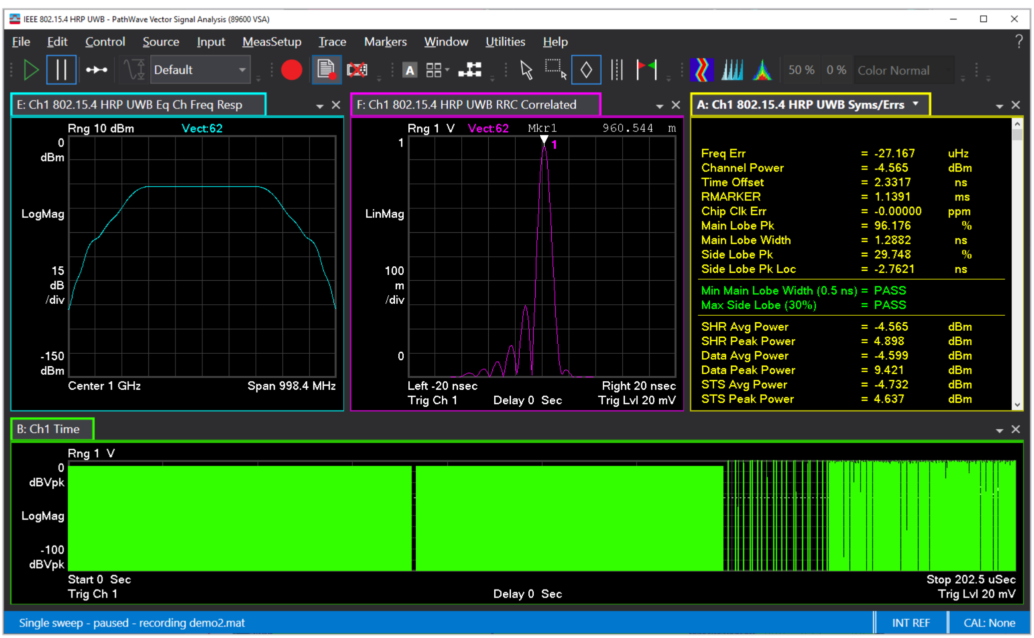
TECHNICAL OVERVIEW

802.15.4 HRP (High Rate Pulse Repetition Frequency) UWB (Ultra-Wide Band) Analysis PathWave Vector Signal Analysis (89600 VSA Software)

Option 89601BHTC (IoT Modulation Analysis)



- See through the complexity of IEEE 802.15.4/4z HRP UWB signals with a comprehensive set of tools for signal analysis
- Analyze HRP UWB signal quality: RRC correlated trace, main lobe/side lobe metrics with pass/fail indication, transmit mask, frequency and chip clock error and more
- Support wideband analyzers for HRP UWB signal analysis

What is HRP UWB?

HRP (High Rate Pulse Repetition Frequency) UWB (Ultra-Wide Band) technology is one of the PHY of the IEEE standard 802.15.4, in which it defines the PHY, MAC, and sublayers, with a focus on low-data-rate wireless connectivity and precision ranging. Different PHYs are defined for devices operating in various license-free brands in various geographic regions.

In January 2018, in response to demand for enhanced operation, the 802.15.4z task group was established. IEEE 802.15.4z is focusing on additional coding and preamble options, as well as improvements to existing modulations to increase the integrity and accuracy of ranging measurements, with a typical range of up 100 meters for the radio. It also enhances the MAC to support control of time of flight ranging procedures and exchange of ranging-related information between the participating ranging devices.

Table 1. HRP UWB Key Parameters as defined in IEEE 802.15.4/4z

Parameter	Description
Channel	1. The sub-gigahertz band (249.6 MHz to 749.6 MHz), which consists of a single channel 2. The low band (3.1 GHz to 4.8 GHz), which consists of four channels 3. The high band (6.0 GHz to 10.6 GHz), which consists of 11 channels
Bandwidth	499.2 MHz, 1081.6 MHz, 1331.2 MHz, 1354.97 MHz
Modulation schemes	BPM (Burst Position Modulation) + BPSK
PHY Mode	Non-HRP-ERDEV (802.15.4) HRP-ERDEV-BPRF (64 MHz PRF) (802.15.4z) HRP-ERDEV-HPRF (128 MHz PRF) (802.15.4z)
Data Rate	SHR: base rate 1 MSym/s (16/64 MHz PRF), 0.25 MSym/s (4 MHz PRF) PHR: 110 kbps, or 850 kbps Data: 110 kbps, 850 kbps, 6.81 Mbps or 27.24 Mbps
Frame Structure	SHR (synchronization header), PHR (Physical header), PHY payload field, STS (scrambled timestamp sequence)

