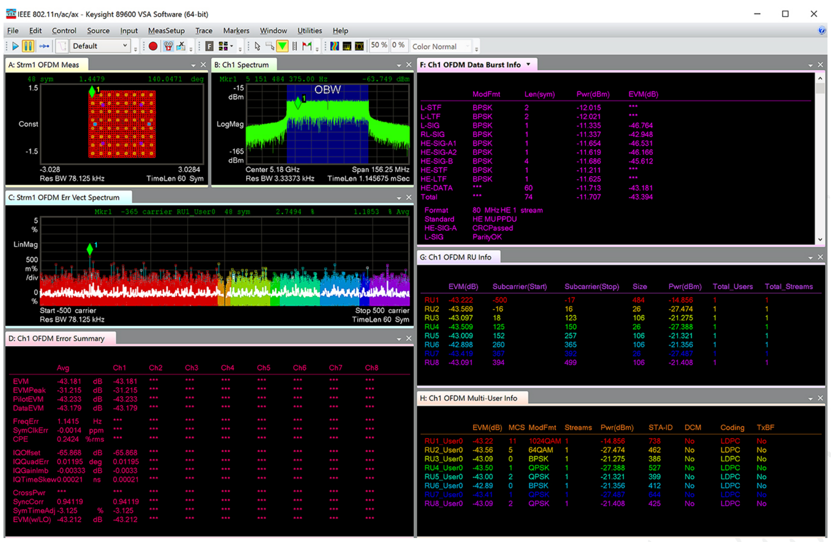
TECHNICAL OVERVIEW

WLAN 802.11n/ac and 802.11ax Modulation Analysis 89600 VSA Software

Option BHJ/BHX



- Perform measurements on the latest IEEE 802.11ax standard as well as 802.11ac and 802.11n formats
- Demodulate all operating modes of 802.11ax: High efficiency (HE) single user, HE multi-user, HE extended range, and HE trigger-based
- Analyze OFDMA, multi-user MIMO (MU-MIMO), up to 8 spatial streams, and 1024QAM 802.11ax signals
- Verify and troubleshoot PHY layer performance and errors down to the bit level

KEYSIGHT TECHNOLOGIES

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WLAN Technology Overview

WLAN products and systems started with 802.11b, 802.11g and 802.11a standard amendments, all of which provided throughput enhancements over the original 802.11 standard introduced in 1997. To meet the requirements of new applications and the need for higher data rates, WLAN technology continued to evolve by integrating the latest technologies. The goal was clear: to continuously improve spectrum utilization, throughput and user experience. 802.11n, the High Throughput (HT) amendment to the 802.11 standard, improved throughput through the adoption of Single-User Multiple-Input Multiple-Output (SU-MIMO) with up to 4 spatial streams and wider bandwidth (40 MHz). This improvement was further extended in 802.11ac, the Very High Throughput (VHT) amendment to the 802.11 standard, with new and enhanced technologies including up to 8x8 SU-MIMO, wider channel bandwidth (up to 160 MHz), new downlink Multi-User MIMO (MU-MIMO) technology, and 256-QAM modulation.

While still in the early stages of development, the next-generation 802.11 standard, 802.11ax or High Efficiency (HE) WLAN, is taking things one step further. 802.11ax promises to add significantly higher efficiency, capacity and coverage for a better user experience, especially for dense deployment scenarios in both indoor and outdoor environments (e.g., stadiums, airports and shopping malls). Unlike 802.11ac, 802.11ax operates in both 2.4- and 5-GHz bands and employs technology building blocks like Orthogonal Frequency Division Multiple Access (OFDMA) for high efficiency, 8x8 MU-MIMO for high capacity, and uplink scheduling for increased capacity, efficiency and better user experience. Other technologies, such as 1024-QAM modulation, are used to improve throughput.

802.11ax devices will be required to be backward compatible and coexist with legacy IEEE 802.11 devices operating in the same band. Table 1 compares key physical layer (PHY) technologies of 802.11n, ac and ax.

Table 1. Key PHY comparison of 802.11n, 802.11ac and 802.11ax

	802.11n **High Throughput (HT) WLAN**	**802.11ac** **Very High Throughput (VHT) WLAN**	**802.11ax** **High Efficiency (HE) WLAN**
Frequency band (GHz)	2.4 and 5	5	2.4 and 5
Multiplexing scheme	OFDM	OFDM	OFDMA
Channel bandwidth (MHz)	20, 40	20, 40, 80, 160, 80+80	20, 40, 80, 160, 80+80
Subcarrier spacing (for non-legacy portion)	312.5 kHz	312.5 kHz	78.125 kHz
Symbol duration, not including guard interval (µsec)	3.2	3.2	3.2, 6.4 or 12.8
Guard interval/cyclic prefix (µsec)	0.8	0.4 or 0.8	0.8, 1.6 or 3.2
Number of spatial streams	1~4	1~8	1~8
Multi-user (MU) technology	Not available	MU-MIMO: downlink only, up to 4 users	MU-MIMO: downlink and uplink, up to 8 users OFDMA: downlink and uplink
Resource unit (RU) size (# of subcarriers, also known as tones)	Full channel bandwidth	Full channel bandwidth	26, 52, 106, 242, 484, 996, 2*996
Data subcarrier modulation	BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM, 256QAM	BPSK, QPSK, 16QAM, 64QAM, 256QAM, 1024QAM
Channel coding	BCC (mandatory) LDPC (optional)	BCC (mandatory) LDPC (optional)	BCC (mandatory) LDPC (mandatory)
Uplink scheduling (managed by access point)	No	No	Yes
Maximum theoretical data rate (Mbps)	600	6933.3	9607.8

IEEE 802.11ax Overview

As previously mentioned, 802.11ax introduces various new technologies. This brief overview focuses solely on transmit modes, or PPDU formats, and the multi-user technologies—OFDMA and MU-MIMO—used in 802.11ax.

PPDU Formats

There are four different transmit modes, known as physical layer convergence procedure (PLCP) protocol data unit (PPDU) formats, defined for 802.11ax. These modes include: HE SU PPDU, HE extended-range SU PPDU, HE MU PPDU, and HE trigger-based Uplink (UL) PPDU. Each is used as follows:

- HE SU PPDU format is used when transmitting to a single user.
- HE extended range SU PPDU format is used when transmitting to a single user, but further away from the Access Point (AP) such as in an outdoor scenario.
- HE MU PPDU format is used when transmitting to one or more users. It is similar to SU format, except that an HE-SIG-B field is present.
- HE trigger-based PPDU format is used for uplink OFDMA and/or MU-MIMO transmission. It carries a single transmission and is sent as an immediate response to a Trigger frame sent by the AP.

