

# Keysight X-Series Signal Analyzers

This manual provides documentation for the following Analyzers:

UXA Signal Analyzer N9040B

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Real-Time  
Spectrum  
Analyzer  
Measurement  
Guide

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## 1 About the RTSA Option

The Real-time Spectrum Analyzer Measurement application uses ASICs and FPGAs to convert sampled signal data into signal spectra at a very high rate, nearly 300,000 spectra per second. Spectrum data is combined to create information-rich displays such as density (also called histograms). Alternatively, the stream of spectra can be sequentially tested against limits and logical criteria to produce a spectrum-specific and behavior-specific frequency-mask trigger (FMT).

The table below shows the license required for UXA with the RTSA option:

License	Description	Notes
N9040B-RT1	Real-time analysis up to maximum available bandwidth. Includes frequency mask triggering on signal duration > 17.3 $\mu$ s	Requires N9040B-B2X 255 MHz Analysis Bandwidth or N9040B-B5X 510 MHz Analysis Bandwidth
N9040B-RT2	Real-time analysis up to maximum available bandwidth. Includes frequency mask triggering on signal duration > 3.837 $\mu$ s	Requires N9040B-B2X 255 MHz Analysis Bandwidth or N9040B-B5X 510 MHz Analysis Bandwidth

- **Wider bandwidth:** As the signal bandwidths and spans to be analyzed continue to increase, greater bandwidth is necessary. The UXA has the required combination of IF bandwidth, signal sampling and signal process to handle 510 MHz continuously. This gap-free bandwidth applies not only to real-time spectrum analysis but also FMT, gap-free time capture and real-time magnitude calculations for IF magnitude triggering.
- **Better dynamic range:** The UXA allows small signals to be detected in the presence of large ones by providing up to 75 dB of spurious-free dynamic range across its full 510-MHz analysis bandwidth.
- **Higher probability of intercept:** The term POI comes from the field of signal surveillance and reflects the likelihood that a transient signal will be detected. The UXA advanced processing architecture combines with its 510-MHz analysis bandwidth and wide dynamic range to provide 100 percent POI for signals with durations as short as 3.837  $\mu$ s.

## Defining Real-time Analysis

In a spectrum or signal analyzer with a digital intermediate frequency (IF) section, Real-time operation is a state in which all signal samples are processed for some sort of measurement result or triggering operation. In most cases the measurement results are scalar, power or magnitude, corresponding to traditional spectrum measurements.

In addition to the gap-free analysis, a real-time RF analyzer may be defined as having four more key attributes:

- high-speed measurement
- consistent measurement speed
- frequency mask triggering
- advanced composite displays

In general, the stream of spectra from real-time processing can be used in one of two ways; the spectra can be combined into a composite spectrum display or successively compared to a limit mask to implement frequency-mask triggering. Both of these capabilities are present in the RTSA option.



## 2 Theory

The following topics are in this chapter:

[“Real-time Analysis” on page 10](#)

[“Block Diagram” on page 10](#)

[“Real-time Operation” on page 11](#)

[“Overlap Processing” on page 12](#)

## Real-time Analysis

In real-time analyzers, measurement operations process all incoming information. For RF signal analysis this is usually sampled IF data.

Modern real-time analyzers can maintain real-time analysis indefinitely, though this is achieved in part by performing only streamlined signal processing such as power spectrum or magnitude. Some applications require only a limited period of real-time operation and can benefit from time capture and post-processing where additional measurement flexibility and vector operations such as demodulation are important.

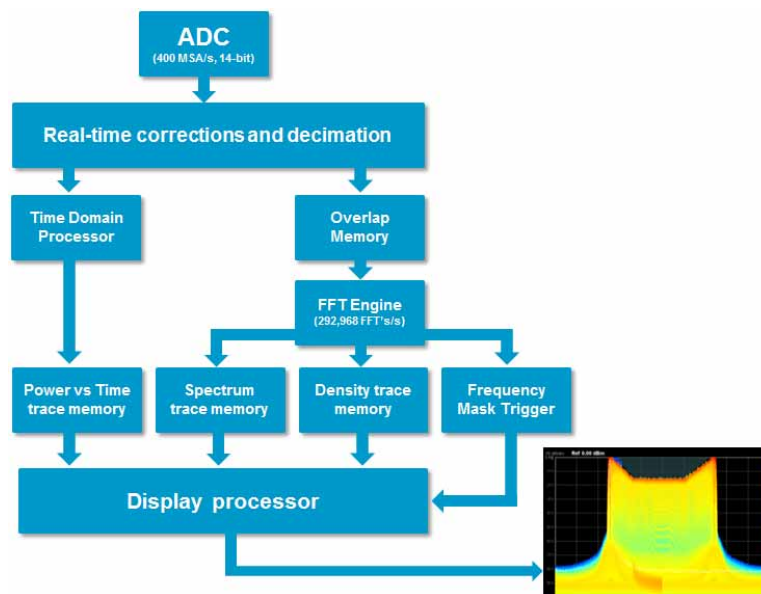
In the area of real-time, the required duration varies widely by application. The emphasis in some measurements is on long duration and live displays, while in others it is essential to avoid gaps and fully process every sample.

The processing power required for continuous real-time operation generally scales with the number of samples/second involved, and thus the analysis bandwidth. Therefore given a specific amount of processing power, there is a maximum bandwidth where the processing can keep up with the sampled data, and this is the analyzers real-time bandwidth (RTBW).

One often overlooked factor in real-time analysis is the resolution or bit depth of the samples and processing. For a given sample rate, for example, it will take significantly more processing power to handle 12-bit samples compared to that required for 8-bit samples.

## Block Diagram

This is a simplified block diagram of the Real-time system implemented in the FPGA.



The ADC is running at 2.4 GSamples/s, 14 bit. Next is the real-time decimation and correction process. It is at this point that the paths are separated into the frequency and time domain. In the frequency domain the overlap memory is where the variable overlapping is handled before going into the FFT engine running at just under 293,000 FFTs/s. The memory is branched into different traces – Spectrum, Density and Power versus Time as well as the Frequency Mask Trigger, which monitors the real time stream of results and compares it to the mask that may have been set up.

These trace memories feed the information to the display processor to provide the required instrument display.

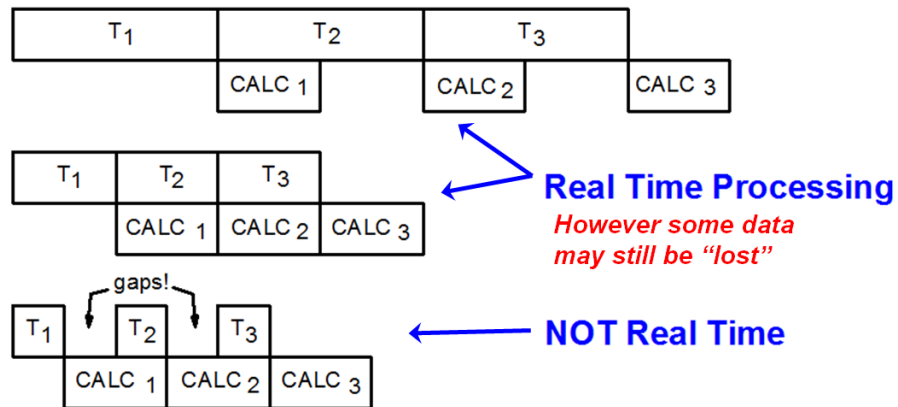
## Windowing

Windowing functions are applied to the digital data before the FFT process. This reduces the effect of spectral leakage that could occur when using FFT analysis. The selected window function is dependent on the type of results needed from your measurement. The following filters are available for this function:

- Gaussian
- Flattop
- Blackman-Harris
- Rectangular
- Hanning
- Kaiser

## Real-time Operation

Real-time operation occurs when the calculation speed is fast enough to ensure gap-free analysis of sampled data. In this case each CALC includes computation of an FFT or a power spectrum as well as averaging, display updates, and so on.



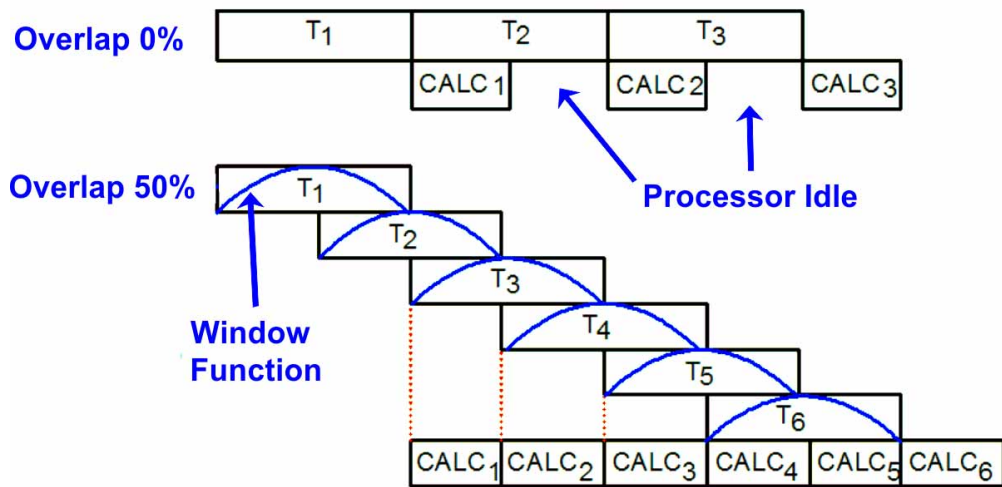
In this diagram T refers to the analyzer's time record for FFT processing. The analyzer collects a block of contiguous samples from the ADC that is digitizing the IF signal and then performs an FFT to obtain a power or vector spectrum. This sample block may vary in size or it may be fixed.

It is important to understand that the time length of the block T will be shorter when bandwidths are higher and sampling is faster.

