver. EVM problems may be caused by imperfections in the IQ modulator, phase noise or error in the LO, or amplifier nonlinearity. Vector signal analysis is a valuable tool for measuring and identifying causes of poor EVM, and Agilent's 89600 VSA software provides detailed analysis of 802.11ac signals, with support for all bandwidths and modulation types and up to 4x4 MIMO.

Improving amplifier linearity is another challenge, and digital pre-distortion (DPD) is one technique to address this. Agilent's SystemVue design automation software provides an application that simplifies and automates digital predistortion design for power amplifiers. The SystemVue W1716 DPD Builder software generates a stimulus waveform which is downloaded to an RF signal generator and applied to the power amplifier. The system captures the amplifier's response using a signal analyzer and compares the result with the desired signal to create the predistortion matrix. The pre-distorted signal is then sent to the power amplifier and the response checked. An example setup is shown in Figure 5. Figure 6 shows an example of DPD using an 80 MHz 802.11ac signal. The original stimulus signal is shown in green, while the blue trace shows the output of the power amplifier without DPD and the red trace shows the results with DPD.

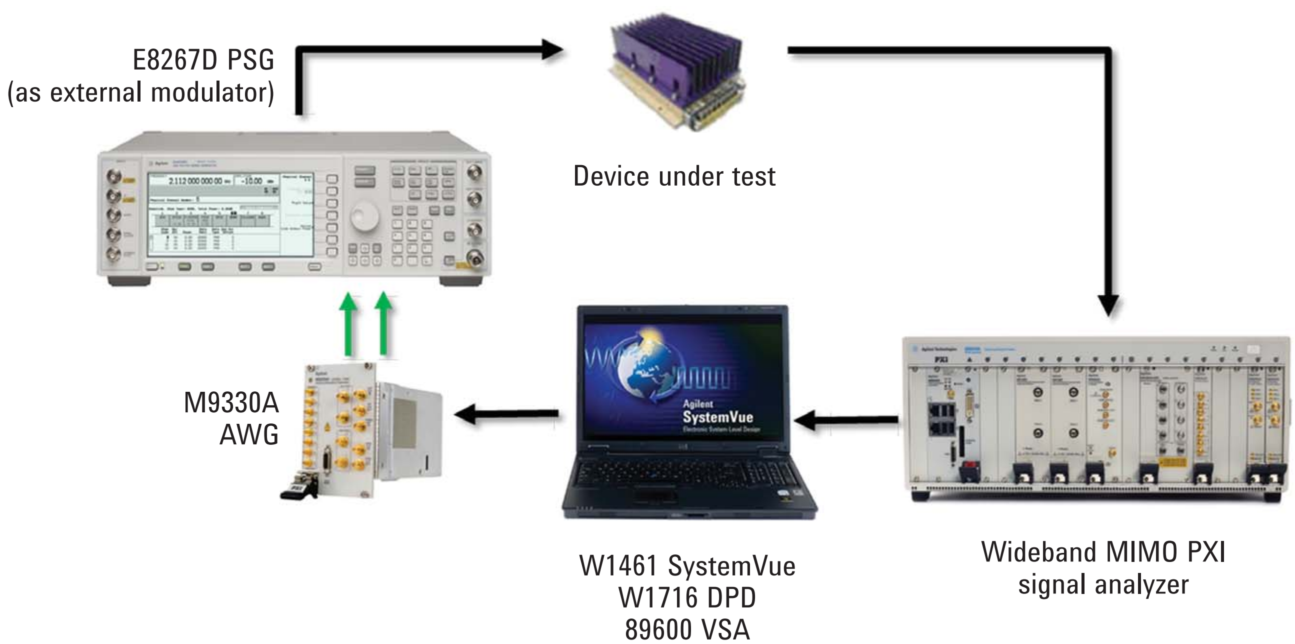


Figure 5. Digital predistortion builder setup.