HRP UWB Modulation Scheme BPM + BPSK

The PSDU (Physical Service Data Unit) performs systematic Reed-Solomon encoding and convolution encoding, and then every two data bits are encoded per BPM-BPSK symbol with $g_0^{(k)} \in \{0, 1\}$ which decides the burst position as first half or second half and $g_1^{(k)} \in \{0, 1\}$ which decides the burst polarity as positive or negative. See the below figure 1 and 2 for HRP UWB BPM+BPSK modulation

Notes: T_{dsym}: Overall symbol period; T_{BPM}: BPM (Burst Position Modulation) interval; $T_{BPM} = 1/2 * T_{dsym}$

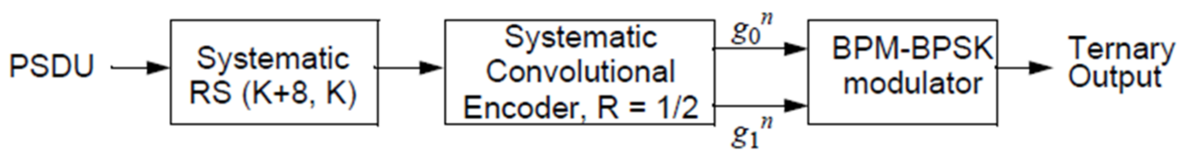


Figure 1 PSDU Encoding and Modulation Procedure

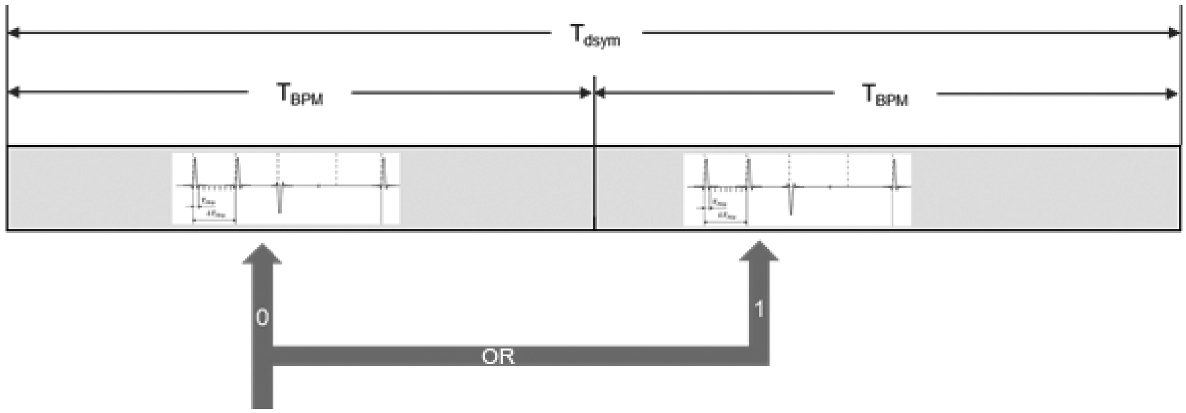


Figure 2 BPM + BPSK Modulation

HRP UWB Modulation Analysis

The 89600 VSA software's Option 89601BHTC provides comprehensive analysis capabilities in the frequency, time, and modulation domains for signals based on IEEE 802.15.4/4z standards (www.ieee.org)

The software provides frequency-, time-, and modulation-domain analysis results in a single measurement. By configuring result traces of spectrum, acquisition time, and HRP UWB-specific, signal quality traces and tables, engineers can identify overall signal characteristics and troubleshoot intermittent error peaks or repeated synchronization failures.

For automated testing, .NET API and SCPI remote interfaces are available to accelerate design, which enables quicker transition to the design verification and manufacturing phases.

HRP UWB is among over 75 signal standards and modulation types supported by the 89600 VSA software. The 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. As you assess your design tradeoffs, the 89600 VSA helps you cut through the complexity.