The loss of data refers to the frequent case where the samples in a time record are "windowed" or attenuated at the beginning and end of the record, to avoid spectral leakage or to form the equivalent of different resolution bandwidth filters. This attenuation of data at the edges of the time record is often so significant that some samples are effectively lost. The solution to this problem is overlap processing.

## Overlap Processing

Overlap processing provides significant benefits for signal analysis when processing is faster than sampling by performing additional FFTs with partially-new time records as samples come in.



In this diagram, 50% overlap is shown, where each new FFT is performed on 50% new samples and 50% from the most recent samples of the previously processed data. Potential overlap percentages vary continuously from 0% to 100% in increments of 1 sample. Actual overlap varies depending on the analyzer and software settings, and may or may not be set-able.

With significant overlap it is possible to configure analysis so that all samples are processed for some FFT result with no or minimal attenuation or de-emphasis due to windowing. Overlap can thus improve probability of intercept (POI) and accuracy.

## 3 Signal Detection and Analysis

A major benefit of real-time analyzers is the ability to find elusive signals and signal behavior quickly and reliably, whether the goal is to discover or characterize the signals, or to understand detail as an element of troubleshooting or optimization.

This chapter contains the following topics:

[“Swept Spectrum vs. Real-time Spectrum Measurements” on page 14](#)

[“Display Views - Real Time Analyzer Measurement” on page 19](#)

[“Hints on Touch UI Operation” on page 30](#)

[“Measure the Hopping Signals” on page 32](#)

[“Measure a Narrow Pulse Signal” on page 41](#)

[“Measure the Transient Signal” on page 47](#)

[“FMT Setup Details” on page 53](#)

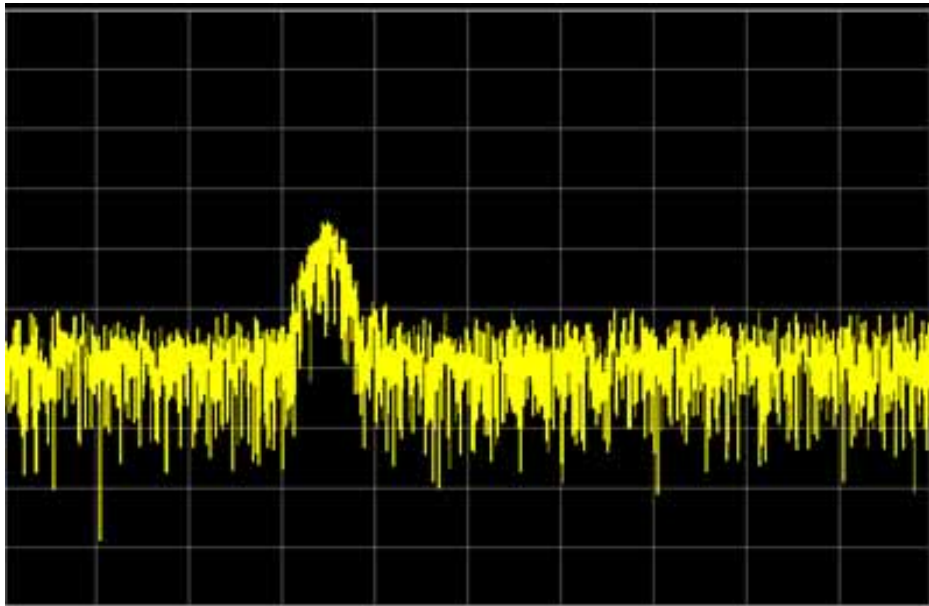
[“Trigger Setup Details” on page 57](#)

[“Save Data” on page 59](#)

## Swept Spectrum vs. Real-time Spectrum Measurements

Real-time spectrum measurements offer an advantage over swept measurements because there is no loss of data. This is important when you are interested in finding elusive signals or small signals that are near the noise floor.

Figure 3-1      **Single Sweep**

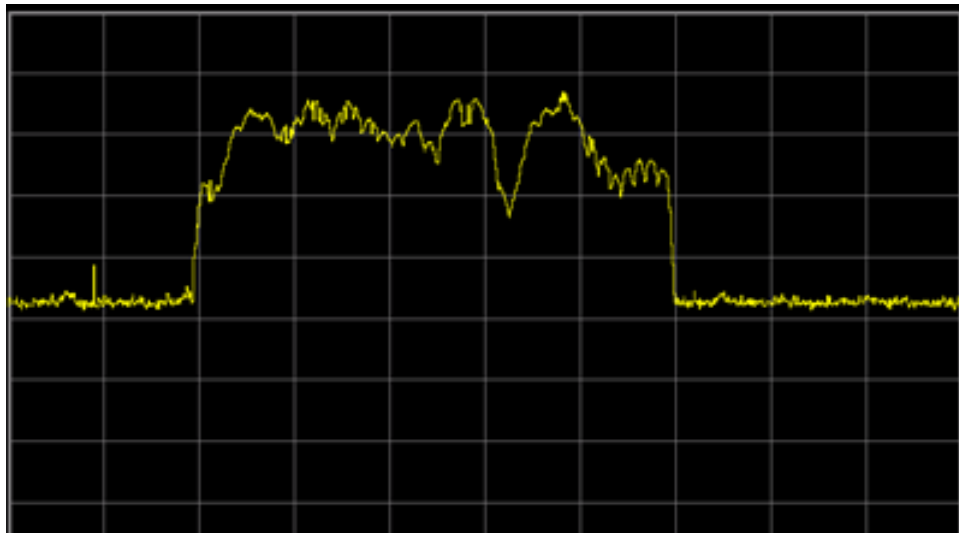


Swept analysis will find events that are stable in the frequency domain and display the amplitude, but no phase information is gathered. The following graphics are examples of swept spectrum analysis of a signal in the ISM 2.45 GHz band. This band is lightly regulated with WLAN the dominate occupant sharing with Bluetooth, cordless phones, microwave ovens and other devices.

Depending on the degree of spectrum/time occupancy, a single sweep from a swept spectrum analyzer may show nothing or a portion of one or more signal bursts. It can be very difficult to interpret such a measurement.

Figure 3-2

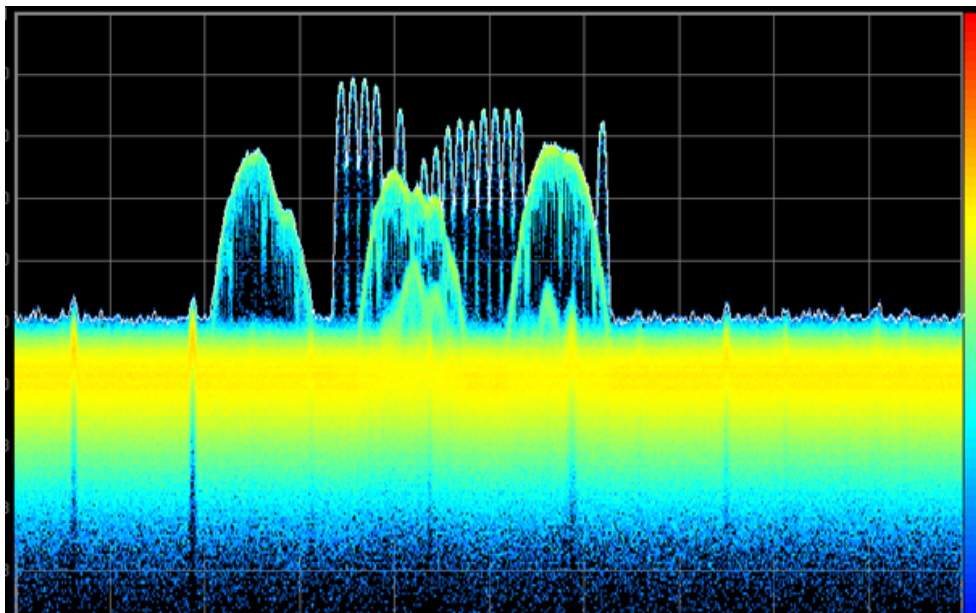
Peak Hold (long duration)



Peak hold is a useful tool for understanding some aspects of the signal environment and a long measurement with peak hold will eventually catch most of the signals in the band. However, long peak hold measurements often result in some signals in the band obscuring others. Swept spectrum analysis is not a very productive way to understand the activity in this band. Refer to the following graphic.

Figure 3-3

Real-time Density view



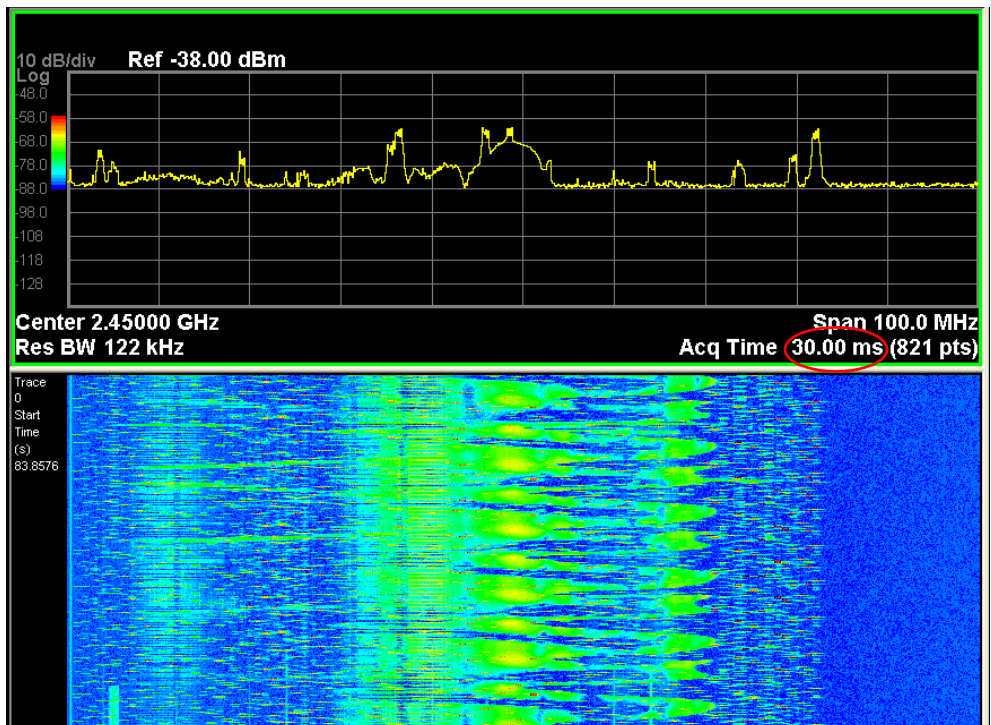
When the results are viewed in a "Density" (Histogram) display, the real-time analyzer provides a good understanding of this frequency band and the signals in it. Since the measurements are gap free and all signal samples are represented in the display, it is possible to see most of the signals in the band

at a glance or over a short measurement time. Individual display updates combine thousands of spectra and shows the signal dynamics and unexpected behavior.

