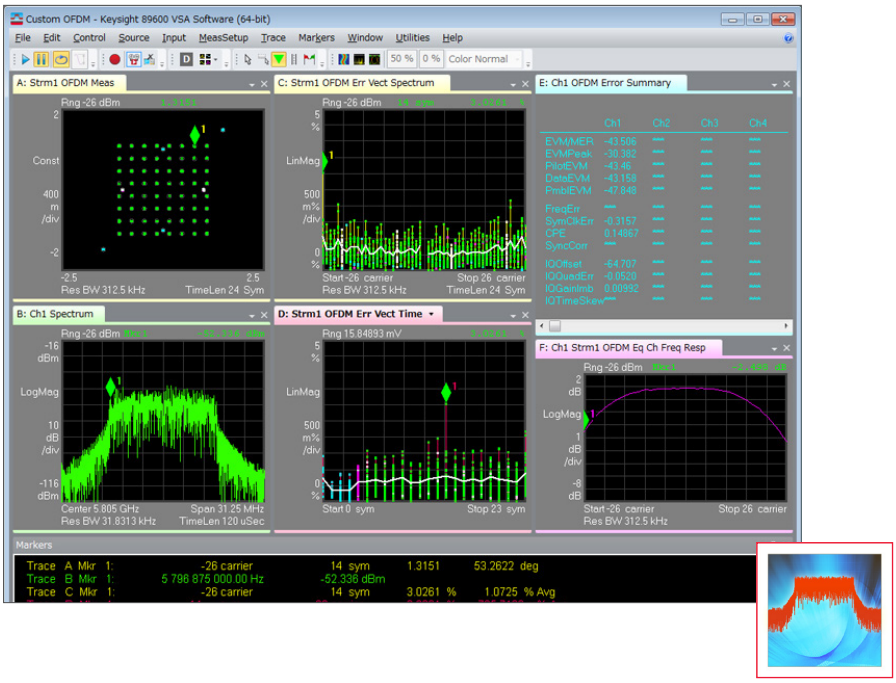
Keysight Technologies
89601B/BN-BHF Custom OFDM Modulation Analysis
89600 VSA Software

Technical Overview



- See through the complexity of custom OFDM systems
- Highly customizable parameter setup handles a wide range of signals
- Flexible measurement displays characterize signals and troubleshoot errors
- Evaluate SISO and MIMO systems with channel, stream, and cross-channel measurements
- Use throughout life-cycle: simulation, development, design verification and test

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Custom OFDM Modulation Analysis

Now you can use the Keysight Technologies, Inc. advanced OFDM measurement tools to analyze your custom OFDM formats, including FDD and TDD, MIMO and multi-user systems. Take advantage of Option BHF's highly-customizable parameter setup capability, including auto-detection of modulation type and the ability to assign users to subcarriers. Use its analysis capability to perform time- and frequency-selective measurements over some or all carriers or symbols. Make channel, cross-channel, and 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. 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 your most advanced designs. As you assess the tradeoffs, the 89600 VSA helps you see through the complexity.

Try Before You Buy!

Download the 89600 VSA software and use it free for 30 days to make measurements with your analysis hardware, or use our recorded demo signals by selecting File > Recall > Recall Demo > Signals > on the software toolbar. Request your free trial license today:

www.keysight.com/find/89600_trial

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.

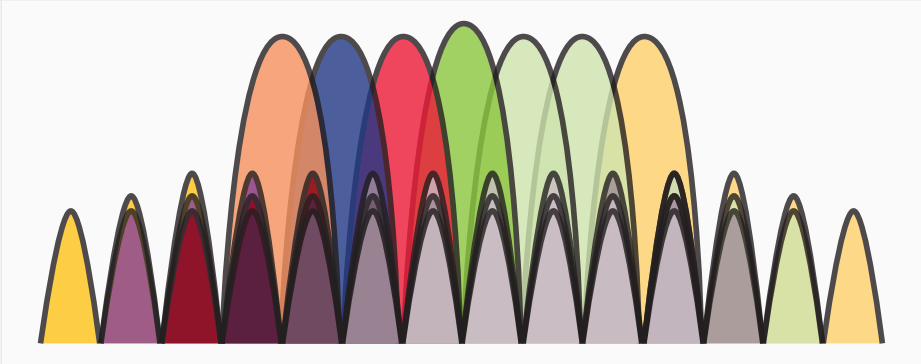


Figure 1. OFDM is a multi-carrier scheme where closely spaced carriers overlap. Nulls in each carrier's spectrum land at the center of all other carriers for zero inter-carrier interference.

