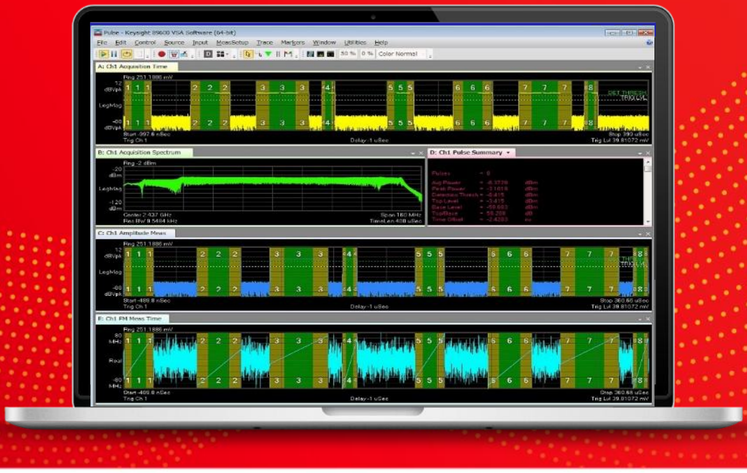

TECHNICAL
OVERVIEW

Pulse Analysis – PathWave Vector Analysis (89600 VSA)

Option 89601BHQC (replacing the 89601B/BN/BK-BHQ)

Key Features

- Identify and log key metrics for pulse modulated radar signals in aerospace, defense, and electronic warfare.
- Verify pulse accuracy relating to modulation quality, RF power, amplitude settling, time metrics, pulse compression, emitter deinterleaving, frequency hopping, pattern search, and angle-of-arrival with detailed summary tables.
- Connect to over 400 Keysight instruments, from broadband oscilloscopes to high-end signal analyzers and streaming digitizers.
- Leverage segmented capture to record only the active part of the pulse, optimizing memory usage of stored waveform files.
- Extend your analysis with advanced radar, enabling independent pulse tables per channel, and analysis of regions of constant phase, frequency or chirp rate within an RF burst.
- Look for pulse metric trends and evaluate system robustness using cumulative statistics, histograms, and trend lines.
- Visualize pulse power, frequency, and time with the instantaneous acquisition spectrogram trace view.
- Determine emitter angle based on multi-channel scan patterns over tens of seconds.
- Compare measured individual and trains of pulses to references, delivering insights on pulse quality and pulse signature patterns.

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The Problem Statement

For military radar engineers, radar is all about protecting the men and women that may be stepping into harm's way. For air and ground traffic control, radar is about safety. For scientists, radar is about collecting data on natural phenomena and planetary systems. Clearly, the applications for radar are vast, and for EW, the implications of failure can be dire. The technology has evolved enormously since World War II when radar was first taken seriously. Teams from around the world are working to improve radar system speed, resolution, and accuracy in the face of noise and even in the presence of hostile electromagnetic environments. Today, electronic warfare systems are required to identify targets and signals quickly to provide appropriate responses in a very dynamic environment. Pulses are now modulated with multiple types of modulation to improve range resolution, with frequencies hopping rapidly to avoid detection. Pulse amplitudes must rise and fall with prescribed envelopes. Our measurement systems and analytical tools need to keep up.

Try Before You Buy!

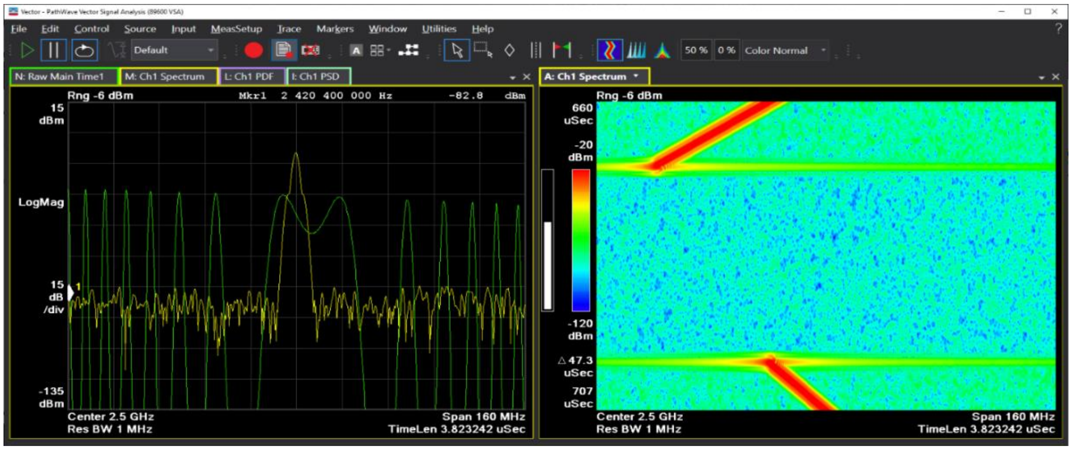
Download the PathWave Vector Signal Analysis (VSA) software and use it free for 30 days to make measurements with your analysis hardware or use our recorded demo signals by selecting File > Recall > Recall Demo > Pulse > on the software toolbar. Request your free trial license today: www.keysight.com/find/89600_trial

Radar systems teams will collect RF and microwave signal data across broad swaths of frequency using the latest instrumentation hardware. From the complex IQ data, individual pulses need to be identified, quantified, and validated. Was the transmitter working as expected? Why did the system drop a pulse? Was the linear ramp in frequency across the pulse width indeed linear? Across many thousands of pulses, what was the statistical distribution of pulse width? What is the trend in pulse repetition interval?

Fortunately, Keysight's PathWave Vector Signal Analysis (89600 VSA) software adds a pulse analysis option that enables answers to these questions. Accurate and timely analyses are of the utmost importance for radar and EW missions.

Explore Your Signal Vector Mode

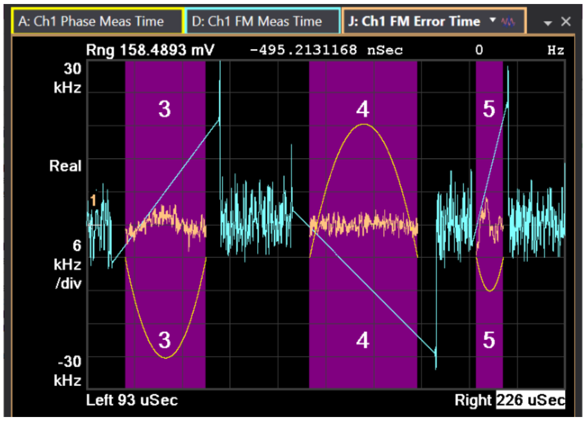
Even with basic VSA (89601200C), one can learn much about their signal in Vector mode, which enables time domain and frequency domain visualizations.



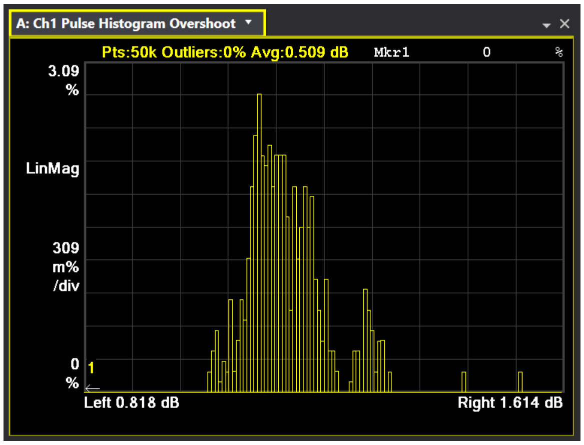
On the left, we see time domain and frequency domain representations of the chirp signal. To the right, we see a spectrogram view that moves synchronously with the graphs on the left. Using markers, one can measure the chirp start and stop frequencies along with relevant timing information.

Now Add Radar Pulse Analysis (option 89601BHQC)

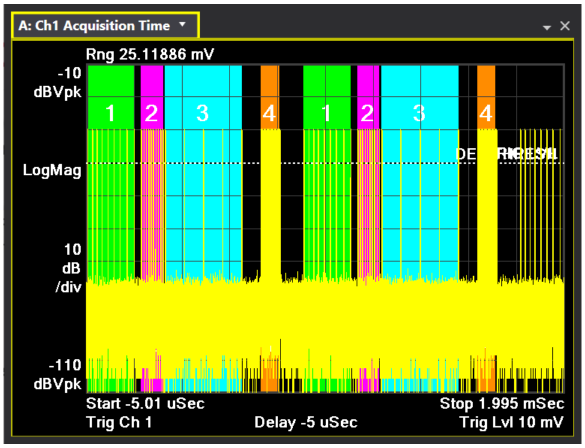
With the radar pulse analysis measurement extension, pulse boundaries are automatically detected with advanced algorithms. A Swiss Army knife of tools becomes available, including new trace types, statistics, measurements and table metrics, all specifically tailored for pulse analysis.



Trace Types - Here we show instantaneous frequency and instantaneous phase versus time. Furthermore, based on a best fit analysis of instantaneous frequency, deviations from the best fit are plotted as “FM Error vs Time.”



Statistics - Any metric that may be tabulated in a pulse table may be analyzed in terms of its statistics and trendlines. In this case, the amplitude envelope overshoot is plotted as a histogram. This way, RF system engineers can answer the question "how accurate and repeatable were my pulses?”



Measurements - Certain workflows require specialized measurements. Some examples include the analysis of pulse sidelobes and pulse compression; angle of arrival; or even pulse pattern search. In this illustration, we present various pulse trains that have been recognized and color-coded appropriately.

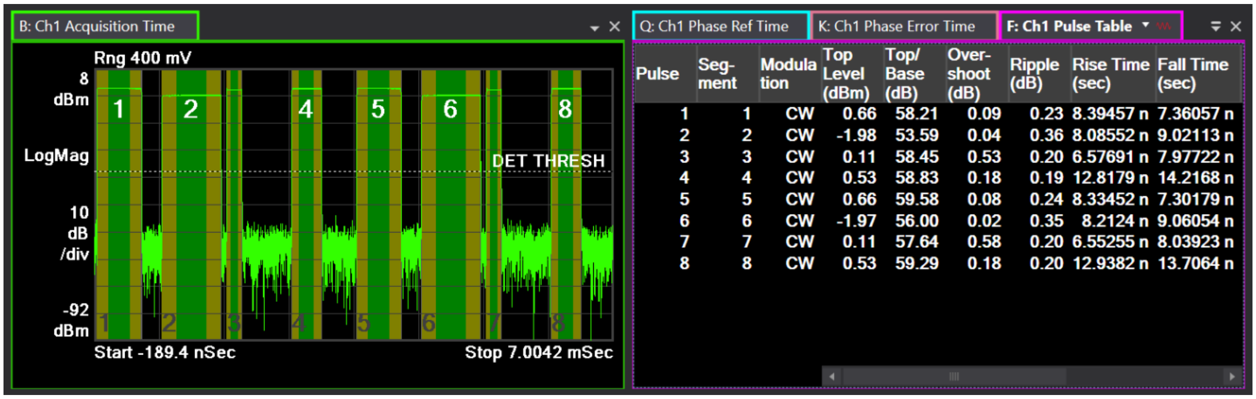
Pulses = 40
Avg Power = -6.4474
Peak Power = -3.1721
Detection Thresh = -13.505
Top Level = -3.5049
Base Level = -59.147
Top/Base = 55.642
Time Offset = 5.2441

Pulse	Top Level (dBm)	Base Level (dBm)	Top/ Base (dB)	Droop (dB)	Overshoot (dB)	Ripple (dB)	Rise Time (sec)	Rise Edge (sec)	Fall Time (sec)	Fall Edge (sec)	Width (sec)	PRI (sec)	Duty Cycle (%)	Freq Mean (Hz)	Freq Error RMS (Hz)	Phase Mean (deg)	Phase Error RMS (deg)	Best-F FM Pk-Dev (Hz)
1	-3.499	-58.42	54.92	-245 m	102 m	261 m	57.9019 n	0	77.6299 n	10.1004 µ	10.1004 µ	50.0011 µ	20.2	-9.923619 M	3.58102 k	41.889	305.6 m	105.16
2	-3.508	-59.72	56.22	-154 m	107 m	258 m	58.5276 n	50.0011 µ	57.4172 n	70.1019 µ	20.1008 µ	50.0023 µ	40.2	9.989555 M	3.60376 k	-56.78	307.2 m	90.1291

All three elements (trace types, statistics, and measurements) are shown above with highly configurable windows. Four pulses (4 through 7) are highlighted and aligned with their corresponding time domain traces. A histogram of the risetime, trend line of the pulse fall time and an overall pulse summary are also included. Along the bottom, detailed pulse metrics are tabulated across the 40 pulses detected.

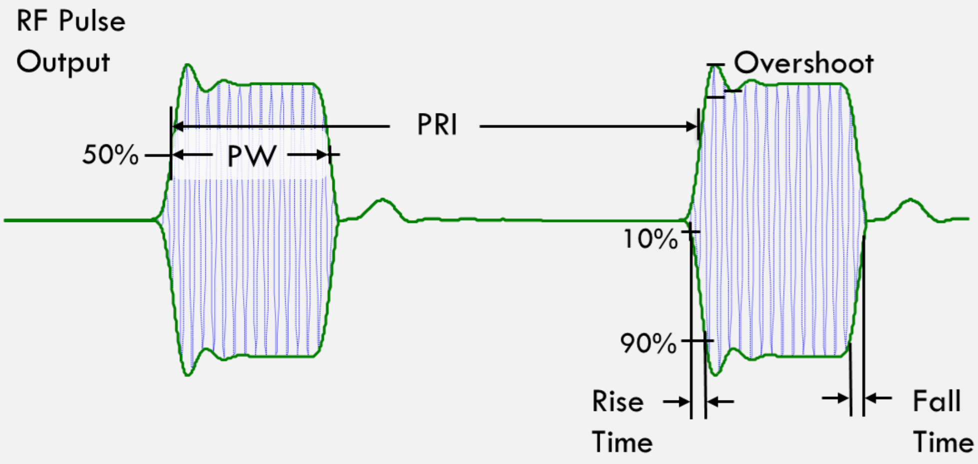
How Accurate and Repeatable were my Pulses?

Since pulses may span many gigahertz of frequency, large data sets must be analyzed to identify individual pulses and quantify various figures of merit. With the 89601BHQC, pulses are automatically identified, labeled, and cataloged in pulse tables.



Pulse	Seg-ment	Modulation	Top Level (dBm)	Top/ Base (dB)	Over-shoot (dB)	Ripple (dB)	Rise Time (sec)	Fall Time (sec)
1	1	CW	0.66	58.21	0.09	0.23	8.39457 n	7.36057 n
2	2	CW	-1.98	53.59	0.04	0.36	8.08552 n	9.02113 n
3	3	CW	0.11	58.45	0.53	0.20	6.57691 n	7.97722 n
4	4	CW	0.53	58.83	0.18	0.19	12.8179 n	14.2168 n
5	5	CW	0.66	59.58	0.08	0.24	8.33452 n	7.30179 n
6	6	CW	-1.97	56.00	0.02	0.35	8.2124 n	9.06054 n
7	7	CW	0.11	57.64	0.58	0.20	6.55255 n	8.03923 n
8	8	CW	0.53	59.29	0.18	0.20	12.9382 n	13.7064 n

The power, frequency, amplitude, and phase vs. time are carefully analyzed for each pulse to calculate figures of merit that can be tabulated in a pulse table. Example metrics are pulse width (PW), pulse repetition interval (PRI), risetime, fall time and amplitude overshoot illustrated below.



