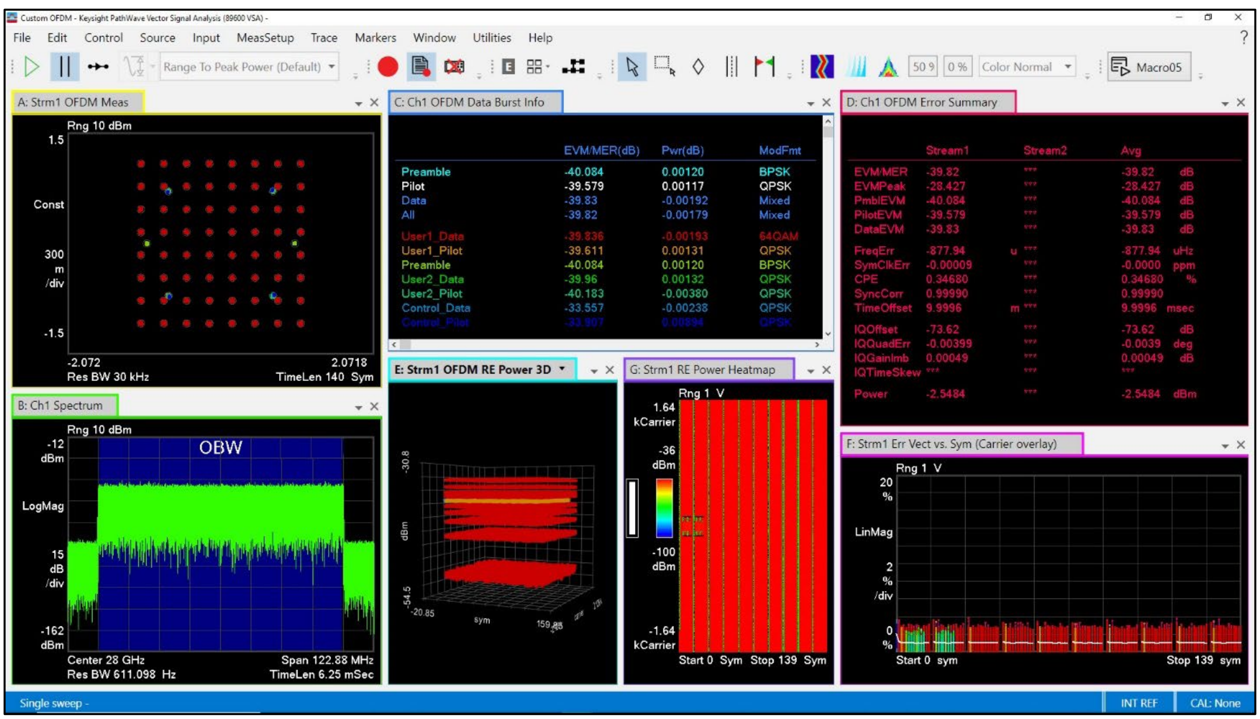
# Custom OFDM Modulation Analysis 89600 VSA Software

## Option 89601BHFC

- See through the complexity of custom OFDM systems
- Highly customizable parameter setup supports a broad range of modulation schemes, including OFDM/OFDMA, F-OFDM and FBMC, as well as multiple access schemes like DFT-S-OFDM and SCMA/NOMA
- FDD/TDD modes, up to 65,539 subcarriers
- Modulation formats from BPSK to 16384QAM
- Evaluate SISO and MIMO systems with channel, stream, and cross-channel measurements
- Use throughout the entire life cycle: from simulation and development to design verification and test
- Overall EVM, EVM across symbols and subcarriers, EVM per MIMO stream, constellation, burst summary, 3D Power, and more
- Flexible measurement displays with color coding and marker coupling features to characterize signals and troubleshoot errors

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# Custom OFDM Modulation Analysis

With Keysight's advanced OFDM measurement tools, you can analyze custom OFDM formats, including FDD, TDD, MIMO and multi-user systems. Take advantage of Option 89601BHFC's highly customizable parameter setup, which includes auto-detection of modulation type and the ability to assign users to symbols and subcarrier allocations. Its analysis capabilities allow for time- and frequency-selective measurements over some or all carriers or symbols, and you can perform channel, cross-channel, and per-stream measurements with error analysis on MIMO systems.

Custom OFDM is just one of over 75 signal standards and modulation types supported by the 89600 VSA software. This comprehensive set of tools for demodulation and vector signal analysis enables you to explore virtually every facet of a signal and optimize your most advanced designs. As you assess the tradeoffs, the 89600 VSA helps you see through the complexity.

## Custom OFDM technology overview

Multi-carrier modulation schemes, such as OFDM, represent significant challenges for those seeking to verify PHY-layer characteristics. Most OFDM signals are designed to an open commercial standard, and so are the tools that test them. While traditional spectrum analysis can measure simpler parameters such as frequency, power level, and spectral mask, the more in-depth quality measures such as error vector magnitude, carrier feedthrough, I-Q match, burst parameters, etc. require special capabilities found only with vector signal analysis tools flexible enough to work with custom OFDM systems.

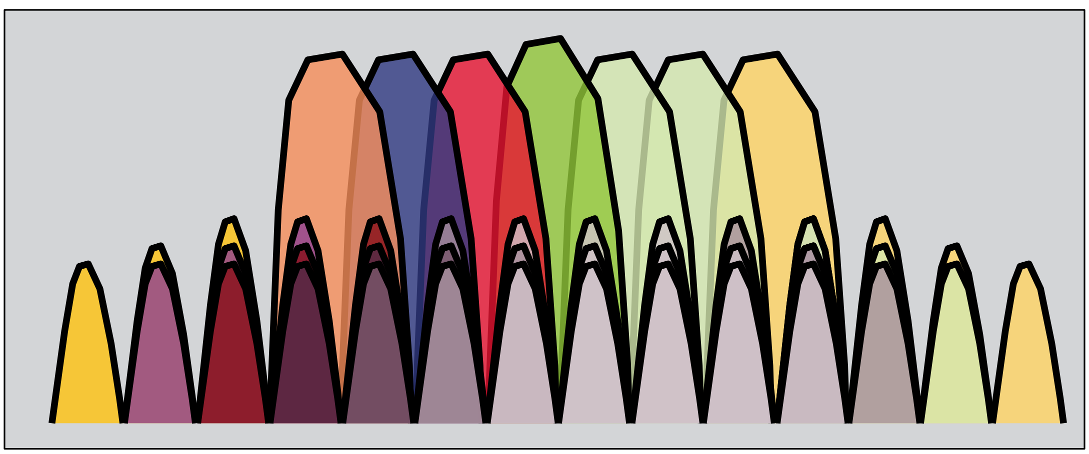

**Figure 1.** OFDM is a multi-carrier scheme where closely spaced carriers overlap. Nulls in each carrier's spectrum land at the center of all other carriers for zero inter-carrier interference

