Wireless Connectivity and High Throughput WLAN Modulation Analysis - 89600 VSA Software

89601B7RC - 802.11a/b/g/j/p

89601BHXC - 802.11n/ac/ax/be/bn

- Perform comprehensive measurements on the latest IEEE 802.11bn/be/ax/ac/n and legacy IEEE 802.11a/b/g/j/p formats
- Demodulate and analyze all WLAN operating modes: from single user to multi-user MIMO (MU-MIMO), supporting up to 8 spatial streams for 802.11ac/ax/be/bn signals
- Analyze high date-rate signals with up to 4096 QAM modulation across the full 802.11bn/be/ax/ac bandwidth
- Improve EVM with ccEVM or IQ-NC technologies (requires option 89601EVMC)
- Verify and troubleshoot PHY-layer performance and errors down to the bit level
- Support efficiency modes like trigger-based signal capture for optimized analysis

KEYSIGHT

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WLAN Technology Overview

Wireless Local Area Network (WLAN) technology has evolved continuously since the introduction of the original IEEE 802.11 standard in 1997. The early amendments — 802.11b, 802.11g, and 802.11a — provided incremental throughput and reliability improvements using Direct Sequence Spread Spectrum (DSSS) and Orthogonal Frequency Division Multiplexing (OFDM). As new applications demanded higher performance, WLAN standards evolved to enhance data rate, coverage, and spectrum efficiency through the integration of advanced physical (PHY) and MAC-layer technologies.

The 802.11n amendment, known as High Throughput (HT) WLAN, was the first to adopt Single-User MIMO (SU-MIMO) with up to four spatial streams, 40 MHz channel bandwidth, and optional short guard intervals for improved throughput and link robustness. It also introduced frame aggregation and block acknowledgment to increase MAC-layer efficiency.

Building on that foundation, 802.11ac or Very High Throughput (VHT) WLAN extended performance with up to 8×8 SU-MIMO, 160 MHz channel bandwidth, 256-QAM modulation, and the introduction of downlink Multi-User MIMO (MU-MIMO). These advances enabled gigabit-class throughput in both consumer and enterprise applications.

Next, 802.11ax, referred to as High Efficiency (HE) WLAN, focused on efficiency, capacity, and reliability in dense environments such as stadiums and airports. Operating across the 2.4, 5, and 6 GHz bands, 802.11ax introduced Orthogonal Frequency Division Multiple Access (OFDMA) for multi-user scheduling, uplink and downlink MU-MIMO, 1024-QAM modulation, and Target Wake Time (TWT) for improved power efficiency. Together, these features significantly improved spectrum utilization and user experience.

The 802.11be amendment, or Extremely High Throughput (EHT) WLAN, further expands these capabilities by introducing 320 MHz channel bandwidth, 4096-QAM modulation, and multi-link operation (MLO) for concurrent transmission across multiple bands, and enhanced MIMO with more spatial streams across 2.4, 5, and 6 GHz bands. These enhancements enable multi-gigabit throughput and better real-time performance for latency-sensitive applications such as AR/VR and 8K streaming.

The upcoming 802.11bn, or Ultra High Reliability (UHR) WLAN, represents a paradigm shift — emphasizing robustness and deterministic reliability rather than raw speed. Based on 802.11be PHY, it maintains the same peak data rate but focuses on low latency, low jitter, and seamless reliability for industrial, automotive, and mission-critical applications.

All new WLAN generations remain backward compatible and are designed to coexist with legacy IEEE 802.11 devices operating in the same spectrum. Table 1 summarizes key PHY-layer technologies introduced across 802.11n, 802.11ac, 802.11ax, and 802.11be.

Table 1. Key PHY comparison of WLAN Standards

Feature	802.11n/Wi-Fi 4	802.11ac/Wi-Fi 5	802.11ax/Wi-Fi 6/ Wi-Fi 6E	802.11be/ 802.11bn Wi-Fi 7/ Wi-Fi 8
Frequency Band (GHz)	2.4, 5	5	2.4, 5, 6	2.4, 5, 6
Multiplexing Scheme	OFDM	OFDM	OFDMA	OFDMA
Channel Bandwidth (MHz)	20, 40	20, 40, 80, 160, 80+80	20, 40, 80, 160, 80+80	20, 40, 80, 160, 320
Subcarrier Spacing (non-legacy portion)	312.5 kHz	312.5 kHz	78.125 kHz	78.125 kHz
Symbol Duration (µs); not including guard interval	3.2	3.2	3.2, 6.4,12.8	3.2, 6.4, 12.8
Guard Interval (µs)	0.8	0.4, 0.8	0.8, 1.6, 3.2	0.8, 1.6, 3.2
Spatial Streams (max)	4	8	8	8
Multi-user (MU) Technology	None	MU-MIMO (downlink, up to 4 users)	MU-MIMO (DL/UL, up to 8 users) OFDMA (DL/UL)	MU-MIMO (DL/UL, up to 8 users) OFDMA (DL/UL, multiple RUs)
Subcarriers per RU (tones)	Full channel bandwidth	Full channel bandwidth	26, 52, 106, 242, 484, 996, 2x996	26, 52, 78,106,132, 242, 484, 996, and combinations
Modulation (Data Subcarrier)	BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM, 256QAM	BPSK, QPSK, 16QAM, 64QAM, 256QAM, 1024QAM	BPSK, QPSK, 16QAM, 64QAM, 256QAM, 1024QAM, 4096QAM
Channel Coding	BCC (mandatory) LDPC (optional)	BCC (mandatory) LDPC (optional)	BCC (mandatory) LDPC (mandatory)	BCC (mandatory) LDPC (mandatory)
Maximum Data Rate	600 Mbps	6933.3 Mbps	9607.8 Mbps	23 Gbps

WLAN Modulation Analysis

Modulation analysis is a critical aspect of WLAN design, validation, and troubleshooting, enabling engineers to assess signal quality, isolate impairments, and optimize overall performance.

The 89600 Vector Signal Analysis (VSA) software provides comprehensive support for WLAN modulation analysis across a broad range of IEEE 802.11 standards — including 802.11a/b/g/j/p/n/ac/ax/be.

With dedicated WLAN measurement extensions, the VSA offers in-depth spectrum, time, and modulation-domain analysis for both next-generation and legacy WLAN signals:

- Option 89601BHXC supports 802.11n/ac/ax/be/bn formats, including advanced modulation schemes and multi-user modes.
- Option 89601B7RC supports 802.11a/b/g/j/p formats for backward-compatibility testing and coexistence evaluation.

These options provide a unified framework to demodulate and analyze single-user and multi-user (MU-MIMO) signals, including OFDMA-based transmissions, uplink/downlink separation, and per-user performance metrics. Engineers can evaluate EVM, spectral flatness, frequency error, IQ imbalance, phase noise, and carrier offset, as well as visualize constellation diagrams, error vector spectrum, and symbol-by-symbol error tables.

The 89600 VSA software supports over 75 wireless standards and modulation types, making it a universal toolset for WLAN and beyond. Its modular measurement architecture allows users to explore every facet of a signal — from constellation mapping and EVM per subcarrier to stream-by-stream decoding — while providing deep insight into physical-layer interactions that affect overall link quality.

Ultimately, the VSA enables faster design evaluation, deeper troubleshooting visibility, and efficient optimization of modern WLAN systems — from legacy 802.11a/g links to Wi-Fi 8 (802.11bn) and beyond.

Analysis and Troubleshooting

Analyze a Wide Range of WLAN Formats

The 89600 VSA software, with options 89601BHXC and 89601B7RC, provides comprehensive tools to measure, demodulate, and troubleshoot WLAN signals across a full spectrum of IEEE 802.11 standards.

- Option **89601BHXC** supports the latest 802.11n/ac/ax/be/bn standards with modulation formats up to 4096 QAM, enabling analysis of next-generation, high-throughput WLAN systems.
- Option **89601B7RC** covers legacy 802.11a/b/g/j/p standards, ensuring backward compatibility and coexistence testing for modern designs.