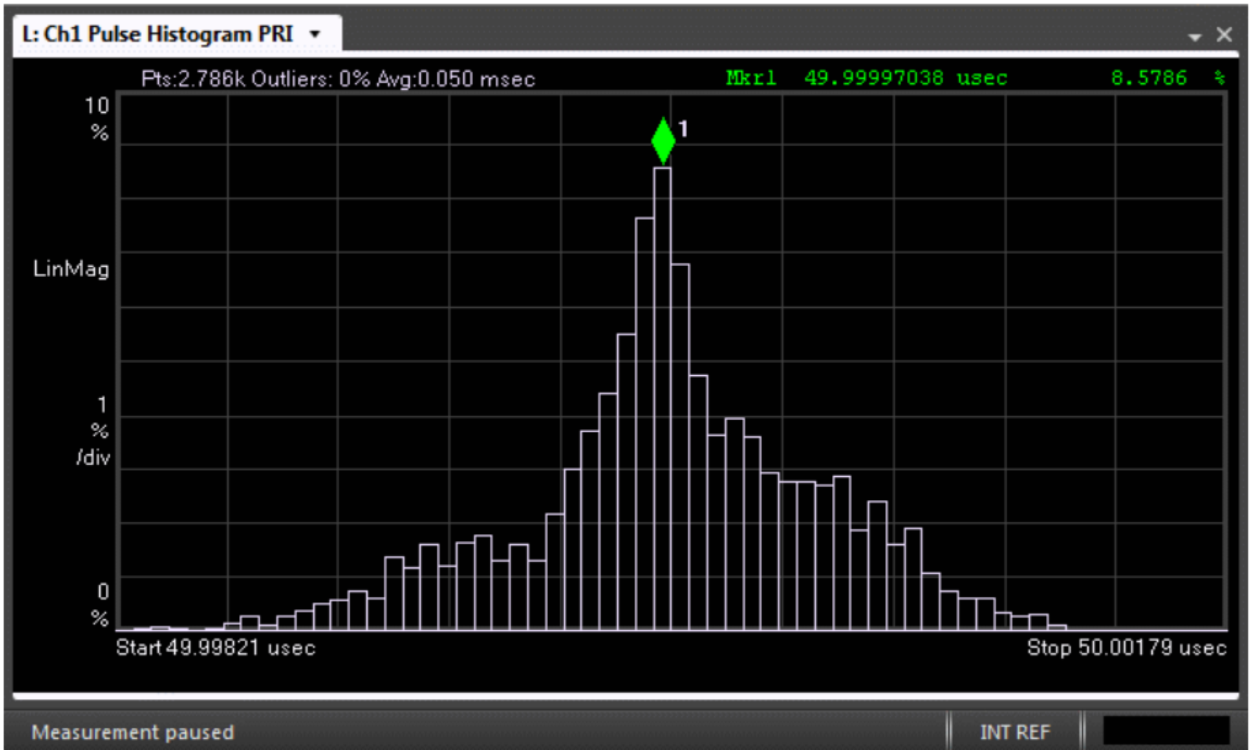
Numerous other metrics are available, and these are organized in the following categories.

- Modulation Metrics – modulation type, modulation code number, chip count, measured bits, chip width, chip offset
- RF Output Level Metrics – top level, base level, top to base ratio, amplitude when pulse is on, peak level, mean level, peak to average ratio
- Amplitude Settling Metrics – pulse droop, droop rate, droop starting amplitude, droop ending amplitude, overshoot, ripple
- Time Metrics – rise time, fall time, rising edge, falling edge, width, duty cycle, pulse repetition frequency, pulse repetition interval, off time
- Frequency Metrics - mean frequency, pulse to first pulse frequency difference, peak-to-peak frequency deviation, and relative to an estimated reference signal, RMS frequency error, peak frequency error and time location of peak frequency error

- Phase Metrics – mean phase, pulse to first pulse phase difference, peak to peak phase deviation, and relative to an estimated reference signal, RMS phase error, peak phase error and time location of peak phase error
- Linear Frequency Modulation Metrics – best fit mean modulation frequency, best fit start modulation frequency, best fit ending modulation frequency, best fit peak-to-peak modulation frequency deviation, best fit FM slope, integrated nonlinearity from best fit
- Triangular Frequency Modulation Metrics – best fit apex frequency, best fit apex time
- Channel to Channel Difference Metrics – time, amplitude, and frequency difference of corresponding pulse on channel 2 as compared to Channel 1
- Pulse Compression Metrics (when enabled) – correlation between reference pulse and measured pulse; peak sidelobe level, peak sidelobe location, compression ratio, main lobe width
- Deinterleaving Metrics (when enabled) – emitter ID
- Frequency Hopping Metrics (when enabled) – hop state index, hop begin time, hop ending time, hop settling time, hop dwell time, hop switching time, hop mean frequency, hop mean frequency deviation
- Non-linear FM Metrics (when enabled) – polynomial coefficients describing frequency vs time.

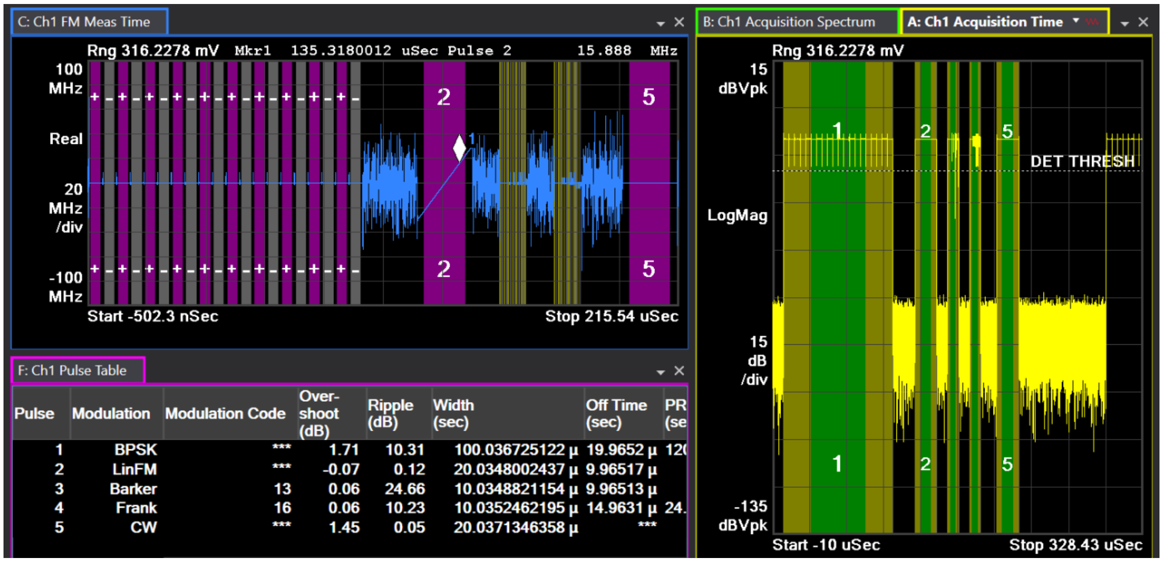
Any of these metrics may be copied to Microsoft Excel or exported to CSV format for further analysis.

Furthermore, statistics and trends on any of these metrics may be visualized. Hypothetically, a radar engineer may have a large population of pulses that are supposed to have the same pulse width or pulse repetition interval. The repeatability of the RF system may be plotted using a histogram. Below we show a histogram of pulse repetition interval using an MXG signal generator. Judging by the limits of the x-axis, we observe very little variation in PRI.



Evaluate Modulation on Pulse

A real-world signal might be hopping in frequency and modulated in different ways. We will need to automatically identify frequency modulation and modulation code. Fortunately, the VSA enables automatic pulse modulation recognition in the pulse results table, even providing decoded bits in some cases.



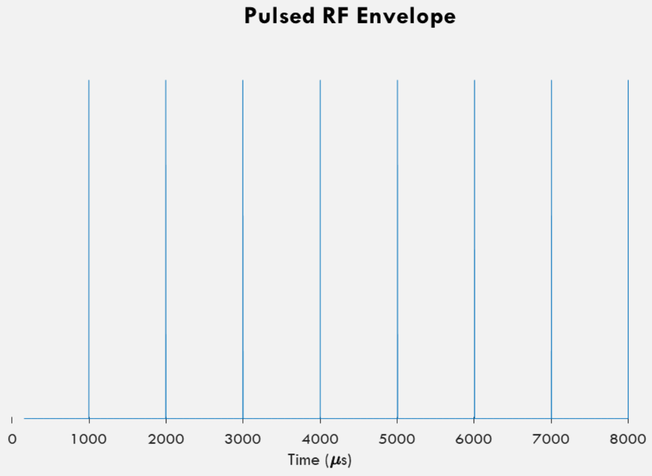
Pulse	Modulation	Modulation Code	Over-shoot (dB)	Ripple (dB)	Width (sec)	Off Time (sec)	PR (se
1	BPSK	***	1.71	10.31	100.036725122 µ	19.9652 µ	120
2	LinFM	***	-0.07	0.12	20.0348002437 µ	9.96517 µ	
3	Barker	13	0.06	24.66	10.0348821154 µ	9.96513 µ	
4	Frank	16	0.06	10.23	10.0352462195 µ	14.9631 µ	24.
5	CW	***	1.45	0.05	20.0371346358 µ	***	

A small subset of the possible modulation types is shown above. A more complete list includes the following types: Continuous Wave, Linear FM, Triangular FM, Barker Phase, BPSK, QPSK, Frank Code, P1 Code, P2 Code, P3 Code and P4 Code. Furthermore, Bipolar Phase Shift Keying (BPSK) modulation may be defined from 0° to an arbitrary phase, including the most typical 180°.

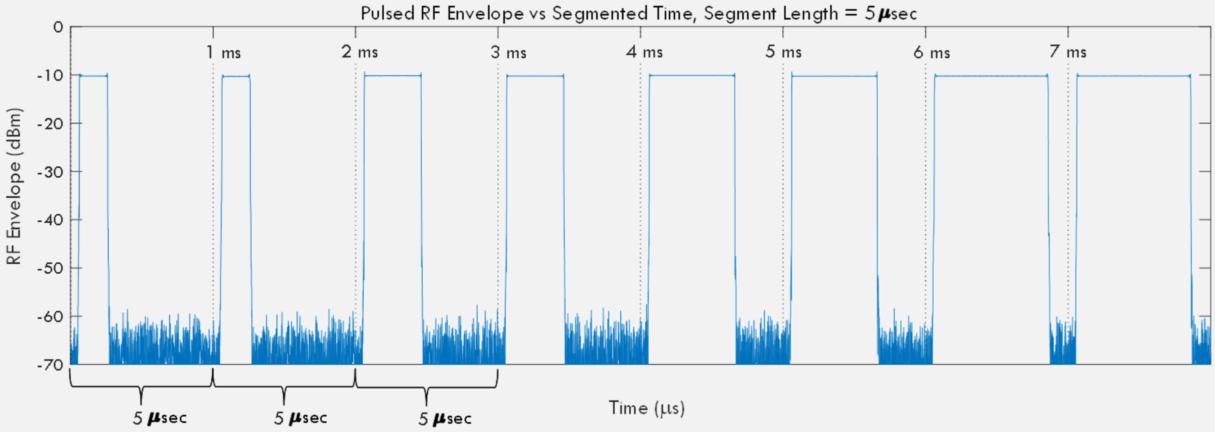
In larger test systems, trigger events may arrive intermittently, with significant pauses in between trigger events. In such cases, it is helpful to tabulate pulse metrics across trigger events and individual acquisitions. For these scenarios, the pulse table may be configured as a cumulative pulse table in that rows describing groups of pulses may come from different acquisitions.

Characterize Angle of Arrival with Segmented Acquisitions

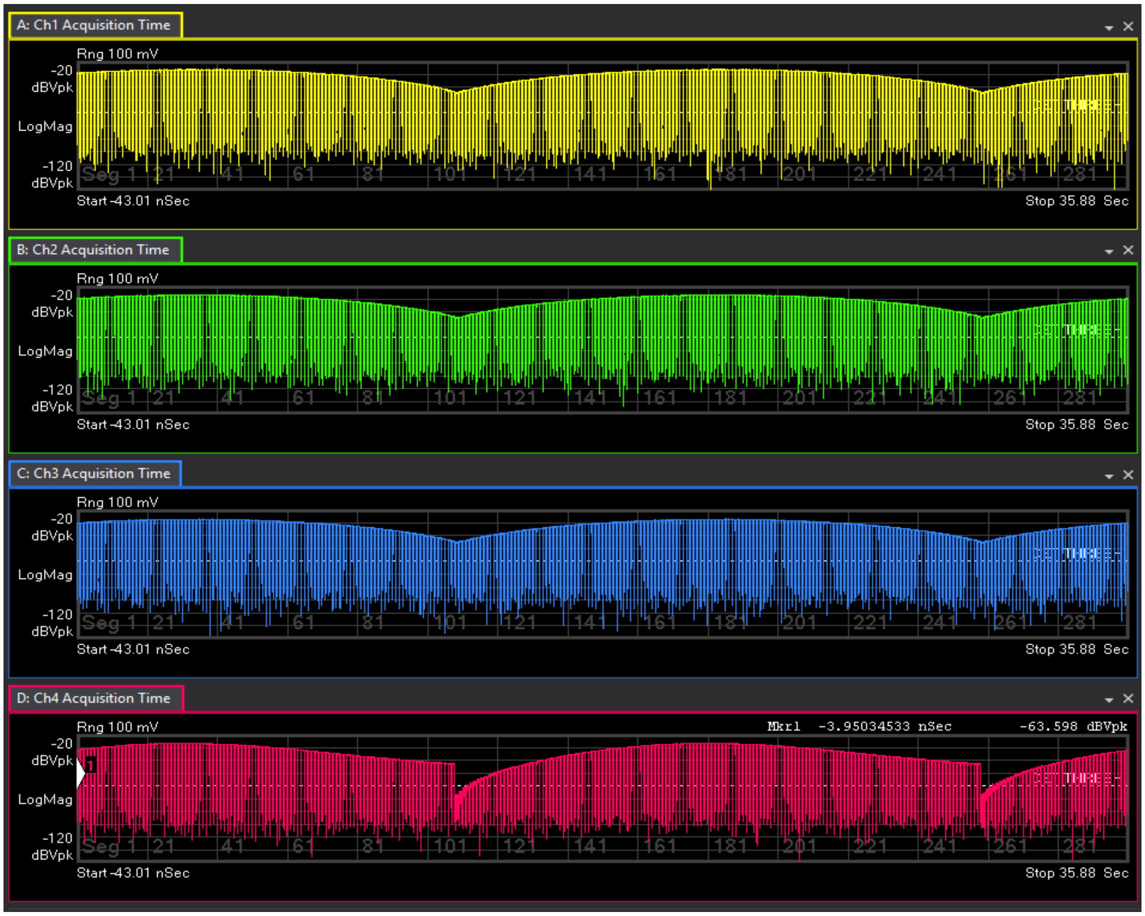
In situations where the duty cycle can be very small, much of the high precision and high bandwidth IQ data captured is wasted. As an illustration, let’s assume a pulse width of 1 µs but with a pulse repetition interval of 1 ms, implying a duty cycle of 0.1%. Graphically, this is not very informative as may be seen below.



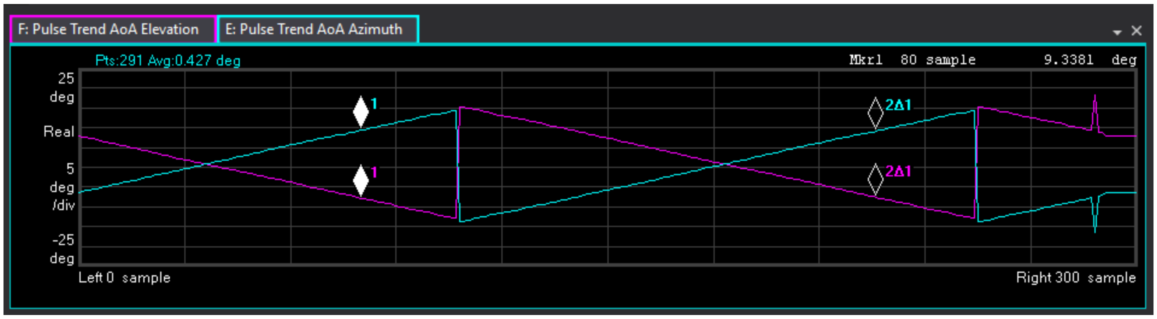
However, if we enable segmented capture, much of the dead time may be eliminated, allowing a closer look at the most salient characteristics of the pulse, like overshoot or ringing.



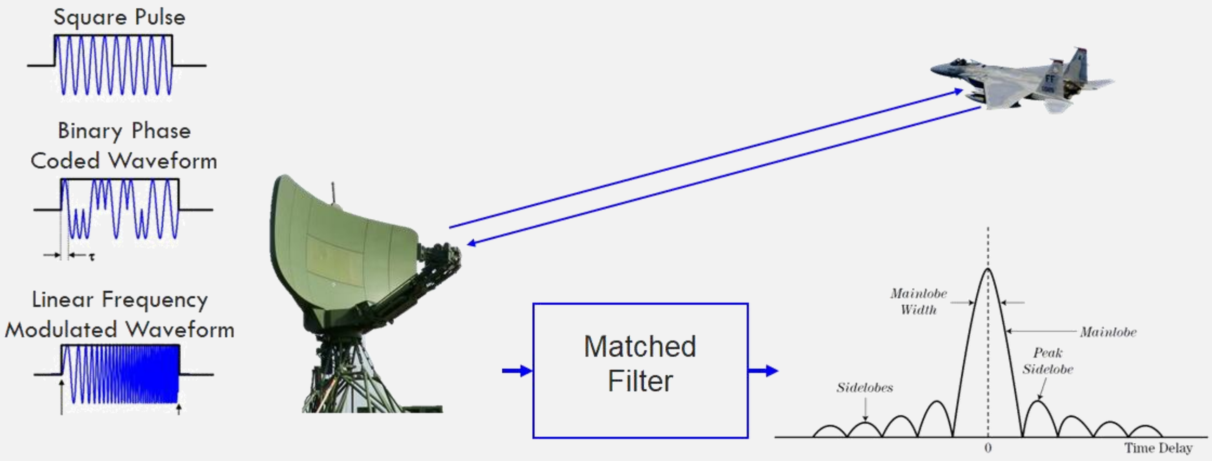
By leveraging segmented capture measured across four oscilloscope channels, scan patterns across four antennas may be characterized over tens of seconds.