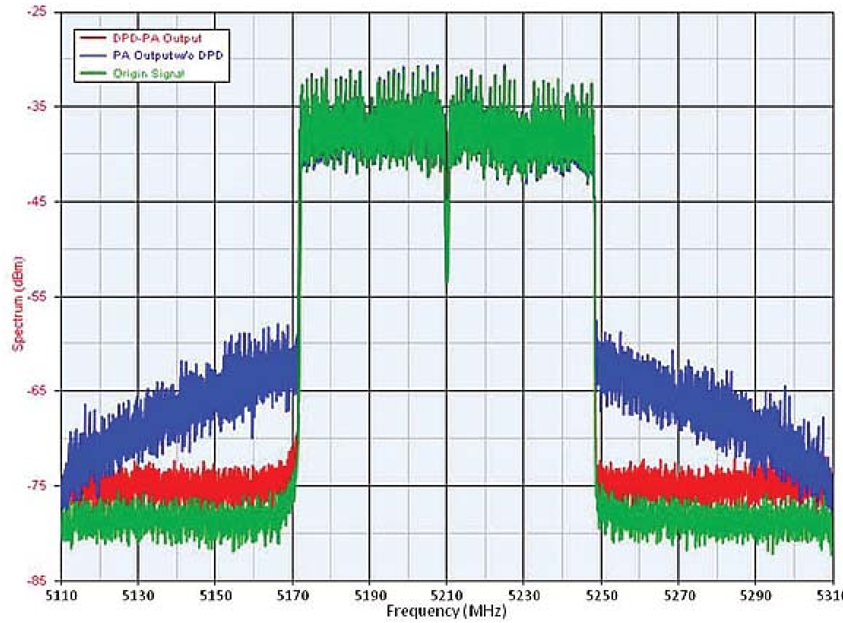


Figure 6. Digital predistortion example

Amongst the more complex challenges for design and development is the generation and analysis of the wider bandwidth signals for 802.11ac. 80 and 160 MHz capabilities are needed to test components, transmitters, and receivers.

For generating 80 MHz signals, many RF signal generators do not have a high enough sampling rate to support the typical minimum 2x oversampling ratio, which can result in images in the signal due to aliasing. However, with proper filtering and oversampling of the waveform file, it is possible to generate 80 MHz signals with good spectral characteristics and EVM using an Agilent N5172B EXG, N5182A MXG or E4438C ESG vector signal generator. The EXG or MXG is recommended due to its wider modulation bandwidth, which provides better EVM performance compared to the ESG.

The N5182B MXG signal generator provides 160 MHz bandwidth RF signals with excellent EVM performance. Another solution is to use a wideband arbitrary waveform generator (AWG) such as the Agilent 81180A, M8190A, or M9330A to create the analog I/Q signals, and these can be applied to the external I/Q inputs in a vector signal generator such as the MXG, ESG, or E8267D PSG for upconversion to RF frequencies. It is also possible to create a 160 MHz signal by using 80+80 MHz mode to create the two 80 MHz segments in separate MXG or ESG signal generators and then combining the RF signals.

802.11ac waveforms can be created using the SystemVue W1917 WLAN Library, which as of release 2011.10, provides a working baseband reference design for both transmit and receive signal processing paths. An open EDA implementation allows more intimate access and control of the inside of the block diagram for baseband developers. It also allows ideal or precisely-impaired signals of all bandwidths and modulation types to be downloaded to arbitrary waveform generators and signal generators, for RF verification. For dedicated, standalone waveform generation, N7617B Signal Studio for WLAN provides fully-coded waveform files with up to 160 MHz bandwidth for use with the EXG, MXG, ESG, and PSG signal generators, as well as the N5106A PXB baseband generator and channel emulator. Signal Studio also supports 80+80 MHz mode using two EXGs, MXGs, or ESGs.

Design and Test Challenges

For signal analysis, signals up to 160 MHz bandwidth can be analyzed using the 89600 VSA software in combination with the N9030A PXA Signal Analyzer, multiple M9392A PXI Microwave VSAs, Wideband MIMO PXI Vector Signal Analyzers, or Infiniium or Infiniivision oscilloscopes. The M9392A can analyze up to 250 MHz bandwidth signals, while the Wideband MIMO PXI Vector Signal Analzyers cover up to 800 MHz bandwidth and the oscilloscopes can support bandwidths beyond 1 GHz. These wider bandwidth instruments can be used in digital predistortion applications, which typically require measurement of signals that are 3 to 5 times the bandwidth of the signal being linearized.

Verifying MIMO design is another difficult challenge. MIMO functionality is a function of the device’s design, so it will not change from one device to another. Manufacturing test will thus be limited to the individual receiver chains. Proving the design, however, is absolutely necessary. Multi-channel signal generation and analysis can be used to provide insight into the performance of MIMO devices and assist in troubleshooting and design verification.