The 802.11ax frame, similar to that of 802.11n and 802.11ac, starts with the preamble. The first part of the preamble consists of legacy (non-HE) training fields, while the second part is the HE preamble. The legacy portion of the preamble includes the L-STF, L-LTF and L-SIG; each is easily decodable by legacy devices and is included for backward compatibility and coexistence with the legacy devices. The HE preamble can only be decoded by 802.11ax devices.

Figure 1 shows the overall structure of the four PPDU formats. Also highlighted is a brief breakdown of the different field sections. The various fields of the PPDU formats are summarized in Table 2.

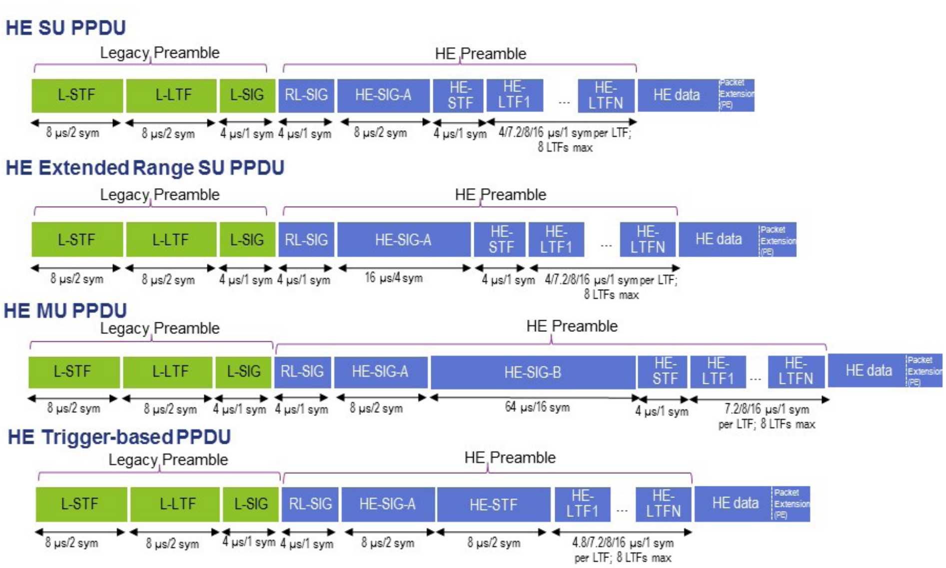

Figure 1. HE PPDU formats

Table 2. HE PPDU fields

Field	Description
L-STF	Legacy (non-HT) Short Training field
L-LTF	Legacy (non-HT) Training field
L-SIG	Legacy (non-HT) SIGNAL field
RL-SIG	Repeated Legacy (non-HT) SIGNAL field
HE-SIG-A	HE Signal A field
HE-SIG-B	HE Signal B field
HT-STF	HE Short Training field
HE-LTF	HE Long Training field
Data	The Data field carrying the PSDU(s)
PE	Packet Extension field

OFDMA

OFDMA is a method to add multiple access in OFDM systems by assigning subsets of subcarriers to different users. To date, it has been adopted by a number of wireless technologies such as 3GPP LTE. 802.11ax is the first WLAN standard to introduce OFDMA into WLAN networks.

OFDMA enables efficient use of available spectrum by allowing multiple users with varying bandwidth needs to be served simultaneously. The subcarriers, also called tones, are divided into several groups, with each group denoted as a resource unit (RU) having a minimum size of 26 subcarriers (~2 MHz wide) and a maximum size of 996 subcarriers (~77.8 MHz wide). In OFDM, used in legacy WLAN technologies, the total channel bandwidth (e.g., 20 MHz, 40 MHz etc...) is used for any one frame transmission. In OFDMA; however, used in 802.11ax, subcarriers can be allocated to transmission in blocks as small as 2 MHz or as large as the maximum bandwidth. Consequently, resources can be scaled for different types of traffic such as Instant Messaging (IM) versus video streaming. The difference between OFDM and OFDMA is shown in Figure 2.

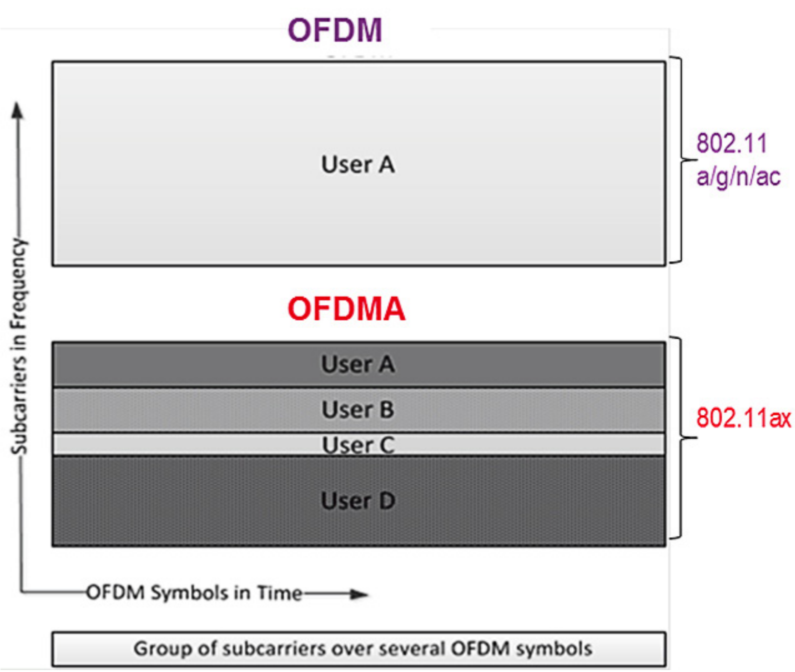

Figure 2: OFDM vs. OFDMA

There are several subcarrier types: data subcarriers, which are used for data transmission; pilot subcarriers used for phase information and parameter tracking; unused subcarriers, which are not used for data/pilot transmission. The unused subcarriers are the DC subcarrier, the guard band subcarriers at the band edges, and null subcarriers. The subcarriers that form a RU are contiguous except at the middle of the band where nulls are placed at DC.