Once the antenna spacing and location have been specified, angle of arrival (AoA) calculations may be completed using one of two methods: noting phase differences or the time difference of arrival (TDOA) between channels. Below, a trend plot shows the evolution of elevation and azimuth across pulses.



Quantify Pulse Compression and Linear FM

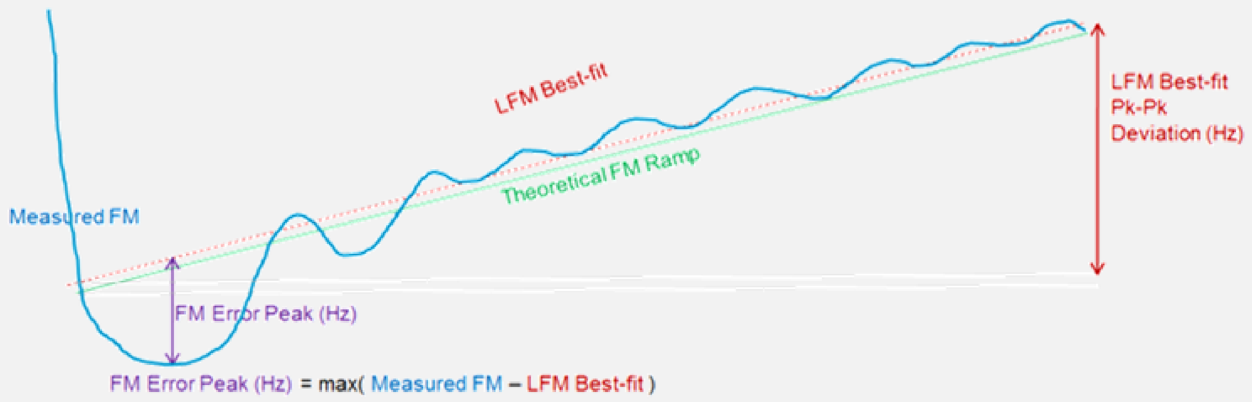


Radar works by sending out a loud pulse and then listening for the echoes of that outbound pulse. In other words, we judge the distance of an object by reflecting a signal off it. By noting the arrival time of the echoes and accounting for the speed of propagation, we can estimate the distance or “range” of the object. Furthermore, by noting the frequency shift of the echoes, we can also gauge the velocity. By changing the shape of the outbound pulse in a specially designed way, the distance resolution and immunity to ambient noise can be improved with the help of a matched filter. Thus the received signal is submitted to a filter that is simply a time reversed version of the original signal. This is the same as taking the correlation of the original signal. Any echoes off real objects will have the same shape as the outbound signal, and so the convolution of the received signal against the time reversed outbound signal leads to taller and narrower peaks, which is great for range resolution. System noise or radar clutter will not have the same signature as the outbound signal, so after taking the correlation against the outbound pulse, it continues to look like noise.

With the VSA, the matched filter is specified by choosing a pulse as a reference pulse and saving its shape to a data register. Pulse compression may then be evaluated in terms of agreement between measured pulses and reference outbound pulse; sidelobe height and time offset; and main lobe width as compared to the overall pulse width (or compression ratio). These are tabulated as metrics in the pulse table.

By the 1950s, the industry had wholeheartedly embraced this concept of pulse compression, and people were looking at improved ways of having sharper main lobes with lower sidelobes. Both experimentally and theoretically, they learned that a wider bandwidth signal leads to lower sidelobes and taller main lobes. The most common approach is to apply linear frequency modulation to the pulse.

To achieve even higher levels of pulse compression, radar engineers have explored “non-linear frequency modulation” or NLFM, typically characterized as a polynomial fit of the frequency versus time data. While some would argue one is a superset of the other, the VSA can analyze both types, returning the polynomial fits of the instantaneous frequency versus time in the case of NLFM. Linear FM metrics are tabulated in the pulse results summary table. For every pulse that has a linear FM chirp, the VSA implements a best fit to the measured frequency versus time data to estimate what would be the instantaneous frequency versus time if we were looking at a perfectly linear modulator. Deviations from this best fit are then tabulated.



Getting Data into the VSA

What type of hardware instrumentation is well-suited for radar pulse analysis?

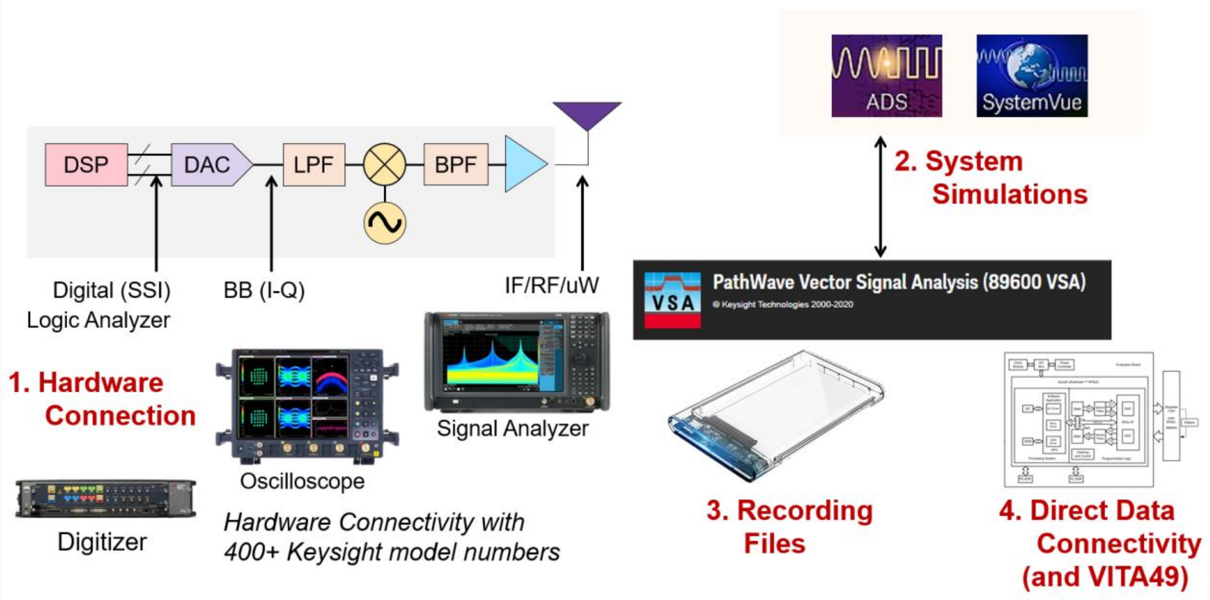
Many radar system engineers require tremendous instantaneous bandwidth, because no one knows precisely what frequency the pulses will be arriving. In such situations, we would recommend a broadband oscilloscope with up to 110 GHz of instantaneous bandwidth. Whereas typically super wide bandwidth oscilloscopes have presented poor dynamic range with the full bandwidth of noise degrading the measured signal-to-noise ratio, this trade-off is not necessary today. The Infiniium UXR scope features hardware accelerated decimation and filtering.

Some radar engineers are trying to find a relatively small signal hidden in the noise of a dynamic spectrum. In that case, we would recommend a state-of-the-art spectrum analyzer like the UXA with dedicated hardware to provide the best possible dynamic range.

Lastly, for a radar engineer on a test range interested in looking for intermittent aberrations in the electromagnetic airspace, they will be interested in collecting huge amounts of data and saving it to robust hard drives without any gaps between acquisitions. In that case, we would recommend a streaming digitizer such as the M8131A with an optical interface to provide adequate data throughput.

The VSA connects to all three classes of instruments. In fact, the VSA provides a hardware extension to over 300 Keysight model numbers allowing an engineer to test anywhere in the transmitter chain, from the DSP with a logic analyzer, to the baseband inputs with an oscilloscope, to the RF output with a signal analyzer.

Once a connection has been established, the software feels like an extension of the instrument, allowing the user to set center frequency, sample rate, trigger on RF bursts of power and even record acquisitions to a binary file for postprocessing. Furthermore, connectivity to third-party receivers may be developed using the 89630B Software Development Kit (SDK) and then leveraged with the 89601300C option. Evidently, the most typical method for getting data into the VSA is by way of a hardware connection.



A second option is through simulation results. The VSA software connect to both PathWave Circuit Design (formerly known as Keysight Advanced Design Systems) and PathWave System Level Design (formerly known as SystemVue). The third option is through recording files. Assuming the sample rate and center frequency are well-known, waveforms may be brought into the VSA that may have been saved to disk in Matlab format or various other binary formats. Lastly, one may submit data from their hardware receiver or software using the 89601101C Direct Data Connectivity, thereby eliminating the need for temporary recording files.

For the purposes of evaluating a radar transmitter, one will need a high-performance spectrum analyzer or wideband scope. For the purposes of evaluating a radar receiver, one will need a high-performance signal generator like the VXG or UXG. But having both together is a great way to test out pulse signal creation and measurement algorithms. For example, a radar engineer can set up a realistic antenna scan pattern and then verify the shape by measuring the resulting pattern using a spectrum analyzer in zero span. This setup also enables the study of a single component like an amplifier. While many engineers will use a CW signal as a proxy for the actual signal, most recognize the benefit of sending the exact same signal, enabling a closer look at phenomena like residual memory affects, thermal tails, heat dissipation, and nonlinear distortion.

PathWave Vector Signal Analysis (89600 VSA)
© Keysight Technologies 2000-2020

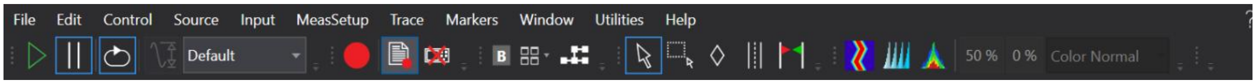
Signal Analyzer

Keysight N7620B
Signal Studio for Pulse Building
© Keysight Technologies 2002 - 2017

Signal Generator

Record Signals as IQ Waveforms or Pulse Descriptor Words for RF Playback

The VSA may be used to record long time records as a way of monitoring trends or capturing unknown signals, irregular events or new threats yet to be understood.



A radar engineer can save measured RF data to an IQ data recording and then use that same data recording to play it back through a vector signal generator. The I and Q outputs from the data recording get played out as pulsed waveforms at RF frequencies.

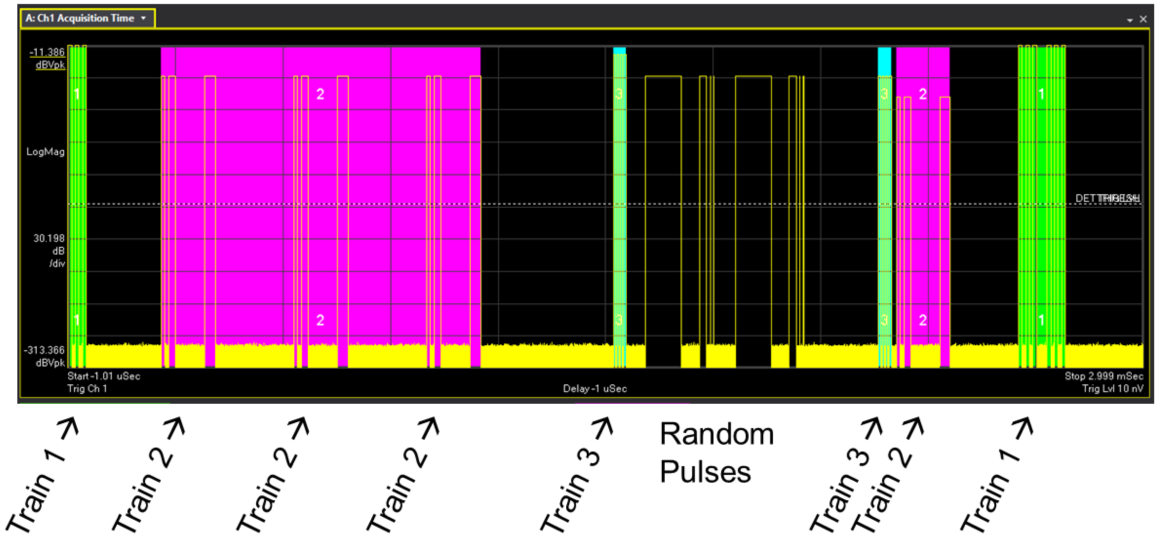
With long time recordings leading to many gigabytes of data, the radar industry invented this concept of Pulse Descriptor Words (PDW's), which allow an entire pulse to be submitted as a series of parameters describing that pulse. The most relevant characteristics like pulse width, PRI and mean frequency are submitted as columns to a PDW file, where every row represents a different pulse. This PDW file may be then uploaded to an agile vector signal generator like the UXG.

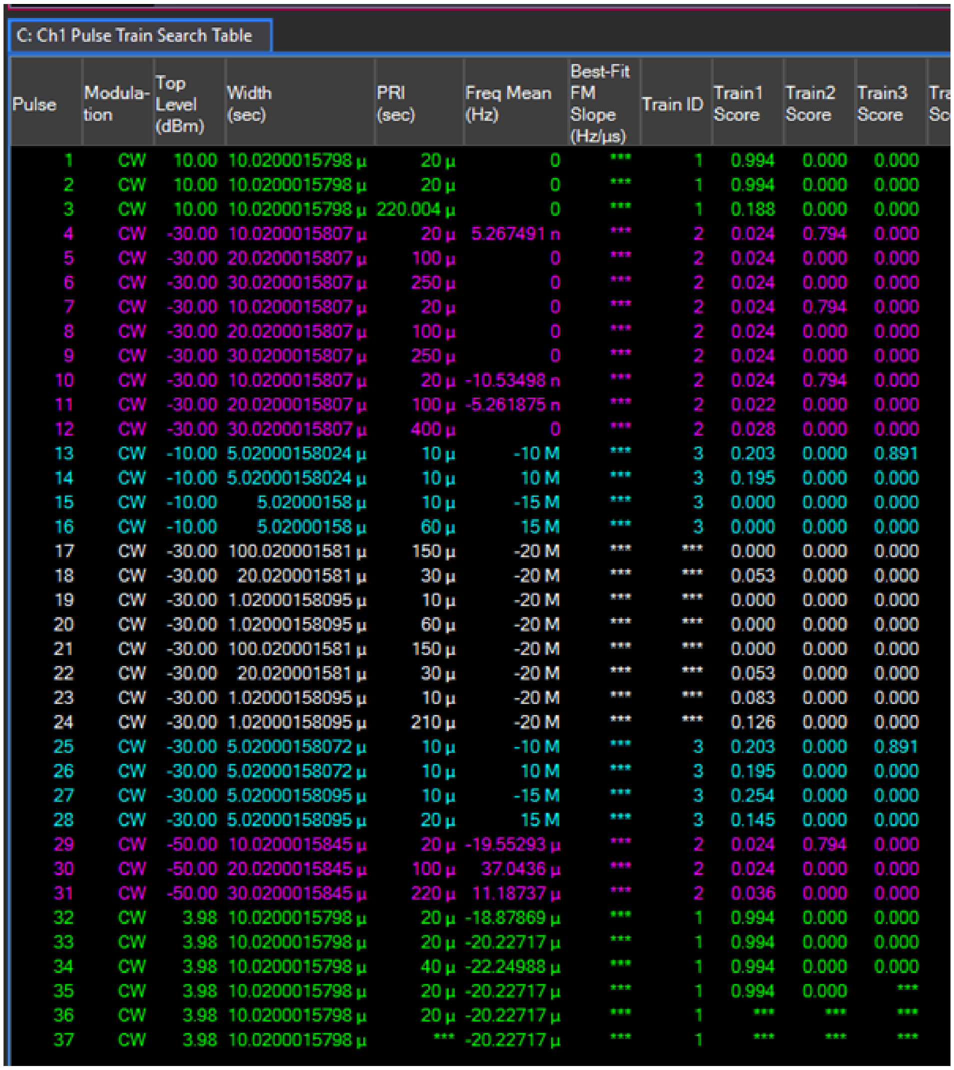
Whether through an IQ data recording or using a PDW file, the recorded signal may be played into a radar receiver under test or radar jammer as a way of verifying its response or in EW parlance, verifying its "techniques." A radar analyst may thus capture signals from the sky or a test range and then submit that same captured signal to a radar receiver under test.

Characterize Individual Pulse and Pulse Train Similarity

An RF system engineer typically knows what the outbound pulses should look like. Their job is to generate accurate pulses and then look for impairments caused by the realities of the actual hardware. If they find a badly formed pulse, they will need to understand why and how to fix component or subsystem responsible. On the other hand, a radar analyst typically collects large volumes of RF data on a test range and checks whether the overall system responded appropriately to an external threat. Typical questions might include: How long did it take for the emitter to change modes? Or, did the radar switch from search mode to track mode at the correct time? On the electronic battlefield, an adversarial signal may be trying to jam or confuse your own radar receiver. To avoid this, the radar analyst maintains a catalog of pulse patterns as well as pulse characteristics identifying the equipment responsible. Measured pulses are thus compared against a catalog of known pulse trains and equipment signatures. To address the divergent requirements of both the RF system engineer and the radar analyst, the VSA provides two features - pulse scoring and pulse train search.