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.

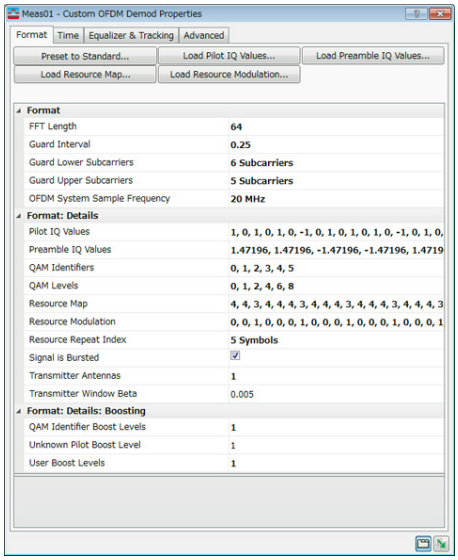


Figure 2. Comprehensive format setup parameters allow complete signal definition. Parameters on the Advanced tab provide a corresponding control of measurement and display configuration parameters as well.

Easy setup

Easily configure a complete signal description. Define subcarrier parameters per symbol using manual menu selections and text-based configuration files. The 89600 VSA software will read subcarrier modulation formats from a resource modulation file, or will auto-detect the modulation type for blocks of similarly-formatted subcarriers. Use simple and familiar tools like Microsoft Excel or Notepad to create the resource map, preamble IQ files and more.

Refer to OFDM demo signal setup parameters as examples or try DOCSIS 3.1 wizard to see how to configure OFDM parameters step-by-step.

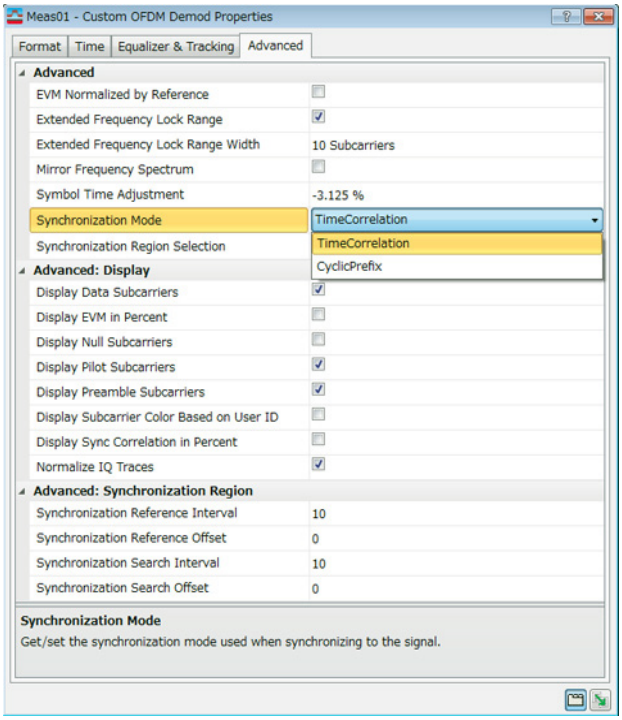
To obtain the DOCSIS 3.1 Downstream and Upstream configuration wizard, visit **http://www.keysight.com/find/89601B** and go to Technical Support, move to Drivers, Firmware & Software tab, and download DOCSIS 3.1 wizard.

For DOCSIS 3.1 MER measurements, you can use Option BHF custom OFDM. Option BHM is also available for DOCSIS 3.1 Downstream MER and BER.