IEEE 802.11a/b/g/j/p

- Supports standards defined in IEEE 802.11a/g OFDM, 802.11g DSSS-OFDM, 802.11a/g Turbo Mode, 802.11p DSRC, 802.11j 10 MHz and HiperLAN2
- Channel bandwidths: 10 MHz, 20 MHz, and 40 MHz
- Modulation formats: BPSK, QPSK, 16QAM, and 64 QAM

IEEE 802.11b/g DSSS/CCK/PBCC

- Support standard defined DSSS, CCK, and PBCC modes
- Modulation formats: Barker1, Barker2, CCK5.5, CCK11, PBCC5.5, PBCC11, PBCC22, PBCC33

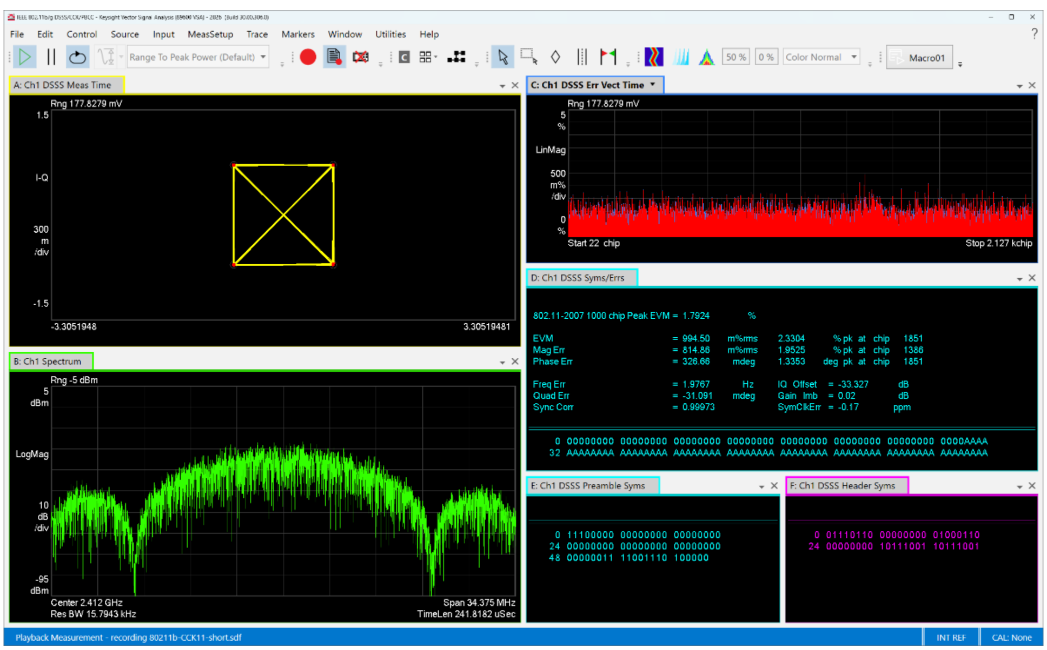

Figure 1. Troubleshoot and analyze 802.11b signals using CCK mode.

IEEE 802.11n/ Wi-Fi 4

- Operating modes: Legacy, Mixed, and Greenfield
- Channel bandwidths: 20 MHz and 40 MHz
- Spatial streams: Up to four
- Modulation formats: BPSK to 64 QAM

IEEE 802.11ac/ Wi-Fi 5

- Operating mode: Very High Throughput (VHT)
- Channel bandwidths: 20 MHz, 40 MHz, 80 MHz, 80 + 80 MHz, and 160 MHz
- Modulation formats: BPSK to 256 QAM
- Spatial streams: Up to eight
- MU-MIMO: Downlink with up to four simultaneous users

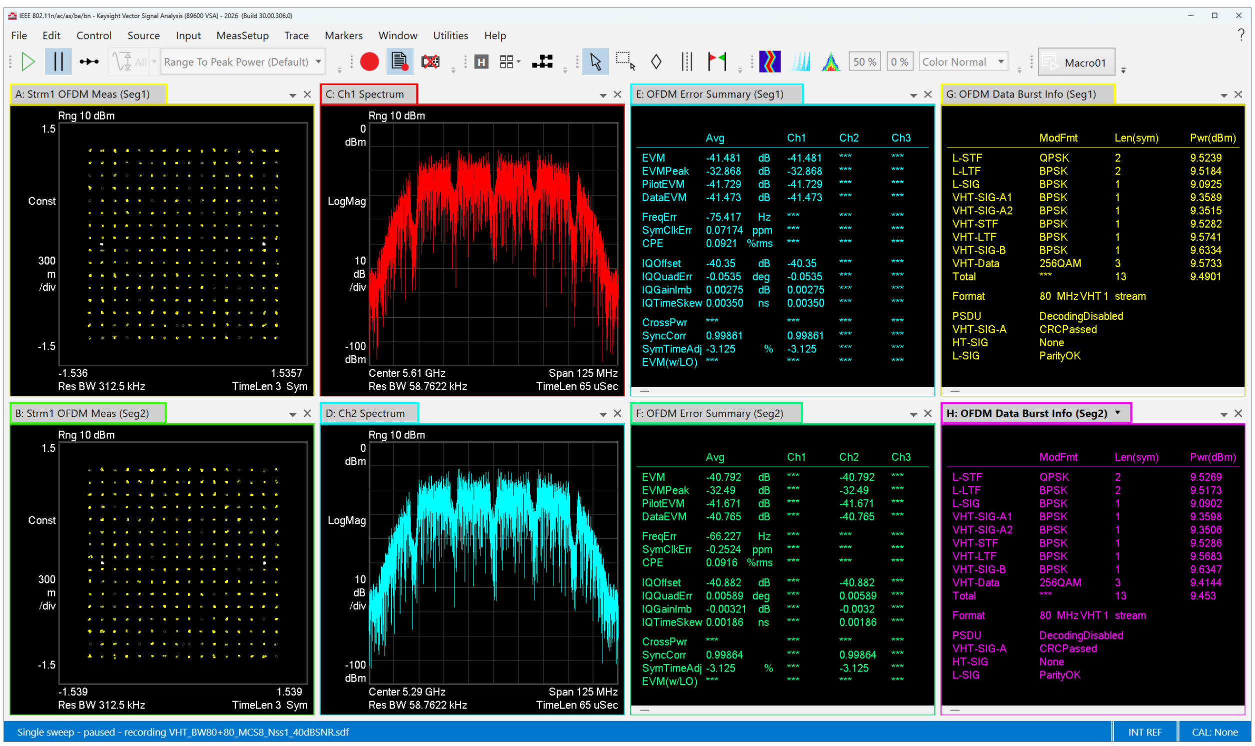

Figure 2. Troubleshoot and analyze 802.11ac signals with 80 + 80 MHz channel bandwidth and 256QAM modulation.

IEEE 802.11ax/ Wi-Fi 6/ Wi-Fi 6E

- High Efficiency (HE) operating modes: Single User (SU), Extended Range, Multi-User (MU), and Trigger-Based
- Channel bandwidths: 20 MHz, 40 MHz, 80 MHz, 80 + 80 MHz, and 160 MHz
- Modulation formats: BPSK to 4096 QAM
- OFDMA: Supported in uplink and downlink
- MU-MIMO: Supported in uplink and downlink with up to eight simultaneous users
- Spatial streams: Up to eight

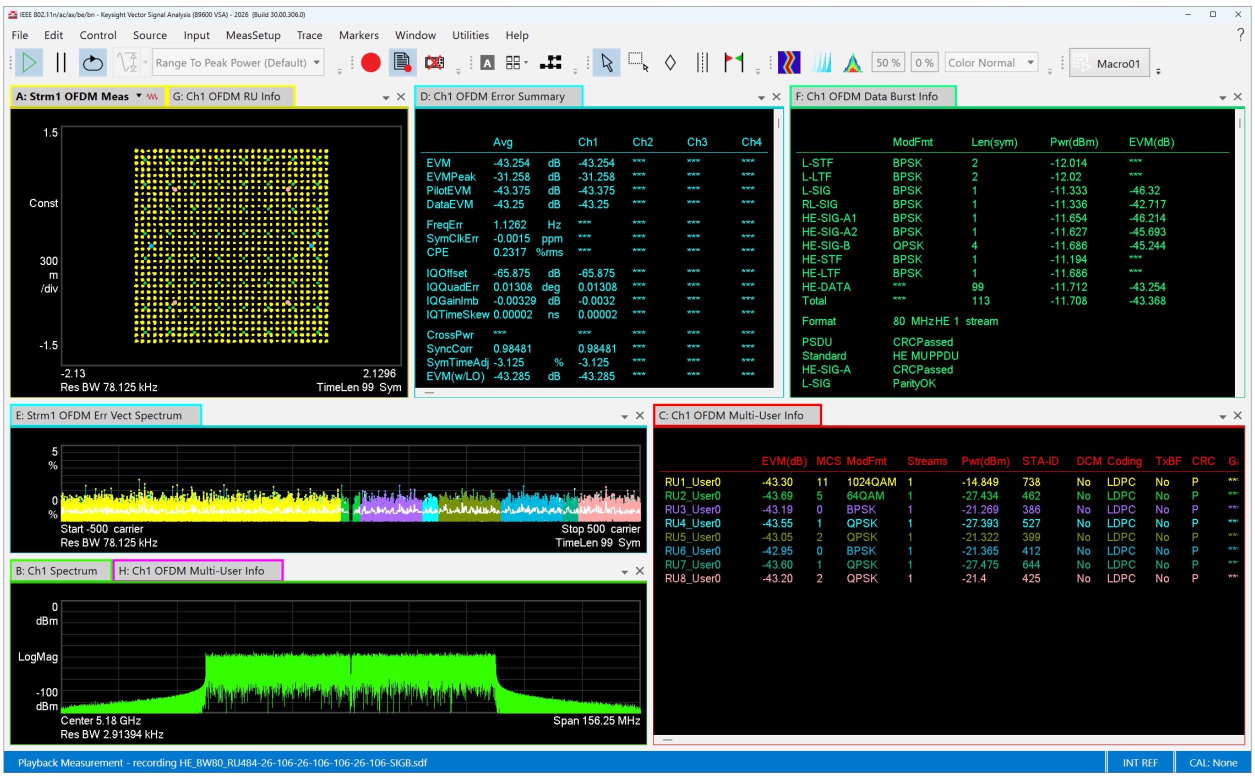

Figure 3. Evaluate signal quality and perform error vector measurements of an 802.11ax signal with up to 160 MHz bandwidth, 1024QAM, and multi-user technologies such as OFDMA and MU-MIMO. Results are color-coded by Resource Unit (RU) and user.