HRP UWB Measurement Summary

Table 2: Required HRP UWB transmitter measurements defined in IEEE 802.15.4

IEEE 802.15.4 Chapter #	Transmitter Test	89601BHTC HRP UWB Modulation Analysis
16.4.1	**Operating frequency bands** Channel 0 is mandatory for sub-gigahertz; Channel 3/9 is mandatory for low/high band	**Supports all channel 0 to 15**
16.4.2	**Channel assignment** support at least two complex channels for one of the mandatory band	**Supports all channels**
16.4.3	**Tx maximum allowable output PSD** comply to regulatory requirements (FCC: <-41.3dBm/MHz @3-10GHz)	**Spectrum**
16.4.4	**Tx maximum temperate range** 0º to 40ºC	**N/A**
16.4.5	**Baseband impulse response** the transmitted pulse p(t) shall have a magnitude of the cross-correlation function $\lvert\phi(\tau)\rvert$ whose main lobe is greater than or equal to 0.8 for a duration of at least Tw (See IEEE 802.15.4 Table 16-12 for Tw value), and any sidelobe shall be no greater than 0.3	**RRC Correlated** **Syms/Errs (Main Lobe Width and Side Lobe Pk, with Pass/Fail Indication)**
16.4.6	**Tx transmit PSD mask** Less than –10 dB relative to the maximum spectral density of the signal for $0.65/T_p < \lvert f - fc\rvert < 0.8/T_p$ Less than –18 dB for $\lvert f - fc\rvert > 0.8/T_p$ T_p is the inverse of the chip frequency The measurements shall be made using a 1 MHz resolution bandwidth and 1 kHz video bandwidth	**Transmit Mask (with auto-generated limit lines)**
16.4.7	**Chip rate clock and chip carrier alignment** UWB transmitter with an accuracy of $\pm 20 \times 10^{-6}$.	**Syms/Errs (Chip Clock Error)**
16.4.10	**Transmit center frequency tolerance** The HRP UWB PHY transmit center frequency tolerance shall be $\pm 20 \times 10^{-6}$.	**Syms/Errs (Frequency Error)**

Easy setup with complete parameter control

For successful demodulation and troubleshooting, configure your 89600 VSA using the easy to follow graphical user interface (GUI) and adjust a range of signal parameters, which are aligned with IEEE 802.15.4/4z specification.

Dynamic Help allows you to access the help text and learn about the HRP UWB format and features available for Option 89601BHTC. Detaching the Dynamic Help window and moving it to the side of the screen, as shown in Figure 3, enables easier viewing as it follows your menu choices. You can even lock it to stay fixed on important Help data topics.