Analysis and Troubleshooting

Maximum format parameter control

Choose FFT lengths up to 64K and arbitrary guard intervals, plus define an asymmetric number of upper and lower guard sub-carriers. Determine the number of pilots, along with arbitrary positions and modulation formats. In fact, you can choose all data, pilot, and preamble subcarrier/symbol modulation formats separately, using formats as simple as BPSK or as complex as 16384QAM, and assign a user ID to each subcarrier for user-based systems.



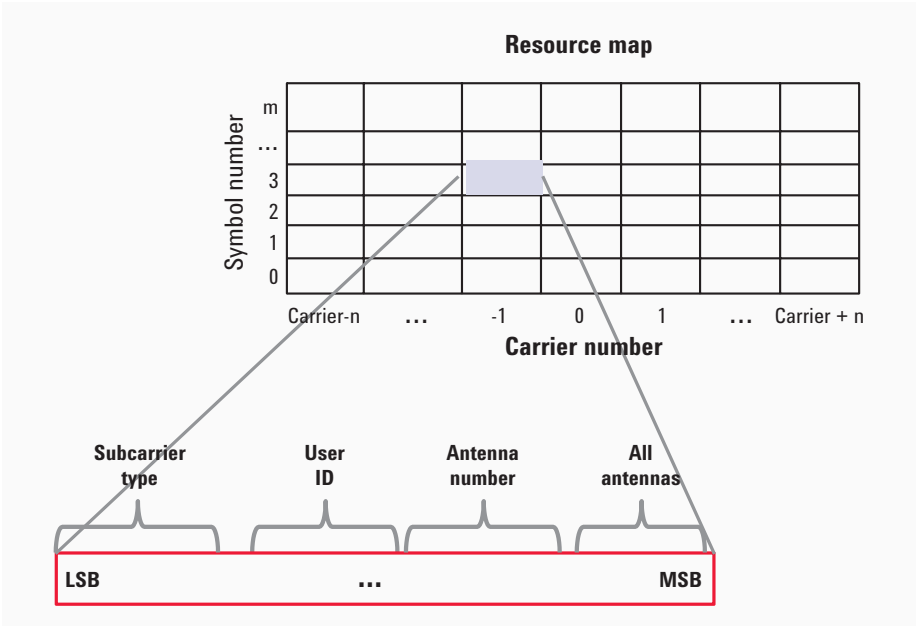


Figure 3. The resource map is a powerful, yet easy to understand, tool to provide signal information for complex custom OFDM formats, where each carrier/symbol combination has a different configuration. Similar tables define pilot and preamble IQ values and modulation type.

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 carrier or symbol, 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.