IEEE 802.11be/ Wi-Fi 7

- Extremely High Throughput (EHT) operating modes: Multi-User (MU) PPDU, Compressed and Non-Compressed modes with Resource Unit (RU) puncturing, and Trigger-Based
- Channel bandwidths: 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 320 MHz
- Modulation formats: BPSK to 4096 QAM
- MU-MIMO: Up to eight simultaneous users
- Spatial streams: Up to eight

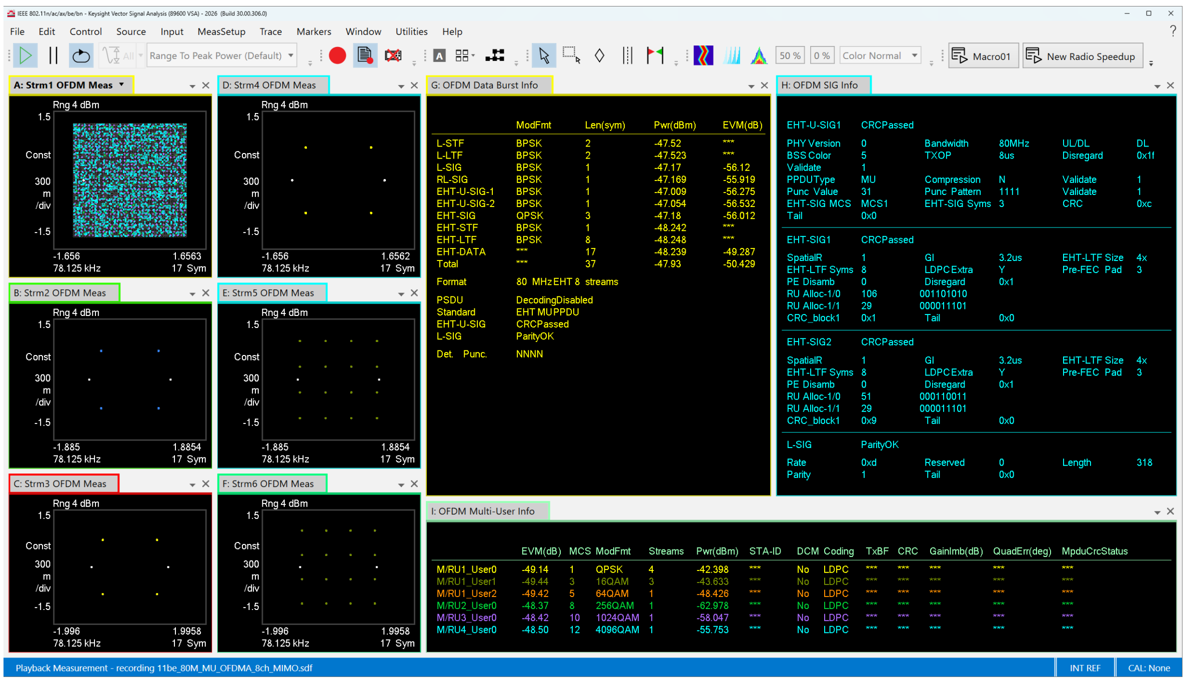

Figure 4. Evaluate signal quality and perform error vector measurements of an 802.11be signal with up to 320 MHz bandwidth, punctured or non-punctured channels, 4096QAM, multiple spatial streams, and multi-user configurations. Results are color-coded by RU and user.

IEEE 802.11bn/ Wi-Fi 8

- Ultra High Reliability (UHR) operating modes: Multi-User (MU) PPDU, Trigger-Based (TB) PPDU, and Extended Long-Range (ELR) PPDU
- Expanded MCS support: MCS 17, 19, 20, and 23
- Distributed Resource Unit (DRU): Measurement in TB PPDUs
- Unequal Modulation (UEQM): Decoding with per-stream modulation detection
- Extended LDPC codewords: 2×1944 demodulation and decoding for improved reliability

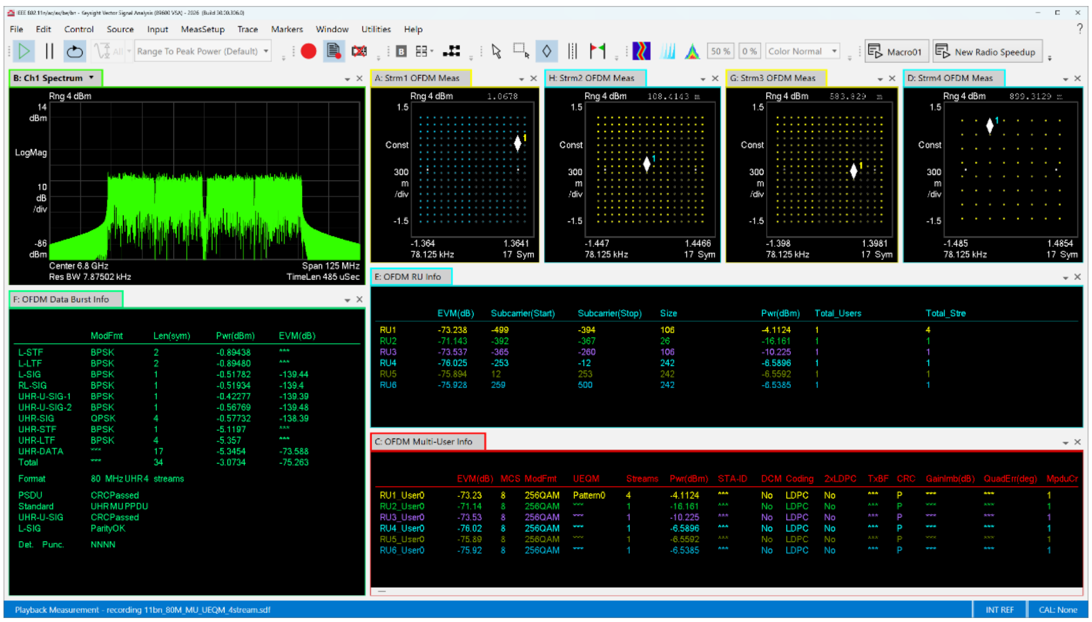

Figure 5. Evaluate signal quality and perform detailed error vector measurements of an 802.11bn signal featuring unequal modulation in multi-stream MIMO, expanded MCS support, and extended LDPC codewords.

As WLAN technologies continue to evolve, designers require powerful and flexible tools to analyze and optimize their systems with confidence. The 89600 VSA software, with its extensive support for both legacy and next-generation IEEE 802.11 standards, empowers engineers to stay ahead in this rapidly advancing landscape.

By delivering comprehensive modulation and signal analysis capabilities across all major WLAN formats, VSA enables users to evaluate performance, troubleshoot impairments, and accelerate innovation — ultimately pushing the boundaries of wireless design and reliability.

Get the Basics Right - Find Major Problems

Spectrum and time-domain measurements provide essential visibility into signal characteristics, helping ensure correct demodulation and system setup. These measurements reveal basic parameters such as frequency content, power distribution, and signal timing — critical for identifying major issues early in the analysis process.

Use measurements such as Occupied Bandwidth (OBW) to quickly and accurately determine occupied bandwidth, band power, and power ratio of the transmitted signal. These metrics provide a fast and reliable view of channel utilization.

Time-gated spectrum measurements are particularly valuable for burst-type signals, especially those with complex preambles. By applying a time gate, you can isolate and examine individual portions of the transmission — such as preamble segments, training sequences, or payload bursts — enabling precise analysis of transient signal behaviors and spectral variations.

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.

Flexible Configuration and Dynamic Help

Easily configure WLAN measurements using standard presets for 802.11n, 802.11ac, 802.11ax, 802.11be, and 802.11bn while maintaining full flexibility to fine-tune parameters for advanced troubleshooting. These presets provide a fast-starting point for measurement setup, while still allowing customization of key parameters such as subcarrier spacing, symbol timing offset, FFT length, pilot tracking, and equalizer training sequences.

For example, measured IQ impairments can be removed from EVM results by enabling the “Compensate IQ Mismatch” option — especially useful when characterizing transmitters that have not been fully calibrated for I/Q balance. This ensures more accurate EVM readings and helps isolate hardware-related impairments from modulation performance.

The Dynamic Help feature provides instant access to context-sensitive guidance and descriptions of WLAN formats, presets, and measurement settings available in the 89600 VSA software. You can detach and reposition the Dynamic Help window for side-by-side reference as it automatically follows your menu selections and activities. Alternatively, you can lock it to stay focused on specific help topics for deeper learning or documentation reference.