OFDM uses a multicarrier scheme to achieve occupied spectrum efficiencies (data rate per Hz of bandwidth) better than traditional, single-carrier schemes (QPSK, QAM, etc.), and with better immunity to common channel impairments.

OFDM is tolerant of multipath; spectral dropouts only affect a limited number of carriers, and the OFDM signal structure lends itself to strong equalization schemes, which can further reduce the effects of multipath. It can be made even more tolerant to multipath with the addition of more channels and MIMO signal processing techniques. Multi-carrier signals such as OFDM offer useful benefits for many digital communications applications, but with a tradeoff in signal and design complexity. OFDM signals are subject to the same sorts of design problems as any vector-modulated signal, but these can be difficult to uncover and troubleshoot without OFDM-specific signal analysis tools.

# Easy setup

The Custom OFDM demodulator offers user-configurable options for analyzing proprietary OFDM signals, including the early stages of emerging standards like 6G. Although it operates independently of specific standards, it includes presets for standards such WLAN and DVB-T/H.

To set up a custom OFDM measurement, the new Frame Definition properties simplify configuration and enhance usability. A frame can contain multiple flexible elements, referred to as allocations, which can be designated as Preamble, Pilot, Data, or Idle periods. Each allocation allows for a customizable payload, either using a PN sequence or a custom sequence, and the modulation type can be defined for each.

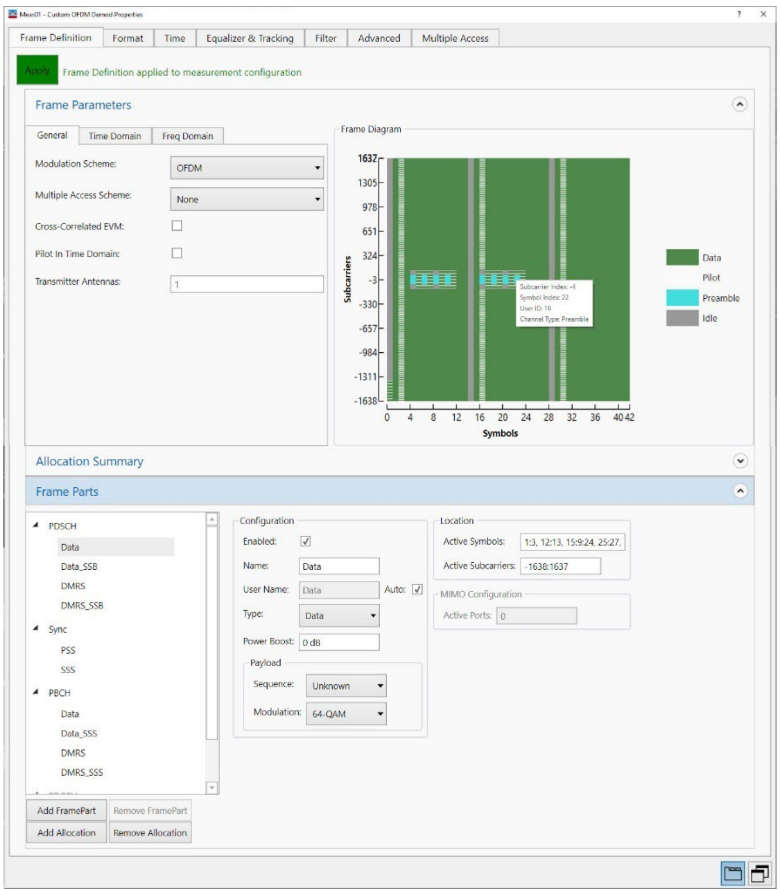


**Figure 2.** The comprehensive Frame Definition tab is used to configure and manage all settings, including both time and frequency domains. It also assembles frame parts and resource allocations necessary for demodulating and analyzing custom signals. The Frame Diagram provides a color-coded visual representation of the resource allocation within the frame. Hovering over the diagram displays a tooltip with Subcarrier Index, Symbol Index, User ID and Channel Type information at the cursor location.

In the legacy method of configuring custom OFDM, text-based configuration files are used to set up the resource map and resource modulation. These files provide detailed descriptions of each subcarrier in every symbol and specify the modulation type for each subcarrier. The modulation type can also be auto detected for blocks of similarly formatted subcarriers. Additionally, the I-Q files for preamble and pilot can be loaded as text files.