In both cases, we begin with the definition of some reference pulses. This is entered as a table with characteristics of amplitude, pulse width, pulse repetition interval, and average frequency. Whereas pulse scoring compares each corresponding pulse against the reference list of pulses, pulse train scoring evaluates the agreement of the entire measured pulse train. With pulse scoring, one may answer the question, “is a pulse or series of pulses similar to a single reference pulse or series of reference pulses?” On the other hand, with pulse train scoring one may answer the question “how do we know that pulses measured in a reference train happened in our latest measurement, and how closely do they match?” Certain figures of merit (like pulse width) may be emphasized more strongly than the others by way of base error tolerances. If the base error tolerances are set small, then that metric will play a stronger role in the overall score. Once the reference pulses and base error tolerances have been defined, measured pulses are color-coded both on the time trace as well as in the pulse summary table, as shown below.



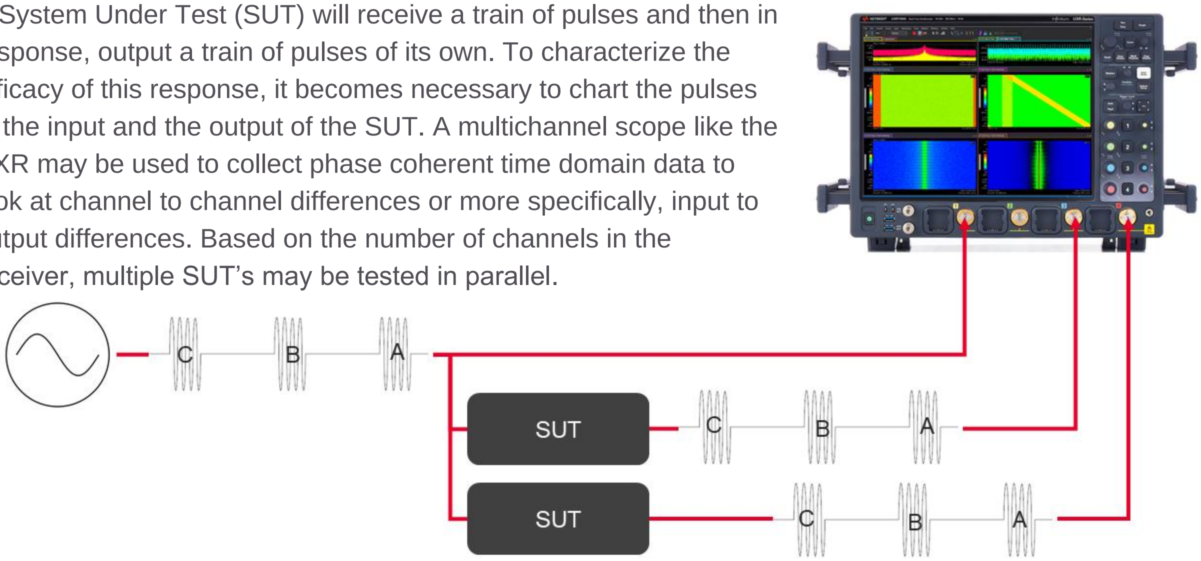


C: Ch1 Pulse Train Search Table

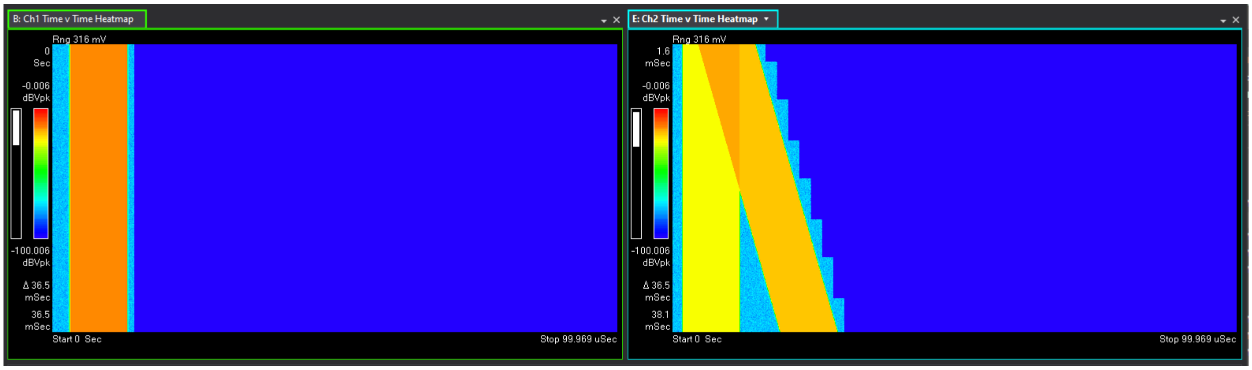
Pulse	Modula-tion	Top Level (dBm)	Width (sec)	PRI (sec)	Freq Mean (Hz)	Best-Fit FM Slope (Hz/µs)	Train ID	Train1 Score	Train2 Score	Train3 Score	Tra Sc
1	CW	10.00	10.0200015798 µ	20 µ	0	***	1	0.994	0.000	0.000	
2	CW	10.00	10.0200015798 µ	20 µ	0	***	1	0.994	0.000	0.000	
3	CW	10.00	10.0200015798 µ	220.004 µ	0	***	1	0.188	0.000	0.000	
4	CW	-30.00	10.0200015807 µ	20 µ	5.267491 n	***	2	0.024	0.794	0.000	
5	CW	-30.00	20.0200015807 µ	100 µ	0	***	2	0.024	0.000	0.000	
6	CW	-30.00	30.0200015807 µ	250 µ	0	***	2	0.024	0.000	0.000	
7	CW	-30.00	10.0200015807 µ	20 µ	0	***	2	0.024	0.794	0.000	
8	CW	-30.00	20.0200015807 µ	100 µ	0	***	2	0.024	0.000	0.000	
9	CW	-30.00	30.0200015807 µ	250 µ	0	***	2	0.024	0.000	0.000	
10	CW	-30.00	10.0200015807 µ	20 µ	-10.53498 n	***	2	0.024	0.794	0.000	
11	CW	-30.00	20.0200015807 µ	100 µ	-5.261875 n	***	2	0.022	0.000	0.000	
12	CW	-30.00	30.0200015807 µ	400 µ	0	***	2	0.028	0.000	0.000	
13	CW	-10.00	5.02000158024 µ	10 µ	-10 M	***	3	0.203	0.000	0.891	
14	CW	-10.00	5.02000158024 µ	10 µ	10 M	***	3	0.195	0.000	0.000	
15	CW	-10.00	5.02000158 µ	10 µ	-15 M	***	3	0.000	0.000	0.000	
16	CW	-10.00	5.02000158 µ	60 µ	15 M	***	3	0.000	0.000	0.000	
17	CW	-30.00	100.020001581 µ	150 µ	-20 M	***	***	0.000	0.000	0.000	
18	CW	-30.00	20.020001581 µ	30 µ	-20 M	***	***	0.053	0.000	0.000	
19	CW	-30.00	1.02000158095 µ	10 µ	-20 M	***	***	0.000	0.000	0.000	
20	CW	-30.00	1.02000158095 µ	60 µ	-20 M	***	***	0.000	0.000	0.000	
21	CW	-30.00	100.020001581 µ	150 µ	-20 M	***	***	0.000	0.000	0.000	
22	CW	-30.00	20.020001581 µ	30 µ	-20 M	***	***	0.053	0.000	0.000	
23	CW	-30.00	1.02000158095 µ	10 µ	-20 M	***	***	0.083	0.000	0.000	
24	CW	-30.00	1.02000158095 µ	210 µ	-20 M	***	***	0.126	0.000	0.000	
25	CW	-30.00	5.02000158072 µ	10 µ	-10 M	***	3	0.203	0.000	0.891	
26	CW	-30.00	5.02000158072 µ	10 µ	10 M	***	3	0.195	0.000	0.000	
27	CW	-30.00	5.02000158095 µ	10 µ	-15 M	***	3	0.254	0.000	0.000	
28	CW	-30.00	5.02000158095 µ	20 µ	15 M	***	3	0.145	0.000	0.000	
29	CW	-50.00	10.0200015845 µ	20 µ	-19.55293 µ	***	2	0.024	0.794	0.000	
30	CW	-50.00	20.0200015845 µ	100 µ	37.0436 µ	***	2	0.024	0.000	0.000	
31	CW	-50.00	30.0200015845 µ	220 µ	11.18737 µ	***	2	0.036	0.000	0.000	
32	CW	3.98	10.0200015798 µ	20 µ	-18.87869 µ	***	1	0.994	0.000	0.000	
33	CW	3.98	10.0200015798 µ	20 µ	-20.22717 µ	***	1	0.994	0.000	0.000	
34	CW	3.98	10.0200015798 µ	40 µ	-22.24988 µ	***	1	0.994	0.000	0.000	
35	CW	3.98	10.0200015798 µ	20 µ	-20.22717 µ	***	1	0.994	0.000	***	
36	CW	3.98	10.0200015798 µ	20 µ	-20.22717 µ	***	1	***	***	***	
37	CW	3.98	10.0200015798 µ	***	-20.22717 µ	***	1	***	***	***	

Fast-Time Slow-Time Display and Doppler Plots

A System Under Test (SUT) will receive a train of pulses and then in response, output a train of pulses of its own. To characterize the efficacy of this response, it becomes necessary to chart the pulses at the input and the output of the SUT. A multichannel scope like the UXR may be used to collect phase coherent time domain data to look at channel to channel differences or more specifically, input to output differences. Based on the number of channels in the receiver, multiple SUT's may be tested in parallel.

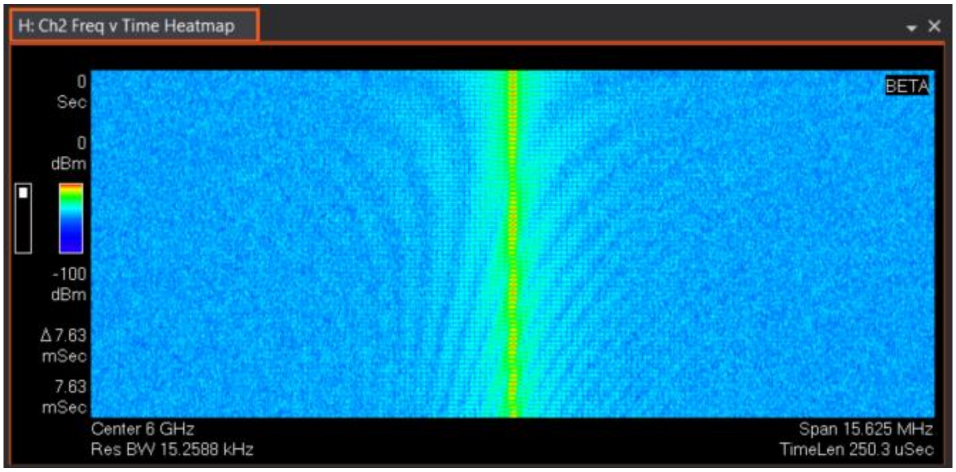


Radar engineers often want to track the evolution of the SUTs response to an incoming pulse, so the pulse repetition interval demarcates a “fast-time” slice. In plotting the evolution of the SUT response across fast-time intervals, a new notion of time lends itself to the name “slow-time.” Below, we show the incoming signal on channel 1 and SUT response on channel 2 in Time vs. Time Heatmap traces, available in vector mode, pulse mode and advanced radar mode. This illustrates a classic “Range Gate Pull-off” technique.

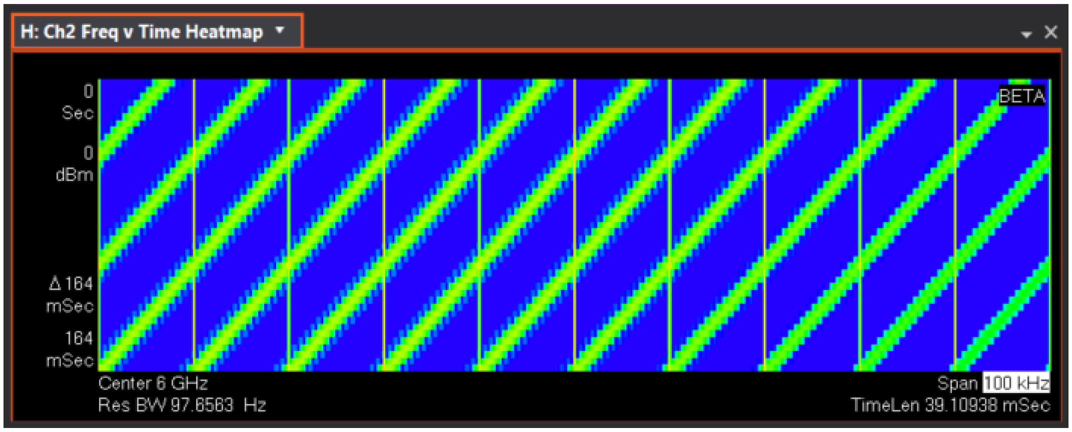


The staircase effect you might notice on channel 2 shows VLSC in action – we only capture the interesting part of the pulse, and the rest of the time is assumed to have no power content.

A frequency domain representation of the output signal can reveal a Doppler shift as evidenced by slight frequency shifts in the SUT output signal. To capture time domain data with high fidelity, a wide bandwidth is required. However, this wide bandwidth provides a macro view of the frequency spectrum, preventing a good look at the frequency shifts due to the velocity change of the target.



The span needs to be narrowed significantly to support the most likely frequency shifts. After changing the span, VSA resamples the same data to show the changing frequency impulses versus time, with the most recent time slice displayed at the bottom.



This however results in a significant blurring of the details in the Time vs. Time Heatmap. So how can we achieve good resolution in the time domain as well in the frequency domain? The multi-measurement capability in the VSA enables this, where the span for Meas01 may be set to 16 MHz for better Time vs. Time resolution and independently, the span for Meas02 may be set to 100 kHz for better Frequency vs. Time resolution. Both the Time vs. Time Heatmap and Frequency vs. Time Heatmap traces are offered in basic vector mode and in pulse analysis mode.

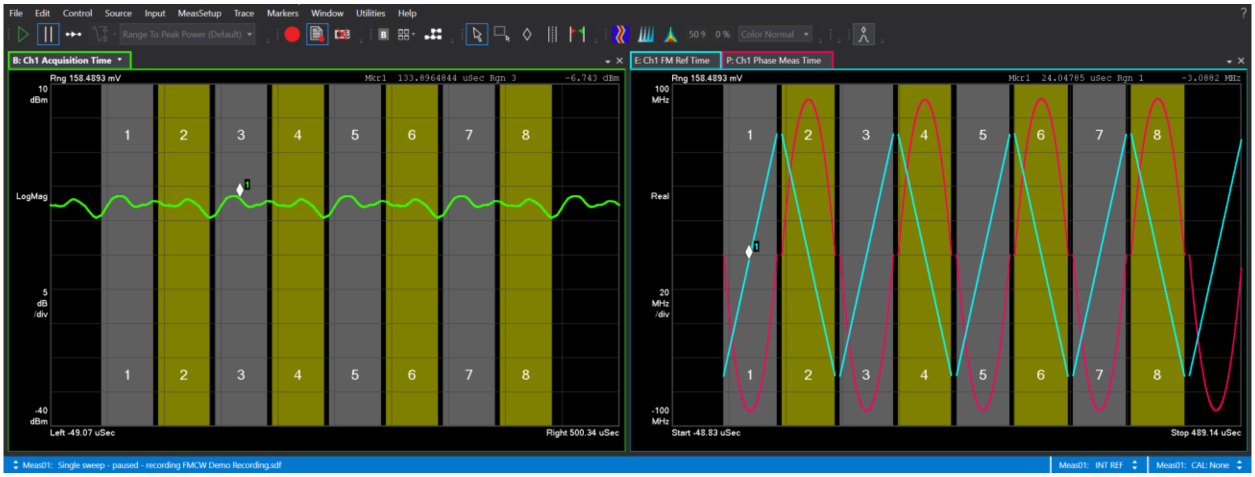
The Advanced Radar Measurement Extension

The 89601BHQC and 89601BHPC modules are both integral to radar signal analysis but cater to different signal types and industries. The distinction lies in their signal handling: 89601BHQC targets transient, noncontinuous signals like pulses, whereas 89601BHPC is built for continuous waveforms with varying chirp rates and frequencies over time.

To illustrate, the following figure shows a typical pulsed signal that might be measured with the “Pulsed Radar Analysis” measurement extension.