For testing receivers, MIMO signals can be created with both the SystemVue WLAN library and Signal Studio. Multiple EXG, MXG or ESG signal generators can be synchronized to simulate the output of a MIMO transmitter. The effects of the fading channel can also be included in the waveform files to provide simulation of the signals at the receive antennas. For MIMO transmitter test, the 89600 VSA software can be used with an Infiniium or Infiniivision oscilloscope or a Wideband MIMO PXI Vector Signal Analyzer to provide analysis of up to 4 channels, including EVM and IQ measurements for all channels as well as cross-channel metrics such as the frequency response of each channel and the channel matrix. Two M9392A PXI Microwave VSAs can be configured for independently tuned, 2-channel measurements up to 250 MHz analysis bandwidth.

Figure 7 shows an example of a two-channel 802.11ac measurement made with the VSA software and a DSO91304A Infiniium oscilloscope. The MIMO signals were created with Signal Studio and generated from two MXG signal generators. The displays show the constellation for both streams, as well as the EVM and IQ errors (lower middle window) and frequency response (lower right window) for both channels.

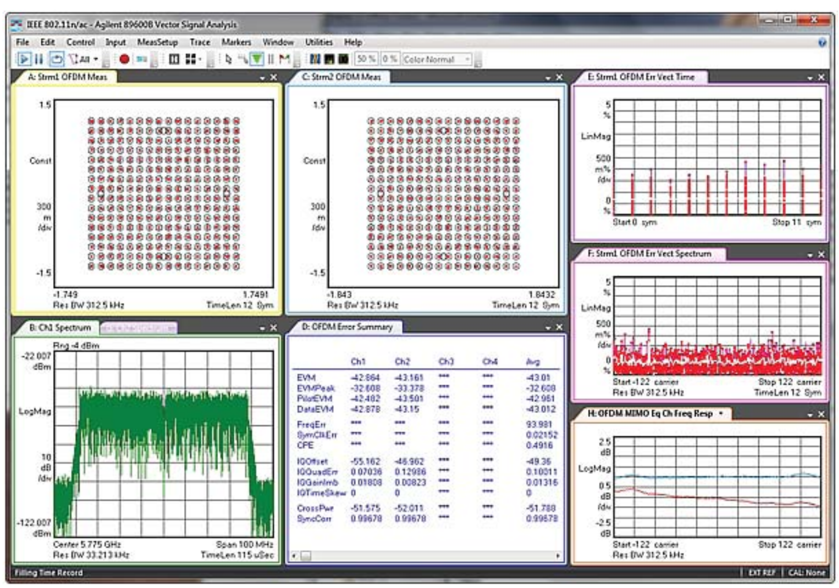


Figure 7. Measurement of a two-channel MIMO signal

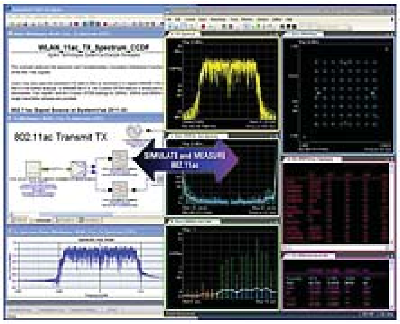
Conclusion

The continuing need for more speed and bandwidth of wireless LAN connections, and the increasing complexity of the standards to support it, bring major challenges for the test and measurement community. Comprehensive design and test capability is critical to the successful implementation of mass-market VHT WLAN products. System simulation tools and the generation and analysis of the wider 80 and 160 MHz bandwidth signals and 256QAM modulation for 802.11ac are key to testing components, transmitters and receivers. Close attention to design for manufacturing will help minimize cost of test and ensure that access points and clients meet consumers' price and performance expectations.

Agilent provides a broad portfolio of design and test solutions to give greater insight into device performance and provide greater confidence in your designs. Additional product information is available at www.agilent.com/find/802.11ac.