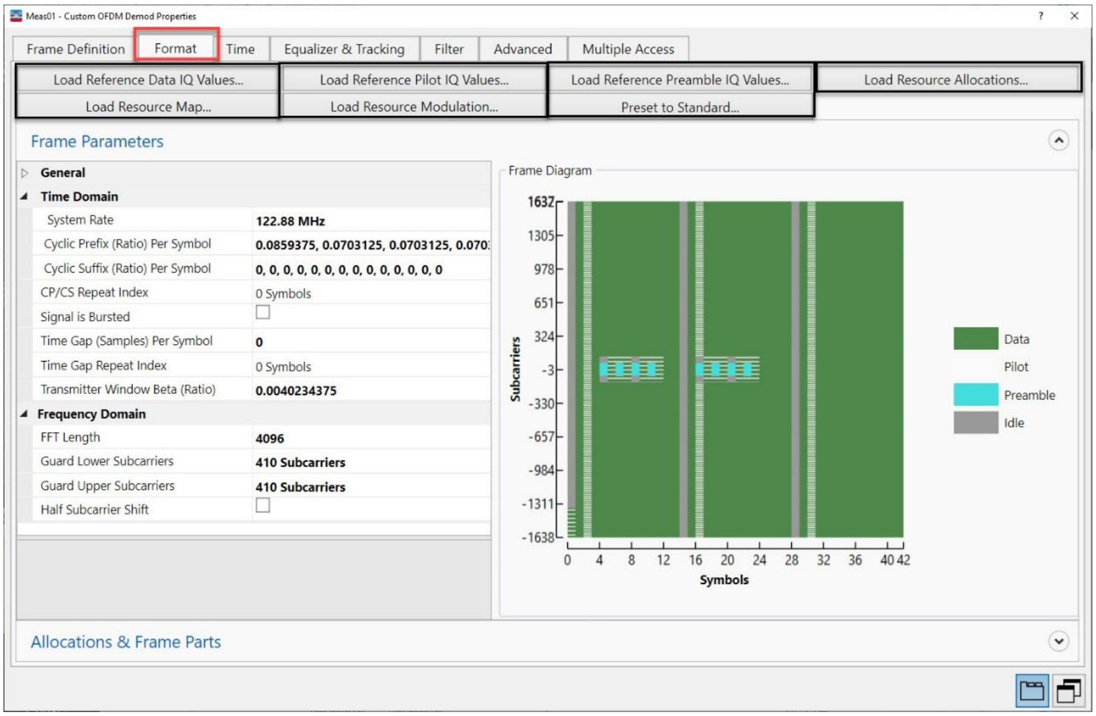


**Figure 3**. In the legacy method of configuring custom OFDM, the Format tab requires users to load multiple files for resource allocations, resource map, modulation formats, IQ values for the preamble and pilot, and more.

# Analysis and Troubleshooting

## Maximum format parameter control

In OFDM systems with hundreds or thousands of subcarriers, with preambles, pilots and payload data, there can be a large number of parameters to enter. However, the 89600 VSA simplifies this process with its highly flexible and easy to use user interface. In addition, the VSA supports up to 65K FFT length, allowing for arbitrary guard intervals and an asymmetric number of upper and lower guard subcarriers. For each allocation – whether data, pilot, or preamble - users can define subcarrier and symbol positions, select modulation formats ranging from simple BPSK to complex 16384QAM, and specify the payload sequence.

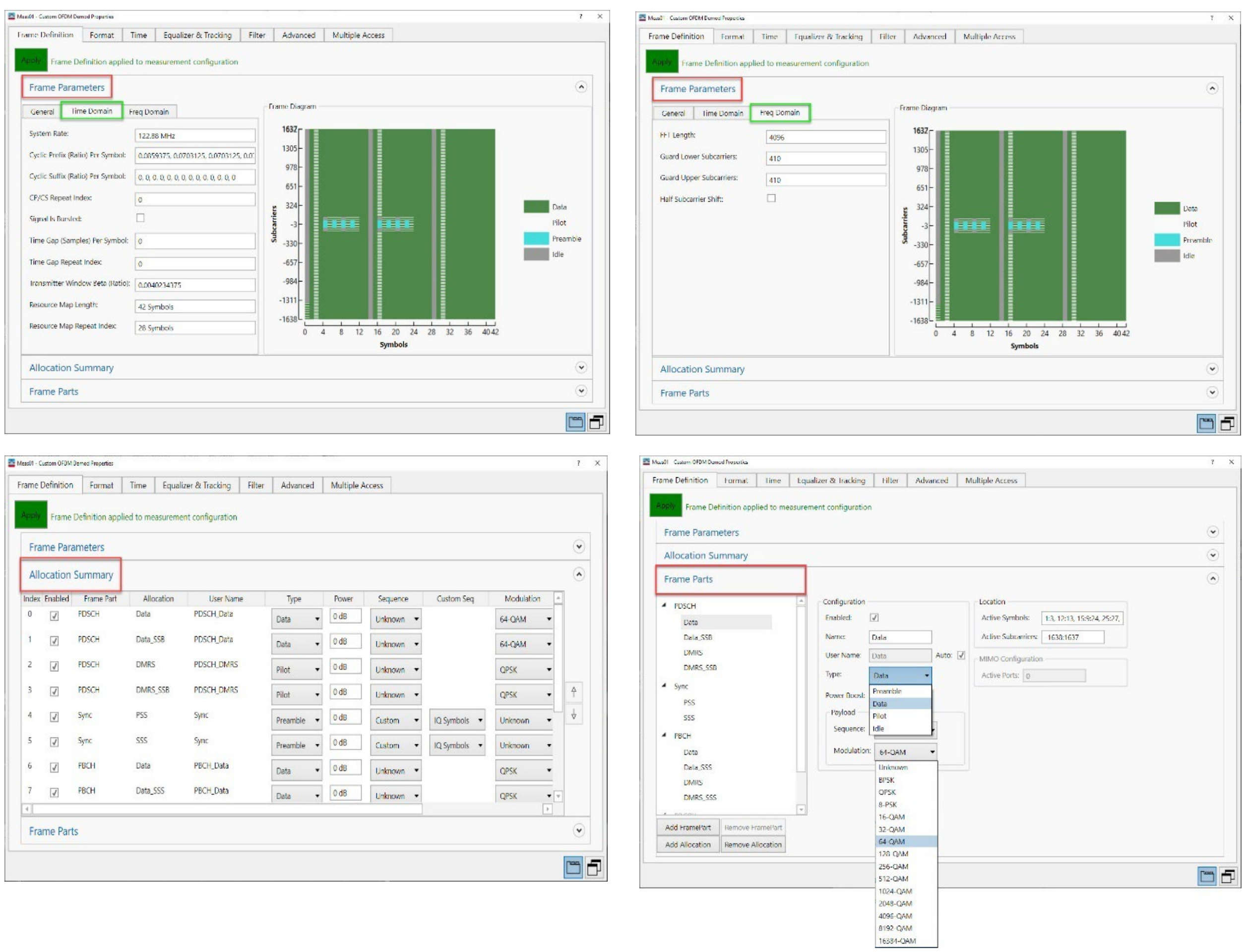


**Figure 4**. The Frame Definition tab in the Custom OFDM Properties Dialog Box is a single interface to configure all aspects of the input signal for successful demodulation. It allows you to set the frame's general settings, including time and frequency, and manage user allocations to define symbol and subcarrier locations, payload sequence and modulation formats.