The OFDMA structure consists of a 26-subcarrier RU, 52-subcarrier RU, 106-subcarrier RU, 242-subcarrier RU, 484-subcarrier RU, and 996-subcarrier RU. The maximum number of RUs is shown in Table 3[1]. The RU locations depend on the channel bandwidth. Figure 3 shows the 26, 52, 106, 242, 484, and 996 subcarrier RU locations for an 80-MHz channel bandwidth. A user can only be assigned to one RU and RU size ≥ 106 can be allocated to more than one user.

Table 3. Total number of RUs for bandwidths

RU type	CBW20	CBW40	CBW80	CBW160 and CBW80+80	Description
26-subcarrier RU	9	18	37	74	Number of available RUs per PPDU
52-subcarrier RU	4	8	16	32	Number of available RUs per PPDU
106-subcarrier RU	2	4	8	16	Number of available RUs per PPDU
242-subcarrier RU	1 SU/ MU-MIMO	2	4	8	Number of available RUs per PPDU
484-subcarrier RU	N/A	1 SU/ MU-MIMO	2	4	Number of available RUs per PPDU
996-subcarrier RU	N/A	N/A	1 SU/ MU-MIMO	2	Number of available RUs per PPDU
2x996 subcarrier RU	N/A	N/A	N/A	1-SU/ MU-MIMO	Number of available RUs per PPDU

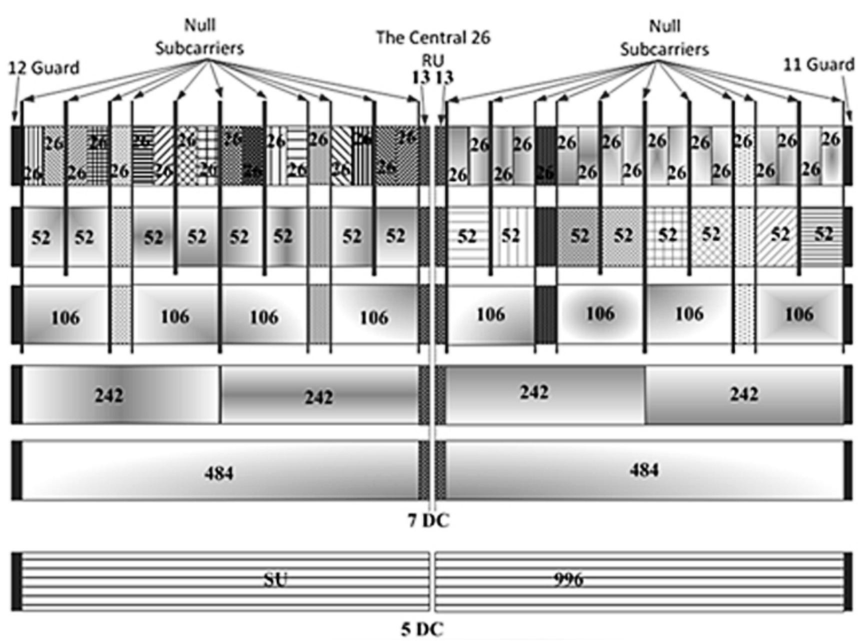

Figure 3. RU locations in an 80-MHz HE PPDU[1]

1. IEEE P802.11ax/D0.4, 2016.

The AP assigns RUs to associated stations (STAs) or client devices. Having uplink resource allocation managed by the AP increases capacity and enables a better user experience, particularly in dense deployments. The HE-SIG-B field in the HE MU PPDU is used to communicate RU assignments to the STAs. The field consists of a common block field followed by a user specific field. The common block field contains 8 bits for RU allocation signaling. It is used for determining the location of the RUs (RU arrangements in frequency domain), the number of users in each RU, RUs allocated for MU-MIMO and number of users in MU-MIMO allocations. It also carries 1-bit to indicate if center 26 subcarrier RU is allocated in 20 MHz and 80 MHz HE PPDU.

MU-MIMO

The 802.11ac standard introduced a 4x4 downlink MU-MIMO in which an AP simultaneously transmits independent data streams to up to four STAs. 802.11ax extends the maximum number of users supported for downlink MU-MIMO to eight. It also adds support for 8x8 uplink MU-MIMO, allowing up to eight STAs to transmit simultaneously, over the same frequency resource, to a single AP. The result is a 2x increase in capacity in the downlink and an 8x increase in capacity in the uplink versus 802.11ac.

MU MIMO and OFDMA technologies can be used simultaneously. To enable uplink MU transmissions, the AP transmits a new control frame called the trigger frame, which contains scheduling information including RU allocation for STAs, coding type and modulation and coding scheme (MCS) to be used for each STA in the trigger-based PPDU. In addition, the trigger frame provides synchronization for uplink transmission.

Since multiple transmitters take part in an UL MU-MIMO transmission, it requires time, frequency, sampling clock and power pre-correction by the participating STAs to mitigate the synchronization related issues at the AP.

WLAN Modulation Analysis

Designers can now gain greater insight into the latest wireless LAN signals with the 89600 VSA software for 802.11n/ac and 802.11ax modulation analysis. The software provides two options for 802.11n/ac and 802.11ax modulation analysis. Option BHJ provides spectrum, time and modulation quality measurements for WLAN 802.11n/ac signals, while Option BHX provides spectrum, time and modulation quality measurements for WLAN 802.11ax signals.

For legacy WLAN 802.11a/b/g modulation analysis, please refer to 89601B-B7R WLAN 802.11a/b/g Modulation Analysis, Technical Overview, literature number 5990-6389EN. WLAN options provide an advanced troubleshooting and evaluation toolset specifically designed to handle the challenge of analyzing legacy and new WLAN signals, covering technologies such as MU-MIMO and OFDMA used in the 802.11ax standard.

802.11 WLAN standards are among over 75 signal standards and modulation types supported by the 89600 VSA software. The 89600 VSA software is a comprehensive set of tools for demodulation and vector signal analysis. These tools enable you to explore virtually every facet of a signal and optimize even the most advanced designs. Just as critically, the software helps you cut through the complexity as you assess your design tradeoffs.