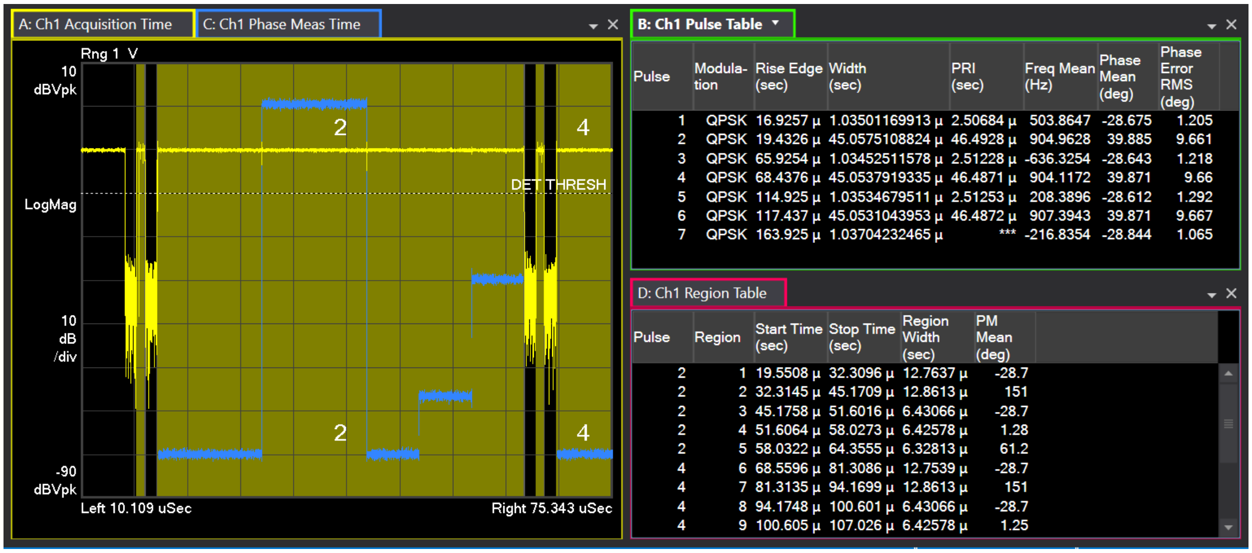
Meas01: Single sweep - paused - recording Typical BHQC Demo Recording.sdf

On the other hand, the following figure shows a typical FMCW signal when there is no drop in RF amplitude between pulses.



Meas01: Single sweep - paused - recording FMCW Demo Recording.sdf

The growing demands from automotive and military radar industries necessitated the capability to analyze multiple chirps within a singular RF burst. This led to the evolution of the requirements to not only detect pulses when the RF amplitude crosses a threshold but also to recognize and quantify specific regions within those pulses. These regions could exhibit constant phase, frequency, or chirp rate. Addressing these advanced requirements resulted in the development of the “Advanced Radar” measurement extension. The figure below illustrates a signal with arbitrary phase changes within 45 µs pulses, interspersed with 1 µs pulses:



B: Ch1 Pulse Table

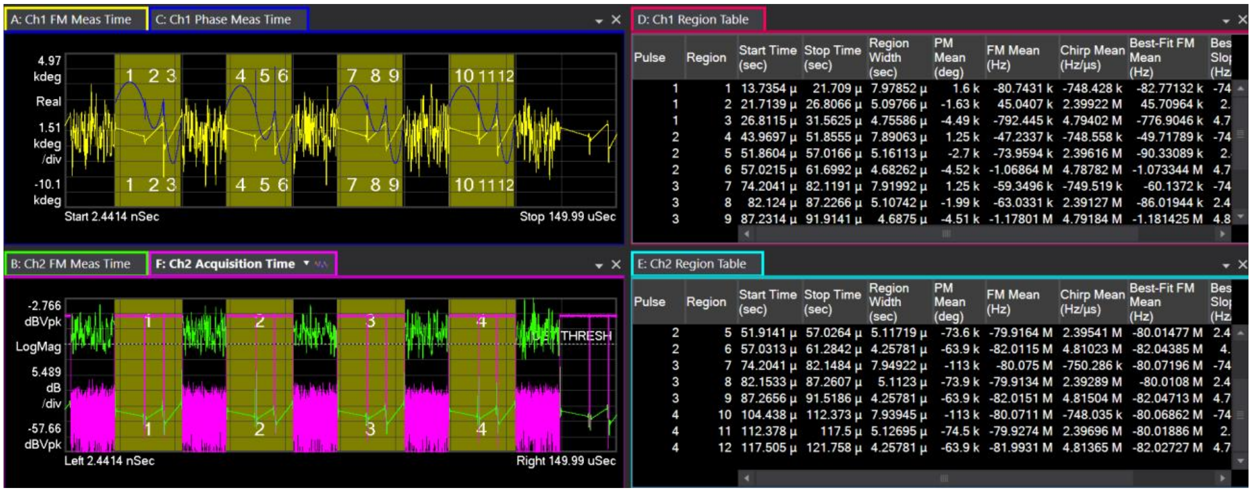
Pulse	Modula-tion	Rise Edge (sec)	Width (sec)	PRI (sec)	Freq Mean (Hz)	Phase Mean (deg)	Phase Error RMS (deg)
1	QPSK	16.9257 µ	1.03501169913 µ	2.50684 µ	503.8647	-28.675	1.205
2	QPSK	19.4326 µ	45.0575108824 µ	46.4928 µ	904.9628	39.885	9.661
3	QPSK	65.9254 µ	1.03452511578 µ	2.51228 µ	-636.3254	-28.643	1.218
4	QPSK	68.4376 µ	45.0537919335 µ	46.4871 µ	904.1172	39.871	9.66
5	QPSK	114.925 µ	1.03534679511 µ	2.51253 µ	208.3896	-28.612	1.292
6	QPSK	117.437 µ	45.0531043953 µ	46.4872 µ	907.3943	39.871	9.667
7	QPSK	163.925 µ	1.03704232465 µ	***	-216.8354	-28.844	1.065

D: Ch1 Region Table

Pulse	Region	Start Time (sec)	Stop Time (sec)	Region Width (sec)	PM Mean (deg)
2	1	19.5508 µ	32.3096 µ	12.7637 µ	-28.7
2	2	32.3145 µ	45.1709 µ	12.8613 µ	151
2	3	45.1758 µ	51.6016 µ	6.43066 µ	-28.7
2	4	51.6064 µ	58.0273 µ	6.42578 µ	1.28
2	5	58.0322 µ	64.3555 µ	6.32813 µ	61.2
4	6	68.5596 µ	81.3086 µ	12.7539 µ	-28.7
4	7	81.3135 µ	94.1699 µ	12.8613 µ	151
4	8	94.1748 µ	100.601 µ	6.43066 µ	-28.7
4	9	100.605 µ	107.026 µ	6.42578 µ	1.25

The wider pulses denoted pulses 2 and 4 contain regions of constant phase, which have been labeled as regions 1 through 9 in Trace D’s pulse region table.

Below, the following signal was collected across 2 channels where each channel was analyzed to show 4 pulses and 3 regions of constant chirp rate within each pulse.



D: Ch1 Region Table

Pulse	Region	Start Time (sec)	Stop Time (sec)	Region Width (sec)	PM Mean (deg)	FM Mean (Hz)	Chirp Mean (Hz/µs)	Best-Fit FM Mean (Hz)	Bes Slo (Hz
1	1	13.7354 µ	21.709 µ	7.97852 µ	1.6 k	-80.7431 k	-748.428 k	-82.77132 k	-74
1	2	21.7139 µ	26.8066 µ	5.09766 µ	-1.63 k	45.0407 k	2.39922 M	45.70964 k	2.
1	3	26.8115 µ	31.5625 µ	4.75586 µ	-4.49 k	-792.445 k	4.79402 M	-776.9046 k	4.7
2	4	43.9697 µ	51.8555 µ	7.89063 µ	1.25 k	-47.2337 k	-748.558 k	-49.71789 k	-74
2	5	51.8604 µ	57.0166 µ	5.16113 µ	-2.7 k	-73.9594 k	2.39616 M	-90.33089 k	2.
2	6	57.0215 µ	61.6992 µ	4.68262 µ	-4.52 k	-1.06864 M	4.78782 M	-1.073344 M	4.7
3	7	74.2041 µ	82.1191 µ	7.91992 µ	1.25 k	-59.3496 k	-749.519 k	-60.1372 k	-74
3	8	82.124 µ	87.2266 µ	5.10742 µ	-1.99 k	-63.0331 k	2.39127 M	-86.01944 k	2.4
3	9	87.2314 µ	91.9141 µ	4.6875 µ	-4.51 k	-1.17801 M	4.79184 M	-1.181425 M	4.8

E: Ch2 Region Table

Pulse	Region	Start Time (sec)	Stop Time (sec)	Region Width (sec)	PM Mean (deg)	FM Mean (Hz)	Chirp Mean (Hz/µs)	Best-Fit FM Mean (Hz)	Bes Slo (Hz
2	5	51.9141 µ	57.0264 µ	5.11719 µ	-73.6 k	-79.9164 M	2.39541 M	-80.01477 M	2.4
2	6	57.0313 µ	61.2842 µ	4.25781 µ	-63.9 k	-82.0115 M	4.81023 M	-82.04385 M	4.
3	7	74.2041 µ	82.1484 µ	7.94922 µ	-113 k	-80.075 M	-750.286 k	-80.07196 M	-74
3	8	82.1533 µ	87.2607 µ	5.1123 µ	-73.9 k	-79.9134 M	2.39289 M	-80.0108 M	2.4
3	9	87.2656 µ	91.5186 µ	4.25781 µ	-63.9 k	-82.0151 M	4.81504 M	-82.04713 M	4.7
4	10	104.438 µ	112.373 µ	7.93945 µ	-113 k	-80.0711 M	-748.035 k	-80.06862 M	-74
4	11	112.378 µ	117.5 µ	5.12695 µ	-74.5 k	-79.9274 M	2.39696 M	-80.01886 M	2.
4	12	117.505 µ	121.758 µ	4.25781 µ	-63.9 k	-81.9931 M	4.81365 M	-82.02727 M	4.7

The traces are described as follows:

- Trace F (pink, lower left) - RF amplitude versus time. Here we see that there are 4 pulses identified.
- Traces A and B (yellow and green) - the measured instantaneous frequency versus time. Here we observe 3 distinct chirp rates within each pulse, suggesting 12 regions of constant chirp rate.
- Trace C (dark blue, upper left) - the measured phase versus time. Linear frequency implies parabolic phase, so observing 3 parabolic phase curves within each pulse is supported by the fact that there are 3 regions within each pulse.
- Traces D and E (right side) – pulses, regions and numerous other metrics are catalogued separately for channels 1 and 2.

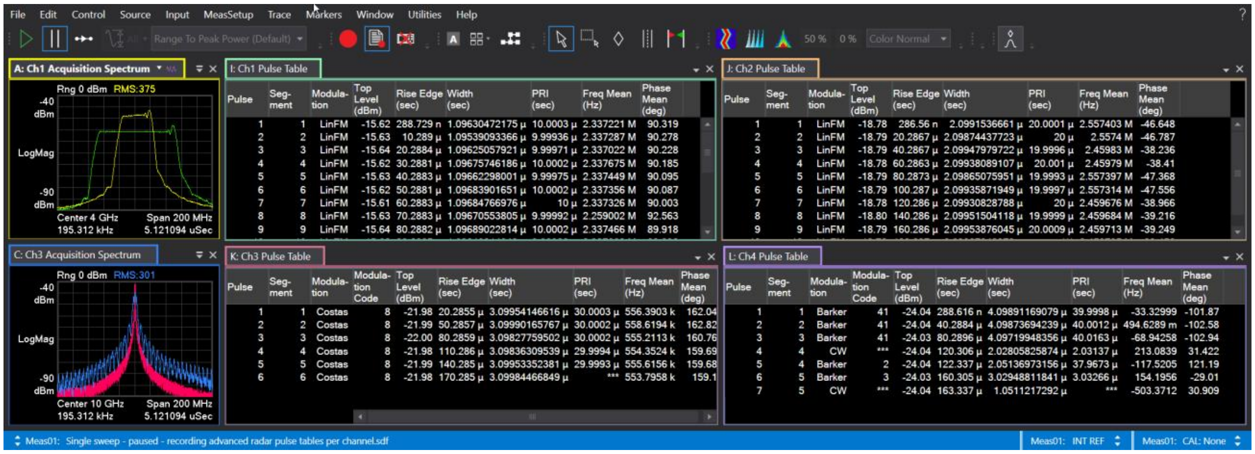
The available synchronization domains include:

- Amplitude: Identifies pulses based on RF bursts of constant amplitude.
- Phase: measures regions of constant phase within an RF burst or a continuous wave (CW) signal.
- Frequency: measures regions of constant frequency within an RF burst or a CW signal.
- Linear Chirp: measures regions of constant chirp rate (assuming linear FM) within an RF burst or a CW signal.

Another important feature of the advanced radar measurement extension is the ability perform pulse and region detection and analysis independently across each measurement channel. This becomes invaluable when acquiring signals with variable length segmented capture, demonstrated in this next example:

Single sweep - paused - recording advanced radar pulse tables per channel.sdf

Different width segments have been labeled appropriately throughout the full acquisition time. By enabling each channel to capture segments independently based on the RF magnitude trigger, it's possible to create synchronous multi-channel pulse tables, as illustrated below.



I: Ch1 Pulse Table

Pulse	Seg-ment	Modula-tion	Top Level (dBm)	Rise Edge (sec)	Width (sec)	PRI (sec)	Freq Mean (Hz)	Phase Mean (deg)
1	1	LinFM	-15.62	288.729 n	1.09630472175 µ	10.0003 µ	2.337221 M	90.319
2	2	LinFM	-15.63	10.289 µ	1.09539093366 µ	9.99936 µ	2.337287 M	90.278
3	3	LinFM	-15.64	20.2884 µ	1.09625057921 µ	9.99971 µ	2.337022 M	90.228
4	4	LinFM	-15.62	30.2881 µ	1.09675746186 µ	10.0002 µ	2.337675 M	90.185
5	5	LinFM	-15.63	40.2883 µ	1.09662298001 µ	9.99975 µ	2.337449 M	90.095
6	6	LinFM	-15.62	50.2881 µ	1.09683901651 µ	10.0002 µ	2.337356 M	90.087
7	7	LinFM	-15.61	60.2883 µ	1.09684766976 µ	10 µ	2.337326 M	90.003
8	8	LinFM	-15.63	70.2883 µ	1.09670553805 µ	9.99992 µ	2.259002 M	92.563
9	9	LinFM	-15.64	80.2882 µ	1.09689022814 µ	10.0002 µ	2.337466 M	89.918

J: Ch2 Pulse Table

Pulse	Seg-ment	Modula-tion	Top Level (dBm)	Rise Edge (sec)	Width (sec)	PRI (sec)	Freq Mean (Hz)	Phase Mean (deg)
1	1	LinFM	-18.78	286.56 n	2.0991536661 µ	20.0001 µ	2.557403 M	-46.648
2	2	LinFM	-18.79	20.2867 µ	2.09874437723 µ	20 µ	2.5574 M	-46.787
3	3	LinFM	-18.79	40.2867 µ	2.09947979722 µ	19.9996 µ	2.45983 M	-38.236
4	4	LinFM	-18.78	60.2863 µ	2.09938089107 µ	20.001 µ	2.45979 M	-38.41
5	5	LinFM	-18.79	80.2873 µ	2.09865075951 µ	19.9993 µ	2.557397 M	-47.368
6	6	LinFM	-18.79	100.287 µ	2.09935871949 µ	19.9997 µ	2.557314 M	-47.556
7	7	LinFM	-18.78	120.286 µ	2.09930828788 µ	20 µ	2.459676 M	-38.966
8	8	LinFM	-18.80	140.286 µ	2.09951504118 µ	19.9999 µ	2.459684 M	-39.216
9	9	LinFM	-18.79	160.286 µ	2.09953876045 µ	20.0009 µ	2.459713 M	-39.249

K: Ch3 Pulse Table

Pulse	Seg-ment	Modula-tion	Modula-tion Code	Top Level (dBm)	Rise Edge (sec)	Width (sec)	PRI (sec)	Freq Mean (Hz)	Phase Mean (deg)
1	1	Costas	8	-21.98	20.2855 µ	3.09954146616 µ	30.0003 µ	556.3903 k	162.04
2	2	Costas	8	-21.99	50.2857 µ	3.09990165767 µ	30.0002 µ	558.6194 k	162.82
3	3	Costas	8	-22.00	80.2859 µ	3.09827759502 µ	30.0002 µ	555.2113 k	160.76
4	4	Costas	8	-21.98	110.286 µ	3.09836309539 µ	29.9994 µ	554.3524 k	159.69
5	5	Costas	8	-21.99	140.285 µ	3.09953352381 µ	29.9993 µ	555.6156 k	159.68
6	6	Costas	8	-21.98	170.285 µ	3.09984466849 µ	***	553.7958 k	159.1

L: Ch4 Pulse Table

Pulse	Seg-ment	Modula-tion	Modula-tion Code	Top Level (dBm)	Rise Edge (sec)	Width (sec)	PRI (sec)	Freq Mean (Hz)	Phase Mean (deg)
1	1	Barker	41	-24.04	288.616 n	4.09891169079 µ	39.9998 µ	-33.32999	-101.87
2	2	Barker	41	-24.04	40.2884 µ	4.09873694239 µ	40.0012 µ	494.6289 m	-102.58
3	3	Barker	41	-24.03	80.2896 µ	4.09719948356 µ	40.0163 µ	-68.94258	-102.94
4	4	CW	***	-24.04	120.306 µ	2.02805825874 µ	2.03137 µ	213.0839	31.422
5	4	Barker	2	-24.04	122.337 µ	2.05136973156 µ	37.9673 µ	-117.5205	121.19
6	5	Barker	3	-24.03	160.305 µ	3.02948811841 µ	3.03266 µ	154.1956	-29.01
7	5	CW	***	-24.04	163.337 µ	1.0511217292 µ	***	-503.3712	30.909

Meas01: Single sweep - paused - recording advanced radar pulse tables per channel.sdf

To help organize which measurement extension should be used for which application, we provide the following matrix of high-level analysis features.