# Unparalleled measurement flexibility

Troubleshoot signals using a wide range of error analysis tools and measurement displays to characterize your signal. Track down error sources using error tools provided by the 89600 VSA software: EVM by subcarriers or symbols, summary data with EVM, frequency and IQ errors by input channel, or burst info by signal type. Statistical analysis tools such as CCDF can help you determine component specifications.

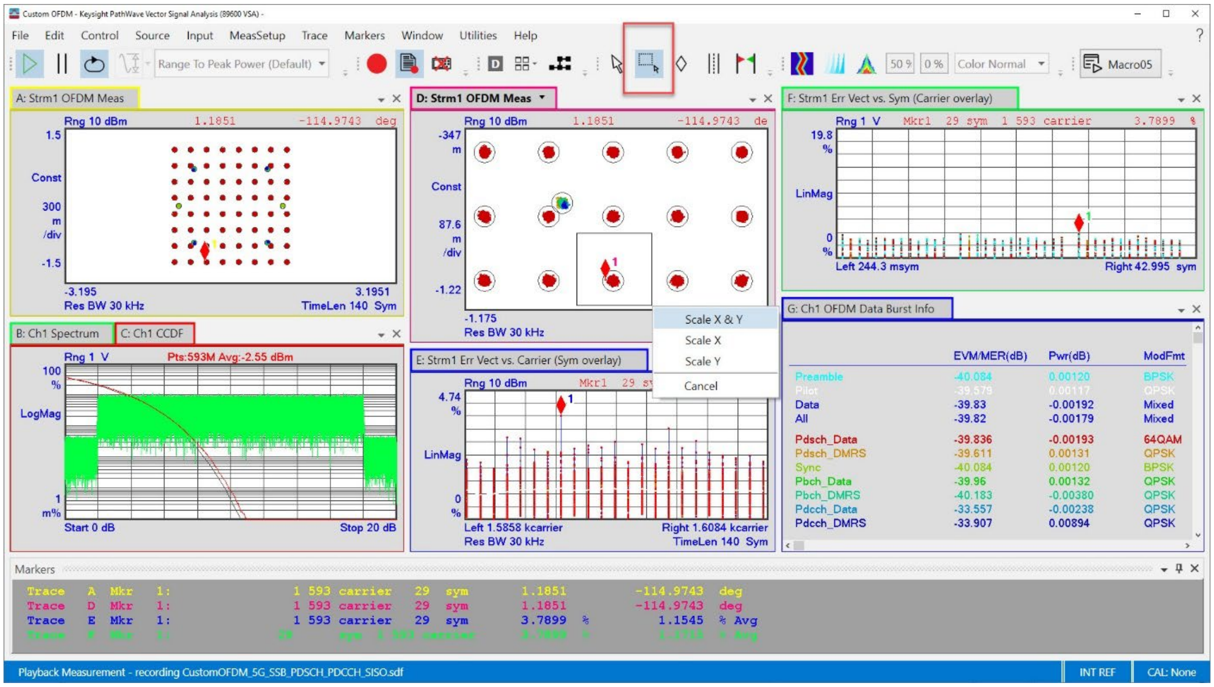


**Figure 5.** Look at the IQ constellation and use the expand tool on the software toolbar. Do the same on the error vector time trace to focus analysis on symbols of interest, or error vector spectrum trace to focus on a range of carriers. Coupled markers are useful to track symbol by symbol in multiple traces

# Insightful views

Traces are color-coded by modulation format or user ID for easy interpretation. Use as many traces and markers as you need to gain exceptional clarity in viewing your signal. Traces such as 3D and 2D power traces are particularly useful for evaluating power over symbols and subcarriers.


**Figure 6.** Easily view error performance by user with color-coding. Error vector traces in the spectrum, time, IQ constellation, and OFDM Data Burst Info are color-coded, making it simple to interpret and analyze errors.

# Perform MIMO analysis using supported multi-channel hardware

Configure the 89600 VSA software to analyze OFDM systems with up to 8x8 MIMO configurations. Various traces are available to provide insights into modulation quality, power, time alignment error (TAE) and phase offsets for each stream. The MIMO Info table (Figure 6, Trace H) presents both per channel and cross channel performance metrics, while the Burst Info table (Figure 6, Trace G) reports composite EVM and  EVM for each stream. Additional traces, including the MIMO condition number and channel frequency response, enables a thorough analysis of these complex systems.  For a list of supported multi-channel platforms, visit www.keysight.com/find/89600_hardware

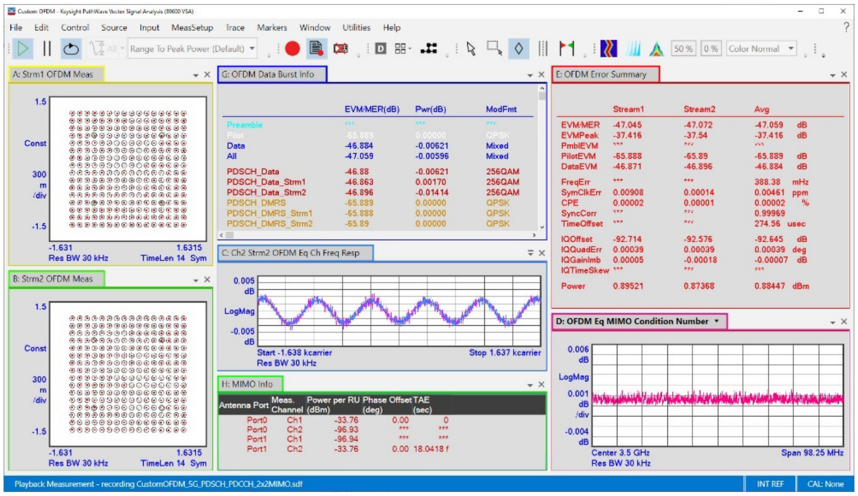

**Figure 7.** Benefit from the wide range of trace data available to thoroughly characterize and troubleshoot multi-channel MIMO systems

# Use the same tool to analyze signals throughout development life-cycle

The 89600 VSA software allows you to dynamically input data from either Keysight EEsof ADS or Keysight SystemVue during early development. Hardware connectivity, part of 89601200C, lets you obtain data from hardware using logic analyzers, oscilloscopes, signal analyzers, and modular instruments for multi-domain and cross-domain measurements during prototype development. Finally, use the remote programming capability to develop test programs for design verification and production test. All engineers use the same GUI with consistent setup and measurements, from the beginning to the end of product development.