Analysis and Troubleshooting

Analyze a wide range of WLAN formats

Combinations of 89601B option BHJ for IEEE 802.11n/ac formats and option BHX for IEEE 802.11ax format provide the tools necessary to measure and troubleshoot IEEE 802.11n/ac/ax signals.

Option BHJ supports modulation analysis measurements according to IEEE 802.11n and IEEE 802.11ac standard. The supported features include the following:

IEEE 802.11n:

– All operating modes: legacy, mixed and greenfield
– Channel bandwidth of 20 MHz and 40 MHz
– Up to four spatial streams

IEEE 802.11ac:

– VHT operating mode
– Channel bandwidth of 20 MHz, 40 MHz, 80 MHz, 80 + 80 MHz and 160 MHz
– Modulation format of BPSK up to 256QAM
– Up to eight spatial streams
– Downlink MU-MIMO with up to four simultaneous users

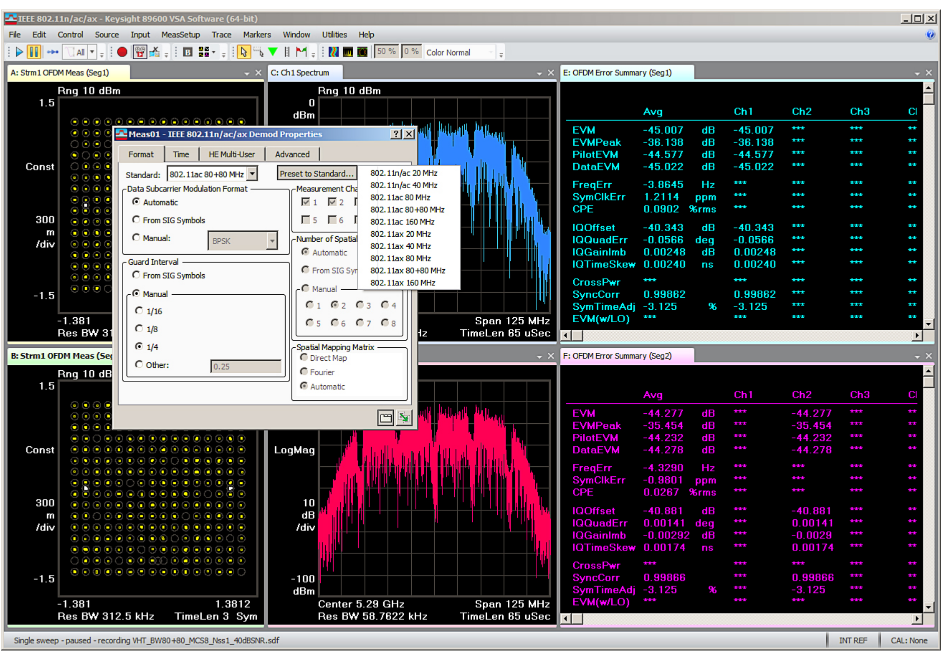

Figure 4. Troubleshoot and analyze 802.11ac signals with 80 + 80 MHz bandwidth and 256QAM

Option BHX supports modulation analysis measurements according to IEEE 802.11ax draft specification. It enables you to view and troubleshoot the entire breadth of the 802.11ax modes, providing greater insight and confidence in validating chipsets and devices regardless of the 802.11ax operating mode implemented. The supported features include the following:

- All operating modes: HE SU, HE extended range, HE MU, and HE trigger-based
- Channel bandwidth of 20 MHz, 40 MHz, 80 MHz, 80 + 80 MHz and 160 MHz
- Modulation formats of BPSK up to 1024QAM
- OFDMA in uplink and downlink
- MU-MIMO in uplink and downlink with up to eight simultaneous users
- Up to 8 spatial streams
- Color coded measurement results by RU and user

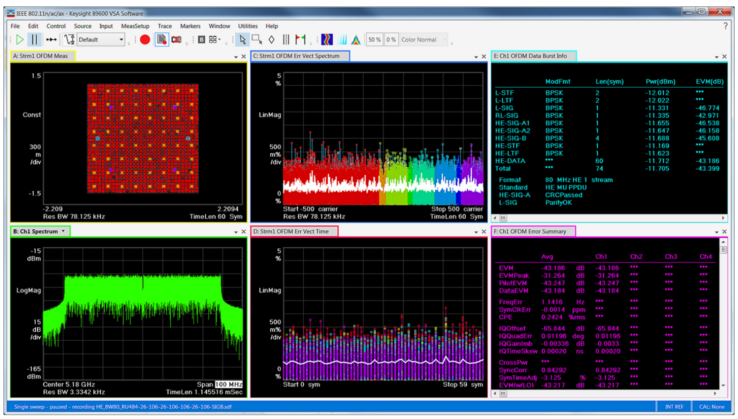

Figure 5. Evaluate signal quality and perform error vector measurements of 802.11ax signal with up to 160 MHz BW, 1024QAM and multi-user technologies such as OFDMA and MU-MIMO

Get basics right, find major problems

Spectrum and time domain measurements give the basic parameters of the signal in frequency and time domain so that correct demodulation can take place. Use measurements such as occupied bandwidth (OBW) to quickly and accurately report the occupied bandwidth, band power and power ratio of the transmitted signal.

In addition, time-gated spectrum measurements are useful for burst signals, especially those with complex preambles. Use gated spectrum to examine the various elements of the preamble.

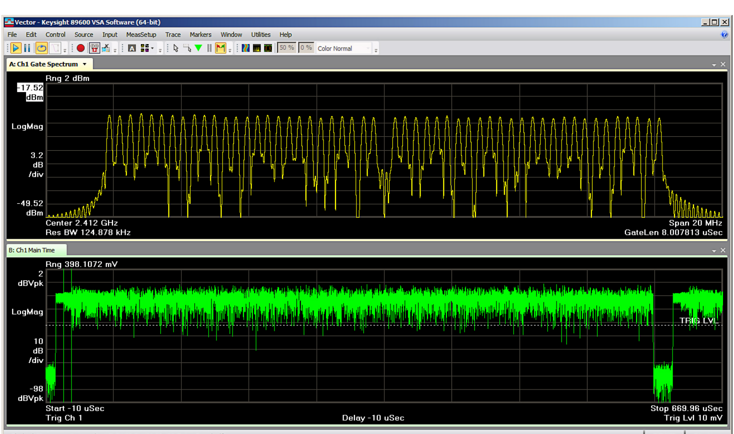

Figure 6. Gated spectrum measurement over the L-LTF portion of the SU-PPDU burst. The spectrum of the L-LTF symbol is displayed on the top trace showing flat amplitude across the 52 subcarriers.