Note that the action of combining 10,000 spectra into one display update can cause signals present at different times to be displayed on the same spectrum update. The signals that appear to be multi-tone in the following graphic are actually Bluetooth frequency hop patterns. The signal is never actually transmitted on multiple frequencies at once.

Figure 3-4

Real-time Spectrogram view: 30 ms frequency acquisition time



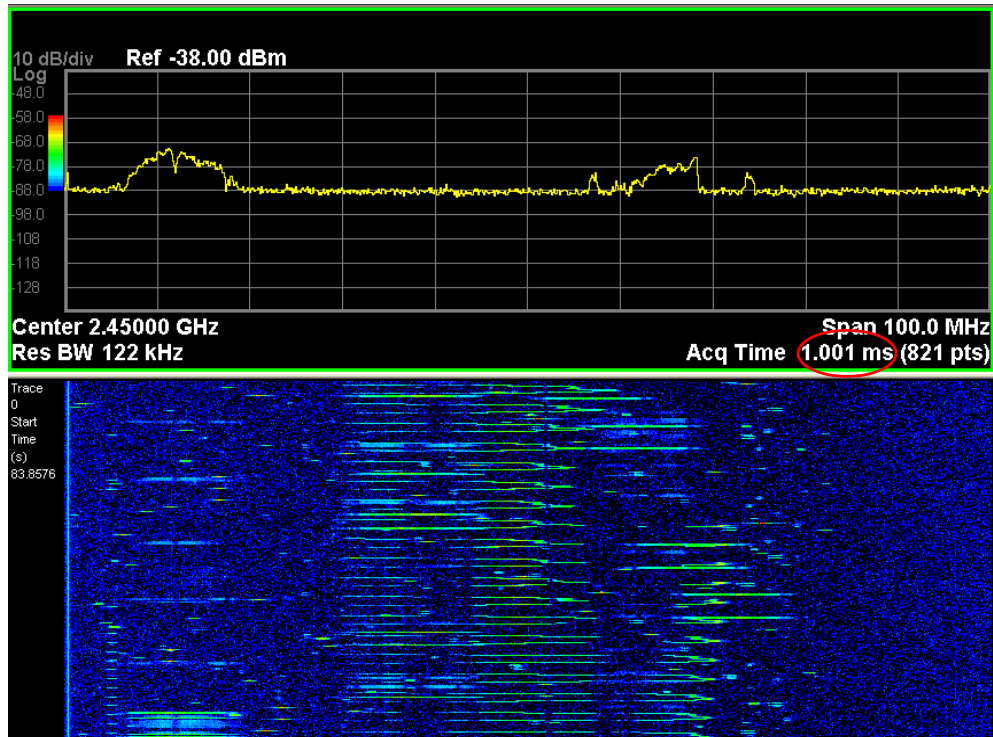
In the "Spectrogram" display, the same spectral data is shown with a time dimension added to the spectrum display.

A short acquisition time has the opposite effect of the longer time of the previous example, and thus a single spectrogram display (or buffer) will represent a shorter time period, with finer time resolution.



Figure 3-5

Real-time Spectrogram view: 1 ms frequency acquisition time



**Top view:**

Individual lines of the bottom view are shown as amplitude vs. frequency.

**Bottom view:**

The individual spectrum lines are real time, but in most cases are formed (as controlled by the analyzer's detector setting) from a number of individual FFT calculations. In this configuration each line represents about 10,000 FFT spectrum calculations. Amplitude is represented by color, as visualized in the top view.

This combination of many spectra to form one spectrum update causes repeated Bluetooth hops over a limited channel pattern to form a set of vertical lines near the top of the spectrogram display.

The time axis view of the spectrogram can reveal important aspects of signal behavior of the spectral environment. Note the group of bursts in the bottom half of the spectrogram, between the rightmost WLAN signals. Note also the diagonal bar in the spectrogram at the same point in time but moving from the leftmost WLAN signal across the center one. This appears to be from some sort of channel scanning and is occasionally visible in the density displays.

The short acquisition time can have a large effect on the appearance and content of the spectrogram display or buffer. The buffer and display will cover a proportionally shorter span of time and may not show some longer-term phenomena, but the additional time resolution can reveal important spectral behavior that would otherwise be obscured.

## Signal Detection and Analysis Swept Spectrum vs. Real-time Spectrum Measurements

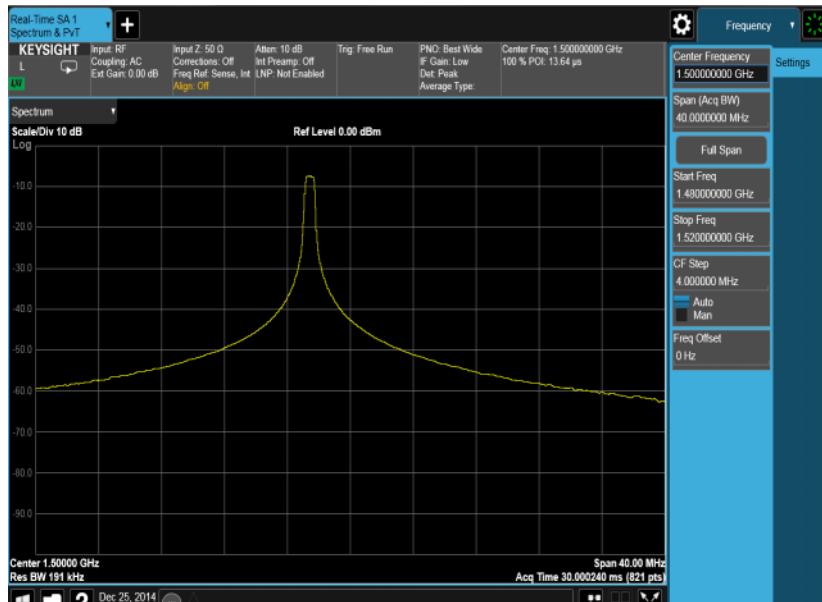
Here the increased time resolution allows the individual WLAN bursts and Bluetooth hops to be much better resolved. It becomes clear that even the Bluetooth hops that overlap the WLAN bursts in frequency often do not overlap in time, and that collisions are not as frequent as the previous display would suggest.

Note, however, that each spectrum line in the spectrogram and in the trace above still represents hundreds of individual FFT results from the real-time measurement engine.

To summarize, when the signal or behavior in question is short in duration or infrequent in occurrence or is unexpected, the large amount of data processed and represented by a real-time analyzer can provide the best chance of detection.

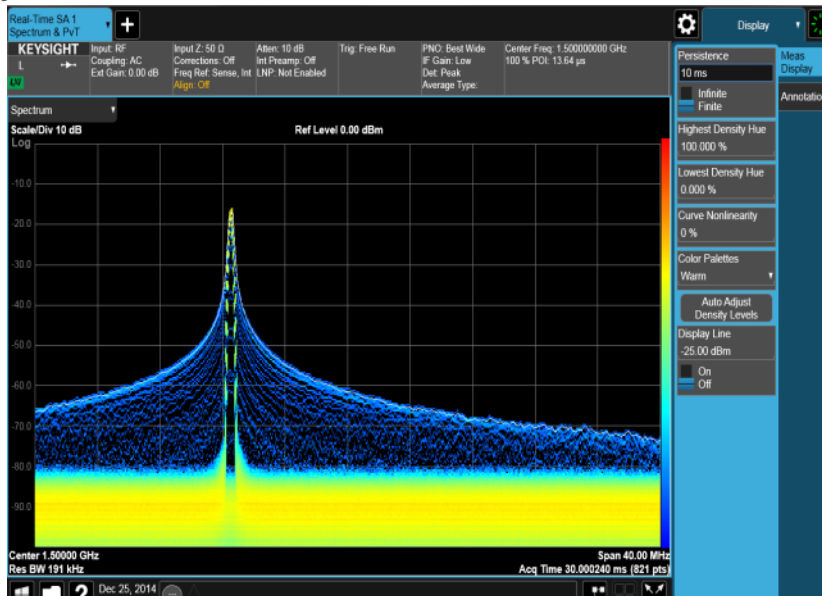
## Display Views - Real Time Analyzer Measurement

### Normal



The Normal view is a single window showing Real Time, Gap Free Frequency vs. Amplitude, with frequency on the X-axis and amplitude on the Y-axis.

### Density



The Density view uses a bitmap to represent the signal density at each frequency and amplitude point determined by the current analyzer settings. The density is defined as the number of times a frequency and amplitude point is hit during a capture interval, which is the time a signal spends at each frequency and amplitude point in a given time period.

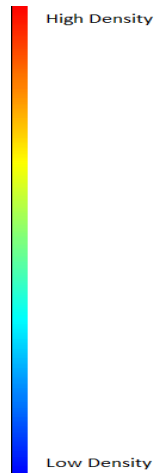
In this view, the X axis represents frequency, the Y axis represents amplitude and the Z axis represents number of hits. This view therefore displays three dimensional data on a two dimensional display, using color to represent the third dimension.