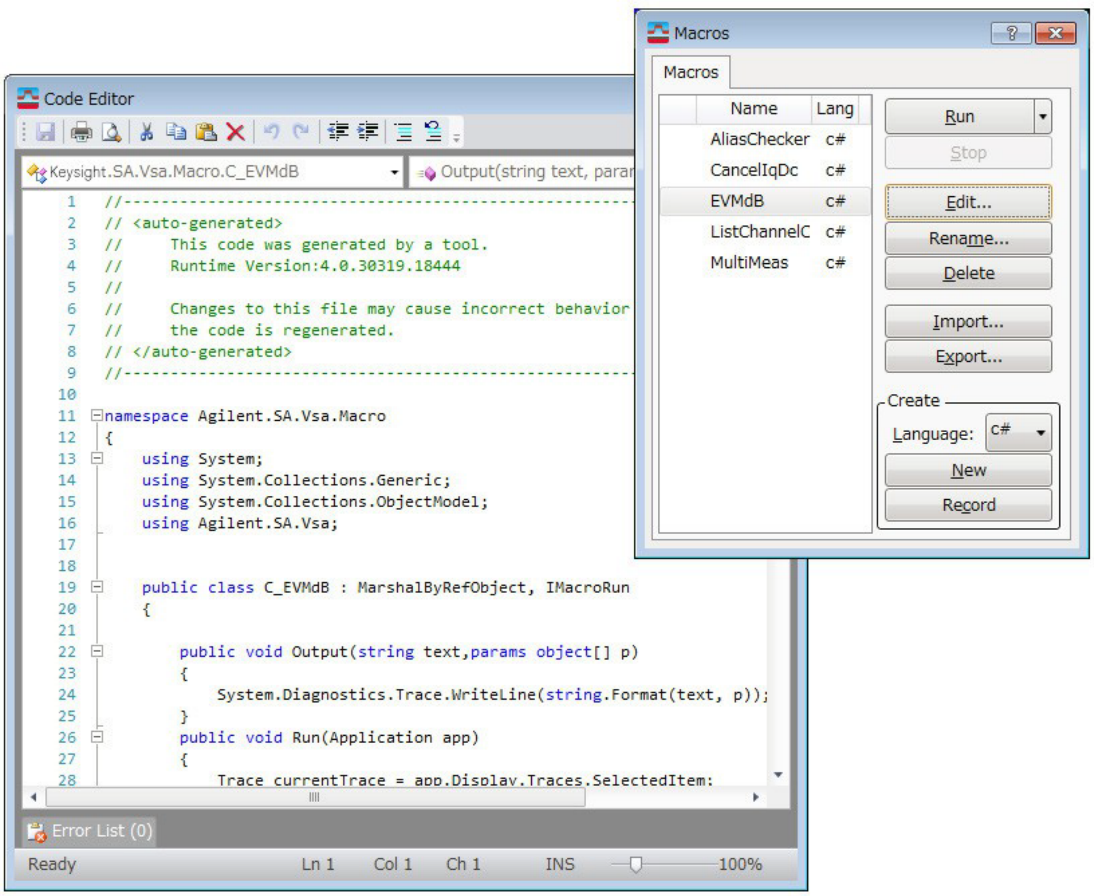


**Figure 8.** Develop test programs using familiar SCPI programming or any supported .NET programming language. For simpler tasks, automate a series of manual steps into a single command with macros

# Capture and re-analyze important signals

The 89600 VSA software includes signal record and playback capabilities. Use it to capture burst and transient signals for analysis. Take advantage of tools like overlap processing for detailed "slow motion" analysis.

The Block Diagram window provides a left-to-right flowing visual representation of the VSA measurement setup. Each block corresponds to a set of related parameters in the Menu Bar. You can click any block to open a dialog that contains the full set of related parameters (also accessible from the Menu Bar).

Dynamic Help allows you to access the help text and learn about the Custom OFDM format and its features. By detaching the Dynamic Help window and positioning it to the side of the screen, as shown in Figure 9, you can easily view it as it tracks your menu selections. You can also lock it to keep important Help topics readily available.