Design and Test Products

System simulation and verification software



SystemVue W1917 WLAN Baseband Verification Library and W1716EP DPD Builder

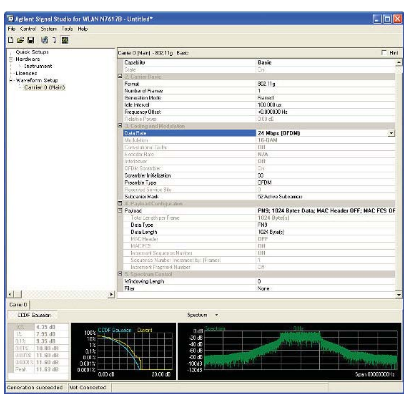
W1917 2011.03 release includes an uncoded 802.11ac transmit reference design, for signal generation. The 2011.10 release adds signal coding and a receiver reference design. Able to co-simulate in software with 89600 VSA for system designer, generate I/Q files for other applications, such as DPD, or download waveforms directly to instruments.

See DPD Technical Overview 5990-8883EN for details of W1716 Digital Predistortion Builder supported hardware and required options.

Supported features in the W1917 2011.10 release:

- Wider channel bandwidths (20, 40, 80, 160, and 80+80 MHz support for 11ac source)
- Aggregate MPDU (A-MPDU)
- All modulation types (BPSK, QPSK, 16QAM, 64QAM and 256QAM)
- SU-MIMO (Single-User MIMO) and MU-MIMO (Multi-User MIMO) up to 8 spatia streams
- BCC (Binary convolutional coder) and LDPC (low density parity check coder) channe coding
- Different spatial mapping schemes: Direct Mapping, Spatial Expansion and User Defined
- Provide EVM measurements compatible with Agilent VSA 89600 software v14.0
- Receiver baseband algorithm (synchronization, channel estimation and phase tracking, soft demapper and decoders)
- Provide WLAN TGac channel model (Version: March 2011)
- Supported instruments:
  - Arbitrary waveform generators: N8241A, M9330A, 81180, M8190A
  - Signal generators: ESG, MXG, PSG
  - Signal analysis receivers: any instruments supported by 89600 VSA

Signal generation



N7617B Signal Studio for WLAN 802.11a/b/g/n/ac

Signal Studio offers a basic 802.11ac option (GFP) to provide partially coded, statistically correct waveforms for component testing, as well as an advanced 802.11ac option (TFP) to create fully coded waveforms for receiver testing.
Key features:

- Create 802.11ac signals with BCC or LDPC channel coding
- Supports all modulation and coding rates (MCS 0-9)
- Supports 20, 40, 80, and 160 MHz bandwidth signals with one signal generator (maximum bandwidth varies by instrument)
- Create 80+80 MHz signals using two signal generators and RF combining
- Supports single or multi-user MIMO (MU-MIMO) with flexible spatial stream configuration and space-time block coding for up to 4 streams/antennas
- Compatible instruments: N5172B EXG, N5182A/B MXG, E4438C ESG, or E8267D PSG signal generators and N5106A PXB baseband generator and channel emulator (MIMO not supported for PSG)

RF vector signal generators

N5172B EXG Vector Signal Generator[1]

Key features:

- 9 kHz to 6 GHz
- Up to 120 MHz RF modulation BW with internal baseband generator
- Up to 512 MSa baseband memory
- ~200 MHz BW using external I/Q inputs
- Built-in I/Q skew and channel corrections for improved EVM performance
- Simple synchronization of baseband generators in multiple EXGs for MIMO
- Option 012 provides LO in/out for phase coherency for MIMO

N5182B MXG Vector Signal Generator

Key features:

- 9 kHz to 6 GHz
- Up to 160 MHz RF modulation BW with internal baseband generator
- Up to 1 GSa baseband memory
- ~200 MHz BW using external I/Q inputs
- Built-in I/Q skew and channel corrections for improved EVM performance
- Simple synchronization of baseband generators in multiple EXGs for MIMO
- Option 012 provides LO in/out for phase coherency for MIMO

N5182A MXG Vector Signal Generator

Key features:

- 100 kHz to 6 GHz
- 64 MSa baseband memory
- Up to 100 MHz RF modulation BW with internal baseband generator
- ~200 MHz BW using external I/Q inputs
- I/Q skew and channel flatness corrections for improved EVM performance
- Simple synchronization of baseband generators in multiple MXGs for MIMO
- Option 012 provides LO in/out for phase coherency for MIMO

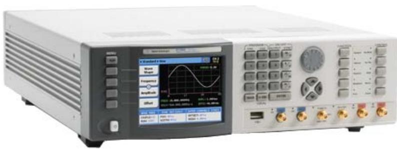
E4438C ESG Vector Signal Generator

Key features:

- 250 kHz to 6 GHz
- 64 MSa baseband memory
- 80 MHz RF modulation BW with internal baseband generator
- ~200 MHz BW using external I/Q inputs

1. The EXG or MXG signal generators are recommended for 802.11ac instead of the ESG due to lower cost, better EVM performance for wideband signals, and simple configuration and synchronization for MIMO applications.