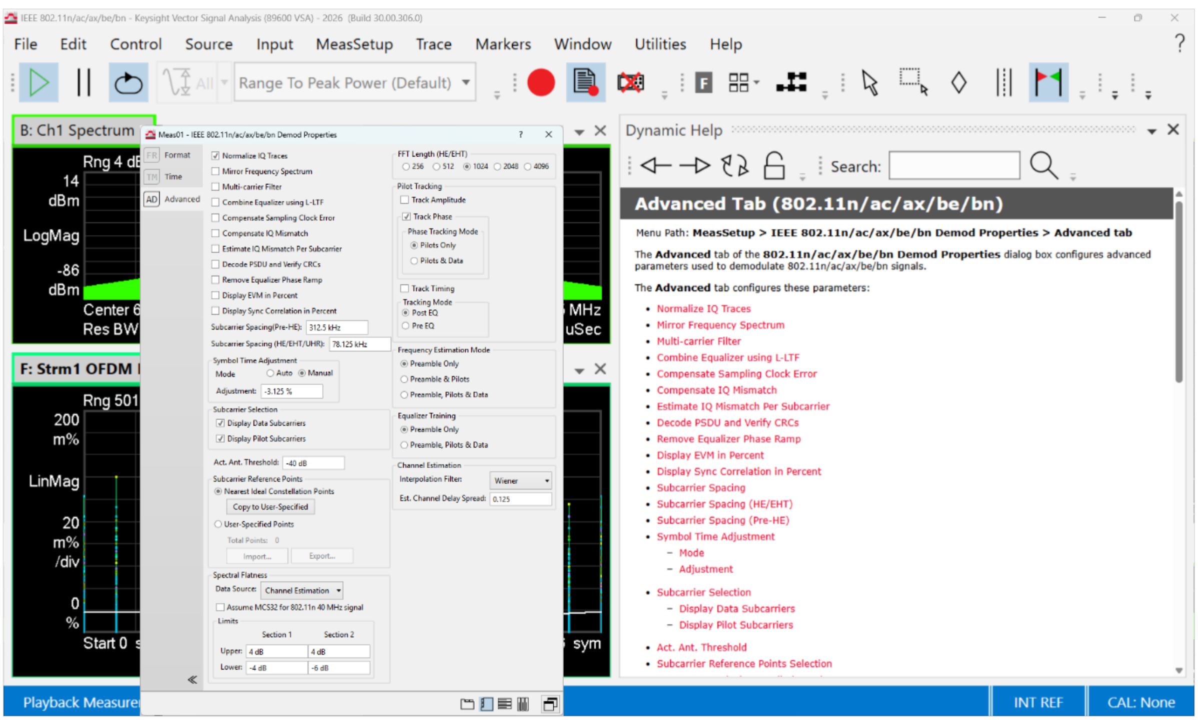

Figure 7. Easy setup for configuring the WLAN demodulator to lock onto and demodulate the test signal. Dynamic Help provides detailed guidance on demodulation properties and other key WLAN and 89600 VSA software operations.

Comprehensive Signal Quality and Error Vector Analysis

Evaluate the signal quality and error vector measurements of transmitted WLAN signals using a comprehensive set of analysis tools. The 89600 VSA software provides detailed insights across all WLAN formats, offering measurement displays such as error vector spectrum, error vector time, common pilot error, channel frequency response, and more.

Composite constellation displays allow engineers to identify and visualize the various modulation formats present within each burst, making it easier to analyze multi-user or multi-format transmissions.

Phase noise, often the dominant contributor to EVM degradation in OFDM-based systems, can be directly characterized within the 802.11n/ac/ax/be/bn demodulation measurements using the phase noise spectrum trace. This enables detailed assessment of oscillator stability and its impact on modulation accuracy.

The 89600 VSA software supports unlimited simultaneous trace displays, allowing you to view results such as EVM versus frequency or time, equalizer channel frequency response, common pilot error, phase noise spectrum, and more — all within a single integrated measurement environment.

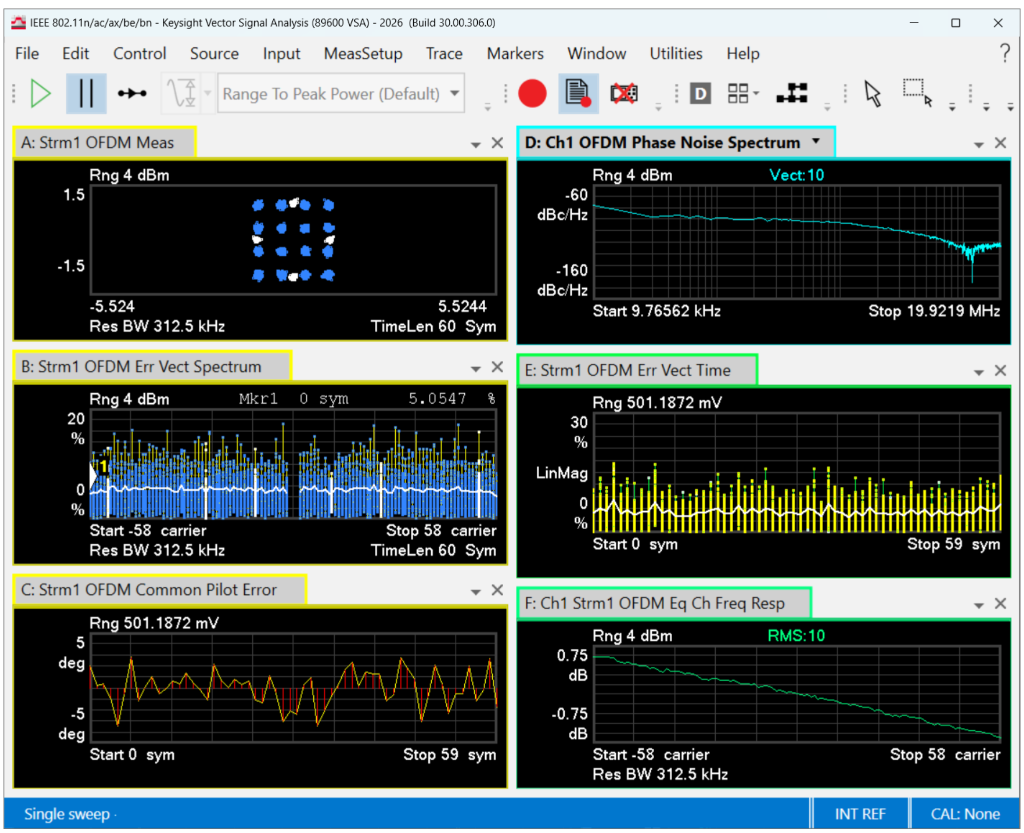

Figure 8. The 89600 VSA software lets you view an unlimited number of simultaneous traces, showing results such as EVM vs. frequency or time, equalizer channel frequency response, common pilot error, phase noise spectrum and more.

Comprehensive EVM Analysis and Burst Decoding

The 89600 VSA software provides a complete suite of EVM measurements and burst decoding tools to evaluate and troubleshoot WLAN signals. EVM can be viewed at multiple levels of granularity — overall burst, per symbol, or per subcarrier within a symbol — enabling precise insight into modulation quality.

The “Ch1 OFDM Error Summary” trace displays key performance metrics such as average, peak, pilot, and data EVM, along with common pilot error, I/Q impairments, synchronization correlation, and symbol timing adjustment — essential for diagnosing signal-quality issues.

The “Strm1 OFDM Syms/Errs” trace provides stream-specific EVM analysis, including average, peak, pilot, and data EVM for each spatial stream. This detailed view is invaluable for troubleshooting multi-stream MIMO configurations.

Complementing the EVM tools, the “Ch1 OFDM SIG Info” and “Ch1 OFDM Data Burst Info” traces deliver detailed decoding of the signal’s preamble and data burst structure. The SIG Info trace reveals key parameters such as bandwidth, spatial configuration, compression mode, and puncturing pattern, ensuring compliance with the latest WLAN standards. The Data Burst Info trace further breaks down modulation type, field length, power, and EVM for individual components (e.g., L-STF, L-SIG, UHR-SIG, UHR-Data) — enabling in-depth verification of burst composition and performance.

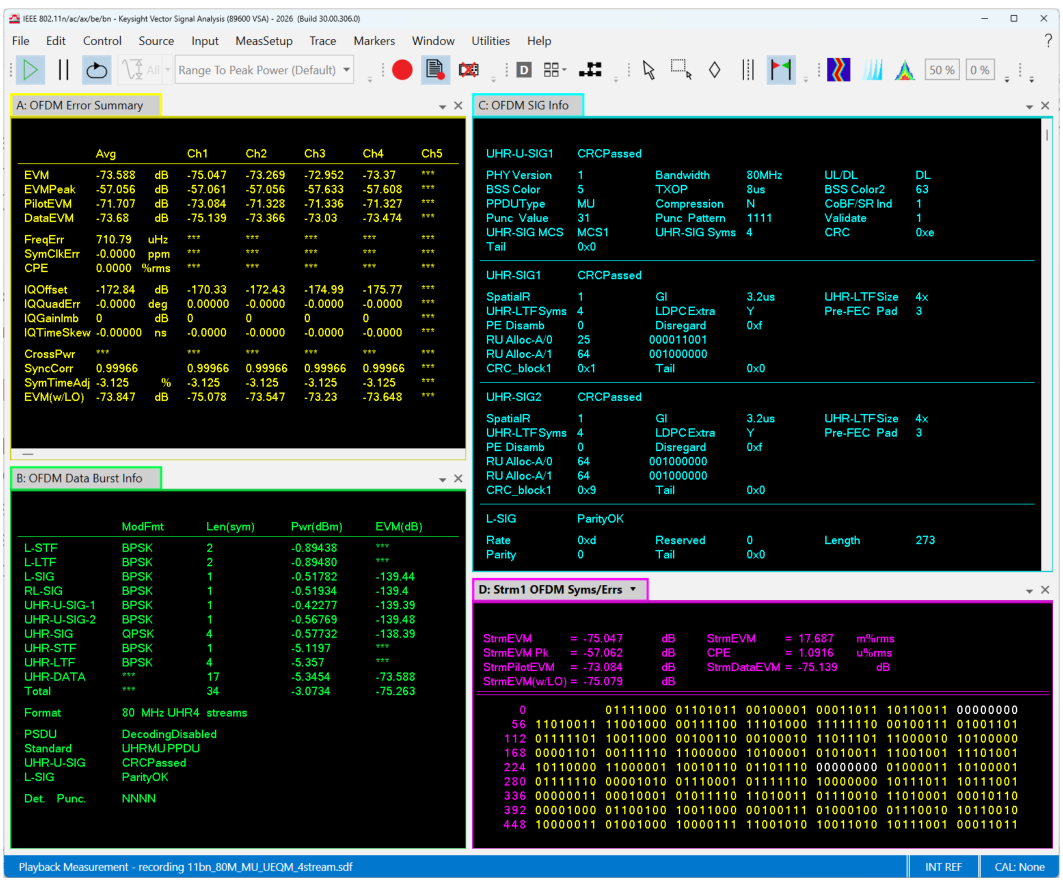

Figure 9. Example of an 802.11bn signal showing bit-level analysis with detailed error summary tables, detected burst information, and decoded SIG information.