The view will also display a white trace over the bitmap. This trace shows the real time spectrum for the latest capture interval. The white trace is Trace 1 with detectors Peak, Negative Peak and Average derived from the density values and Sample being the last FFT that was used by the density bitmap.

The bitmap is made up of cell values that are floating point numbers from 0 to 1, with 0 being no signal present and 1 indicating constant signal presence. For example, 0.5 indicates a signal was at the given frequency and amplitude point exactly half of the time.

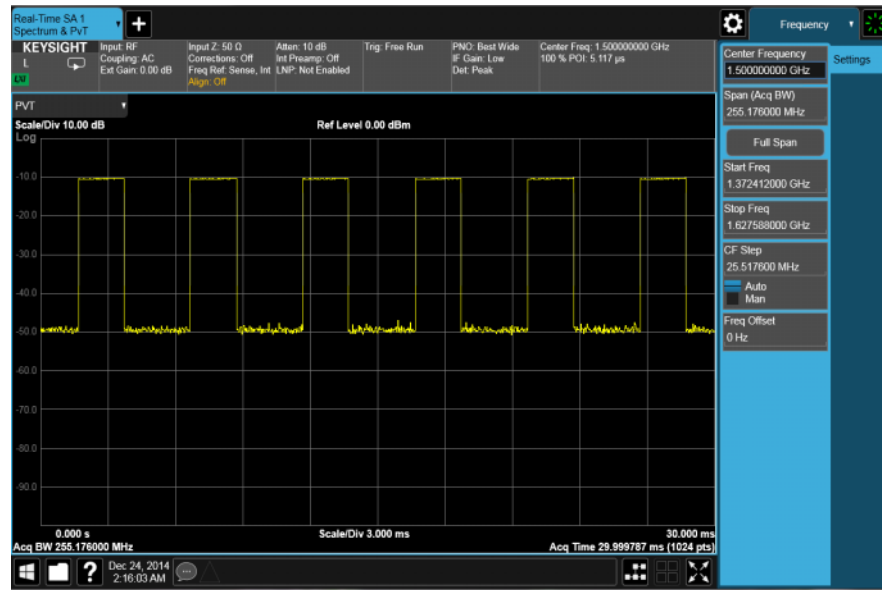
The key to these colors is displayed as a color bar on the right side of the graphical display, as opposed to the left side of the display where Spectrogram shows the color bar. This is to avoid confusion that the color bar represents amplitude, as it does in the other views.

In Density view, high density is represented by the color at the top of the color bar and low density by the color at the bottom of the color bar.



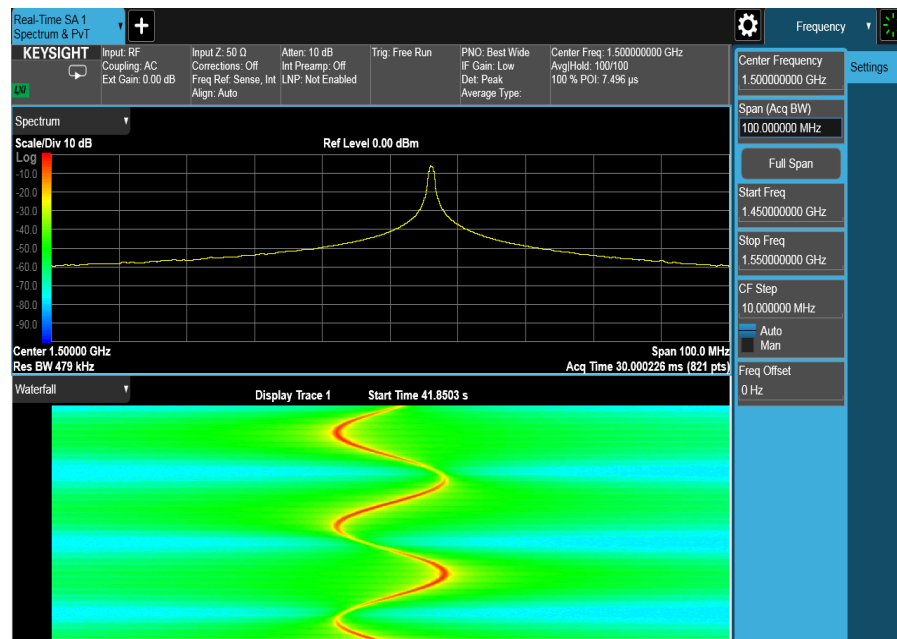
## Signal Detection and Analysis Display Views - Real Time Analyzer Measurement

PvT



The PvT view shows the RF envelope power over a user defined time period. The horizontal axis represents time and the vertical axis represents amplitude.

Spectrogram



The Spectrogram View allows you to view a history of 10,000 traces, with up to 633 traces being displayed at any one time. In the Spectrogram View, each horizontal line in the spectrogram display represents one historical trace, which is the summary of an accumulation over an acquisition time interval. The data streams upwards from newest to oldest; the latest trace displays on the bottom and the oldest trace on the top.

Note that whenever you save state while in Spectrogram, and then recall the state, Spectrogram comes back with all the settings just as they were when you saved the state, but not including the Spectrogram data itself. If you want to save the Spectrogram data, you can Export it using Meas Results, and import it into a PC, although you cannot load it back into the analyzer.

In the Spectrogram View, the spectrogram window allows you to view a history of the last 10,000 traces. If the Spectrogram view is active at the same time as Normal View in a multi window layout, the two views will be coupled together. The Normal window shows the trace indicated by the Display Trace parameter in the View/Display menu. The Display Trace key determines which of the traces in the Spectrogram window is currently being viewed in the Normal window. A white line across the Spectrogram window shows the current position of the Display Trace. Display Trace can be selected as a Trace Number or Time. We will use Trace Number to describe the functionality in this section. On entry to the Spectrogram view, Display Trace has a value of 1, which means it is set to the latest trace to be acquired.

Every time an acquisition completes, the latest trace is displayed at the bottom of the Spectrogram and the historical traces are moved up one position. If active, the data displayed in the Normal window is the extracted trace from the Spectrogram data determined by the Display Trace value. Once the trace data has been written into the Spectrogram, it cannot be modified.

The Spectrogram can hold 10,000 traces. When the Spectrogram occupies a full vertical size Window, 633 traces can be displayed in the trace window at any one time. The Display Trace will be used to determine which traces are to be displayed. Navigating through the Spectrogram will be the same as navigating through any window, with the Display Trace being the equivalent of the cursor and the scroll bar used to indicate and control where in the 10,000 trace range is currently being displayed.

When you select a Display Trace that causes scrolling down through the Spectrogram traces, i.e. a Display Trace value less than the current Display Trace value, the lower value of the Spectrogram window will be the new Display Trace value. When you request a Display Trace that causes scrolling up, i.e. a Display Trace value greater than the current Display Trace value, the upper value of the Spectrogram window will be the new Display Trace value.

For example, if you have Display Trace set to 100, the lower value of the Spectrogram window will be 1 and the upper value 633. If you then set the Display Trace to 1000, this is scrolling up therefore the upper value of the Spectrogram window will be 1000 and the lower value 368. If you then set the Display Trace to 200 this is scrolling down, therefore the lower value of the Spectrogram window will be 200 and the upper value 32.

If the Spectrogram display window has not yet filled with 633 traces, the oldest trace is the highest numbered trace that has data in it. The value of Display Trace is annunciated in the upper left corner of the bottom window, along with the start time of that trace.

If you select a historical trace that has not yet been acquired, both the trace window and spectrogram window will remain blank until such time as the trace you requested is available. The Spectrogram window will then be populated one trace at a time as the subsequent traces are acquired, with the trace window showing the trace corresponding to the Display Trace value you requested. If you select a historical trace that is has been acquired, the Spectrogram window will be populated with the available historical traces and the trace window will show the trace corresponding to the Display Trace value you requested.

Any variable change that restarts an acquisition will clear out the spectrogram and start it over, unless you are in the idle state (single mode or waiting for a trigger), in which case it will be cleared out when you start an acquisition again. The Restart key will clear out all spectrogram traces and start over. The spectrogram display is also cleared on exit from the Spectrogram View, so every time you enter the Spectrogram View, the spectrogram window is empty.

You can Pause and Resume the spectrogram at any time. Pausing the spectrogram will cause the accumulation of traces to stop and allow adjustment of the Display Trace parameter to view any historical traces. On resume, the existing historical trace data will not be cleared, and subsequent captures will be added to the historical data. Although this will result in a gap in the spectrogram data, the data captured will still be done so in real time. The time stamp of each trace will identify that the spectrogram data is not gap free after a pause and resume.

The colors in the Spectrogram represent signal amplitude. The key to these colors is displayed next to the Y Axis in the upper window. By changing the Y Axis parameters you can change the scaling; that is, by changing the Ref Level or Scale/Div, the colors will get remapped to new Amplitude values. Note that this will, however, restart the Spectrogram.

Each horizontal line in the spectrogram represents a single trace, and the vertical axis represents time. For all values of Display Trace, the trace in the trace window will be updated on completion of an acquisition. To freeze the spectrogram, put Trace into View, or put the analyzer into Single mode (note that unless the Average/Hold Number=1, putting the analyzer into Single will not freeze the Spectrogram until the number of traces specified by the Average/Hold Number have been taken).

While in Spectrogram View, all functions and settings work as normal, except as noted below.

- The Single key causes a specified number of traces to be read into the spectrogram, after which the acquisition stops. The number of traces to be read into the spectrogram is controlled with the "Average/Hold Number" key in the Meas Setup menu. For example, if you set the "Average/Hold Number" to 5, then every time you press Single, it will take 5 acquisitions and put the 5 traces into the Spectrogram; then it will stop the acquisition. Note that you can set the "Average/Hold Number" to 1 to capture a single trace into the Spectrogram when the Single key is pressed.