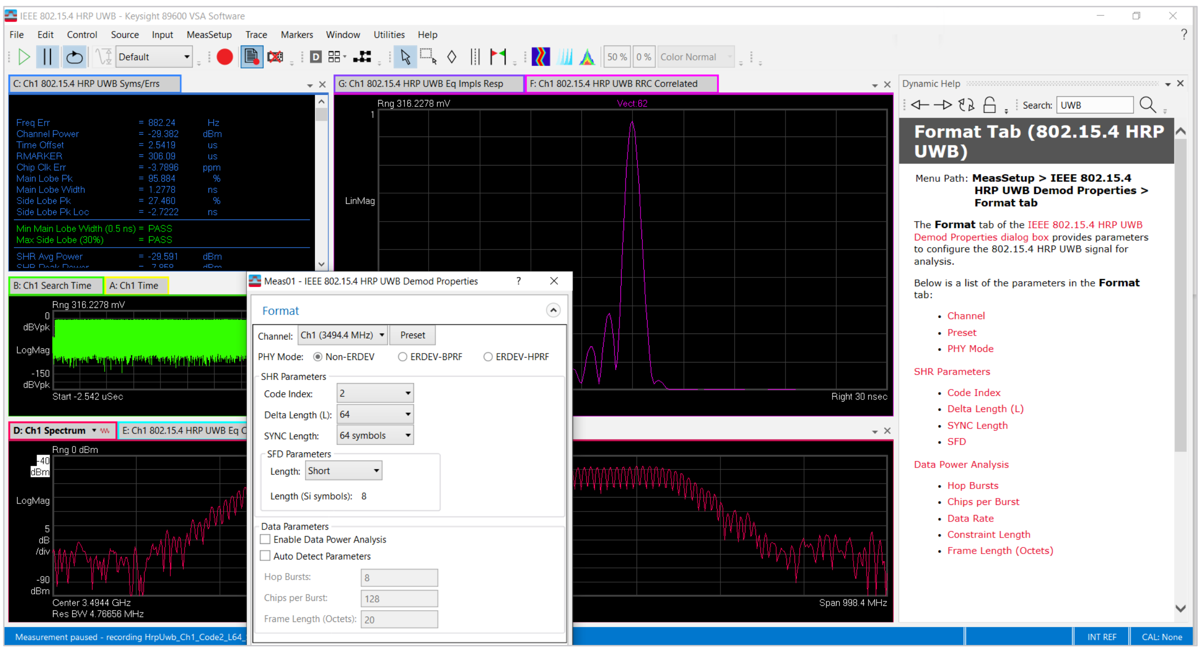


Figure 3: Setup is easy with complete parameter control. Dynamic Help provides useful information to explain measurements and other important HRP UWB and 89600 VSA software operations.

Understand the structure and quality of HRP UWB signal

Use the powerful demodulation and analysis tools to understand the structure and quality of the transmitted HRP UWB signal. A user has complete flexibility to choose the trace format and number of simultaneous traces. Figure 4 shows an example of an HRP UWB signal as Channel 1 with center frequency at 3494.2 MHz, and pulse bandwidth 499.2 MHz. Each of the six traces show an orthogonal view of the signal, and many more views are possible depending on the purpose of the analysis.

Descriptions of some of the HRP UWB measurement traces

- Trace C (top left) shows the Syms/Errs table including the frequency error, channel power, time offset, RMARKER location, Chip clock error, Main lobe Peak, Main Lobe Width, Side Lobe Peak, Side Lobe Location, Min Main Lobe Width and Max Side Lobe with Pass/Fail indication, SHR Avg/Peak Power, Data Avg/Peak Power, STS Avg/Peak Power
- Trace D (bottom left) shows the search time
- Trace G (top middle) shows the HRP UWB channel impulse response
- Trace B (bottom middle) shows the HRP UWB transmit mask
- Traces F (top right) shows the HRP UWB impulse response correlated with a root raised cosine filter, as specified by the standard
- Trace E (bottom right) shows the HRP UWB channel frequency response