Easy digital demodulation setup with complete parameter control

Quickly set up measurements with standard presets for 802.11n, 802.11ac and 802.11ax, while maintaining the ability to adjust a wide range of signal parameters for troubleshooting. For example, the measured IQ impairments can be removed from the EVM results by enabling “Compensate IQ Mismatch” which is useful when testing transmitters that have not been fully calibrated for IQ mismatch. In addition, you can modify sub-carrier spacing, symbol timing offset, FFT length, pilot tracking, equalizer training sequence and more.

Use Dynamic Help to access the Help text and learn about WLAN formats and presets available for Option BHJ or BHX. Detach the Dynamic Help window and move it to the side for easier viewing as it follows your menu choices. Lock it to stay on important Help data topics.

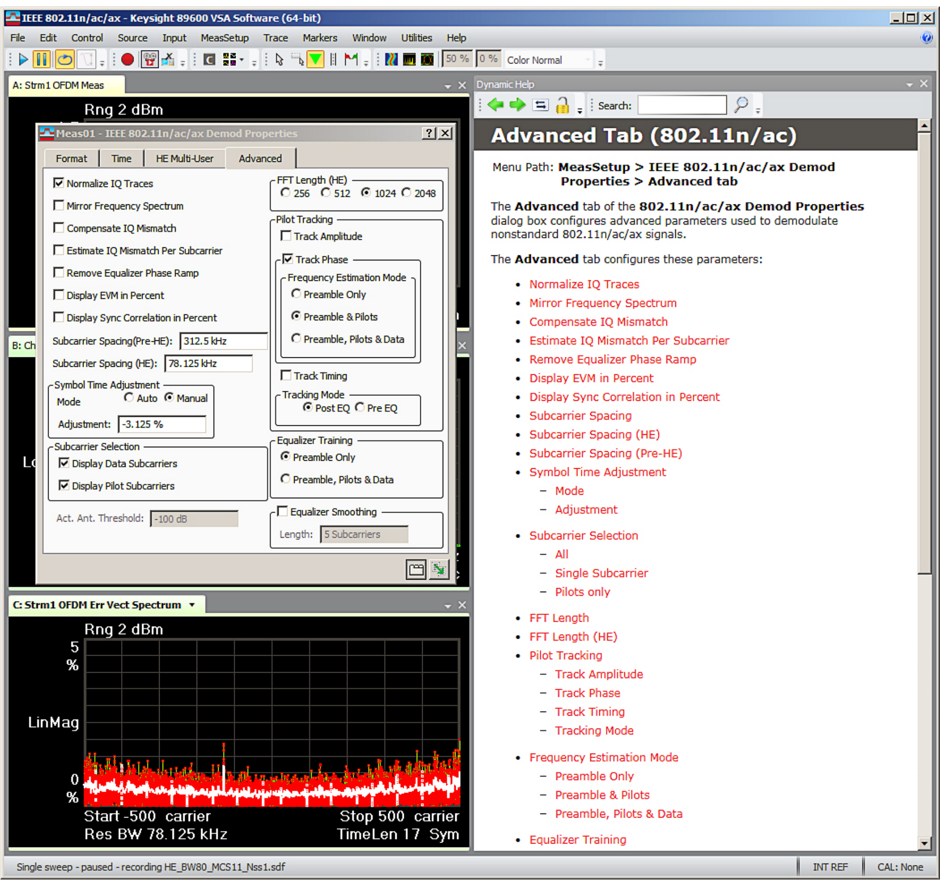

Figure 7. Easy setup to configure the WLAN demodulator to lock on to, and demodulate the test signal. Dynamic Help provides useful information to explain the demod properties and other important WLAN and 89600 VSA software operations.

Powerful measurements to let you look at signal performance and investigate causes of errors in detail

Evaluate signal quality and error vector measurements of transmitted WLAN signals. Error vector spectrum, error vector time, common pilot error, channel frequency response and more, are available for all WLAN formats. Composite constellation displays let you determine and display all modulation formats in the burst.

Phase noise, often the dominant cause of EVM in OFDM systems, can be characterized within the 802.11n/ac/ax demodulation measurement directly using the phase noise spectrum trace.