Arbitrary waveform generators (AWG)



81180A 4.2 GSa/s Arbitrary Waveform Generator

Key features:

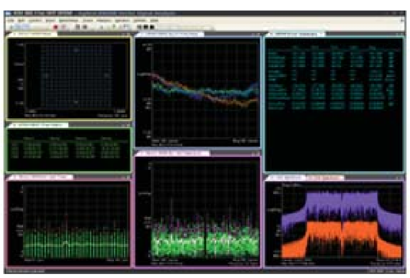
- 12-bit resolution
- Variable sample rate from 10 MSa/s to 4.2 GSa/s
- 1 or 2 channels, coupled and phase coherent or uncoupled
- 1 GHz modulation bandwidth per channel (2 GHz IQ modulation)
- 1.5 GHz carrier frequency
- Up to 64 MSa memory per channel
- Advanced sequencing capabilities
- Over 64 dBc spurious-free dynamic range
- Harmonic distortion less than -56 dBc

M8190A 12 GSa/s Arbitrary Waveform Generator

Key features:

- 14-bit resolution up to 8 GSa/s
- 12-bit resolution up to 12 GSa/s
- Variable sample rate from 125 MSa/s to 8 / 12 GSa/s
- Spurious-free-dynamic range (SFDR) up to 80 dBc typical
- Harmonic distortion (HD) less than -72 dBc typical
- Up to 2 GSa arbitrary waveform memory per channel with advanced sequencing
- Analog bandwidth 5 GHz (direct DAC out)

Signal analysis



89600 Vector Signal Analysis Software

Option BHJ 802.11ac Modulation Analysis

Key features:

- Supports all channel bandwidths and modulation types
- Supports up to 4 spatial streams with auto or manual detection
- Provides measurements of EVM, OFDM errors, IQ parameters, single channel and cross-channel power
- MIMO measurements include EVM per stream, channel frequency response, channel matrix, and condition number
- Displays OFDM data burst information and VHT-SIG informationFlexible display for optimal viewing of MIMO results

Supports a variety of hardware configurations for the performance, bandwidth, and number of channels you need, including PXA, MXA and EXA signal analyzers and 80000 and 90000 series Infiniium oscilloscopes. See Technical Overview 5990-6389EN for details of supported hardware and required options.

N9030A PXA Signal Analyzer
N9020A MXA Signal Analyzer
N9010A EXA Signal Analyzer

Key features:

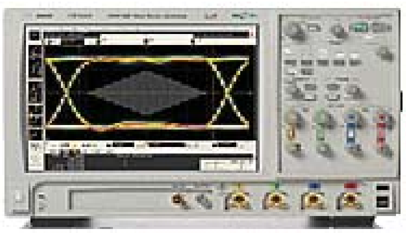
- Frequency coverage up to 26.5 GHz (MXA/EXA) or 50 GHz (PXA)
- Up to 40 MHz demodulation bandwidth (MXA/EXA)
- Up to 160 MHz demodulation bandwidth (PXA)
- Range of performance to meet your test requirements and budget
- Supports over 25 measurement applications as well as 89600 VSA

Signal analysis

N7109A PXIe Multi-channel Signal Analysis System

Key features:

- 2 or 4 channels
- Up to 40 MHz demodulation bandwidth
- 20 MHz to 6 GHz



Infiniium and Infiniivision oscilloscopes

Key features:

- 1 GHz or wider bandwidth
- 4 channels
- Range of bandwidths, maximum sampling rates, and memory depth available

Dual Channel PXI Vector Signal Analyzer

Key features:

- 50 MHz to 26.5 GHz frequency coverage
- Up to 250 MHz demodulation bandwidth
- 2 GSa/s digitizer
- Support up to 2 channels in 1 chassis
- Independently tuned multichannel receiver
- Continuous data capture to disk (up to 100 MHz BW)