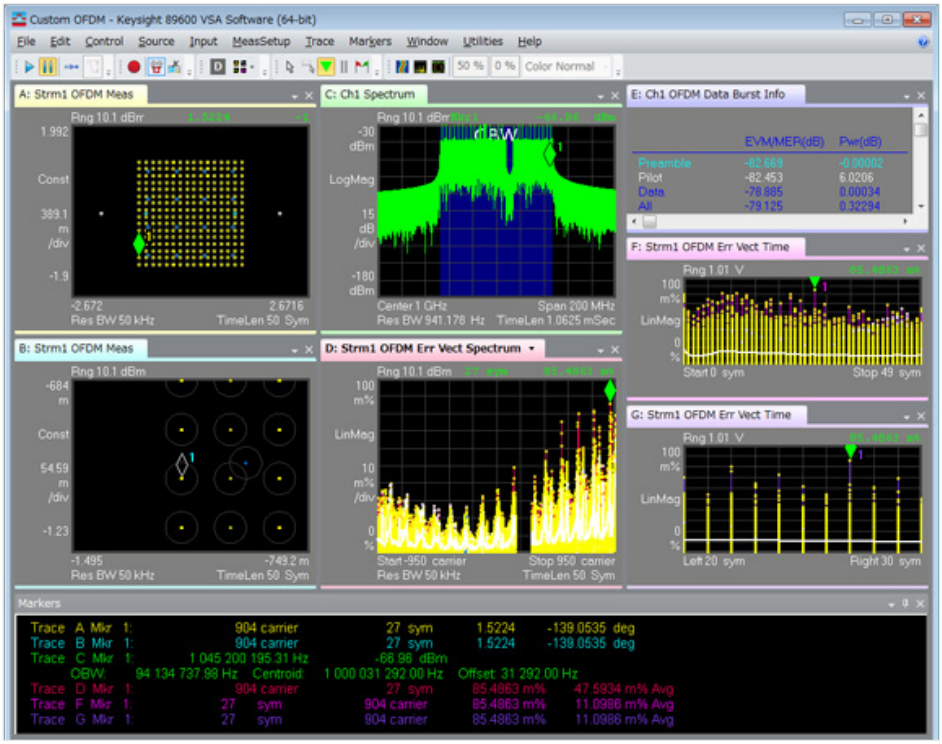


Figure 4. Look at the IQ constellation and use the expand tool on the software toolbar. Do the same on the error vector time trace to focus analysis on symbols of interest, or error vector spectrum trace to focus on a range of carriers. Coupled markers are useful to track symbol by symbol in multiple 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.

Figure 5. Easily view error performance by user with color-coding. Error vector traces in spectrum, time, IQ constellation and OFDM Data Burst Info are color-coded so you can easily understand error symbol profiles.

Perform MIMO analysis using supported multi-channel hardware

Set up the 89600 VSA software to analyze 2x2, 3x3, and 4x4 MIMO OFDM systems. Look at input channel data, stream data, and cross-channel data. Important information like common pilot error, MIMO condition number, and an error summary table help you thoroughly analyze these complex systems in a logical and comprehensive manner. For a listing of supported multi-channel platforms, go to **www.keysight.com/find/89600_hardware**.

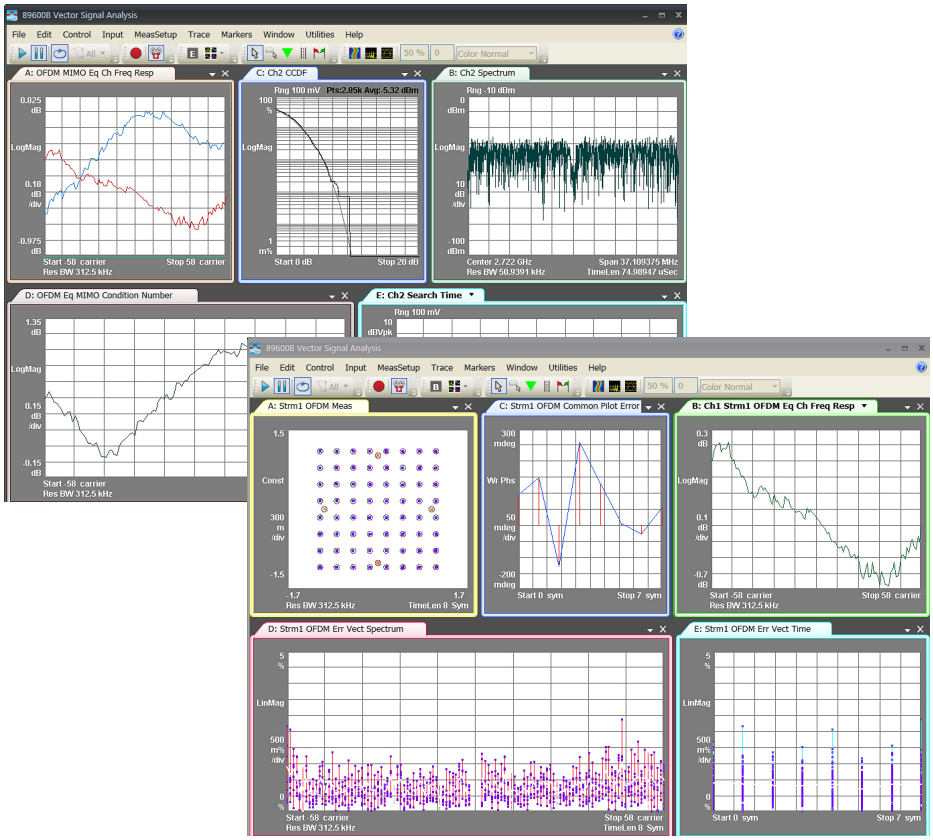


Figure 6. Benefit from the wide range of trace data available to thoroughly characterize and troubleshoot multi-channel MIMO systems.