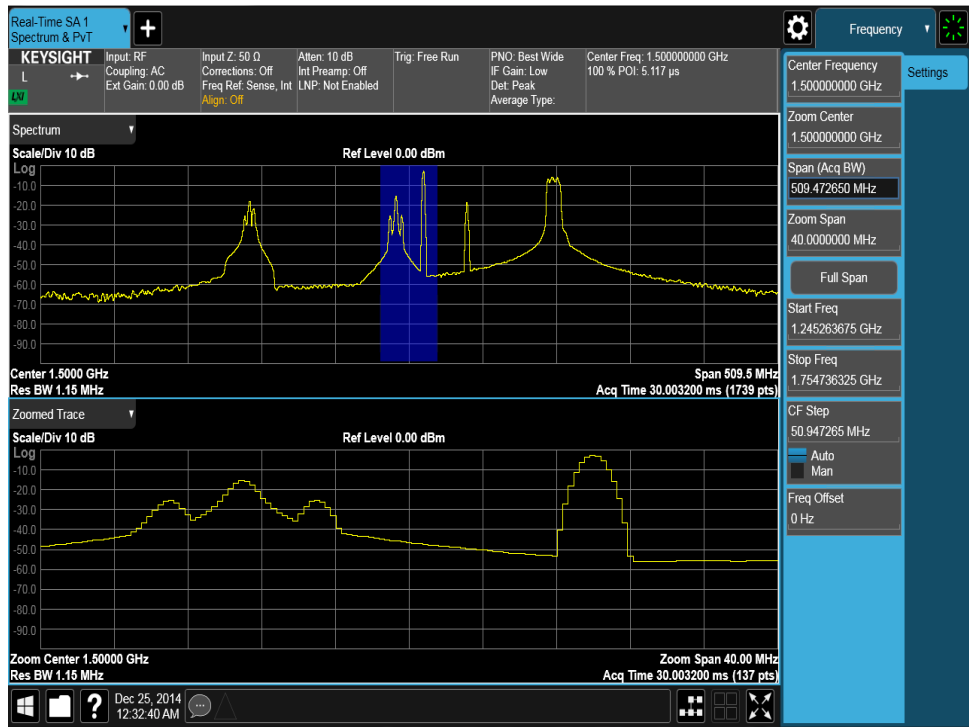
- In the Spectrogram View, if the Trace is saved, exported or queried, the data that gets saved or returned is the data from the Display Trace in the spectrogram.
- Selecting or moving a marker that is turned on but not on the current Display Trace will NOT move the marker to the current Display Trace. A marker must remain on the trace that originally added it.
- Turning on a marker which is turned off will turn it on in the center of the current Display Trace.
- When a Peak Search is performed, if the selected marker is turned on but is not on the current Display Trace, it is first moved to the center of the current Display Trace before performing the search.

### Representation of Time

In the Spectrogram view, zero time is the point where the first trace started, meaning that each subsequent trace point is at a positive time that represents when that point was gathered, relative to the start point. Each trace is time stamped as it starts, and this time is remembered for each trace. As successive traces appear their start times get successively larger, relative to the start time of the oldest trace. If a marker is placed on the live trace and its readout is set to Time, the time of this marker will increment by about the acquisition time for every new acquisition. If the measurement is paused, the Spectrogram will stop updating. When resume is selected the spectrogram will retain the existing traces and continue updating using traces from the point at which Resume was selected. The time stamp of the individual Spectrogram traces will show the time from the beginning of the measurement the trace relates therefore showing there was a gap in the Spectrogram capture.



## Trace Zoom



In the Trace Zoom view, the screen is split into two windows. The top window is a normal spectrum analyzer window, and the bottom window ("Zoom Window") shows a "zoomed" representation of the traces in the top window. The data in both windows is identical, but the bottom window typically shows fewer data points, spread across the whole display, which allows you to see the data in those points more clearly.

The zoom region is indicated by a blue shading over the whole region. In the top window, this indicates which subset of the data is zoomed in the bottom window. The entire Zoom Window is shaded, to indicate that it represents the zoom region. You can set the span of the Zoom Window using the Zoom Span key (in the Span menu) and you can set the Center Frequency of the Zoom Window using the Zoom Center key (in the Frequency menu).

It is important to emphasize that the data and state in the two windows is IDENTICAL. The Zoom Window is simply a close-up view of a region of the top windows' traces. Therefore all traces and markers are the same in both windows; and any state changes you make affect both windows.

You set the number of sweep points shown in the Zoom Window separately from the top window. Changing the number of points in the bottom window WILL change the Zoom Span and does NOT change the number of points in the top window, because the more points you show in the bottom window, the greater is the percentage of the top window that you are showing in the bottom.

Two functions in Trace Zoom depend on which window is selected (the selected window has a thick green border around it). When the Zoom Window (bottom window) is selected, the Points key in the Sweep/Control menu changes to Zoom Points and adjusts the number of points in the bottom window. Also, for all Peak Search functions, if the bottom window is selected the search function will operate ONLY within that window. This allows you to perform a Peak Search over a specified, limited frequency range, while still viewing the larger frequency range in the top window.

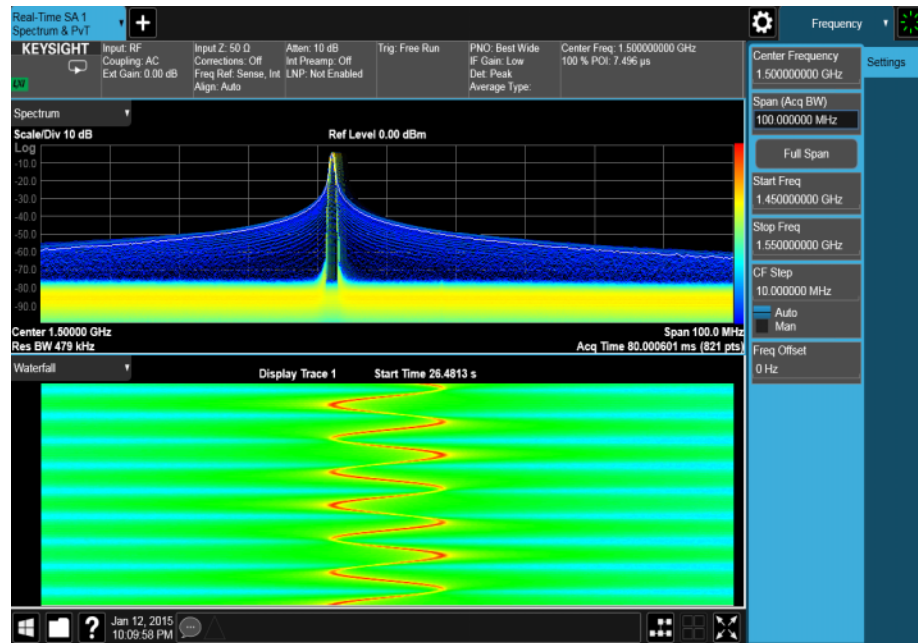
**NOTE**

If you have just switched to the Zoom Window via SCPI (using the :DISP:WIND function) you should wait at least one second before performing a Peak Search, to ensure that SCPI will direct the Peak Search command to the correct window.

---

## Combination Views

### Density Spectrogram



The Density Spectrogram provides a dual view with the top window showing the Density trace and the bottom window showing the Spectrogram trace.

In this view, the top window X axis represents frequency, the Y axis represents amplitude, and the Z axis represents number of hits. This view therefore displays three dimensional data on a two dimensional display, using color to represent the third dimension. The X axis for the bottom window represents frequency and the Y represents the Spectrogram trace history and the Z axis colors represent the signal amplitude.

As with the Density view, the top window will display a white trace over the bitmap. This trace shows the Spectrogram trace specified by the Display Trace parameter. The default will show the most current Spectrogram trace.

See [“Density” on page 19](#) and [“Spectrogram” on page 21](#).

## PvT Spectrum

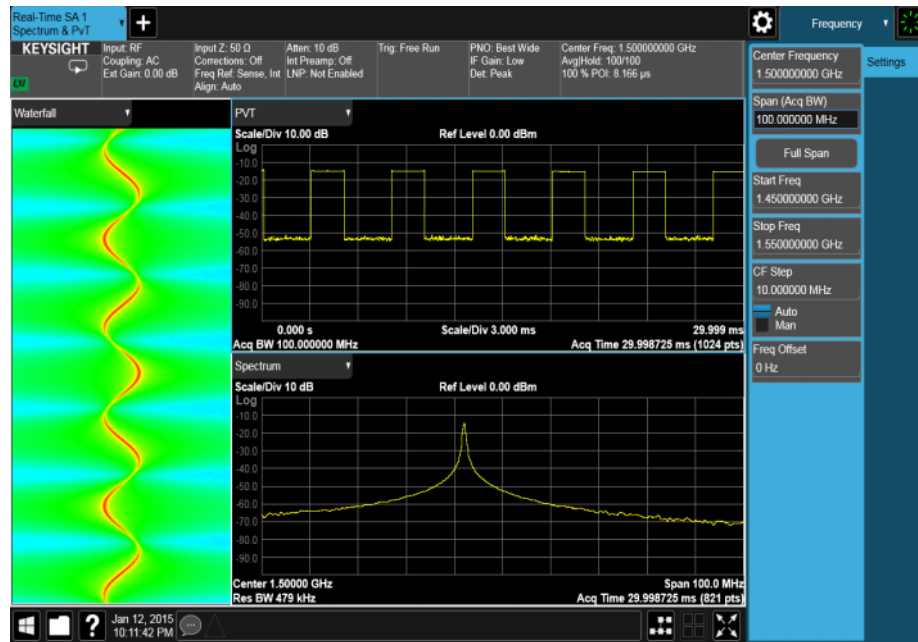


The PvT Spectrum provides a dual view with the top window showing the Power vs Time trace and the bottom window showing the Spectrum trace.

The horizontal axis for the top window represents time and for the bottom window represents frequency. In both the top and bottom windows, the vertical axis represents amplitude.

See “PvT” on page 21 and “Normal” on page 19.