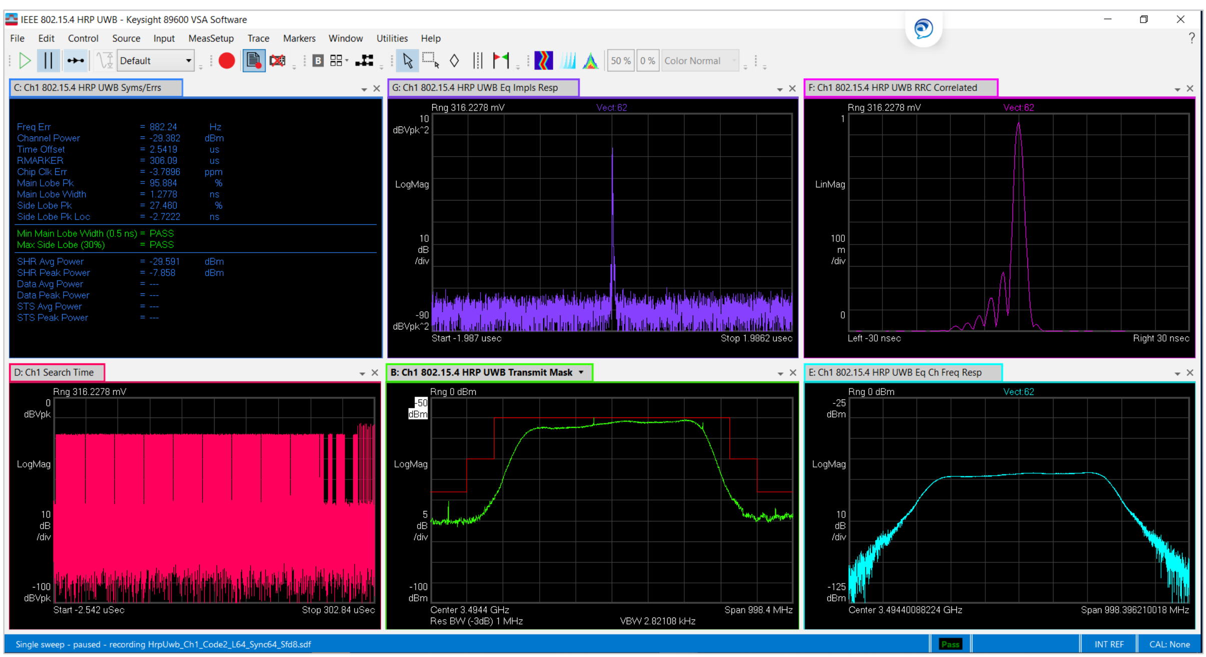


Figure 4: Example analysis of an HRP UWB signal

Software Features

Core supported features

Features	Description
Standard	IEEE 802.15.4 and 802.15.4z (www.ieee.org)
Format parameters	
Channel	Channel 0 (499.2 MHz as mandatory), Channel 1 (3494.4 MHz), Channel 2 (3993.6 MHz), Channel 3 (4492.8 MHz as mandatory), Channel 4 (3993.6 MHz), Channel 5 (6489.6 MHz), Channel 6 (6988.8 MHz), Channel 7 (6489.6 MHz), Channel 8 (7488.0 MHz), Channel 9 (7987.2 MHz as mandatory), Channel 10 (8486.4 MHz), Channel 11 (7987.2 MHz), Channel 12 (8985.6 MHz), Channel 13 (9484.8 MHz), Channel 14 (9984.0 MHz), Channel 15 (9484.8 MHz)
PHY Mode	Non-ERDEV (802.15.4-2015), ERDEV-BPRF (802.15.4z-D5) ERDEV-HPRF (802.15.4z-D5)
SHR Parameters	
STS Packet Configuration	No STS (0), After SFD (1), After PHR/Payload (2), After SFD (3)
Code Index	1-8 (non-ERDEV), 9-32 (all modes), 25-32 (ERDEV-HPRF)
Delta Length	4, 16, 64
Sync Length	16, 24, 32, 48, 64, 96, 128, 256, 512, 1024, 4096 symbols
SFD Length	Non-ERDEV: Short (8 symbols) or Long (64 symbols)
SFD #	HRP-ERDEV BPRF: 0, 2 HRP-ERDEV HPRF: 1, 2, 3, 4
Length (Si Symbols)	Short (8 symbols), Long (64 symbols) (Read-only)
STS Parameters	
Segment Length (x512 chips)	32, 64, 128, 256
Number of Segments	1, 2, 3, 4
Extra Gap (x4 chips)	0-127

Data Parameters	
Enable Data Power Analysis	On/Off (default Off)
Hop Burst	# set the number of hopping burst location in each half of BPM-BPSK symbol (only for Non-ERDEV)
Chip Per Burst	# sets the number of chips in each burst (only for Non-ERDEV)
Frame Length (Octets)	0-127 (Non-ERDEV), 0-4095 (ERDEV)
Data Rate	Low or High (only for ERDEV modes)

Constraint Length	CL3 or CL7 (only for HPRF-ERDEV)
Time Parameters	
Search Length	# in Seconds
Advanced Parameters	
Initial Frequency Error Compensation	On/Off (default On)
Chip Clock Error Compensation	On/Off (default On)

Core supported measurements

Pre-demodulation measurements	
CCDF	Displays the complementary cumulative distribution function (CCDF) for the data in the Time trace
CDF	Cumulative density function for the data in the Time trace
Correction	Correction curve used to correct for the frequency response of the input hardware and input digital filtering
Instantaneous Spectrum	Non-averaged frequency spectrum of the data in the Time trace
PDF	Probability density function (PDF), a normalized histogram of the data in the Time trace
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 frame
Spectrum	Frequency spectrum of the Time trace
Time	Time data of the frame that is to be analyzed
Demodulation	
Eq Ch Frequency Response	shows the channel frequency response calculated from the SYNC portion of the SHR
RRC Correlated	shows the cross-correlation between the measured UWB pulse and a root raised cosine (RRC) pulse. The RRC pulse has a 3 dB bandwidth as defined in Table 16-11 of the standard for the selected Channel.
Transmit Mask	shows the spectrum of the signal with limit lines as defined by the standard (0 dBr is set to the maximum value within $\|f\| \leqslant 0.65$ / Tp).
Eq Impulse Response	shows the 802.15.4 HRP UWB signal's impulse response, which is computed from the SYNC portion of the SHR. Eq Impulse Response is averaged over all repetitions of the Si symbol, except for the first and last repetition.