Comprehensive MIMO Analysis in WLAN Systems

The 89600 VSA software provides powerful tools for comprehensive MIMO analysis in WLAN systems, supporting configurations up to 8×8 SU-MIMO and MU-MIMO. Well-structured trace displays offer both a high-level system overview and detailed per-stream analysis, delivering insight into key channel, stream, and data characteristics.

These measurement capabilities can be applied from baseband to receiver and from simulation to antenna, enabling thorough evaluation, debugging, and optimization of MIMO system performance across all WLAN generations.

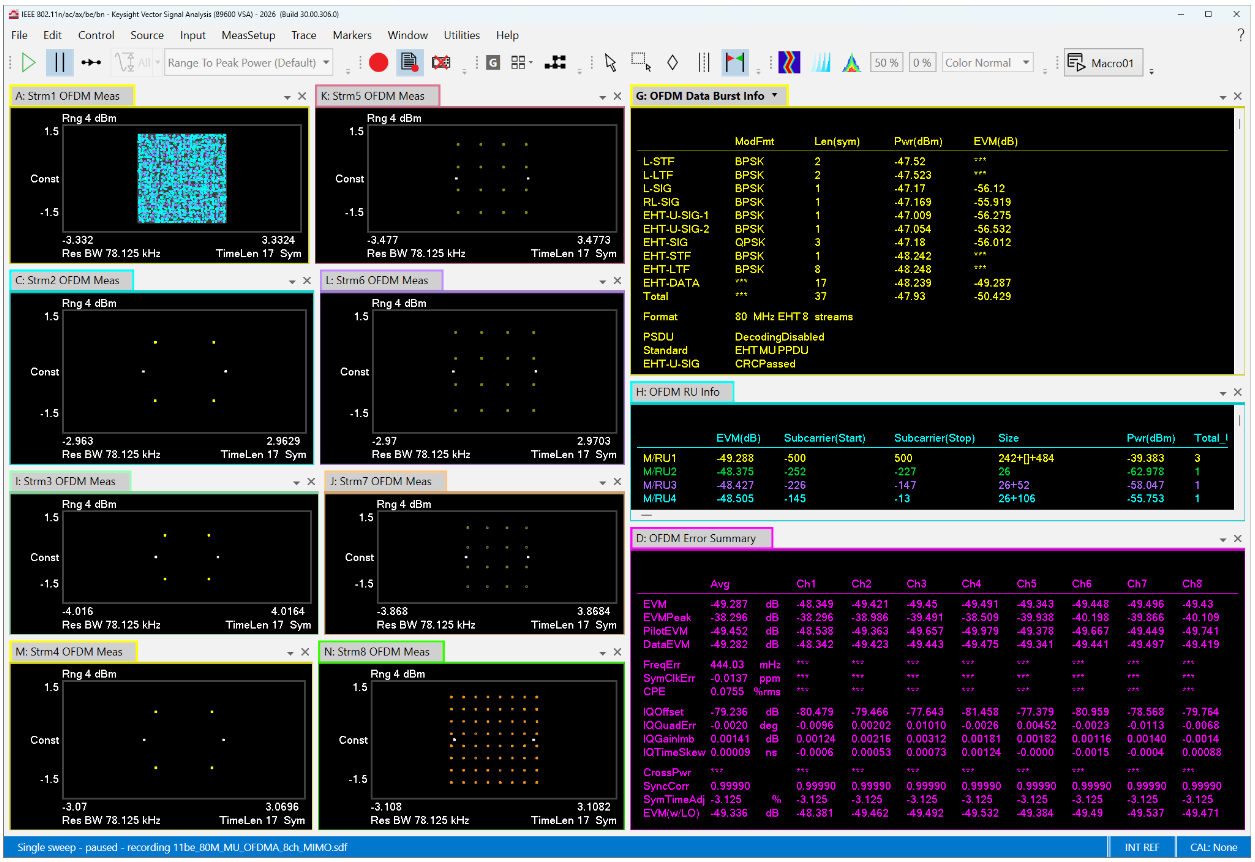

Figure 10. View key WLAN MIMO parameters simultaneously, including multiple constellation displays and error summaries for each combination of stream and channel.

Advanced Multi-User and OFDMA Analysis

For OFDMA and MU-MIMO operation in 802.11ax, 802.11be, and 802.11bn, the 89600 VSA software provides advanced analysis tools to evaluate the performance of these next-generation technologies. Beyond composite EVM, the software computes and displays EVM for individual resource units (RUs) and for individual users within each RU, giving clear visibility into multi-user transmissions and resource-specific performance.

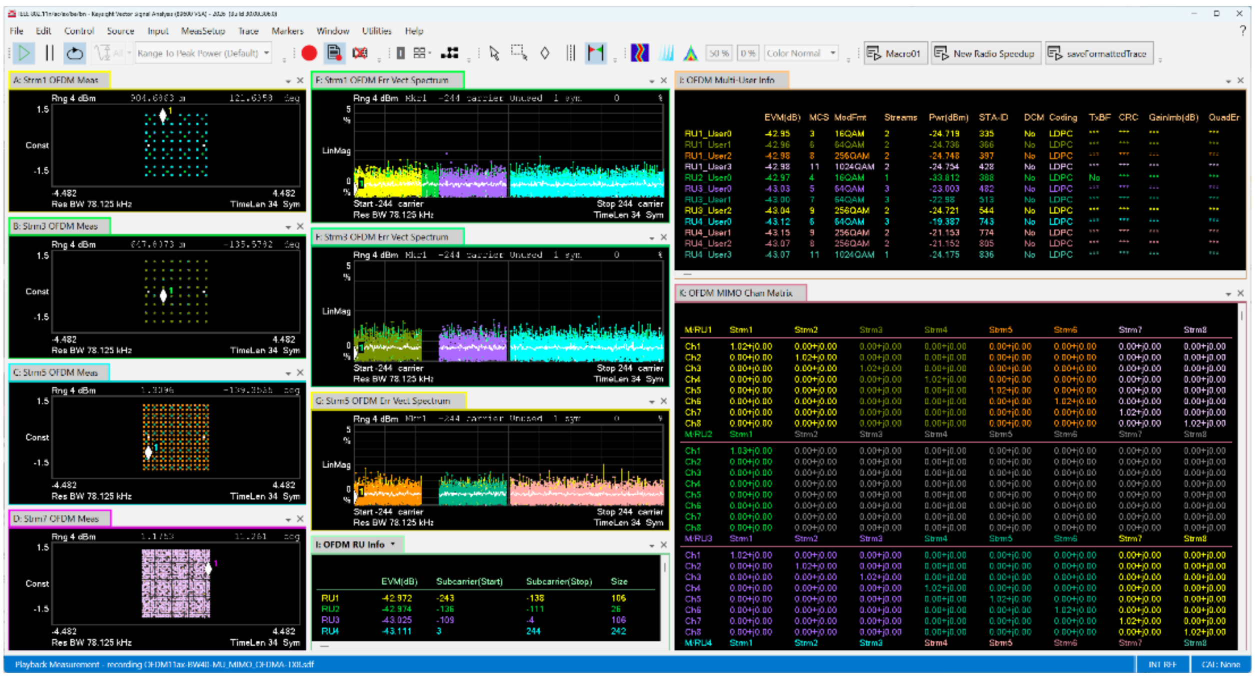

Figure 11. The 89600 VSA software allows simultaneous viewing of multiple color-coded traces by RU and user, showing results such as constellation diagrams, I/Q errors, and — for 802.11ax, 802.11be, and 802.11bn MU-PPDU measurements — EVM per RU and per user.

Trigger-Based (TB) PPDU Analysis

For Trigger-Based (TB) PPDUs used in uplink OFDMA transmission, the 89600 VSA software provides detailed analysis of both the transmitted Resource Unit (RU) and the unoccupied tones outside of the RU.