## PvT Spectrogram



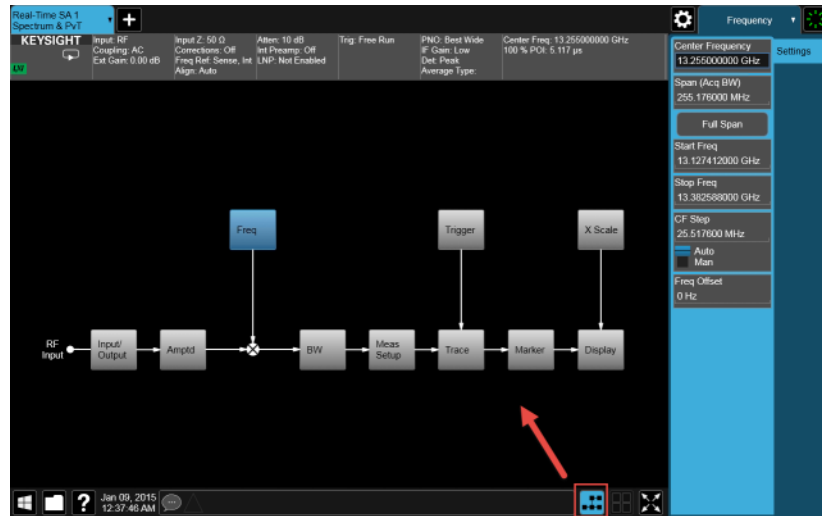
The PvT Spectrogram provides a triple view with the top window showing the PvT trace, the bottom window showing the Spectrum trace, and the left window showing the Spectrogram.

The horizontal axis for the top window represents time and for the bottom window represents frequency. In both the top and bottom windows, the vertical axis represents amplitude.

See “PvT” on page 21 and “Spectrogram” on page 21.

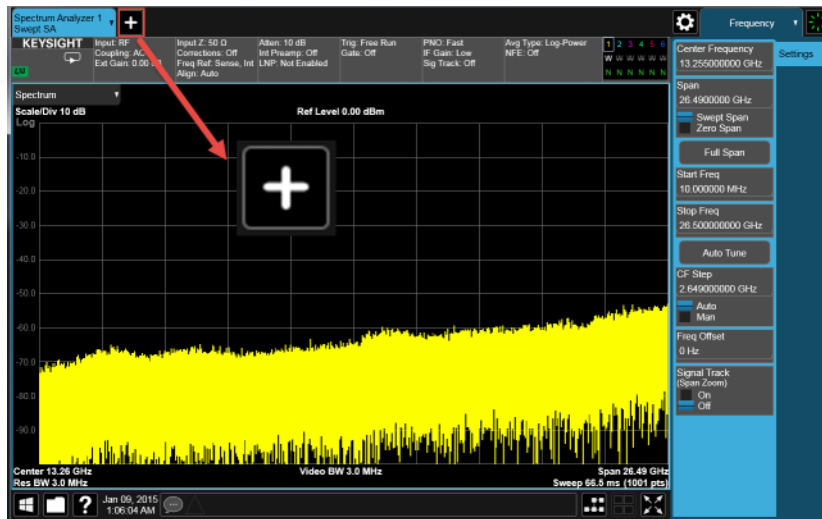
## Hints on Touch UI Operation

### Measurement Block Diagram



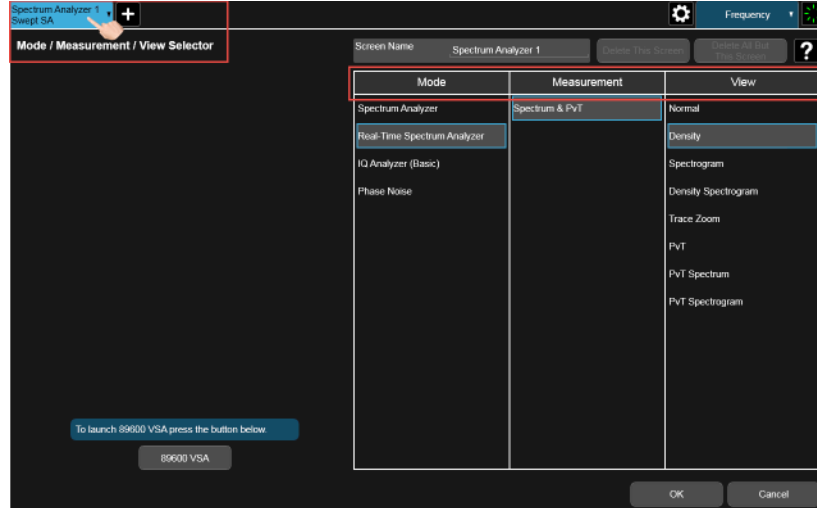
The block diagram provides a quick way to view and change different settings for the current measurement. Tapping different blocks will bring up different menu panels on the right side.

### Add a Measurement



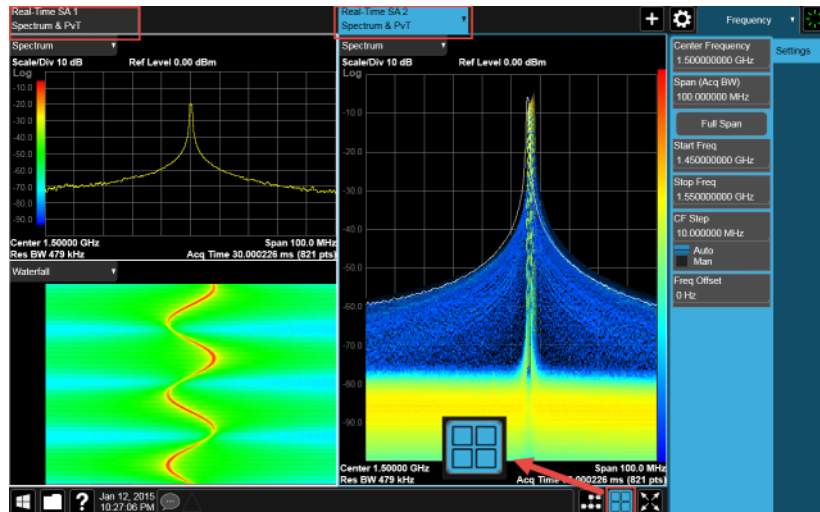
Tap the "+" sign on the top of the screen, and a new measurement screen is added, which is the copy of previous screen. Tap the screen tab and it brings you to the Mode/Meas/View browser.

## Select a Measurement



Tap the screen tab on the top, it brings you to the Mode/Measurement/View Selector dialog. The dialog has three columns that enable you to choose which mode, measurement and view will be used in the current screen.

## Multi Screen

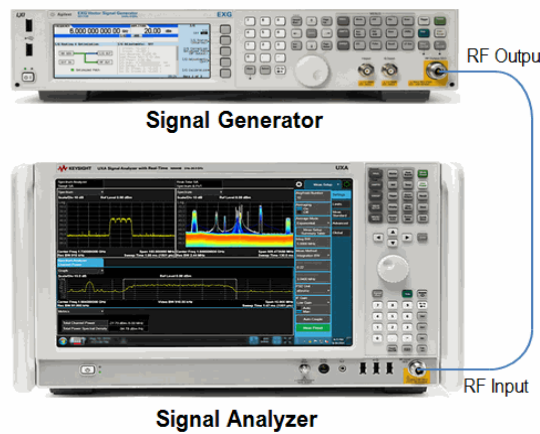


Multi-Screen allows you to view all the screens at one time. To make one screen active, tap it and the remaining screens are suspended with their last measurement result in view.

## Measure the Hopping Signals

To demonstrate the following procedure, we are using a signal generator to create a list sweep waveform with combinations of WCDMA, WLAN, GSM, WiMAX and CW signals.

### Procedure

Step	Action	Notes
1 Configure the instruments	 <p>The diagram shows two pieces of equipment: a Signal Generator (top) and a Signal Analyzer (bottom). A blue line connects the RF Output of the Signal Generator to the RF Input of the Signal Analyzer. The Signal Analyzer screen displays a spectrum plot with multiple peaks.</p>	
2 Preset the UX	a. Press the <b>Mode Preset</b> key on the front panel. Or tap Mode Preset in the preset drop down list on the top right corner of the touch screen.	<p>Mode Preset - Returns the current Mode to a known state. Mode Preset only presets the current Screen, it does not affect any other Screens.</p> <p>Restore Mode Defaults - Resets all additional settings of the current mode as well as all of the Mode Preset settings.</p> <p>Restore Screen Defaults - Resets the Screen configuration to the factory default; deleting all screens, all screen names, and all screen states. A single screen will remain, set to the power-on Mode in a preset state with the default screen name.</p>