Syms/Errs	contains error information and other measurement data • Freq Err - Average carrier frequency error • Channel Power - Average power of the SYNC portion of the frame • SHR Avg Power - Average SHR power • SHR Peak Power - Peak SHR power • Data Avg Power - Average data (PHR+Payload) power • Data Peak Power - Peak data (PHR+Payload) sample power • Time Offset - Time offset between the Time and Search Time traces (second) • RMARKER (second) • Chip Clk Err - Error between standard chip clock (499.2 MHz) and signal chip clock (ppm) • Main Lobe Pk - Amplitude of main lobe (%) • Main Lobe Width - Width of main lobe • Side Lobe Pk - Amplitude of peak sidelobe (%) • Side Lobe Pk Loc - Location of peak sidelobe relative to main lobe • Min Main Lobe Width – PASS/FAIL of the minimum main lobe width requirement • Max Side Lobe – PASS/FAIL of the maximum sidelobe height requirement
Demodulated bits	• Shows the bits for each symbol after demodulation
Decoded bits	• Show PSDU decoding bits after Reed-Solomn decoding (if applicable) • Show PHR + PSDU decoding bits with FEC containing the bits after convolutional encoding is removed

Ordering Information

Software licensing and configuration

Flexible licensing types and configuration

- Perpetual: License can be used in perpetuity.
- Time-based: License is time limited to a defined period, such as 6, 12, 24, or 36 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

Upgrade your Existing Software

All 89600 VSA software options can be added after initial purchase and are license-key enabled. Some require the latest software version with update subscription service. To learn more and upgrade your software, visit: www.keysight.com/find/89600_upgrades.

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

IoT modulation analysis (89601BHTC)

Software License Type	Software License	Support Subscription
Node-locked perpetual	R-Y5A-001-A	R-Y6A-001-z[2]
Node-locked time-based	R-Y4A-001-y[1]	Included
Transportable perpetual	R-Y5A-004-D	R-Y6A-004-z[2]
Transportable time-based	R-Y4A-004- y[1]	Included
Floating perpetual (single site)	R-Y5A-002-B	R-Y6A-002- z[2]
Floating time-based (single site)	R-Y4A-002- y[1]	Included
Floating perpetual (regional)	R-Y5A-006-F	R-Y6A-006- z[2]
Floating time-based (regional)	R-Y4A-006- y[1]	Included
Floating perpetual (worldwide)	R-Y5A-010-J	R-Y6A-010- z[2]
Floating time-based (worldwide)	R-Y4A-010- y[1]	Included
USB portable perpetual	R-Y5A-005-E	R-Y6A-005-z[2]
USB portable time-based	R-Y4A-005- y[1]	Included

1. y means different time-based license duration. F for six months, L for 12 months, X for 24 months, and Y for 36 months. All time-based licenses have included the support subscription same as the time-base duration.
2. z means different support subscription duration. L for 12 months (as default), X for 24 months, Y for 36 months, and Z for 60-months. Support subscription must be purchased for all perpetual licenses with 12-months as the default. All software upgrades and KeysightCare support are provided for software licenses with valid support subscription.

Hardware configuration

The 89600 VSA software supports more than 45 Keysight hardware platforms including signal analyzers, one-box-testers, and oscilloscopes. For a complete list of currently supported hardware, please visit:
www.keysight.com/find/89600_hardware

Keep your 89600 VSA up-to-date

With rapidly evolving standards and continuous advancements in signal analysis, the 89600 VSA software with valid 89601200C and 89601BHTC KeysightCare support subscription can offers you the advantage of immediate access to the latest features and enhancements available for the 89600 VSA software. Refer the VSA Configuration Guide (5990-6386EN) for more details.

Upgrade your 89600 VSA software up to date (89601B to 89601C)

Keysight now launches the new 89600 VSA software as 89601C after September 2019 as version 2019 update 1.0, the existing 89601B customers can continue to use the new 89601C software with valid 89601B licenses or can visit the Keysight software upgrade webpage to fill in their current 89601B software license information and get a quote for upgrading from 89601B licenses to 89601C licenses.

https://upgrade.software.keysight.com/software_upgrade_form.html

Additional Resources

Literature

- 89600 VSA Software, Brochure, 5990-6553EN
- 89600 VSA Software, Configuration Guide, 5990-6386EN
- 89600 VSA Software Basic Vector Signal Analysis and Hardware Connectivity Option 89601200C, Technical Overview , 5990-4210EN
- 89600 VSA Software NB-IoT modulation analysis (IoT Modulation Analysis) Option 89601BHTC, Technical Overview, 5990-4207EN
- 89600 VSA Software RFID Modulation Analysis (IoT Modulation Analysis) Option 89601BHTC, Technical Overview, 5990-4223EN

Web

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