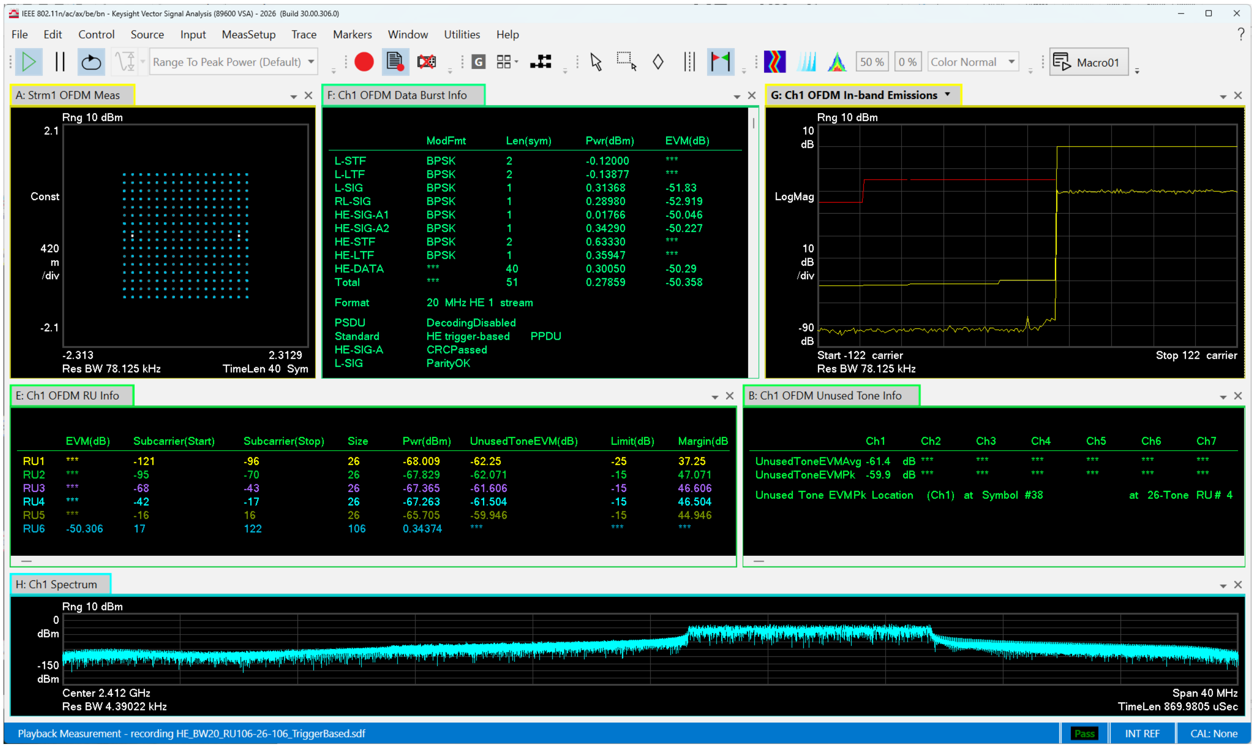

Figure 12. Example of an EVM measurement of a trigger-based PPDU, showing:

- EVM of the transmitted RU
- The “Unused Tone Info” trace, displaying average and peak EVM of unoccupied tones outside the RU
- “In-Band Emissions” results, providing average power per subcarrier, limit levels for each unoccupied RU, and unused tone EVM across all RUs

By leveraging these advanced analysis tools, wireless LAN designers can thoroughly evaluate the performance of their 802.11ax, 802.11be, and 802.11bn implementations. The VSA enables engineers to identify and mitigate impairments associated with OFDMA and MU-MIMO transmissions and to optimize overall system efficiency and user experience.

Spectrum Emissions Mask (SEM)

The IEEE 802.11 specification includes a Spectral Emission Mask (SEM) requirement that defines acceptable power levels across specific frequency offsets relative to the transmission frequency. This requirement establishes the maximum permitted emissions at various offsets, effectively controlling the occupied bandwidth and minimizing adjacent-channel interference.

The WLAN measurement application performs SEM and EVM measurements simultaneously from a single data acquisition. By combining spectral mask compliance and modulation analysis in one capture, engineers eliminate a separate measurement step and accelerate WLAN transmitter validation as well as ensure time-correlated results between modulation accuracy and out-of-band emissions.

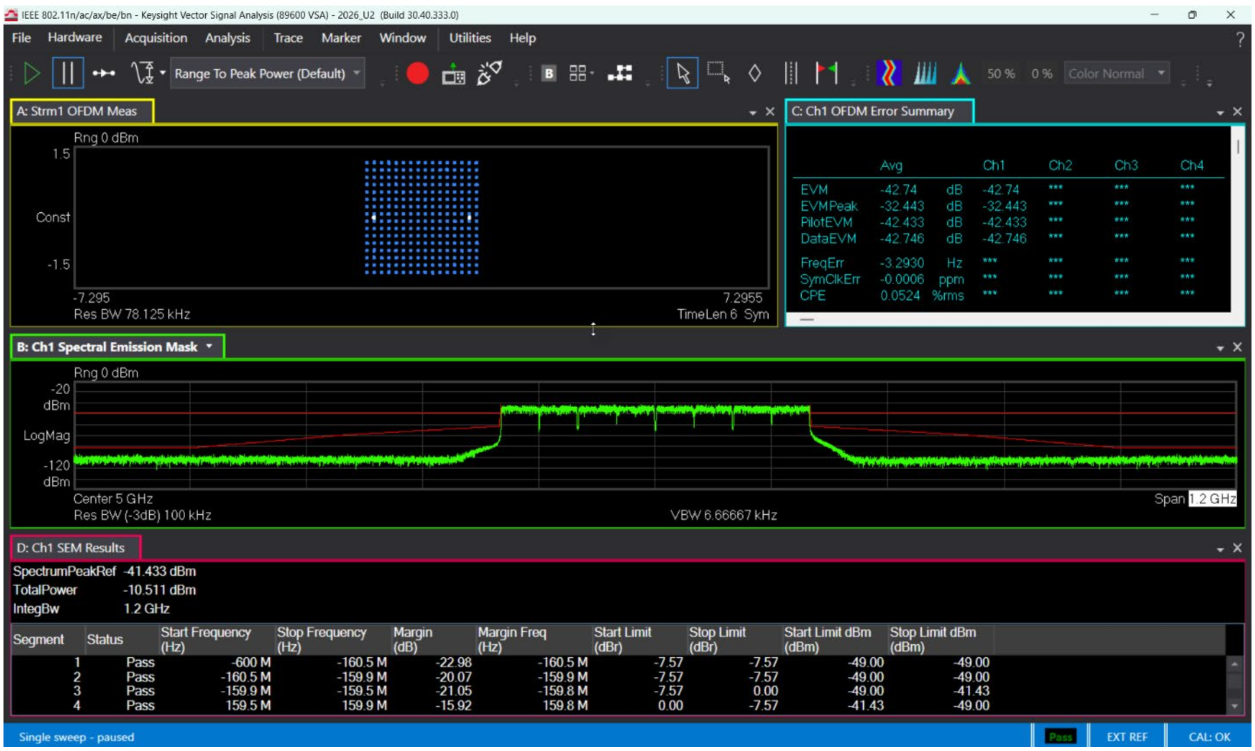

Figure 13. SEM measurement with the 802.11be limit mask. The **Spectral Emission Mask** trace shows the spectrum of the detected WLAN burst with SEM limit lines overlaid, providing a frequency-domain view of out-of-band emissions relative to the IEEE 802.11 mask. The **SEM Results** trace provides per-segment pass/fail status and margin information.

NOTE: For SEM measurements across other wireless technologies the 89600 VSA software offers the 89601PSMC Power Suite measurement application, which provides dedicated standards-compliant SEM and ACP measurements.

Extending EVM Dynamic Range with Cross-Correlated EVM (ccEVM) and IQ Noise Correction (IQ-NC)

Modern WLAN technologies — with bandwidths up to 320 MHz and modulation rates as high as 4096 QAM — make achieving low Error Vector Magnitude (EVM) more challenging, especially at low signal power levels.

To improve EVM performance, the 89600 VSA software, with the 89601EVMC option, provides two powerful techniques: Cross-Correlated EVM (ccEVM) and IQ Noise Correction (IQ-NC). Both methods effectively lower the EVM floor by reducing analyzer noise, ensuring the measured EVM reflects the performance of the Device Under Test (DUT) rather than the measurement hardware.

Cross-Correlated EVM (ccEVM)

ccEVM extends the receiver's dynamic range for superior EVM performance. Two independent receivers capture and demodulate the same signal, and the VSA performs cross-correlation on their error vectors to cancel uncorrelated noise added by the receivers.

This results in a much lower EVM that primarily represents DUT noise — or, in the case of amplifiers, noise from the signal source plus the DUT.