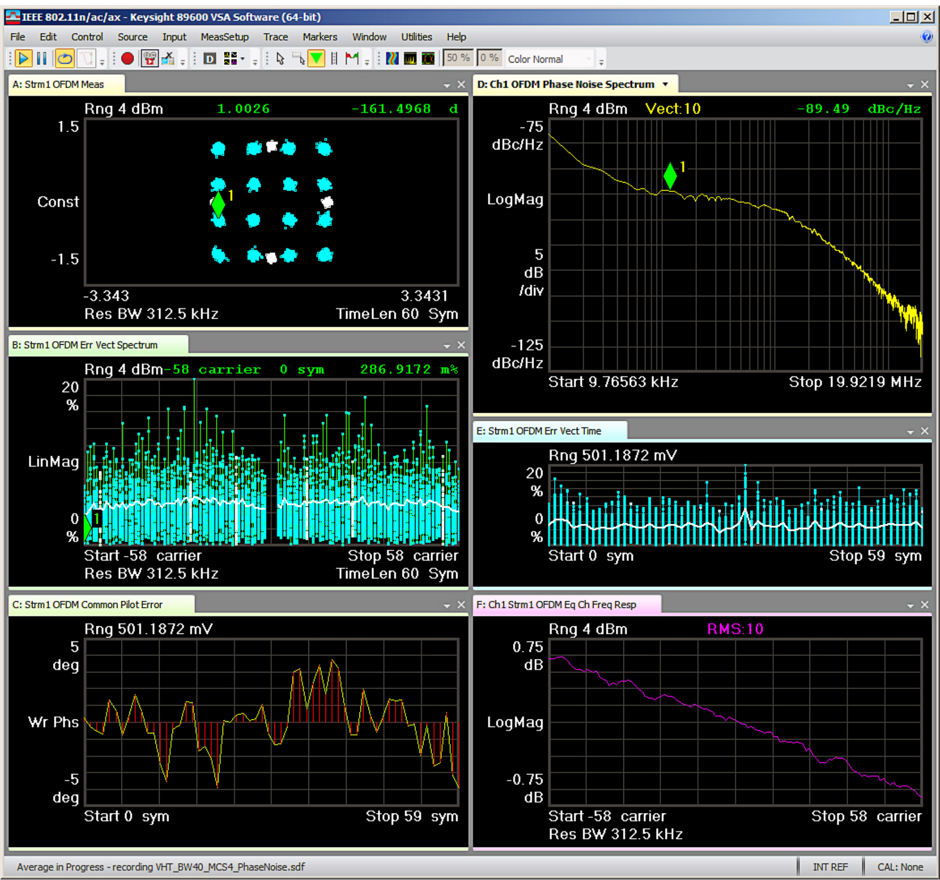

Figure 8. The 89600 VSA software lets you view an unlimited number of simultaneous traces, showing results such as EVM vs. frequency or time, equalizer channel frequency response, common pilot error, phase noise spectrum and more.

Evaluate modulation quality down to the bit level

Make EVM measurements at the level needed: overall burst, per symbol, or per each subcarrier in a symbol. Examine the symbols and error table for information on average EVM, peak EVM, demodulated bits, detected header information and more.
The Data Burst Info trace provides decoded information of legacy and non-legacy preamble as well as data.

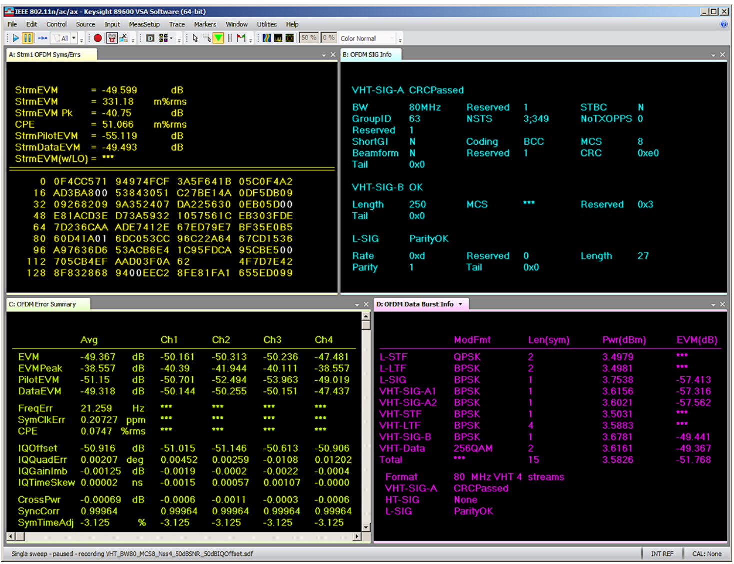

Figure 9. Example of 802.11ac signal with four transmit steams, showing in-depth, bit-level analysis with error summary tables, detected burst info and decoded SIG info.

Multi-user analysis for 802.11ax: OFDMA and MU-MIMO

For OFDMA and MU-MIMO used in 802.11ax, in addition to composite EVM, EVM of individual RUs and individual users within each RU are computed and displayed.
For MU-MIMO, enabling SIG-B compression field enables full bandwidth MU-MIMO, instead of OFDMA MU-MIMO.

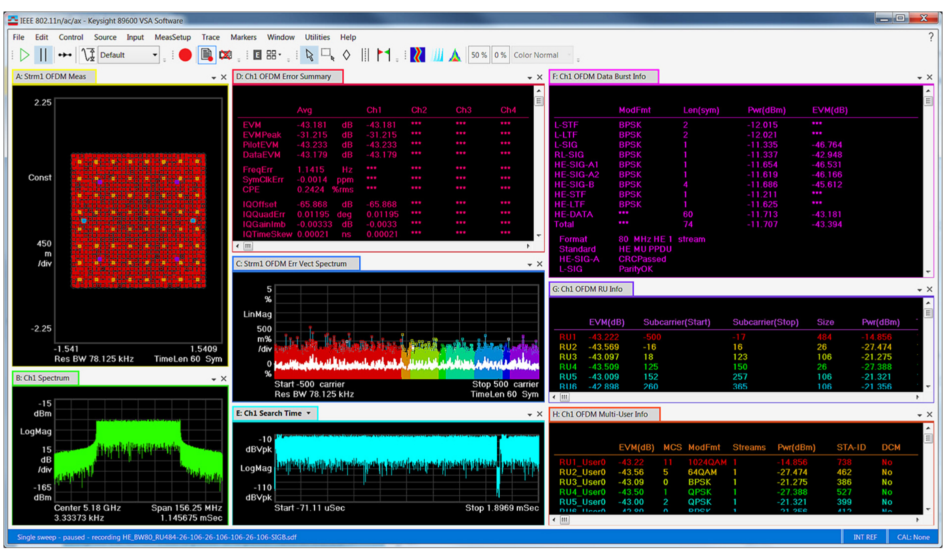

Figure 10. The 89600 VSA software lets you view an unlimited number of simultaneous traces color coded by RU and user, showing results such as constellation diagram, IQ errors, and in the case of 802.11ax MU-PPDU, EVM of individual RUs and individual users are also provided.

For trigger based PPDU of 802.11ax signal, which is used in UL OFDMA and/or MU-MIMO transmission, EVM of the transmitted RU as well as EVM of the unoccupied tones outside of the RU are measured. The averaged and peak unused tone EVM values for each measurement channel as well as the position of the peak unused tone EVM of the first measurement channel are displayed.