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. Option 300 Hardware Connectivity 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.

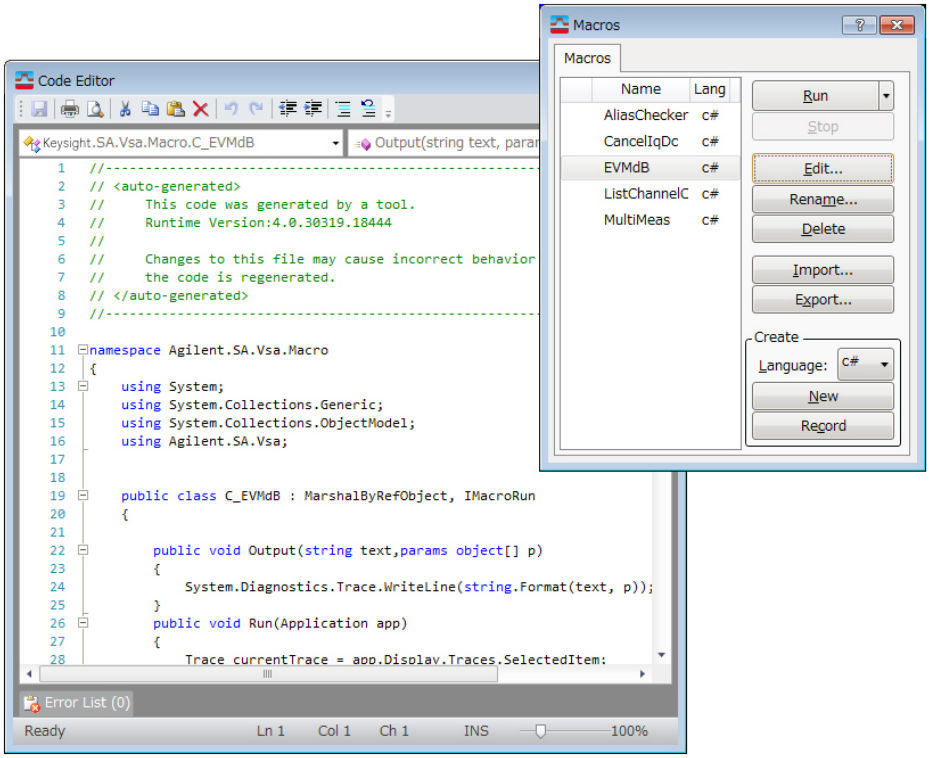


Figure 7. Develop test programs using familiar SCPI programming or any supported .NET programming language. For simpler tasks, automate a series of manual steps into a single command with macros.

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 and the spectrogram and cumulative history traces for evaluating the dynamic frequency and amplitude behavior of your signal over time.