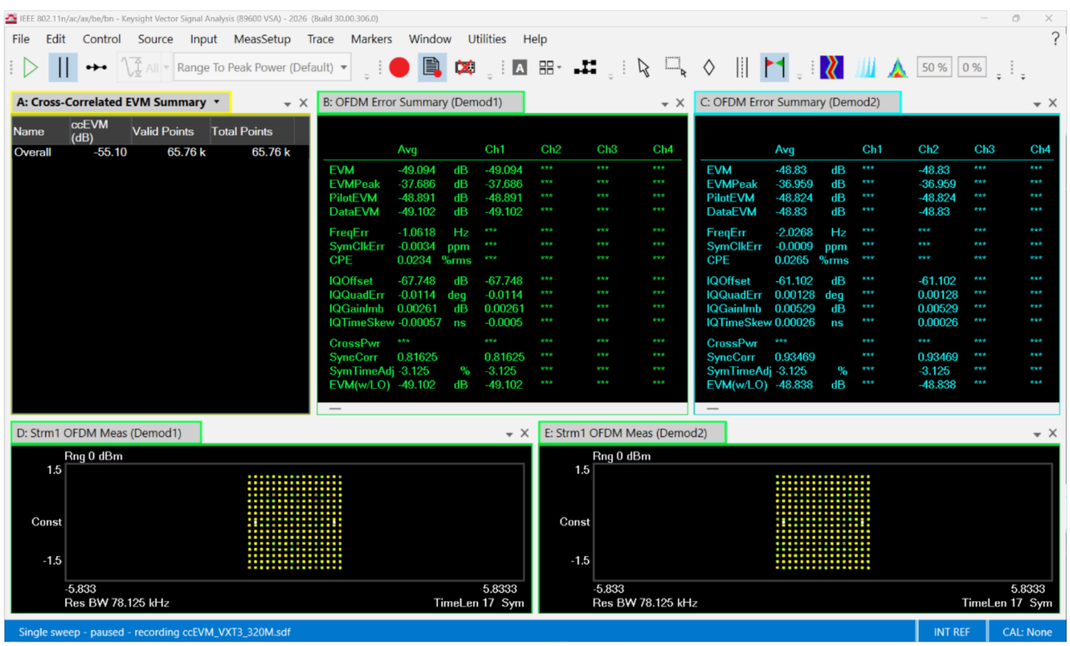

Figure 14. Cross-correlated EVM measurement demonstration.

Figure 14 compares the EVM from combined receiver data (Trace A) against the EVM from individual receivers (Traces B and C). In this test, a Keysight Vector Signal Transceiver was configured in loopback, with the signal generator output split into two analyzer channels. Using two receivers achieved an approximate 6 dB improvement in EVM for an 802.11be WLAN signal, demonstrating the significant gain in EVM performance through cross-correlation.

IQ Noise Correction (IQ-NC)

IQ-NC enhances EVM performance using a single receiver. Multiple acquisitions of the same signal are averaged to separate the deterministic signal from random noise; the noise is then scaled and subtracted, effectively removing analyzer noise from the measurement.

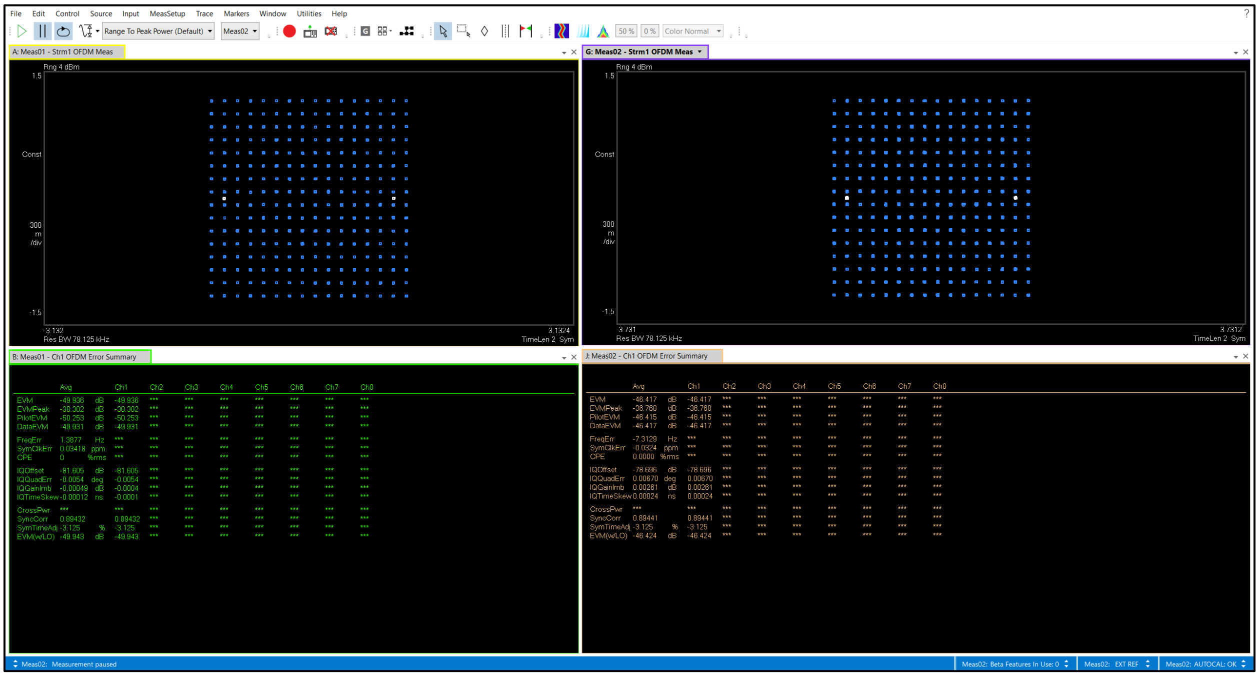

Figure 15. IQ-NC EVM measurement demonstration

Figure 15 compares EVM with IQ-NC enabled (Trace A) and without IQ-NC (Trace G). With IQ-NC enabled, a 3.5 dB improvement in EVM was achieved for a 320 MHz, 4096 QAM WLAN signal.

This technique provides a clear improvement in EVM performance using only a single receiver, delivering higher accuracy without additional hardware cost.

Software Features

Core Features (802.11a/b/g/j/p)

Option	**89601B7RC**	
Technology	**IEEE 802.11a/g/j/p OFDM**	**IEEE 802.11b/g DSSS/CCK/PBCC**
Operating modes		IEEE 802.11b long or short preamble/PBCC IEEE 802.11g PBCC22/ PBCC33
Preset to standard	IEEE 802.11a/g OFDM HiperLAN2 IEEE 802.11g DSSS-OFDM IEEE 802.11a/g turbo mode IEEE 802.11p DSRC IEEE 802.11j 10 MHz	DSSS CCK PBCC
Data modulation format	BPSK, QPSK,16QAM, 64QAM	Barker1/Barker2 CCK5.5/CCK11 PBCC5.5/PBCC11/PBCC22/PBCC33
Measure Results		
Time	•	•
Spectrum	•	•
Search time	•	•
CCDF	•	•
CDF	•	•
Equalizer impulse response	•	•
Channel frequency response	•	•
CPE (common pilot error)	•	
Correction	•	•
Error vector spectrum	•	•
Error vector time	•	•
IQ measured	•	•
IQ reference	•	•
Marker data	•	•
PDF	•	•
Preamble error	•	
Preamble frequency error	•	
Table Results		
Symbols/Errors	Symbol data bits, EVM, pilot EVM, CPE (common pilot error), IQ (origin) offset, frequency error, symbol clock error, sync correlation, number of symbols, modulation format, code rate, bit rate, IQ gain imbalance, IQ quadrature skew	Symbol data bits, IEEE 802.11b 1,000-chip peak EVM, EVM, magnitude error, phase error, IQ offset, frequency error, sync correlation, burst type, bit rate, number of data octets, data length

Core Features (802.11n/ac/ax/be/bn)

Option	89601BHXC				
Technology	**IEEE 802.11n**	**IEEE 802.11ac**	**IEEE 802.11ax**	**IEEE 802.11be**	**IEEE 802.11bn**
Operating modes	HT-greenfield HT-mixed Non-HT duplicate HT duplicate	VHT	SU MU Trigger-based Extended range	MU SU (non-OFDMA) Trigger-based	MU SU (non-OFDMA) Trigger-based (Distributed and non-Distributed) Extended Long Range
OFDMA	N/A	N/A	Uplink and downlink	Uplink and downlink	Uplink and downlink
SIG information	HT-SIG	SIG-A, SIG-B	SIG-A, SIG-B	EHT-U-SIG, EHT-SIG	UHR-U-SIG, UHR-SIG
MU -MIMO	N/A	Downlink Up to 4 users	Uplink and downlink Up to 8 users		
SU-MIMO	Up to 4 spatial streams	Up to 8 spatial streams			
Preset to standard	20 MHz 40 MHz	20 MHz 40 MHz 80 MHz 80+80 MHz 160 MHz	20 MHz 40 MHz 80 MHz 80+80 MHz 160 MHz	20 MHz, 40 MHz, 80 MHz, 160 MHz, 320 MHz	
Data modulation format	BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM, 256QAM	BPSK, QPSK, 16QAM, 64QAM, 256QAM, 1024QAM	BPSK, QPSK,16QAM, 64QAM, 256QAM,1024QAM, 4096QAM	
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	256, 128, 1024, 2048, 4096	
Pilot tracking	Amplitude, Phase and Timing				
Frequency estimation mode	Preamble only; Preamble & Pilots; Preamble, Pilots & Data				
Equalizer training	Preamble only; Preamble, Pilots & Data				
Channel Estimation Interpolation Filter	None/Linear; Triangular (with subcarrier length); Wiener (with channel delay spread)				
Compensate IQ mismatch	Yes				
Symbol time adjustment	Auto or manual				
Subcarrier spacing manual adjustment	Yes				
Subcarrier selection (for display)	Data subcarriers; pilot subcarriers				
Active antenna threshold	Yes				
Subcarrier reference points	Nearest ideal constellation points; user-specified points				
Multi-carrier filter	Yes				