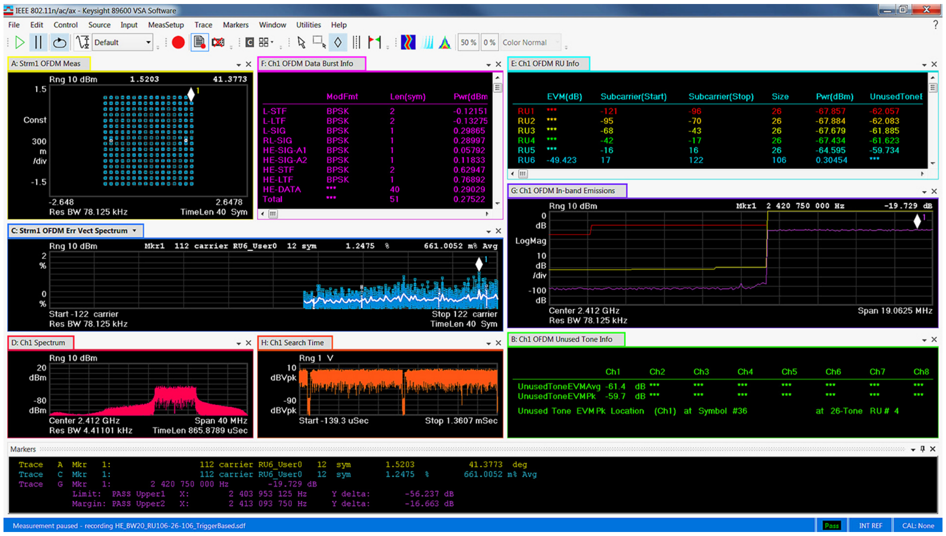

Figure 11. EVM measurement of trigger-based PPDU showing EVM of transmitted RU and new "Unused Tone EVM" trace displaying average and peak EVM of unoccupied tones outside of the RU and "In-band Emissions" providing average power over each subcarrier, limit over each unoccupied RU and unused tone EVM over each RU

MIMO analysis

Based on the format and use of the appropriate multi-channel front end, the 89600 software easily accommodates up to 8x8 SU-MIMO and MU-MIMO analysis with well-designed traces which provide data for both quick system overview as well as detailed analysis of the signal. Important channel, stream, and data information is available to you in user-selectable traces. Use these options anywhere from baseband to receiver, from simulation to antenna.

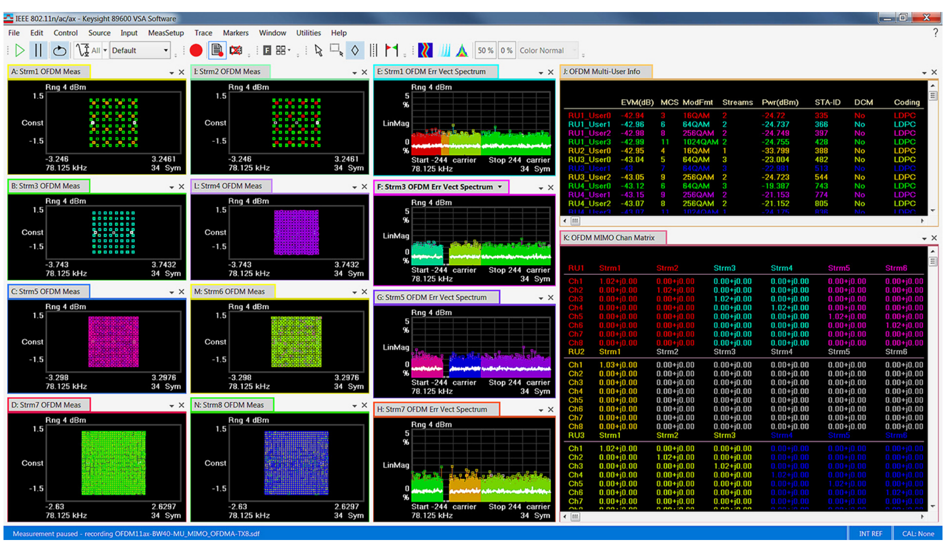

Figure 12. View key WLAN MIMO parameters simultaneously such as multiple constellations, error summary and channel matrix for each combination of Stream and Channel.

Software Features

Core features

	Option BHJ		Option BHX
	IEEE 802.11n	**IEEE 802.11ac**	**IEEE 802.11ax**
Operating modes	HT-greenfield HT-mixed Non-HT duplicate HT duplicate	VHT	HE-SU HE-MU HE-extended range HE-trigger-based
OFDMA	N/A	N/A	Uplink and downlink
MU -MIMO	N/A	Downlink Up to 4 users	Uplink and downlink Up to 8 users
SIG-B compression	N/A	N/A	Yes
SU-MIMO	Up to 4 spatial streams	Up to 8 spatial streams	Up to 8 spatial streams
Preset to standard	802.11n 20 MHz 802.11n 40 MHz	802.11ac 20 MHz 802.11ac 40 MHz 802.11ac 80 MHz 802.11ac 80+80 MHz 802.11ac 160 MHz	802.11ax 20 MHz 802.11ax 40 MHz 802.11ax 80 MHz 802.11ax 80+80 MHz 802.11ax 160 MHz
Data modulation format	BPSK QPSK 16QAM 64QAM	BPSK QPSK 16QAM 64QAM 256QAM	BPSK QPSK 16QAM 64QAM 256QAM 1024QAM
Dual-carrier modulation	N/A	N/A	Yes
HE-LTF duration	N/A	N/A	1x, 2x, 4x
Guard interval length	1/16, 1/8, 1/4		
FFT length	64, 128, 256, 512	64, 128, 256, 512	256, 512, 1024, 2048
Pilot tracking	Amplitude, phase and timing		
Pilot tracking mode	Post Eq; Pre Eq		
Frequency estimation mode	Preamble only; preamble & pilots; Preamble, pilots & data		
Equalizer training	Preamble only; preamble, pilots & data		
Equalizer smoothing	Yes, with specified subcarrier length		
Compensate IQ mismatch	Yes		
Symbol time adjustment	Auto or manual		
Subcarrier spacing manual adjustment	Yes	Yes	Yes for Pre-HE & HE
Subcarrier selection (for display)	All; single subcarrier; pilots only	All; single subcarrier; pilots only	Data subcarriers; pilot subcarriers
Active antenna threshold (for improving MIMO EVM)	Yes		