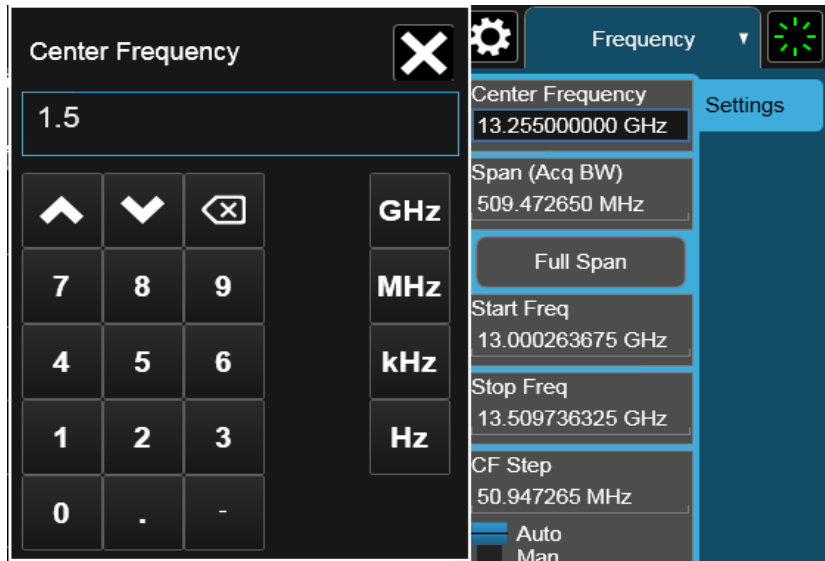


Signal Detection and Analysis  
Measure the Hopping Signals

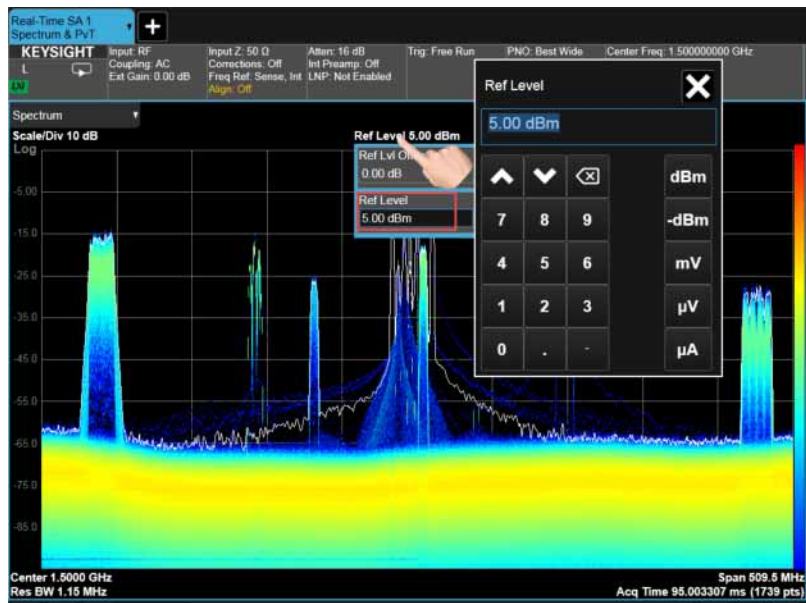
Step

Action

Notes



- d. You may configure the settings such as **Ref Level** using annotation hotspot.

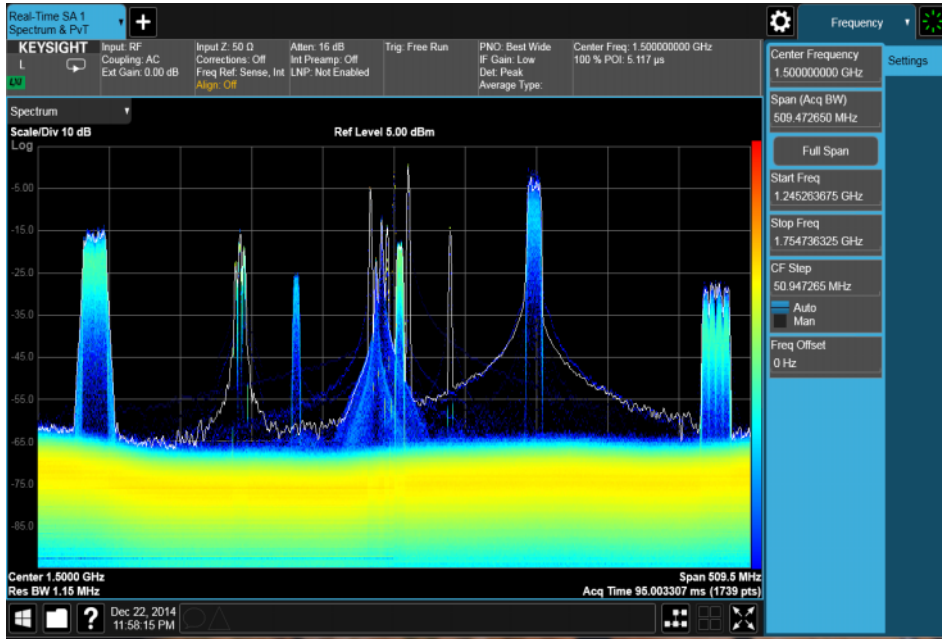


Signal Detection and Analysis  
Measure the Hopping Signals

Step

Action

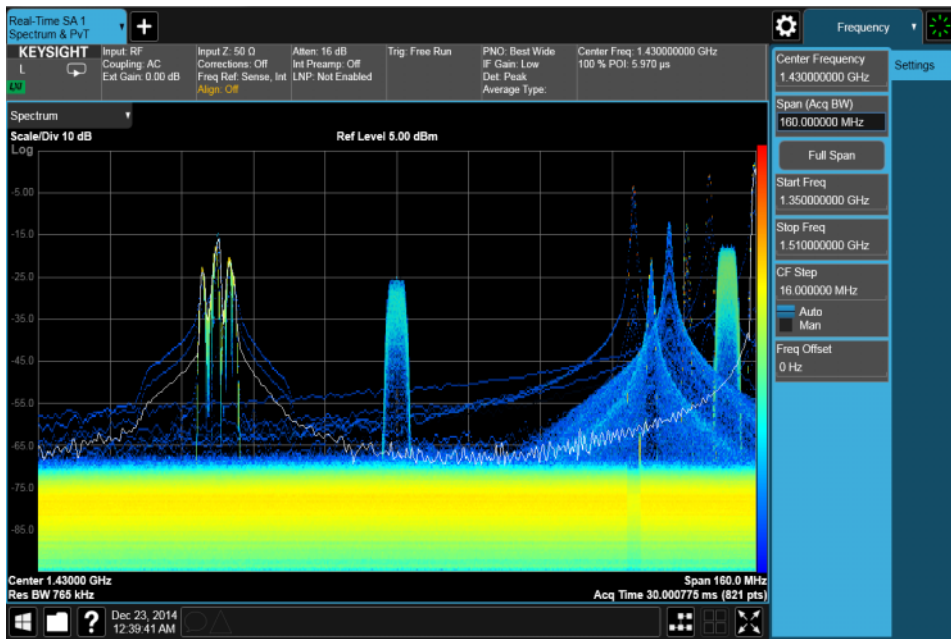
Notes



This shows a highly dynamic signal that is a challenge to view and measure. Note that in this view some signals are obscured by others.

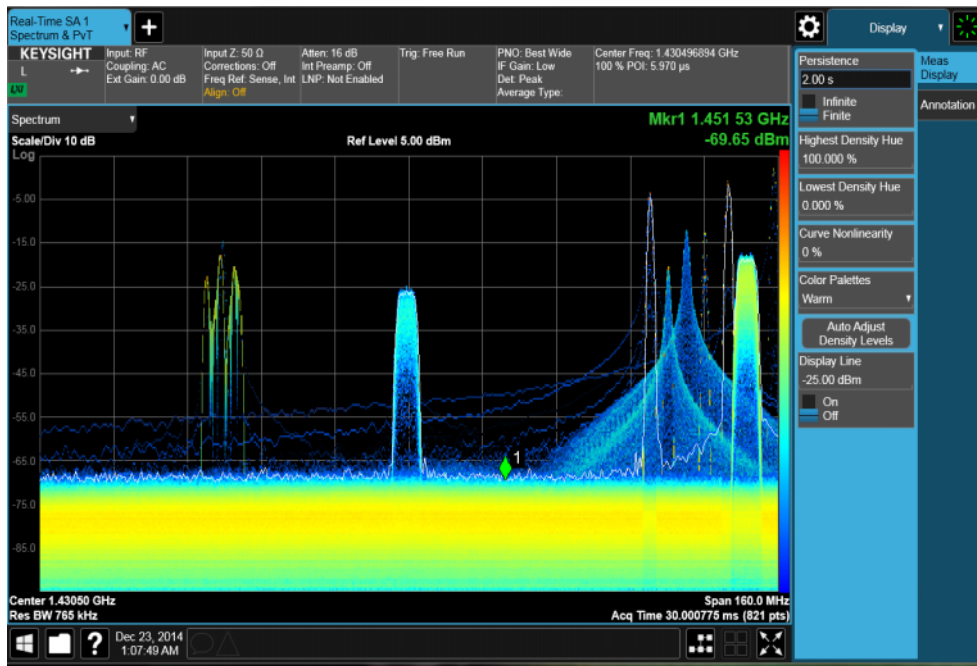
4 Zoom in to the interested signals

- a. Drag the signal and pinch open to zoom in and observe the middle left WCDMA signal as shown below.
- b. Or you may tap **Center Frequency 1.43 GHz, SPAN, 160, MHz.**



Signal Detection and Analysis  
Measure the Hopping Signals

Step	Action	Notes
5	Change the persistence setting a. Tap the hardkey drop down menu and select <b>Display, Persistence</b> , and enter <b>1.5, s</b> .	Persistence is a trade-off between a fast-reacting display and extending time to see very rare events.
6	Add a marker a. Tap the hardkey drop down menu and select <b>Marker</b> and Marker Mode, Normal then drag the marker or enter the value 1.451 GHz.	



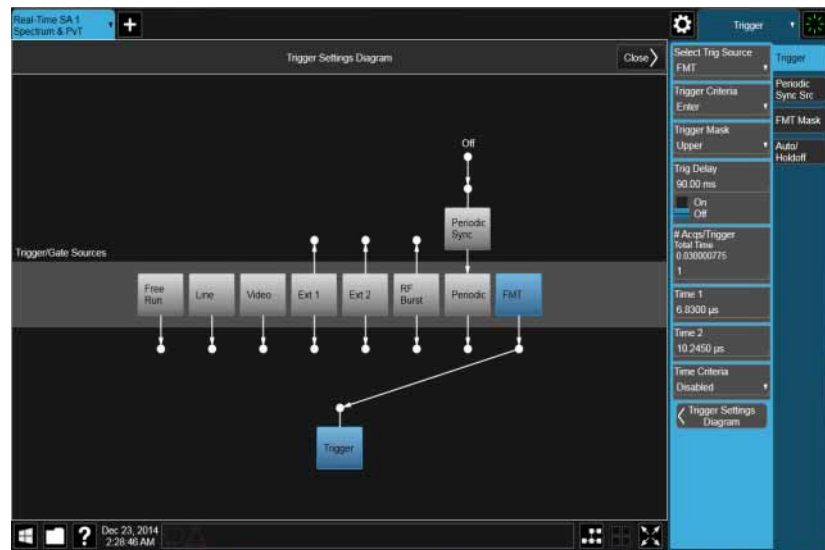
The high dynamic range enables you to see a -70 dBm signal.