Measurement Results

Option	89601BHXC				
Pre-Demodulation	**IEEE 802.11n**	**IEEE 802.11ac**	**IEEE 802.11ax**	**IEEE 802.11be**	**IEEE 802.11be**
Time	•	•	•	•	•
Spectrum	•	•	•	•	•
Phase noise spectrum	•	•	•	•	•
Search time	•	•	•	•	•
Raw main time	•	•	•	•	•
CCDF	•	•	•	•	•
CDF	•	•	•	•	•
PDF	•	•	•	•	•
Correction	•	•	•	•	•
OBW	•	•	•	•	•
Fixed equalization time	•	•	•	•	•
Demodulation – Non-Tabular Results					
Channel frequency response	•	•	•	•	•
Spectral flatness with limit mask	•	•	•	•	•
Common pilot error (CPE)	•	•	•	•	•
Equalizer impulse response	•	•	•	•	•
Error vector spectrum	•	•	•	•	•
Error vector time	•	•	•	•	•
IQ measured and IQ reference	•	•	•	•	•
IQ gain imbalance per subcarrier	•	•	•	•	•
IQ quad error per subcarrier	•	•	•	•	•
Preamble frequency error	•	•	•	•	•
In-band emissions			•	•	•
Phase noise spectrum	•	•	•	•	•
Eq MIMO condition number	•	•	•	•	•
MIMO frequency response	•	•	•	•	•
Demodulation - Tabular Results for IEEE 802.11n, IEEE 802.11ac					
Error summary (for each channel)	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, PSDU, 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, IEEE 802.11be, IEEE 802.11bn					
Error summary (for each channel, up to 8 channels)	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 (802.11ax)	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, PSDU CRC pass/fail, HE-SIG-A CRC pass/fail, L-SIG status, and detected punctured segments	
Burst info (802.11be)	Detected symbols for active burst (L-STF, L-LTF, L-SIG, RL-SIG, EHT-U-SIG1, EHT-U-SIG2, EHT-SIG, EHT-STF, EHT-LTF, EHT-DATA) with modulation format, length, power and EVM; total burst length, power, EVM; format, number of streams, standard, PSDU CRC pass/fail, EHT-U-SIG CRC pass/fail, Gamma phase rotation, L-SIG status, and detected punctured segments	
Burst info (802.11bn)	Detected symbols for active burst (L-STF, L-LTF, L-SIG, RL-SIG, UHR-U-SIG1, UHR-U-SIG2, UHR-SIG, UHR-STF, UHR-LTF, UHR-DATA) with modulation format, length, power and EVM; total burst length, power, EVM; format, number of streams, standard, PSDU CRC pass/fail, UHR-U-SIG CRC pass/fail, Gamma phase rotation, L-SIG status, and detected punctured segments	
SIG info	For 802.11ax, decoded fields of the HE-SIG-A and L-SIG and elements carried in the SIG symbols For 802.11be, decoded fields of the EHT-U-SIG, EHT-SIG1 and L-SIG and elements carried in the SIG symbols For 802.11bn, decoded fields of the UHR-U-SIG1, UHR-SIG1 and L-SIG symbols and elements carried in the SIG symbols	
RU info (for each detected RU)	EVM, start/stop subcarrier index, size (# of subcarrier), power, total users, total streams. For 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, CRC, gain imbalance (dB), quadrature error (dB) and MPDU CRC status For 802.11bn it includes equal modulation (UEQM) and 2xLDPC	
Unused tone EVM (for each channel; only for HE and EHT 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

Flexible Licensing and Configuration

- **Perpetual**: License can be used in perpetuity.
- **Subscription (time-based)**: License is time limited to a defined period, such as 12-months.
- **Node-locked**: Allows you to use the license on one specified instrument/computer.
- **Transportable**: Allows you to use the license on one instrument/computer at a time. This license may be transferred to another instrument/computer using Keysight's online tool.
- **Floating**: Allows you to access the license on networked instruments/computers from a server, one at a time. For concurrent access, multiple licenses may be purchased.
- **USB portable**: Allows you to move the license from one instrument/computer to another by end-user only with certified USB dongle, purchased separately.
- **Software support subscription**: Allows the license holder access to Keysight technical support and all software upgrades

Licenses Ordering Information

Option	Title	Description
89601200C (Legacy) **89601201C/89601202C/89601203C (New)**	Basic vector signal analysis and hardware connectivity	(One Required) This option provides the foundational vector signal analysis functionality and hardware connectivity necessary for WLAN signal analysis.
89601201C (or 89601200C)	Basic vector signal analysis and hardware connectivity	Advanced vector signal analysis all-inclusive with no frequency, bandwidth limits, up to 64 channels.
89601202C	Basic vector signal analysis and hardware connectivity	Standard vector signal analysis up to 55 GHz center frequency, 2.16 GHz bandwidth, and up to 4 channels support.
89601203C	Basic vector signal analysis and hardware connectivity	Essentials tier up to 8 GHz center frequency, 160 MHz bandwidth, single measurement channel and VSA instance.
89601B7RC	Wireless Connectivity Modulation Analysis	Enables modulation analysis for legacy WLAN standards, including 802.11a/b/g/j/p.
89601BHXC	High Throughput WLAN Modulation Analysis	Adds support for modulation analysis of the latest high-throughput WLAN standards, including 802.11n/ac/ax/be/bn.

Note: By selecting the appropriate combination of these options, customers can tailor the 89600 VSA software to meet their specific WLAN signal analysis requirements, ensuring comprehensive support for both legacy and cutting-edge WLAN standards, as well as advanced modulation formats like 4096QAM.

Software License Types and Terms

Software License Type	Software License	Support Subscription
Node-locked perpetual	SW1000-LIC-01	SW1000-SUP-01
Node-locked time-based	SW1000-SUB-01	Included
Transportable perpetual	SW1000-LIC-01	SW1000-SUP-01
Transportable time-based	SW1000-SUB-01	Included
Floating perpetual (single site)	SW1000-LIC-01	SW1000-SUP-01
Floating time-based (single site)	SW1000-SUB-01	Included
Floating perpetual (regional)	SW1000-LIC-01	SW1000-SUP-01
Floating time-based (regional)	SW1000-SUB-01	Included
Floating perpetual (worldwide)	SW1000-LIC-01	SW1000-SUP-01
Floating time-based (worldwide)	SW1000-SUB-01	Included
USB portable perpetual	SW1000-LIC-01	SW1000-SUP-01
USB portable time-based	SW1000-SUB-01	Included

For time-based licenses, KeysightCare support is included. For perpetual licenses, KeysightCare support subscription may be purchased using the following model numbers. For example, a one-month

One Month Software Support Subscription Extensions

Support Subscription	Description
SW1000-SUP-01	Perpetual KeysightCare support (1 month to 60 months)
SW1000-B2S	Back to KeysightCare support fee (Perpetual support only, one time fee) Minimum of 12 months required for a renewal

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/be/bn 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		
N9042B UXA	Up to 75 GHz	Up to 4 GHz
N9042B+V3050A	Up to 110 GHz	Up to 4 GHz
N9041B UXA	Up to 110 GHz	Up to 1 GHz
N9040B UXA	Up to 50 GHz	Up to 1 GHz
N9032B PXA	Up to 55 GHz	Up to 2 GHz
N9030B PXA	Up to 50 GHz	Up to 510 MHz
N9021B MXA	Up to 50 GHz	Up to 510 MHz
N9020B MXA	Up to 50 GHz	Up to 160 MHz
N9010B EXA	Up to 44 GHz	Up to 40 MHz
Modular Product		
M9415A/16A VXT PXIe Vector Transceiver	Up to 12 GHz per channel	Up to 1.2 GHz per channel
M9410A/11A VXT PXIe Vector Transceiver	Up to 6 GHz per channel	Up to 1.2 GHz per channel
M9421A VXT PXIe Vector Transceiver	Up to 6 GHz per channel	Up to 160 MHz per channel
Wireless Test Set		
E6680A/E6680E Wireless Test Set	6 GHz or 7.3 GHz per channel	Up to 800 MHz per channel

Keep Your 89600 VSA Software Up to Date

With rapidly evolving WLAN standards and continuous advancements in signal analysis, maintaining an active 89600 VSA software license ensures access to the latest features and enhancements.

To stay current, users must have a valid KeysightCare support subscription for one of the following base platform for vector signal analysis and hardware connectivity option:

- Legacy base platform option: 89601200C
- New base platform tiered option: 89601201C, 89601202C, or 89601203C

Only one of the above base platform option (legacy or new) is required.

In addition, users can select 89601B7RC and/or 89601BHXC for WLAN analysis capabilities:

- 89601B7RC — supports IEEE 802.11a/b/g/j/p
- 89601BHXC — supports IEEE 802.11n/ac/ax/be/bn

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 Software Option 89601200C/89601201C/89601202C/89601203C Basic VSA and Hardware Connectivity, Technical Overview, 5992-4210EN

Web

- www.keysight.com/find/89600VSA
- www.keysight.com/find/89601B7RC
- www.keysight.com/find/89601BHXC
- www.keysight.com/find/vsa_trial
- www.keysight.com/find/89600_software
- www.keysight.com/find/89600_hardware