Measurement results

	Option BHJ		Option BHX
	IEEE 802.11n	IEEE 802.11ac	IEEE 802.11ax
Pre-demodulation			
Time	•	•	•
Spectrum	•	•	•
Search time	•	•	•
Raw main time	•	•	•
CCDF	•	•	•
CDF	•	•	•
PDF	•	•	•
Correction	•	•	•
OBW	•	•	•
Demodulation – non-tabular results			
Channel frequency response	•	•	•
Common pilot error (CPE)	•	•	•
Equalizer impulse response	•	•	•
Error vector spectrum	•	•	•
Error vector time	•	•	•
IQ measured and IQ reference	• (All subcarriers, single carrier, pilots only)	• (All subcarriers, single carrier, pilots only)	• (All subcarriers, pilots only)
IQ gain imbalance per subcarrier	•	•	•
IQ quad error per subcarrier	•	•	•
Preamble frequency error	•	•	•
Phase noise spectrum	•	•	•
Equalizer MIMO condition number	•	•	•
MIMO channel frequency response	•	•	•
Demodulation - tabular results for IEEE 802.11n, IEEE 802.11ac			
Error summary (for each channel - up to 4 for 802.11n; up to 8 for 802.11ac)	EVM, EVM peak, pilot EVM, data EVM, frequency error, symbol clock error, CPE, IQ offset, IQ quadrature error, IQ gain imbalance, IQ time skew, cross power, sync correlation , symbol clock error		
Burst info	Detected symbols for active burst (L-STF, L-LTF, L-SIG, HT-STF, HT-LTF, HT-SIG, HT-Data, VHT-SIG-A1, VHT-SIG-A2, VHT-STF, VHT-LTF, VHT-SIG-B, VHT-Data) with modulation format, length, power and EVM; total burst length, power, EVM; format, number of streams, VHT-SIG-A and HT-SIG CRC pass/fail and L-SIG status		
SIG info	Decoded fields of the L-SIG, HT-SIG, and/or VHT-SIG symbols present in the burst, as described in the 802.11n/ac standards		
Multi-user info (for each detected user; valid for 802.11ac)	EVM, MCS, Mod format, number of streams, length, power		
Symbols/errors (for each stream)	Stream EVM, stream peak EVM, stream pilot EVM, stream data EVM,CPE; raw binary bits for data symbols		
MIMO channel matrix	A complex value (displayed in real + j*imag format) of the linear average over all subcarriers of the equalizer channel frequency response for each available channel/stream.		

Demodulation - tabular results for IEEE 802.11ax	
Error summary (for each channel, up to 8)	EVM, EVM peak, pilot EVM, data EVM, frequency error, symbol clock error, CPE, IQ offset, IQ quadrature error, IQ gain imbalance, IQ time skew, cross power, sync correlation, symbol time adjustment, EVM with LO
Burst info	Detected symbols for active burst (L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A1, HE-SIG-A2, HE-SIG-B, HE-STF, HE-LTF, HE-DATA) with modulation format, length, power and EVM; total burst length, power, EVM; format, number of streams, standard, HE-SIG-A CRC pass/fail and L-SIG status
SIG info	Decoded fields of the HE-SIG-A symbols present in the burst
RU info (for each detected RU)	EVM, start/stop subcarrier index, size (# of subcarrier) power total users, total streams. For HE trigger based PPDU, it also includes unused tone EVM, limit and margin
Multi-user info (for each detected user)	EVM, MCS, modulation format, number of streams, power, STA-ID, DCM, coding, TxBF
Unused tone EVM (for each channel; only for HE trigger based PPDU)	Unused tone EVM Avg, unused tone EVM Pk, unused tone EVM Pk location
Symbols/errors (for each stream)	Stream EVM, Stream EVM with LO, stream peak EVM, stream pilot EVM, stream data EVM,CPE; raw binary bits for data symbols
MIMO Chan Matrix for SU and MU-MIMO with result for individual RU	A complex value (displayed in real + j*imag format) of the linear average over all subcarriers of the equalizer channel frequency response for each available channel/stream.

Ordering Information

Software licensing and configuration

89600 VSA software offers flexible licensing options, including:

- **Transportable:** Highly flexible. License may be used on one instrument/computer at a time but may be transferred to another using Keysight's online tools or USB dongle.
- **Floating (network):** Maximum flexibility. Networked instruments/computers can access a license from a server one at a time. For concurrent usage, multiple licenses may be purchased.

The table below lists transportable licenses only; USB portable (89601BK) or floating (89601BN) license types are also available. For detailed licensing information and pricing, please refer to the 89600 VSA webpage at www.keysight.com/find/89600vsa.

Model-Option	Description	Notes
89601B-BHJ	WLAN 802.11n/ac Modulation Analysis, transportable license	
89601B-BHJ-1TY	WLAN 802.11n/ac Modulation Analysis, transportable 1-year time-based license	
89601B-BHX	WLAN 802.11ax Modulation Analysis, transportable license	BHJ is required
89601B-BHX-1TY	WLAN 802.11ax Modulation Analysis, transportable 1-year time-based license	BHJ-1TY required

Hardware configuration

The 89600 VSA software supports more than 45 Keysight hardware platforms. The table below shows the recommended signal analyzer hardware for IEEE 802.11n/ac/ax transmitter test. For a complete list of currently supported hardware, please visit: www.keysight.com/find/89600_hardware

Product	Frequency range (option dependent)	Internal analysis bandwidth
X-Series signal analyzers		
N9041B UXA	Up to 110 GHz	Up to 1 GHz
N9040B UXA	Up to 50 GHz	Up to 1 GHz
N9030A/B PXA	Up to 50 GHz	Up to 510 MHz
N9020A/B MXA	Up to 26.5 GHz	Up to 160 MHz
Modular product, for MIMO analysis		
M9421A VXT PXIe Vector Transceiver	Up to 6 GHz per channel	Up to 160 MHz per channel

Keep your 89600 VSA software up-to-date

With rapidly evolving standards and continuous advancements in signal analysis, the 89601BU/BKU/BNU software update and subscription service offers you the advantage of immediate access to the latest features and enhancements available for the 89600 VSA software. Refer to the 89600 VSA Configuration Guide **(5990-6386EN)** for more details.

Upgrade

All 89600 VSA options can be added after your initial purchase and are license-key enabled. For more information please refer to www.keysight.com/find/89600_upgrades

Additional Resources

Literature

89600 VSA Software, Brochure, 5990-6553EN

89600 VSA Software, Configuration Guide, 5990-6386EN

89600 VSA Basic VSA and Hardware Connectivity,
Technical Overview, 5990-6405EN

89600 VSA Software Opt B7R WLAN 802.11a/b/g Modulation Analysis,
Technical Overview, 5990-6389EN

Keysight Equalization Techniques and OFDM Troubleshooting for Wireless LANs,
Application Note, 5988-9440EN

Web

www.keysight.com/find/89600VSA
www.keysight.com/find/WLAN