	89601BHQC		89601BHPC
Feature	**Pulse**	**Advanced Radar**	**FMCW**
Pulse Analysis	✓	✓	
Intra-pulse Modulation Analysis	✓	✓	
PMCW Analysis (Regions of Constant Phase)		✓	
Frequency Hopping (Regions of Constant Frequency)		✓	
FMCW Analysis (Regions of Constant Chirp Rate)		✓	✓
Region Analysis Within Pulses		✓	
Multi-Channel Pulse and Region Metrics		✓	
Statistics	✓	✓	✓
Pulse Compression Analysis	✓		
Pulse Similarity Scoring	✓		
Train Scoring	✓		
Emitter Identification	✓		
Frequency Hopping	✓	✓	
Non-linear FM	✓		
Angle of Arrival	✓		

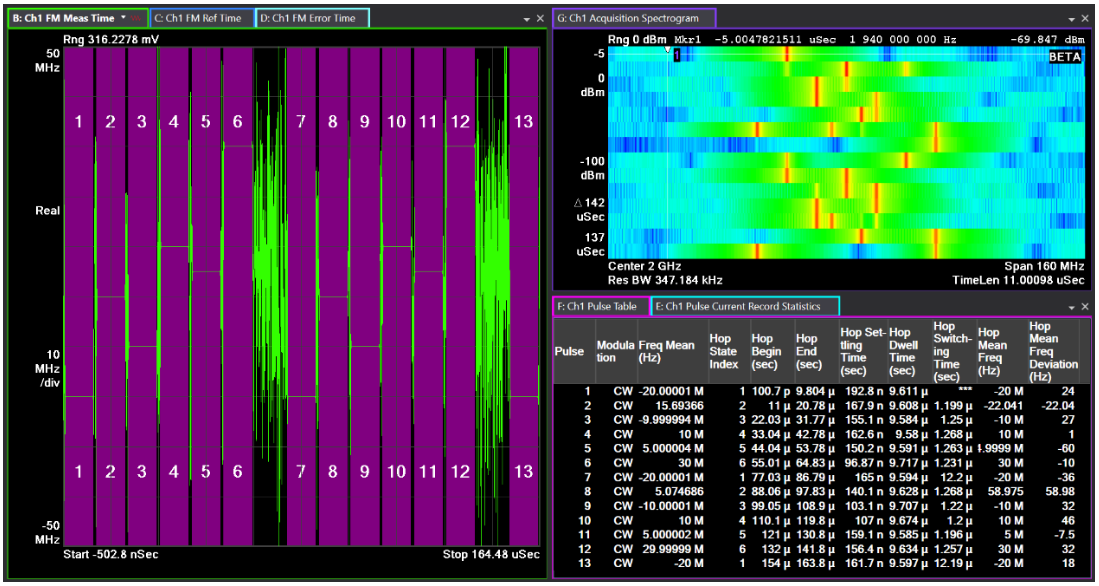
Military Radio and Hopping Analysis

The 89600 VSA software delivers sophisticated frequency hopping analysis capabilities essential for characterizing agile communication systems, including military radios, secure communications, and electronic warfare applications.

Engineers responsible for validating frequency-hopping systems face significant challenges: rapid frequency transitions, short dwell times, and complex signal behavior. The VSA software automatically identifies each hop event and provides comprehensive analysis through a unified measurement interface.

Key Metrics at a Glance:

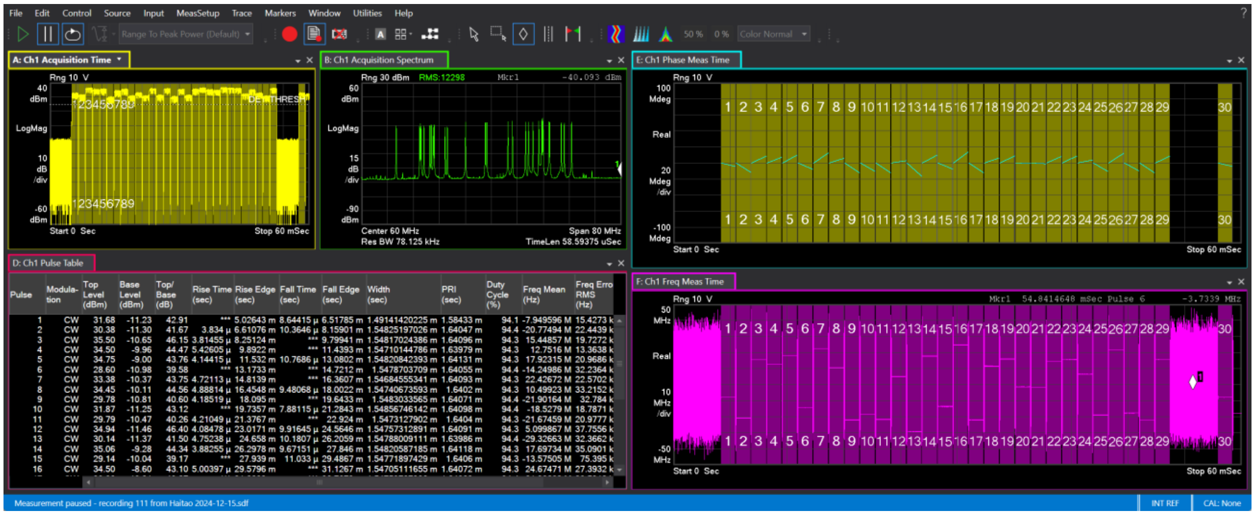
- **Hop Frequency Analysis:** Tracks mean frequency and frequency error per hop
- **Hop Timing Measurements:** Captures dwell time, PRI, and switching intervals
- **Settling Performance:** Measures settling time with user-defined tolerance thresholds
- **State Analysis:** Automatically matches hops to predefined frequency states



Pulse	Modulation	Freq Mean (Hz)	Hop State Index	Hop Begin (sec)	Hop End (sec)	Hop Settling Time (sec)	Hop Dwell Time (sec)	Hop Switching Time (sec)	Hop Mean Freq (Hz)	Hop Mean Freq Deviation (Hz)
1	CW	-20.00001 M	1	100.7 p	9.804 µ	192.8 n	9.611 µ	***	-20 M	24
2	CW	15.69366	2	11 µ	20.78 µ	167.9 n	9.608 µ	1.199 µ	-22.041	-22.04
3	CW	-9.999994 M	3	22.03 µ	31.77 µ	155.1 n	9.584 µ	1.25 µ	-10 M	27
4	CW	10 M	4	33.04 µ	42.78 µ	162.6 n	9.58 µ	1.268 µ	10 M	1
5	CW	5.000004 M	5	44.04 µ	53.78 µ	150.2 n	9.591 µ	1.263 µ	4.9999 M	-60
6	CW	30 M	6	55.01 µ	64.83 µ	96.87 n	9.717 µ	1.231 µ	30 M	-10
7	CW	-20.00001 M	1	77.03 µ	86.79 µ	165 n	9.594 µ	12.2 µ	-20 M	-36
8	CW	5.074686	2	88.06 µ	97.83 µ	140.1 n	9.628 µ	1.268 µ	58.975	58.98
9	CW	-10.00001 M	3	99.05 µ	108.9 µ	103.1 n	9.707 µ	1.22 µ	-10 M	32
10	CW	10 M	4	110.1 µ	119.8 µ	107 n	9.674 µ	1.2 µ	10 M	46
11	CW	5.000002 M	5	121 µ	130.8 µ	159.1 n	9.585 µ	1.196 µ	5 M	-7.5
12	CW	29.99999 M	6	132 µ	141.8 µ	156.4 n	9.634 µ	1.257 µ	30 M	32
13	CW	-20 M	1	154 µ	163.8 µ	161.7 n	9.597 µ	12.19 µ	-20 M	18

The VSA's pulse table presents all metrics in a sortable format, enabling engineers to quickly identify anomalies across thousands of hops. Statistical analysis tools provide insight into the consistency and reliability of the hopping sequence, critical for mission-critical applications. The figure above shows measurements taken with the pulse analysis measurement extension.

The advanced radar measurement extension, on the other hand, allows measurements of frequency transients across an extended burst of RF power without gaps. As shown in the figure below, there are no appreciable drops in RF power amplitude as the signal alternates between two frequencies.



Pulse	Modulation	Top Level (dBm)	Base Level (dBm)	Top/ Base (dB)	Rise Time (sec)	Rise Edge (sec)	Fall Time (sec)	Fall Edge (sec)	Width (sec)	PRI (sec)	Duty Cycle (%)	Freq Mean (Hz)	Freq Erro RMS (Hz)
1	CW	31.68	-11.23	42.91	***	5.02643 m	8.64415 µ	6.51785 m	1.49141420225 m	1.58433 m	94.1	-7.949596 M	15.4273 k
2	CW	30.38	-11.30	41.67	3.834 µ	6.61076 m	10.3646 µ	8.15901 m	1.54825197026 m	1.64047 m	94.4	-20.77494 M	22.4439 k
3	CW	35.50	-10.65	46.15	3.81455 µ	8.25124 m	***	9.79941 m	1.54817024386 m	1.64096 m	94.3	15.44857 M	19.7272 k
4	CW	34.50	-9.96	44.47	5.42605 µ	9.8922 m	***	11.4393 m	1.54710144786 m	1.63979 m	94.3	12.7516 M	13.3638 k
5	CW	34.75	-9.00	43.76	4.14415 µ	11.532 m	10.7686 µ	13.0802 m	1.54820842393 m	1.64131 m	94.3	17.92315 M	20.9686 k
6	CW	28.60	-10.98	39.58	***	13.1733 m	***	14.7212 m	1.5478703709 m	1.64055 m	94.4	-14.24986 M	32.2364 k
7	CW	33.38	-10.37	43.75	4.72113 µ	14.8139 m	***	16.3607 m	1.54684555341 m	1.64093 m	94.3	22.42672 M	22.5702 k
8	CW	34.45	-10.11	44.56	4.88814 µ	16.4548 m	9.48068 µ	18.0022 m	1.54740673593 m	1.6402 m	94.3	10.49923 M	33.2152 k
9	CW	29.78	-10.81	40.60	4.18519 µ	18.095 m	***	19.6433 m	1.5483033565 m	1.64071 m	94.4	-21.90164 M	32.784 k
10	CW	31.87	-11.25	43.12	***	19.7357 m	7.88115 µ	21.2843 m	1.54856746142 m	1.64098 m	94.4	-18.5279 M	18.7871 k
11	CW	29.79	-10.47	40.26	4.21049 µ	21.3767 m	***	22.924 m	1.5473127902 m	1.6404 m	94.3	-21.67459 M	20.9777 k
12	CW	34.94	-11.46	46.40	4.08478 µ	23.0171 m	9.91645 µ	24.5646 m	1.54757312891 m	1.64091 m	94.3	5.099867 M	37.7556 k
13	CW	30.14	-11.37	41.50	4.75238 µ	24.658 m	10.1807 µ	26.2059 m	1.54788009111 m	1.63986 m	94.4	-29.32663 M	32.3662 k
14	CW	35.06	-9.28	44.34	3.88255 µ	26.2978 m	9.67151 µ	27.846 m	1.54820587185 m	1.64118 m	94.3	17.69734 M	35.0901 k
15	CW	29.14	-10.04	39.17	***	27.939 m	11.033 µ	29.4867 m	1.54771897429 m	1.6406 m	94.3	-13.57505 M	75.395 k
16	CW	34.50	-8.60	43.10	5.00397 µ	29.5796 m	***	31.1267 m	1.54705111655 m	1.64072 m	94.3	24.67471 M	27.3932 k

Measurement paused - recording 111 from Haitao 2024-12-15.sdf

Military systems like SINCGARS, HAVE QUICK, and Link-16 benefit from this analysis by ensuring reliable operation in contested environments. Advanced triggering capabilities allow engineers to isolate specific hopping events or patterns for detailed investigation.

When paired with Keysight oscilloscopes or signal analyzers offering wide acquisition bandwidth, the VSA software can capture even the most agile frequency hopping signals spanning hundreds of MHz.

Software Features

Note: The following features are independent of hardware platform used, unless otherwise noted.

Pulse Detection Configuration	
Reference	Specifies a reference power level for pulse detection threshold. It may be selected as relative to peak power, relative to the noise floor, relative to ADC range of the receiver, or absolute power in dBm.
Threshold	Provides a numerical value to the “Reference” parameter above.
Hysteresis	Allows pulse to drop by specified offset level (0 to 50 dB) from the Threshold before determining an off transition.
Ignore Dropouts	Transient drops in amplitude may optionally be rejected and still counted as the pulse “on” time.
Min/Max Pulse Width	Pulses may be filtered out based on a minimum and/or maximum pulse width time.
Display Detection Threshold Line	Detection threshold line may be drawn on amplitude vs. time traces.
Chirp, Phase, and Frequency Region Detection	
Min/Max Chirp Rate	Specified the minimum or maximum chirp rate allowed for a region to be considered valid and be detected.
Minimum Phase Delta for Transitions	Specifies the minimum phase delta required for a change in phase to be considered a region transition.
Min/Max Frequency	Specifies the minimum or maximum frequency allowed for a region to be considered valid and be detected.
Minimum Frequency Delta for Transitions	Specifies the minimum frequency delta required for a change in frequency to be considered a region transition.
Settling Tolerance	Specifies the allowed tolerance for region “level” deviation. The level can be frequency, phase, or chirp rate, depending on the selected synchronization domain.
Region Detection Filtering	
Min/Max Region Width	Regions may be filtered out based on a minimum and/or maximum region time widths.
Max Detection Count per-Pulse	An upper limit to the number of detected regions within pulse may be specified.

Time Capture Configuration	
Acquisition Length	Specifies the total measurement acquisition length in seconds.
Extra Acquisition	Sets the number of extra acquisition samples before and after the valid detected pulse results. Disabled when segmented capture mode is enabled.
Sample Rate	Specifies the measurement sample rate in Hz.

Bandwidth	The measurement span (or bandwidth) in Hz is calculated as the measurement sample rate/1.28. This property may also be set directly as Span (Hz) under VSA Meas Setup property in the frequency tab.
Maximum Pulse Count	An upper limit to the number of detected pulses may be specified.
Time Values Are Relative to	Reference time used for time-based trace results and pulse table metrics. Choices are first pulse or event trigger time.
Frequency Values Are	Frequencies may be reported as absolute values or relative to the measurement center frequency.
Segmented Capture	Record only the on-section of the pulse, eliminating the dead time. Only available for supported front-end hardware or when a segmented recording file is loaded.
• Segment type	Selects between Fixed and Variable segmented capture type.
• Capture Length type	Selects the segment length unit (count or duration).
• Segment length (Fixed)	Specifies the per-segment acquisition length in seconds.
• Segment count (Fixed)	Specifies the desired number of segments to acquire.
• Desired Segment length (Variable)	Specifies the desired number of segments to capture in the acquisition.
• Desired Segment count (Variable)	Specifies the desired number of segments to capture in the acquisition.
• Total acquisition length	Displays the total combined segmented acquisition length, equal to segment length * segment count.
Pulse Selection Configuration	
Select All Pulses	All detected pulses are reported in relevant trace results.
Select Subset	Users can specify a subset of detected pulses for amplitude, phase and FM vs. time trace results.
Sub-Part Selection	Specifies which part of the selected pulses is displayed and highlighted within the synchronized time trace results. Choices are entire pulse, on part, top part, ripple analysis, frequency/phase analysis, pulse-to-pulse analysis, rising edge, falling edge or automatic selection.
Highlight Selected Pulses on Traces	Enables or disables pulse highlighting within the time trace results.
Include Extra Data Before and After	Enables or disables the display of extra data samples (specified by *Extra Acquisition*) acquired before and after selected pulse trace results.