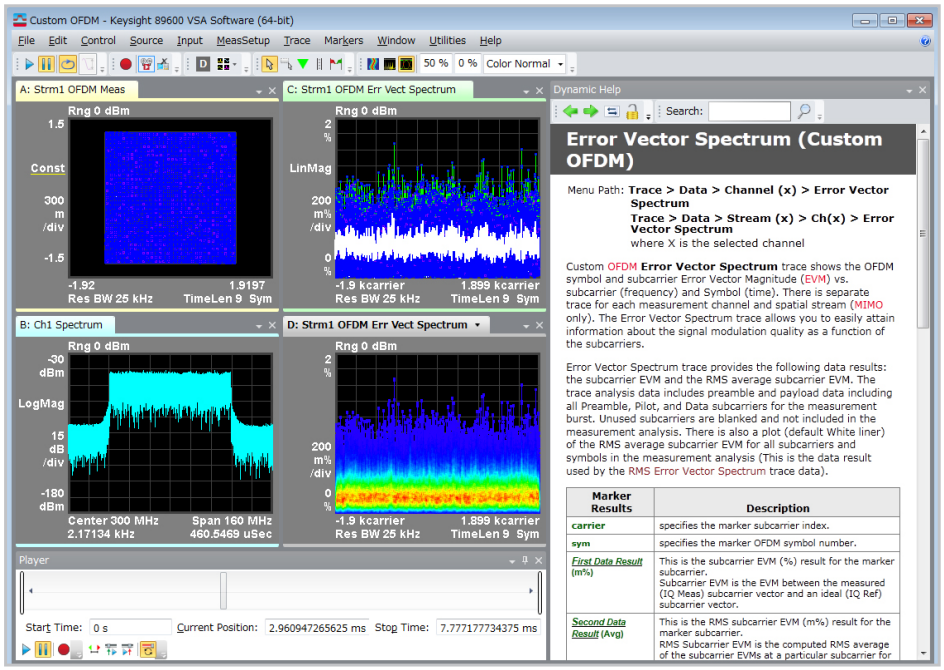


Figure 8. Dynamic Help explains overlap processing and other important custom OFDM and 89600 VSA software operations with over 4000 pages of useful information.

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Software Features

Signal acquisition	
Required configuration data	Symbol resource map, resource modulation information, preamble IQ, Pilot IQ
Supported subcarrier types	Data, pilot, unknown pilot, preamble, null
Resource modulation formats supported	BPSK, QPSK, 8PSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 1024QAM, 2048QAM, 4096QAM, 8192QAM, 16384QAM, 32768QAM, 65536QAM, unknown
Input configuration file formats	.txt, .csv
MIMO spatial streams supported	2x2, 3x3, 4x4 using supported hardware
Format adjustable parameters	
Signal format parameters setup	
Preset to standard	DAB mode 1, 2, 3, 4; DVB-T/H mode 2k, 4k, 8k; DVB-SH mode 1k; ISDB-T mode 3; WLAN 802.11a, 802.11ah
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 symbol
Load resource modulation	Loads text file listing expected constellation for each subcarrier in each symbol
Manual configuration parameters	
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 QamLevels 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 (T_{FFT}) within the OFDM extended symbol time period (T_S)
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. When manual is selected, users can manually define the reference interval/offset and search interval/offset for synchronization region.

Measurement results	
Channel data	**These results are available for data appearing at channels 1 to n (n ≤ 4) of the measurement platform**
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**
ChN 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)
ChN equalizer impulse response	Equalizer impulse response between the selected data stream and input channel N (where N is the selected channel)
ChN instantaneous channel frequency response	Non-averaged ChN Ch Frequency Response trace data
Common pilot error	Shows the difference between the measured and ideal pilot subcarrier symbols
Error vector spectrum	Computed difference between IQ Measured vector value and IQ Reference vector value, showing the signal EVM vs. frequency (subcarrier), a complex value at each subcarrier for each OFDM symbol
Error vector time	Signal EVM vs. time (symbols); a complex value at each subcarrier at each symbol-time showing the difference between IQ Meas and IQ Ref
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
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**
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

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

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www.keysight.com/find/89600_upgrades

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Additional Resources

Literature

89600 VSA Software, Brochure,
Literature number 5990-6553EN

89600 VSA Software, Configuration Guide,
Literature number 5990-6386EN

89600 VSA software Opt 200 Basic VSA and Opt 300 Hardware Connectivity, Technical Overview,
Literature number 5990-6405EN

Understanding the use of OFDM in 802.16, Keysight Measurement Journal,
Literature number 5989-6649EN

DOCSIS 3.1 Test Solution Reference Solution Overview,
Literature number 5991-4301EN

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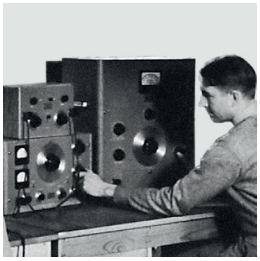

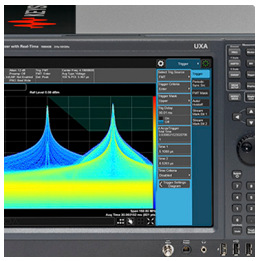

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