Wideband MIMO PXI Signal Analyzers

Key features:

- 10 MHz to 26.5 GHz downconverter with 4 channels of coherent downconversion
- Digitizer offers up to 2 GSa/s sampling rate, and 12-bit resolution
- 800 MHz bandwidth when used with the 89600 VSA software
- Up to 100 MHz bandwidth, continuous data capture to disc
- Fast PCIe based measurements
- Up to 4 channels in one chassis

Choosing receiver hardware for signal analysis

For single-channel measurements, the PXA/MXA/EXA provide a range of choices for performance vs. price up to 160 MHz bandwidth. For wider bandwidths and multi-channel measurements, the PXI products or oscilloscopes are available. The PXI products provide better dynamic range and measurement speed, while oscilloscopes provide the widest bandwidth. An example PXI configuration is shown in Figure 8 below. For specifications and configuration details see www.agilent.com/find/pxi

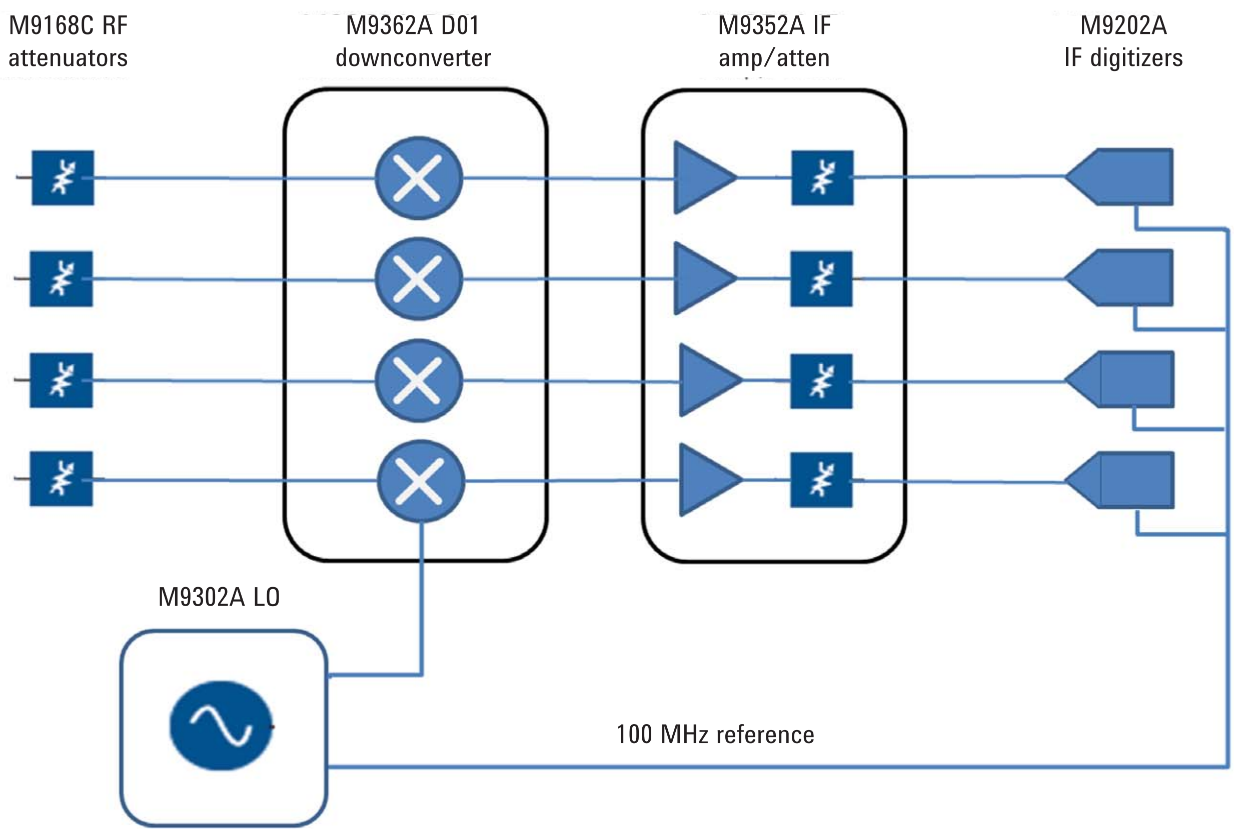


Figure 8. Example MIMO receiver configuration.

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