Fast-Time Slow-Time Heatmap Display Configuration	
Time vs. Time ► Fast-Time Length	Length of each captured time domain slice as the horizontal axis of the Fast-Time Slow-Time heat map display
Time vs. Time ► Auto-detect Fast-Time Length	Automatically set the fast time length based on the PRI of the signal.

Time vs. Time ► Fast-Time Offset	Time offset in the Fast-Time axis
Frequency vs. Time ► ResBW	Resolution bandwidth for Frequency vs. Time measurements, also known as Doppler plots.
Frequency vs. Time ► Time Step	Time increments between slices of input time domain data.
Frequency vs. Time ► Window Type	Windowing type to be applied prior to the FFT.
Max Analysis Points	Upper bound of the analysis time, beyond which analysis stops.
Max Analysis Duration (read-only)	Displays maximum analysis points in time, accounting for the sample rate.

Pulse Regions for Threshold, Measurement Analysis and Windowing	
Threshold Configuration	
Rise/Fall Time, Upper and Lower	Specifies thresholds of power level as % of measured pulse top power level, used for calculating rise and fall time analysis result metrics.
Pulse Width	Specifies power threshold as % of measured pulse top power level for calculating pulse width result metric.
Amplitude Domain	Specifies the amplitude domain used for determining rise time, fall time and pulse width thresholds. The choices are Voltage (V) or Power (W).
Top/Base Calculation Method	Chooses the method for calculating the pulse top and pulse base power levels. Choices are mode, median and mean.
Adjust Thresholds for Droop	When checked, the rise time, fall time, and pulse width calculations are compensated for droop of the top pulse power level.
Pulse Analysis Region Configuration	
	Note: all percentages are assumed centered in the middle of the Pulse-ON time.
Droop Estimation Width	Specifies the percentage of the pulse top used for droop calculation.
Ripple Analysis Width	Specifies the percentage of the pulse top time used for ripple analysis.
Frequency/Phase Analysis Width	Specifies the percentage of the pulse top time for FM or Barker code analysis. These are sub-divided as: • % of pulse top for CW/Linear FM analyses • % of chirp region for Triangular FM waveforms • % of a chip for Barker Phase coded waveform analysis
Pulse-to-Pulse Analysis	Can optionally use the same settings as frequency/phase analysis or manually specify reference time, offset and window length.
• Reference Time	Sets pulse-to-pulse measurement reference time. The choices are pulse rising edge, pulse center or pulse falling edge.
• Offset	Time offset in seconds from user-selected Reference Time location to center of pulse-to-pulse measurement sample window.
• Window Length	Specifies the pulse-to-pulse measurement sample window length in seconds.

Spectrum Window	Specify window type for FFT analysis. Choices are Uniform, Hanning, Gaussian Top, Flat Top, Blackman-Harris, Kaiser-Bessel and Gaussian.
Max Spectrum FFT Length	Maximum FFT length for the current measurement.

Advanced Pulse Analysis	
Modulation on Pulse Configuration	
Pulse Modulation	Select which pulse modulation types should be automatically detected. Select All or select from: Continuous Wave, Linear FM, Triangular FM, Barker Phase, BPSK, QPSK, Frank Code, P1 Code, P2 Code, P3 Code, P4 Code
Enable extended bits (BPSK/QPSK)	Enables BPSK/QPSK demodulation of up to 1024 bits.
Enable Custom BPSK	Choose custom angle of BPSK constellation from 30° to 180°
CW Frequency Offset	For CW modulation, the frequency error may be relative to the mean frequency of the pulse or to a user-specified frequency.
FM Filter Bandwidth	Filter out unwanted signals and control the amount of noise included in the FM and FM Slope demodulation traces. Bandwidth Relative to Span specifies the FM differentiating filter bandwidth relative to measurement span.
Triangular FM is Symmetrical	Specify symmetrical slopes for the Triangular FM reference “best-fit” signal.
Compensate Phase Results for Frequency offset	When enabled, the reported per-pulse measured and reference synchronized phase trace results are automatically compensated for each specific pulse measured mean frequency offset from the current Center Frequency.
Nonlinear FM Analysis Configuration	
Nonlinear FM Analysis	Enables or disables polynomial fitting of instantaneous frequency versus time.
Max Polynomial Degree	Maximum order of the polynomial coefficients for curve fitting
Time Scaling Region for Polynomial	Each pulse’s time vector is centered about zero and scaled to ± 1. Pulse region for time vector may be defined as Top Region, Analysis Region, Pulse Width or User-Defined.
User-Defined Pulse Region for Polynomial	Time (in seconds) if time scaling region for polynomial is user-defined.
Reference Trace Calculation	Polynomial coefficients may be automatically extracted or user defined.
Copy Measured Pulse	If user-defined, a pulse may be selected for automatic coefficient estimation.
Import from CSV	User-defined polynomial coefficients may be imported from a CSV file.

Pulse Correlation and Sidelobe Analysis Configuration	
Enable Correlation/Sidelobe Calculations	Enables or disables correlation and time sidelobe calculations. This feature assumes the user has defined a reference correlation pulse or saved the reference outbound pulse to a data register.
Set Correlation Reference from Register	Copy data register to correlation reference to be used as the basis for the matched filter.
Correlation Reference Window	Reduce the effect of transient noise in the rising or falling edges with windowing. Choices are Uniform (Rectangular), Hanning, Gaussian Top, Flat Top, Blackman-Harris, Kaiser-Bessel or Gaussian.
Sidelobe Keep Out Mode	Define a minimum time delta from the main lobe of the correlation trace to look for a sidelobe. Choices are to look beyond the first null of the correlation trace or a user-specified time.
Sidelobe Keep Out Time	Look beyond a user-specified time to find the peak sidelobe.
Sidelobe Minimum Rho	Sets the minimum similarity for sidelobe identification.
Sidelobe Search Range Ratio	Sets the search range for time sidelobe calculations as a percent of the pulse width. Default = 200%

Pulse Similarity Scoring Configuration	
Scoring Enable	Enables or disables pulse scoring for the current measurement.
Start Pulse Number	Specifies index of first measured pulse to be copied into the reference pulse table.
Stop Pulse Number	Specifies index of the last measured pulse to be copied into the reference pulse table.
Copy Measured Pulses	Copies measured pulse characteristics of selected pulses into the reference pulse table.
Sequences Offset Auto	Automatically detects the correct sequence offset to best align the reference sequence with the measured sequence. When unchecked, a manual pulse offset may also be specified.
Scoring Metrics and Base Error	Emphasize one metric over another in the scoring calculation by making the tolerances tighter or looser. Top Level, Width, PRI, Mean Frequency, and FM Slope may be independently enabled.

Pulse Train Similarity Scoring Configuration	
Train Scoring Enabled	Enables or disables pulse train scoring for the current measurement with up to 4 trains.
Train n (1-4)	Expands or collapses the parameter group for the selected pulse train.
Enabled	Includes or excludes the selected train in the pulse train analysis.
Identification Threshold	Specifies the minimum train score threshold level required to consider the measured pulse train a match with the reference train.
Start Pulse	Specifies the index of the first measured pulse to be copied into the reference pulse table for the selected pulse train.
Stop Pulse	Specifies the index of the last measured pulse to be copied into the reference pulse table for the selected pulse train.

Copy Measured Pulses	Copies pulse characteristics for up to 1024 selected measured pulses into the selected train’s reference table.
Scoring Metrics and Base Error	Like individual pulse scoring, one may emphasize one metric over another in the train scoring calculation. Top Level, Pulse Width, PRI, Mean Frequency and FM Slope may be independently enabled.
Skip Unwanted Intermediate Pulse	When enabled, the scoring algorithm allows for an extraneous pulse in the measured train that is not part of the reference train without a degradation to the train score.
Emitter Deinterleaving Configuration	
Frequency	Sets the upper and lower frequency thresholds to be used for the selected emitter when filtering the pulse table based on frequency.
Amplitude	Sets the upper and lower amplitude thresholds to be used for the selected emitter when filtering the pulse table based on amplitude.
Modulation	Sets the modulation format to be used for the selected emitter when filtering the pulse table based on modulation type.
Frequency Hopping Analysis Configuration	
Hop Analysis	Enables or disables frequency hop analysis.
Settling Tolerance	Sets how much frequency settling (in Hz) to allow at the hop edges.
Max/Min Hop Dwell Time	Specifies maximum and minimum dwell time for hop measurement.
Analysis Region (% of dwell)	Sets the percentage of hop dwell time to be used in hop mean frequency and hop mean deviation calculation. Analysis region is centered at the middle of each hop.
Hop State Analysis	Reference hop states may be defined by the user and later identified in the pulse metric table by index.
Detection Mode	Toggles identification of hop states in the pulse table. The choices are Off (no identification) or Manual (based on user supplied table).
Start Frequency	Sets the start frequency for a linear sweep in hop state definition.
Stop Frequency	Sets the stop frequency for a linear sweep in hop state definition.
Step Frequency	Sets the increment, or step spacing, for the user-defined list of hop states.
Tolerance	Sets the tolerance for all frequency entries in the hop state table.
Hop State Table Display	Hop state table is displayed with columns: Index, Frequency and Tolerance. The table is automatically updated after changes to Start/Stop/Step Frequency and Tolerance settings.

Angle of Arrival (AoA) Analysis Configuration	
Angle of Arrival Analysis	Enables or disables AoA analysis
Antenna Orientation	Select from various preset antenna orientation configurations: 2 Antenna Horizontal/Vertical, 3 Antenna L-shaped (and flipped), 4 Antennas in a square pattern. Each antenna represents a different VSA measurement channel.

Antenna Spacing	The spacing between the antennas around the SUT (system under test) may be expressed in meters or in wavelengths of a user-specified frequency.
Antenna Configuration Table	The coordinates of the enabled antennas are tabulated here. Note that all antennas are assumed to be in the X-Z plane. They are illustrated graphically in an “Antenna Orientation Visual."
AoA Calculation Method	Selects the AoA analysis mode as Delta Phase or TDOA.
Delta Phase	Delta Phase detects the difference of phase between the channels. This analysis method can be used when the antennas are closely spaced.
Time Difference of Arrival (TDOA)	TDOA leverages the difference of pulse rising edge times, falling edge times, or center of rising and falling edges between the channels as specified by the “TDOA Criteria” enumeration.
Statistics Analysis Configuration	
Statistics Enabled	Enables or disables all trend, histogram, and cumulative results table trace results and pulse metrics.
Remove Mean	When enabled (checked), all Trend and Histogram trace results will be reported after first removing the accumulated Trend and Histogram statistical data set for the selected computation (mean value, first order linear slope best-fit, or second order curve best-fit).
Remove Slope	
Remove Second Order	
Display Length	Specifies the number of points displayed within Trend trace results, or pulses displayed within the Cumulative Pulse Table.
Internal Buffer Length	Specifies the maximum number of points used for statistics data gathering and analysis.
Histogram Range Limit	The range (x-axis) of the histogram may be set to the data extents or $\pm 3\sigma$ of the mean.
Misc Features (under “Advanced”)	
Measurement Pause Enable	Trap intermittent events by enabling or disabling a conditional test which when met, will cause the pulse measurement to pause.
• Metric	Specifies the pulse metric to be used in the conditional check. The choices include all possible pulse table metrics.
• Operator	Specifies a conditional test operator, for example, t1 ≤ Value ≤ t2. Up to two threshold parameters (t1, t2) maybe specified separately.
• t1	First of two thresholds specifying the associated limit for the conditional (Operator) test.
• t2	Second of two thresholds specifying the associated limit for the conditional (Operator) test.
Acquisition Spectrogram	This group contains settings that determine the time and frequency resolution for the Acquisition Spectrogram trace.
• Scan Length	Sets the length of each scan (in sec). Each acquisition is split into slices matching this scan length.
• Scan Overlap	Set the frequency resolution of the spectrogram by setting the percentage of overlap between scans

Increase Speed for Exporting Entire Recording	Removes all trace displays but one (trace A) to increase acquisition length and improve playback speed.
Measurement and Trace Results	
Channel <N> ►	Acquisition Spectrogram, Acquisition Time, Auto Correlation, CCDF Summary, CCDF (complementary cumulative distribution function), CDF (cumulative distribution function), Correction (Calibration Data), Correlation Time (relevant only for Correlation/Sidelobe analysis), Instantaneous Spectrum, PDF (probability density function), PSD (power spectral density), Raw Main Time (no time corrections or resampling filters), Spectrum (power versus frequency).
Amplitude ► Channel <N> ►	Measured amplitude vs. time (averaged and instantaneous), reference signal amplitude vs. time, error amplitude vs. time (averaged and instantaneous).
Phase ► Channel <N> ►	Measured phase vs. time (average and instantaneous), reference signal phase vs. time, phase error vs. time (average and instantaneous), phase noise spectrum (average and instantaneous).
FM ► Channel <N> ►	Measured FM vs. time (average and instantaneous), reference FM signal vs. time, FM error vs. time (average and instantaneous), measured FM spectrum (FFT of measured FM vs. time, average and instantaneous), reference signal FM spectrum, error signal spectrum (average and instantaneous), FM filter coefficients.
Time vs. Time Heatmap	Power heatmap based on the concept of a Fast-Time Slow-Time chart. X-axis is fast-time, Y-axis is slow-time and Color is power.
Frequency vs. Time Heatmap	Doppler plot, where the X-axis is frequency, the Y-axis is slow-time and Color is power.
Result Tables	
Pulse Table	Table display of many dozens of metrics, organized in the following categories: modulation, RF output level, amplitude settling, time measurements, phase measurements, linear frequency modulation, triangular frequency modulation, channel to channel differences, pulse compression, de-interleaving and frequency hopping.
Region Table	Table display of many metrics, organized in the following categories: Time/Level, Settling/Switching Time, and sync domain dependent metrics. In PM Sync Domain - Phase Modulation and PM Error In FM and Linear Chirp Sync Domain – Phase / Frequency Modulation, PM/FM Error, Best-fit FM
Cumulative Result Table	Same as Pulse Table, except that the table continues to add rows across multiple acquisitions.
Current Statistics	For every column in the pulse table, tabulate the following statistics for the current measurement acquisition: Minimum, Maximum, RMS Value, Average (mean), Standard Deviation, Count (N)
Cumulative Statistics	Same as Current Statistics, except that the statistics consider measured data across multiple acquisitions. Furthermore, this result table adds the following statistics: Median and Mode.
Demod Bits	Returns Pulse Number, Modulation Type (BPSK or QPSK), Chip Length and the demodulated bits in hexadecimal. This trace

	summary is only available when BPSK and/or QPSK modulation types are selected (under Modulation on Pulse Configuration) and the BPSK/QPSK Extended Bit detection is enabled.
Summary	Provides the following metrics for the current acquisition: # of pulses, average power, peak power, detection threshold, pulse-on ("Top") power level, pulse-off ("Base") power level, top/base ratio (dB), and time between trigger and first detected pulse
Pulse Train Search Table	Returns the following metrics relevant for pulse pattern search: Pulse Index, Modulation, Top Level, Width, PRI, Mean Frequency's, Best-Fit FM Slope, Train ID, Train 1/2/3/4 Score, Train 1/2/3/4 Search Skip Index. This is only available when "Train Scoring" has been enabled.
Metrics for Pulse Tables, Trend Lines and Histograms	
Common	Pulse number or index; detected modulation type.
Modulation Decode	Modulation code number, chip count, measured bits, chip time width, chip offset time
RF Power Level	Top level (dBm), Base Level (dBm), Top/Base Ratio (dB), Pulse-on Power (dBm), Peak Power (dBm), Mean Power (dBm), Peak-to-Average Ratio (dB).
Droop	Power Droop (%), Power Droop (dB), Droop Rate (dB/µs), Droop Starting Amplitude (dBm), Droop Stop Amplitude (dBm).
Overshoot	Magnitude of amplitude peak level above the estimated amplitude envelope at the rising edge, expressed in % and dB.
Ripple	Amplitude variations during the Pulse Top region, expressed in % and dB's.
Time Metrics	Rise Time (sec), Rising Edge (sec), Fall Time (sec), Falling Edge (sec), Width (sec), Off-Time (sec), Pulse Repetition Interval (sec), Pulse Repetition Frequency (Hz), Duty Cycle (%).
Frequency	Mean frequency, pulse to first pulse frequency difference, peak-to-peak frequency deviation. Relative to an estimated reference signal, the following are also available: RMS frequency error, peak frequency error and time location of peak frequency error
Phase	Mean phase, pulse to first pulse phase difference, peak-to-peak phase deviation. Relative to an estimated reference signal, the following are also available: RMS phase error, peak phase error and time location of peak phase error.
Linear FM	When linear FM modulation analysis is selected, the VSA will calculate a best fit LFM model to the measured instantaneous frequency vs. time. The following model parameters may be tabulated: mean frequency, start frequency, stop frequency, peak to peak deviation, FM slope (Hz/µs) and integrated nonlinearity (INL) relative to best fit in %.
Triangular FM	Same as Linear FM analysis, except that when triangular FM modulation analysis is selected, the VSA will calculate the analogous metric for the second chirp, labeled as <metric> + "2nd." Furthermore, the frequency and time locations of the triangular FM peak are also available.