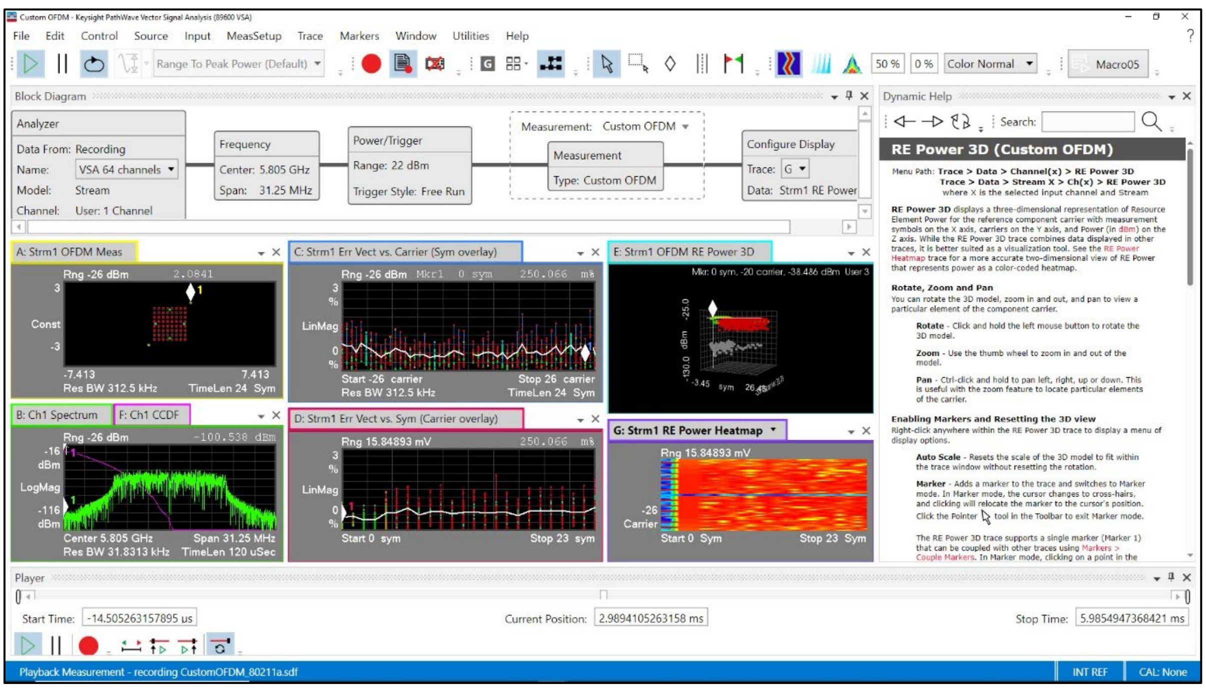


**Figure 9.** Dynamic Help explains useful information to explain measurements and other important Custom OFDM and 89600 VSA software operations with over 4000 pages of useful information.

# Enhanced EVM analysis with ccEVM and IQ-NC

Emerging technologies with wide bandwidth and high modulation format make EVM measurement performance more challenging, in particular when the transmitted signal power is low. Noise cancellation can reduce noise contributed by the signal analysis hardware, ensuring the measured EVM value mainly reflects the noise from the device under test (DUT). The 89600 VSA, with the 89601EVMC option, offers two noise cancellation techniques—Cross Correlated EVM (ccEVM) and IQ Noise Correction (IQ-NC)—to improve the EVM floor of the measurement hardware.

In ccEVM, multiple time synchronous signal analysis hardware (e.g., 2 for SISO, 4 for 2x2 MIMO) simultaneously capture and demodulate the same signal. By cross correlating the error vectors, uncorrelated noise introduced by the hardware is canceled out, resulting in a much lower EVM. This allows the ccEVM value to primarily reflect noise from the DUT, or from both the signal source and DUT in the case of an amplifier test.

In IQ-NC, a single receiver is used to compensate the acquired signal such that the measured EVM excludes noise contributions from the analysis hardware.  This is achieved by acquiring multiple repetitions of the same signal, using averaging to separate the noise from the signal, scaling the noise, and then recombining. In VSA2025, IQ-NC is in BETA support.

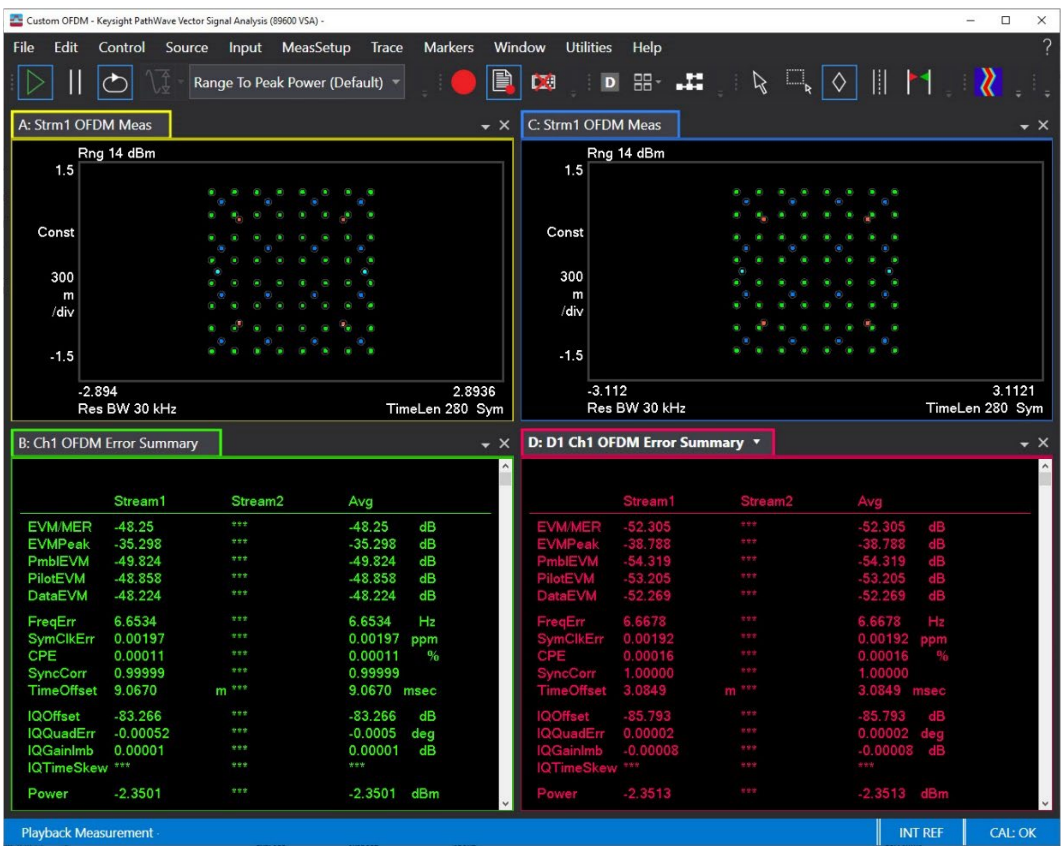


**Figure 10**. EVM without IQ-NC (Trace B) compared with IQ-NC EVM (Trace D). In this example, IQ-NC provides a 4 dB improvement in EVM.

# Software Features

## Core features

| Feature | Description |
|---|---|
| **Signal acquisition** | |
| Supported subcarrier types | Data, pilot, preamble, idle |
| Resource modulation formats supported | BPSK, QPSK, 8PSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM, 2048QAM, 4096QAM, 8192QAM,16384QAM |
| Input configuration file formats | .txt, .csv |
| MIMO spatial streams supported | 2x2, 3x3, 4x4, 8x8 using supported hardware |
| **Format adjustable parameters** | |
| **Signal format parameters setup** | |
| Preset to standard | WLAN 802.11a, 802.11ah; DAB mode 1, 2, 3, 4; DVB-T/H mode 2k, 4k, 8k; DVB-SH 1k; ISDB-T (mode 3); 5G NR provided as demo signal. |
| **Configuration file setup** | |
| Load pilot IQ values | Loads text file listing target IQ values for each defined pilot |
| Load preamble IQ values | Loads text file listing target IQ values for each defined preamble subcarrier |
| Load resource map | Loads text file listing subcarrier type, user ID, antenna number, all antennas for each subcarrier in each |
| Load resource modulation | Loads text file listing expected constellation for each subcarrier in each symbol |
| **Manual configuration parameters** | |
| Cross-correlated EVM | Enable the measurement for ccEVM (requires the 89601EVMC license) |
| FFT length | Set the FFT length used for OFDM transmission; must be a power of 2 up to 64K |
| Guard interval | Set the guard interval (cyclic prefix) |
| Guard lower subcarriers | Set the number of lower guard subcarriers which will be ignored for results |
| Guard upper subcarriers | Set the number of upper guard subcarriers which will be ignored for results |
| OFDM system sample frequency | Set the OFDM FFT sample rate |
| **Format details** | |
| Pilot IQ values | Specifies ideal I-Q values for each subcarrier identified as a pilot |
| Preamble IQ values | Specifies ideal I-Q values for each subcarrier identified as a preamble tone |
| QAM identifiers | Each entry provides index into QAM Levels array |
| QAM levels | Each entry in array specifies modulation type |
| Resource map | Specifies the subcarrier resource type (preamble, pilot, data, etc.) |
| Resource modulation | Specifies modulation used on each resource (subcarrier/symbol time) |
| Resource repeat index | Tells the analyzer where to loop after it reaches the end of the Resource Map file; for resource maps which include a repeating pattern of similarly-formatted symbols so that it is only necessary to define the pattern once |
| Burst signal status | Specifies whether the signal is bursted (pulsed) or continuous |
| Number of transmitter antennas | Set the number of transmitter antennas; max 4 |

| | |
|---|---|
| Transmitter window beta | Set how much windowing was used in the transmitter to smooth the transition between symbols |
| **Boosting details** | |
| QAM identifier boost levels | Set the boost power level for each QAM identifier |
| Unknown pilot boost level | Set the boosting level used for unknown pilot subcarriers |
| User boost levels | Set the boost power level for each user |
| **Time parameters** | **Accesses the signal capture parameters used to configure the pulse search length and isolate a segment of the time record for further viewing and data analysis** |
| Measurement interval | Set the time length, in symbols, of the measurement region used for computing and displaying the trace data results |
| Measurement offset | Set the time offset, in symbols, to the measurement region used for computing and displaying the trace data results |
| Result length | Set the maximum number of symbols analyzed, including preamble symbols |
| Result length selection | Enable/disable auto-determination of result length |
| Search length | Set the measurement acquisition length, in seconds |
| Pulse search details | Sets pulse search and automatic threshold status (on/ off); sets pulse search threshold value in dB |
| **Equalizer and tracking** | **Specifies equalizer and pilot tracking parameters** |
| Equalizer training | Equalizer training using any/all of data, DC pilot, pilots, preamble |
| Equalizer details | Sets details of equalizer behavior |
| • Averaging mode | Sets averaging mode used when averaging equalizer across multiple symbols |
| • Pilot tracking | Track any/all of amplitude, phase, timing |
| **Advanced parameters** | **Accesses advanced parameters used to adjust demodulation measurements and displays** |
| EVM normalized by reference | Specifies whether EVM calculations are normalized by the IQ Reference signal power |
| Extended frequency lock range | Set extended frequency lock range plus lock range width, in subcarriers |
| Mirror frequency spectrum | Enables/disables time-domain conjugation, which mirrors the frequency domain around the center frequency |
| Symbol time adjustment | Set symbol time adjustment to adjust the useful symbol time period (TFFT) within the OFDM extended symbol time period (TS) |
| Synchronization mode | Set the synchronization mode used when synchronizing to the signal, either time correlation or cyclic prefix |
| Display parameters | Enables/disables the display of any/all: Data subcarriers, EVM in %, pilot subcarriers, preamble subcarriers, subcarrier color based on user ID, sync correlation in %, null subcarriers |
| Normalize IQ traces | Enables/disables normalization of IQ Meas, IQ Ref, and Error Vector traces |
| Synchronization region | When automatic is selected, the full resource map for defining the reference signal for synchronization is utilized and the first 10 symbols of the acquisition are searched to synchronize the measured signal with the reference signal.<br>When manual is selected, users can manually define the reference interval/offset and search interval/offset for synchronization region. |

# Measurements results

| Feature | Description |
|---|---|
| **Channel data** | **These results are available for data appearing at channels 1 to n (n ≤ 8) of the measurement platform** |
| CCDF summary | Summary data including average and peak power, power level at different percentages of the power, and total number of points accumulated. |
| CCDF | Displays the complementary cumulative distribution function (CCDF) for the selected input channel |
| CDF | Cumulative distribution function for the data in the measurement interval |
| Correction | Correction curve used to correct for the frequency response of the input hardware and input digital filtering |
| Instantaneous spectrum | Spectrum computed before data is averaged |
| PDF | Probability density function (PDF) of the signal |
| Raw main time | Raw time data read from the input hardware or playback file for the selected channel, prior to correction or resampling |
| Search time | Time record data after resampling and time adjustment, used to search for the pulse (or burst) |
| Spectrum | Averaged Instantaneous Spectrum display |
| Time | Time record before digital demodulation and after pulse search |
| **Demodulation data** | **These results are available for each spatial stream in MIMO systems** |
| Channel frequency response | Channel frequency response for the specified spatial stream and measurement hardware input channel N (where N is the number of the channel) |
| Common pilot error | Shows the difference between the measured and ideal pilot subcarrier symbols |
| Eq impulse response | Equalizer impulse response between the selected data stream and input channel N (where N is the selected channel) |
| Inst Ch frequency response | Non-averaged Ch Frequency Response trace data |
| Error vect vs. sample (Sym overlay) | Shows the error vector values for each point in the pre-OFDM time grid (sample x OFDM symbol). To view the Error Vector data after the FFT is performed, use the Error Vect vs. Carrier (Sym overlay) trace |
| Error vect vs. sym (Sample overlay) | Shows the error vector values for each point in the pre-OFDM time grid (sample x OFDM symbol). This trace contains the same data as the Error Vector vs. Sample (Symbol overlay) trace, but with OFDM symbols on the x-axis and samples on the z-axis (overlay axis) |
| Error vect vs. carrier (Sym overlay) | Shows the error vector values for each point in the OFDM time-frequency grid. This trace contains the same data as the Error Vect vs. Sym (Carrier overlay) trace, but with subcarriers on the x-axis and OFDM symbols on the z-axis (overlay axis) |
| Error vect vs. sym (Carrier overlay) | Shows the error vector values for each point in the OFDM time-frequency grid (subcarrier x OFDM symbol). The x-axis represents OFDM symbols, while the overlay unit (z-axis) represents subcarriers |
| IQ measured | Measured IQ symbol values of the subcarriers, with one complex value for each subcarrier for each symbol-time in the burst |
| IQ reference | Reference IQ symbol values of the subcarriers, with one complex value for each subcarrier for each symbol-time in the burst |
| OFDM Burst Info | Summary table of basic burst information grouped by subcarrier type and modulation format. Burst information includes EVM, Power, modulation format and resource unit information. Resource type = "All" includes all Preamble, Pilot, and Data subcarriers |