Nonlinear FM	When NLFM is enabled, the coefficients for a best-fit polynomial describing the time-normalized instantaneous frequency vs time are available. The columns are a0, a1, … depending on the polynomial order.
Frequency Hopping	When Frequency Hopping is enabled, the following frequency transient metrics are available: Hop State Index, Hop Begin Time, Hop End Time, Hop Settling Time, Hop Dwell Time, Hop Switching Time, Hop Mean Frequency, Hop Mean Frequency Deviation.
Pulse Compression	These metrics are enabled with “Enable Correlation/Sidelobe Calculations” and when a reference pulse has been identified and stored to a data register. The correlation analysis provides the following metrics: Rho (similarity to reference pulse), Peak Sidelobe Level (dB), Peak Sidelobe Time Location, Compression Ratio (%) and Mainlobe Width.
Pulse Similarity Scoring	When enabled, pulse scoring is displayed as the similarity of pulse metrics between measured and user-defined reference pulses.
Deinterleaving	When enabled, emitter ID’s may be tabulated based on frequency, amplitude and modulation type.
Channel to Channel Comparison	When channel 1 and channel 2 data are available, the following metrics are available: time difference between pulse rising edge on Ch2 vs. Ch1, amplitude and frequency differences of corresponding pulses.
Angle-of-Arrival	When AoA is enabled and 2-4 channel data are available, AoA Azimuth and Elevation are tabulated in degrees.
Stimulus-Response “Graph” Measurements on 2-Port Devices (i.e. amplifiers, etc.)	
AM/AM	Scatter plot of the instantaneous output response magnitude versus input stimulus magnitude.
AM/PM	Scatter plot of the instantaneous output response phase versus input stimulus magnitude.
Gain Compression	Scatter plot of the instantaneous gain (response/stimulus) versus input stimulus magnitude.
Stimulus Time	Shows the stimulus signal after amplitude normalization, time alignment and phase error compensation.
Response Time	Shows the response signal after amplitude normalization, time alignment and phase error compensation.
Delta EVM Time	Shows the magnitude of the differential error vector between the stimulus and response signals, calculated at each time point.
Data Plot	Plot arbitrary pulse measurement metrics against each other to view the comparative relationship.

Key Specifications

This technical overview provides nominal performance specifications for the software when making measurements with the specified platform [1]. Nominal values indicate expected performance or describe product performance that is useful in the application of the product but is not covered by the product warranty. For a complete list of specifications refer to the measurement platform literature.

General	
Frequency	Depends on connected hardware platforms
Trigger Types	Free Run, External, IF Magnitude, Periodic, Frequency Mask [2]
Sample intervals, Time resolution	Depends on analysis bandwidth (BW) of connected hardware minimum sample interval = 1/(1.28 * BW) Max sample rate = 1/(Sample Interval) = 1.28 * BW
Min Pulse Width	< 6 x Sample Interval
Min Rise-/Fall-time	< 3 x Sample Interval
Live Acquisition Length	10 MSa per 4 GB of physical memory on the PC running the 89600 VSA software. 5 MSa on 89600 VSA software running on an X-Series signal analyzer.
Recording Length	Depends on the measurement hardware. Visit http://www.keysight.com/find/89600_hardware to find the maximum capture depth supported by each hardware platform.
Max # of Pulses	Depends on time length, BW of each pulse, and whether segmented memory capable hardware is connected up to 100,000 in pulse tables
Min Freq Hop Dwell Time	Frequency hop dwell must be contained within a pulse-on period. User parameter called “Min Hop Dwell Time” may be set to an absolute minimum of 5 samples for a dwell to be measured. Furthermore, frequency hopping analysis is only applicable for CW pulses without additional modulation.
Measurement Accuracy	
FM Uncertainty	These values represent the 95% confidence interval (±) around the listed center frequency. The input signal to the measurement instrument is a 0 dBm unmodulated carrier at the listed center frequency. In this case, the output of the FM meas time trace should be a constant zero value. However, due to random noise (phase noise and other), the FM meas time trace will contain a non-zero signal with a mean and standard deviation (stddev). The contents of the cells represent (1.96 * stddev). Standard deviation does not include the error due to frequency offset. Measurement time: < 10 ms. Input range is optimized without overloading. 10 MHz reference source is locked with signal source.

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1. Data subject to change.
2. Frequency mask is included with RT1 and RT2 real-time spectrum analysis licenses. It works with UXA, PXA, and MXA X-Series signal analyzers with required hardware. Refer to instrument configuration guides for more detail.

Frequency Error						
PXA N9030B Signal Analyzer						
See PXA data sheet (5990-3952EN) for frequency accuracy specifications						
FM filter bandwidth (% of measurement bandwidth)	50%	25%	10%	5%	1%	0.1%
2 GHz Center Frequency						
10 MHz	± 1.1 kHz	± 420 Hz	± 170 Hz	± 120 Hz	± 25 Hz [1]	± 1.0 Hz [1]
25 MHz	± 4.2 kHz	± 1.5 kHz	± 420 Hz	± 200 Hz	± 80 Hz	± 3.2 Hz [1]
28 MHz	± 5.4 kHz	± 2.0 kHz	± 560 Hz	± 240 Hz	± 82 Hz	± 4.0 Hz [1]
40 MHz	± 8.7 kHz	± 3.3 kHz	± 920 Hz	± 360 Hz	± 100 Hz	± 6.4 Hz [1]
80 MHz	± 22 kHz	± 7.8 kHz	± 2.1 kHz	± 760 Hz	± 150 Hz	± 19 Hz [1]
160 MHz	± 65 kHz	± 22 kHz	± 5.6 kHz	± 2.0 kHz	± 250 Hz	± 51 Hz [1]
8 GHz Center Frequency						
10 MHz	± 1.5 kHz	± 630 Hz	± 300 Hz	± 230 Hz	± 75 Hz [1]	± 2.9 Hz [1]
25 MHz	± 4.6 kHz	± 1.8 kHz	± 560 Hz	± 330 Hz	± 170 Hz	± 9.4 Hz [1]
28 MHz	± 6.3 kHz	± 2.4 kHz	± 700 Hz	± 360 Hz	± 180 Hz	± 10 Hz [1]
40 MHz	± 11 kHz	± 4.0 kHz	± 1.1 kHz	± 490 Hz	± 220 Hz	± 18 Hz [1]
80 MHz	± 27 kHz	± 9.6 kHz	± 2.6 kHz	± 950 Hz	± 270 Hz	± 59 Hz [1]
160 MHz	± 77 kHz	± 27 kHz	± 6.8 kHz	± 2.5 kHz	± 400 Hz	± 130 Hz [1]
26 GHz Center Frequency						
10 MHz	± 3.5 kHz	± 1.6 Hz	± 910 Hz	± 690 Hz	± 230 Hz [1]	± 9.8 Hz [1]
25 MHz	± 13 kHz	± 4.9 kHz	± 1.6 kHz	± 970 Hz	± 500 Hz	± 31 Hz [1]
28 MHz	± 17 kHz	± 6.4 kHz	± 1.9 kHz	± 1.1 kHz	± 540 Hz	± 36 Hz [1]
40 MHz	± 27 kHz	± 10 kHz	± 3.0 kHz	± 1.4 kHz	± 630 Hz	± 67 Hz [1]
80 MHz	± 68 kHz	± 25 kHz	± 6.8 kHz	± 2.7 kHz	± 820 Hz	± 190 Hz [1]
160 MHz	± 190 kHz	± 70 kHz	± 18 kHz	± 6.9 kHz	± 1.1 kHz	± 360 Hz [1]
43 GHz Center Frequency						
10 MHz	± 4.7 kHz	± 2.4 kHz	± 1.5 kHz	± 1.2 kHz	± 370 Hz [1]	± 17 Hz [1]
25 MHz	± 15 kHz	± 6.5 kHz	± 2.4 kHz	± 1.6 kHz	± 860 Hz	± 47 Hz [1]
28 MHz	± 19 kHz	± 7.9 kHz	± 2.7 kHz	± 1.7 kHz	± 910 Hz	± 59 Hz [1]
40 MHz	± 31 kHz	± 12 kHz	± 3.9 kHz	± 2.1 kHz	± 1.1 kHz	± 110 Hz [1]
80 MHz	± 85 kHz	± 31 kHz	± 9.1 kHz	± 3.8 kHz	± 1.4 kHz	± 270 Hz [1]
160 MHz	± 230 kHz	± 88 kHz	± 23 kHz	± 9.0 kHz	± 1.8 kHz	± 530 Hz [1]

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[1] With PXA phase noise optimization set to best close in. Others are set to best wide offset. Infiniium DSO/MSO S-Series Oscilloscope.

Frequency Error						
Infiniium DSO/MSO S-Series Oscilloscope						
FM filter bandwidth (% of measurement bandwidth)	50%	25%	10%	5%	1%	0.1%
1 GHz Center Frequency						
10 MHz	± 1.7 kHz	± 720 Hz	± 280 Hz	± 190 Hz	± 62 Hz	± 2.3 Hz
25 MHz	± 6.5 kHz	± 2.4 kHz	± 730 Hz	± 340 Hz	± 140 Hz	± 7.6 Hz
28 MHz	± 7.7 kHz	± 2.9 kHz	± 830 Hz	± 380 Hz	± 150 Hz	± 9.3 Hz
40 MHz	± 13 kHz	± 4.8 kHz	± 1.3 kHz	± 560 Hz	± 180 Hz	± 15 Hz
80 MHz	± 37 kHz	± 13 kHz	± 3.5 kHz	± 1.3 kHz	± 260 Hz	± 45 Hz
160 MHz	± 100 kHz	± 37 kHz	± 9.8 kHz	± 3.6 kHz	± 430 Hz	± 110 Hz
320 MHz	± 290 kHz	± 100 kHz	± 27 kHz	± 9.8 kHz	± 980 Hz	± 140 Hz
500 MHz	± 580 kHz	± 210 kHz	± 53 kHz	± 19 kHz	± 1.9 kHz	± 190 Hz
1 GHz	± 1.6 MHz	± 590 kHz	± 150 kHz	± 53 kHz	± 4.9 kHz	± 300 Hz
2 GHz	± 9.4 MHz	± 1.6 MHz	± 430 kHz	± 150 kHz	± 13 kHz	± 680 Hz
2 GHz Center Frequency						
10 MHz	± 2.1 kHz	± 1.0 kHz	± 520 Hz	± 380 Hz	± 120 Hz	± 4.6 Hz
25 MHz	± 7.0 kHz	± 2.9 kHz	± 1.0 kHz	± 580 Hz	± 290 Hz	± 14 Hz
28 MHz	± 8.1 kHz	± 3.4 kHz	± 1.2 kHz	± 630 Hz	± 310 Hz	± 19 Hz
40 MHz	± 13 kHz	± 5.4 kHz	± 1.7 kHz	± 830 Hz	± 340 Hz	± 30 Hz
80 MHz	± 36 kHz	± 14 kHz	± 4.1 kHz	± 1.7 kHz	± 470 Hz	± 93 Hz
160 MHz	± 100 kHz	± 37 kHz	± 10 kHz	± 4.1 kHz	± 690 Hz	± 210 Hz
320 MHz	± 290 kHz	± 110 kHz	± 27 kHz	± 10 kHz	± 1.3 kHz	± 290 Hz
500 MHz	± 580 kHz	± 200 kHz	± 52 kHz	± 19 kHz	± 2.2 kHz	± 400 Hz
1 GHz	± 1.6 MHz	± 590 kHz	± 150 kHz	± 52 kHz	± 5.5 kHz	± 490 Hz
2 GHz	± 4.9 MHz	± 1.8 MHz	± 430 kHz	± 150 kHz	± 14 kHz	± 740 Hz
4 GHz	± 22 MHz	± 5.1 MHz	± 1.3 MHz	± 420 kHz	±38 kHz	± 1.8 kHz
4 GHz Center Frequency						
10 MHz	± 3.3 kHz	± 1.8 Hz	± 990 Hz	± 730 Hz	± 240 Hz	± 8.9 Hz
25 MHz	± 9.2 kHz	± 4.4 kHz	± 1.8 kHz	± 1.1 kHz	± 580 Hz	± 32 Hz
28 MHz	± 10 kHz	± 5.1 kHz	± 2.1 kHz	± 1.2 kHz	± 600 Hz	± 38 Hz
40 MHz	± 16 kHz	± 7.5 kHz	± 2.8 kHz	± 1.5 kHz	± 700 Hz	± 65 Hz
80 MHz	± 40 kHz	± 16 kHz	± 6.0 kHz	± 2.8 kHz	± 920 Hz	± 200 Hz
160 MHz	± 100 kHz	± 41 kHz	± 13 kHz	± 6.1 kHz	± 1.3 kHz	± 440 Hz
320 MHz	± 290 kHz	± 110 kHz	± 31 kHz	± 13 kHz	± 2.4 kHz	± 660 Hz
500 MHz	± 560 kHz	± 210 kHz	± 56 kHz	± 22 kHz	± 3.3 kHz	± 690 Hz
1 GHz	± 1.6 MHz	± 580 kHz	± 150 kHz	± 56 kHz	± 7.5 kHz	± 950 Hz
2 GHz	± 4.6 MHz	± 1.6 MHz	± 420 kHz	± 150 kHz	± 17 kHz	± 1.6 kHz
4 GHz	± 13 MHz	± 4.7 MHz	± 1.2 MHz	± 410 kHz	± 41 kHz	± 2.4 kHz

Phase Uncertainty	These values represent the 95% confidence interval (±) around the expected phase of the input signal. The input signal to the measurement instrument is a 0 dBm unmodulated carrier at the listed center frequency. In this case, the output of the phase meas time trace should be a constant zero value. However, due to random noise (phase noise and other), the phase meas time trace will contain a non-zero signal with a particular mean and standard deviation. The contents of the cells represent (1.96 * stddev). PXA phase noise optimization is set to Best Wide Offset. Measurement time: < 10 ms. Input range is optimized without overloading. 10 MHz reference source is locked with signal source.			
PXA N9030B Signal Analyzer				
Measurement Bandwidth	**Center Frequency**			
	2.0 GHz	8.0 GHz	26.0 GHz	43.0 GHz
10 MHz	± 0.06°	± 0.15°	± 0.33°	± 0.49°
25 MHz	± 0.07°	± 0.10°	± 0.34°	± 0.51°
28 MHz	± 0.06°	± 0.12°	± 0.40°	± 0.49°
40 MHz	± 0.08°	± 0.16°	± 0.35°	± 0.55°
80 MHz	± 0.08°	± 0.12°	± 0.33°	± 0.51°
160 MHz	± 0.09°	± 0.14°	± 0.35°	± 0.66°
Infiniium DSO/MSO S-Series Oscilloscope				
Measurement Bandwidth	**Center Frequency**			
	1.0 GHz	2.0 GHz	4.0 GHz	
10 MHz	± 0.11°	± 0.15°	± 0.33°	
25 MHz	± 0.11°	± 0.18°	± 0.33°	
28 MHz	± 0.11°	± 0.16°	± 0.29°	
40 MHz	± 0.10°	± 0.19°	± 0.36°	
80 MHz	± 0.12°	± 0.18°	± 0.30°	
160 MHz	± 0.15°	± 0.20°	± 0.33°	
320 MHz	± 0.24°	± 0.23°	± 0.38°	
500 MHz	± 0.25°	± 0.29°	± 0.36°	
1 GHz	± 0.39°	± 0.42°	± 0.46°	
2 GHz	± 0.83°	± 0.68°	± 0.54°	
4 GHz	N/A	± 1.0°	± 0.92°	

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 (One required)

(89601200C – Advanced tier with no center frequency, bandwidth or channel count limits)
(89601201C – Advanced tier with no center frequency, bandwidth or channel count limits)
(89601202C – Standard tier up to 55 GHz CF, 2.16 GHz bandwidth, and 4 channel support)
(89601203C – Essentials tier up to 8 GHz center frequency, 160 MHz bandwidth and single channel support)

Pulse Analysis (89601BHQC)

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

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

Additional Information

Literature

- 89600 VSA Software Brochure, literature number 5990-6553EN
- 89600 VSA Software Configuration Guide, literature number 5990-6386EN
- 89601B200C Basic VSA and Hardware Connectivity Technical Overview, literature number 5992-4232EN
- 89601BHPC FMCW Radar Analysis Technical Overview, literature number 5992-0319EN
- N9067EM0E Pulse Analysis Measurement Software Technical Overview, literature number 5992-2855EN
- Waveguide Harmonic Mixers Technical Overview, literature number 5990-7718EN

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