| | |
|---|---|
| OFDM Error Summary | Table providing signal quality metrics of the demodulated signal within the measurement interval: EVM/MER, pk EVM, preamble EVM, pilot EVM, data EVM, frequency error, symbol clock error, CPE, sync correlation, time offset, IQ offset, IQ gain imbalance, IQ quadrature error, IQ time skew, and power |
| RE power 3D | Resource element (RE) power per symbol and per subcarrier |
| RE power heatmap | Two-dimensional representation of RE power, with symbols on the x-axis, carriers on the y-axis, and power (in dBm) represented by color. |
| RMS error vector spectrum | Computed difference between IQ Measured vector value and IQ Reference vector value, a complex value at each subcarrier for each OFDM symbol. The RMS Error Vector Spectrum is the RMS average EVM for each subcarrier for all symbols within the burst |
| RMS error vector time | Average error vector magnitude at each symbol-time |
| Symbols | Demodulated symbol data (raw binary bits) for each OFDM symbol and subcarrier detected |
| **Cross channel data** | **This data incorporates all input channels and provides data for MIMO measurements** |
| Cross-correlated error vector vs. carrier | Similar to the RMS Error Vect vs. Carrier trace, but it is calculated using the results of two measurements, similar to the ccEVM metric |
| Cross-correlated error vector vs. symbol | Similar to the RMS Error Vect vs. Sym trace, but it is calculated using the results of two measurements, similar to the ccEVM metric |
| Cross-correlated EVM summary | Shows the calculated cross-correlated EVM results when Cross-Correlated EVM is selected (true). The first row of the matrix displays the overall result. For MIMO signals, a separate result for each stream will be shown after the overall result |
| MIMO channel frequency response | Shows an overlay of all the individual Stream(N) Channel(N) Frequency Response trace data results for the current MIMO measurement; enables easy viewing and comparison of each measurement stream(N) channel(N) frequency response trace data result on a single display |
| OFDM burst info | Table showing what fields were detected in the burst along with EVM, power level, modulation format, and number of resource units for each field |
| OFDM equalizer MIMO condition number | Vector containing the "condition number" of the equalizer channel frequency response matrices; one condition number value for each subcarrier |
| OFDM error summary | Table providing a wide range of error information per physical channel plus an average of all channels |
| OFDM MIMO info | Shows a MIMO measurement's power per RU, phase offset and TAE for each antenna port |

# Key Specifications

This technical overview provides nominal performance specifications for the software when making measurements with the specified platform. Nominal values indicate expected performance, or describe product performance that is useful in the application of the product.

For a complete list of specifications refer to the measurement platform literature.

## X-Series signal analyzers

| Accuracy | PXA with Option B1X | MXA with Option B25 | EXA with Option B25 |
|---|---|---|---|
| Accuracy conditions | Sample IEEE 802.11a/g OFDM signal; 64 QAM format; Fc= 2.412 GHz; span = 25 MHz; 20 averages; input range = –20 dBm and signal level within 2 dB of full scale; | | |
| **Residual EVM** | | | |
| Equalizer training = preamble and data and pilots; pilot tracking = timing and phase | < –47 dB | < –46 dB | < –46 dB |

# Ordering Information

## Software licensing and configuration

Flexible licensing and configuration

- **Perpetual**: License can be used in perpetuity.
- **Subscription**: 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

## Basic vector signal analysis and hardware connectivity (89601200C) (required)

## Custom OFDM modulation analysis (89601BHFC)

| 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 |
| USB portable perpetual | SW1000-LIC-01 | SW1000-SUP-01 |
| USB portable time-based | SW1000-SUB-01 | Included |
| Floating (single site) perpetual | SW1000-LIC-01 | SW1000-SUP-01 |
| Floating (single site) time-based | SW1000-SUB-01 | Included |
| Floating (regional) perpetual | SW1000-LIC-01 | SW1000-SUP-01 |
| Floating (regional) time-based | SW1000-SUB-01 | Included |
| Floating (worldwide) perpetual | SW1000-LIC-01 | SW1000-SUP-01 |
| Floating (worldwide) time-based | SW1000-SUB-01 | Included |

**One-month KeysightCare Support and subscription**

| Software license | Software license type |
|---|---|
| SW1000-SUP-01 | 1-month support subscription renewal for perpetual license |

# Additional Resources

## Literature

- 89600 VSA Software - Brochure, literature number 5990-6553EN
- 89600 VSA Software - Configuration Guide, literature number 5990-6386EN
- 89600 VSA Software Basic Vector Signal Analysis and Hardware Connectivity Option 89601200C - Technical Overview, literature number 5992-4210EN
- Quickly Validate Designs for DOCSIS 3.1 Compliance - Application Brief, literature number 5991-4301EN

## Web

- www.keysight.com/find/89600
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- www.keysight.com/find/vsa_trial


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