7	Change the trigger setting a. Tap the hardkey menu panel drop down and select <b>Trigger, Trigger Settings Diagram</b> , then tap <b>FMT</b> . Trigger will be changed from Free Run to FMT.	Frequency Mask Trigger (FMT) is a trigger type available in the real time mode to help address the problem of finding and identifying intermittent, interfering or transient signals.
---	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Step

Action

Notes



- b. Tap the **FMT Mask** tab then **Edit Mask**. To edit the mask, you may directly drag the circle at the edge of mask. For more information, see [“FMT Setup Details” on page 53](#).

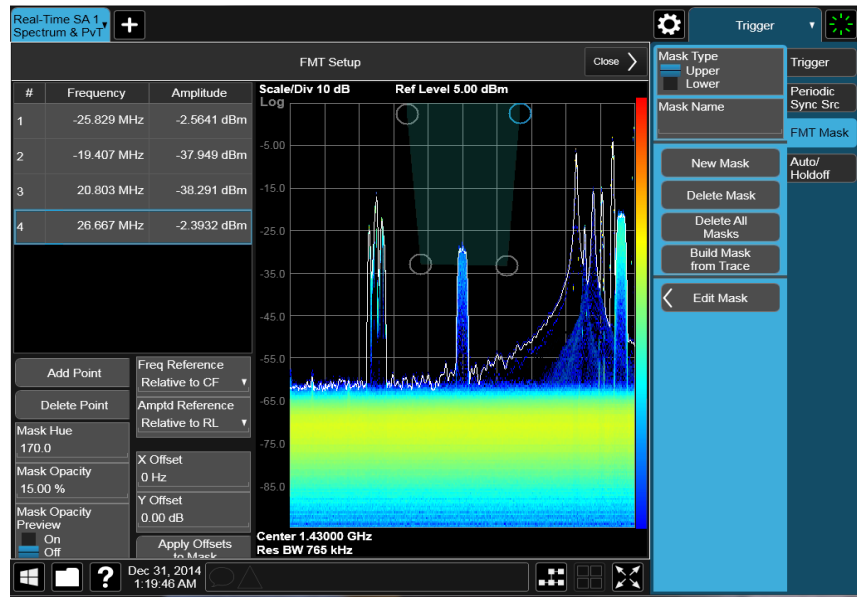
FMT can be used to create a mask on the display and then set your trigger criteria around how that trigger will be generated. The mask can be generated by adding points to a table or by editing an existing mask and you can drag each point to the desired location. Upper and Lower masks can be created depending on the signal you are looking to capture. You can also choose to build the mask from an existing trace and then add an offset to the trace as required. These masks can be saved and recalled as required.

Signal Detection and Analysis  
Measure the Hopping Signals

Step

Action

Notes



- c. Tap Close to go back to measurement screen.
- d. Tap the **Trigger** tab and select **Trigger Criteria, Inside**. For more information, see **“Trigger Setup Details”** on page 57.

Once you have the mask created you need to decide on the trigger criteria and there are a number of choices here. You can choose to trigger when a signal enters a mask (e.g. an interferer popping up) or when it leaves the mask (e.g. an intermittent drop out of a signal). You can also trigger when a signal is inside or outside the mask or if it enters and leaves the mask or leaves then enter which could be useful for transient signals.

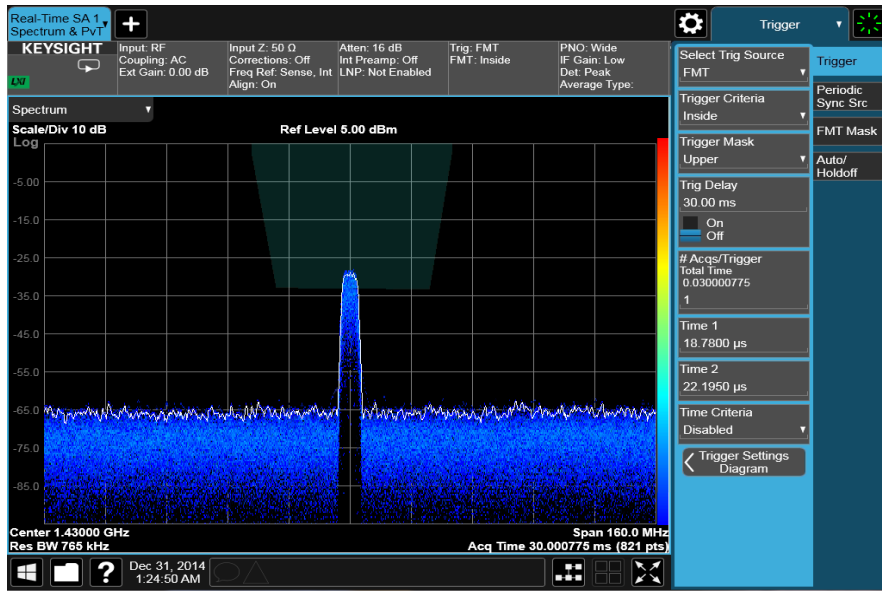
For further in depth analysis the Frequency Mask Trigger can be combined with the 89600B VSA software to provide more thorough characterization of complex signals and to help find the root cause of problems.

Signal Detection and Analysis  
Measure the Hopping Signals

Step

Action

Notes



8 (Optional) Open the VSA application

a. Tap screen tab drop down and at the bottom of the window, there is a button to launch **89600 VSA**.

This may take some time to load the first time.

9 Configure the VSA

- a. Select **Meas Setup, Frequency** and enter **1.43 GHz** in the **Center** input box.
- b. Select **ResBW**, and select **12801** from the **Frequency Points** drop-down list.
- c. Select **Arbitrary** from the **ResBW Mode** drop-down list.
- d. Select **Time** and enter **30%** in the **Max Overlap (Avg Off)** input box.

You can use the 89600 VSA time capture function to explore the list sweep sequence in detail.

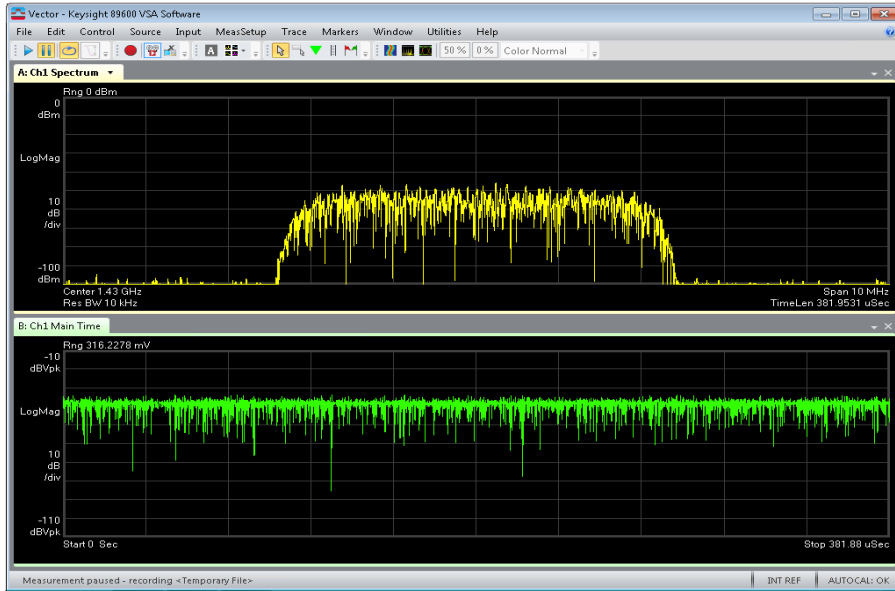
# Signal Detection and Analysis

## Measure the Hopping Signals

Step

Action

Notes



The capture playback process is entirely gap-free and allows almost infinite settings of overlap. Playback will allow you to see and measure the list sweep sequence in any way desired.



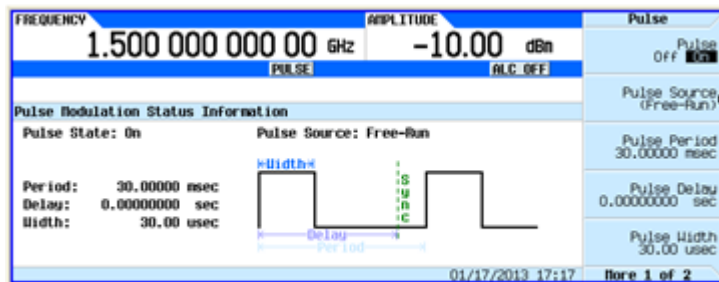
## Measure a Narrow Pulse Signal

A major benefit of real-time analyzers is the ability to find elusive signals and signal behavior quickly and reliably, whether the goal is to discover or characterize the signals, or to understand detail as an element of troubleshooting or optimization.

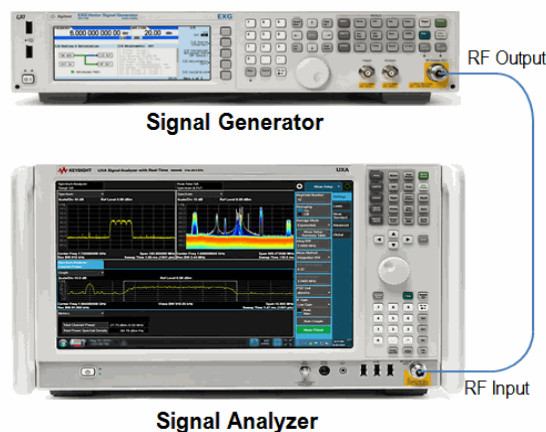
The following procedure shows that the Real-Time Spectrum Analyzer measurement application is capable of capturing a signal with a small pulse width, 5.117  $\mu\text{s}$ , with 100% amplitude accuracy.


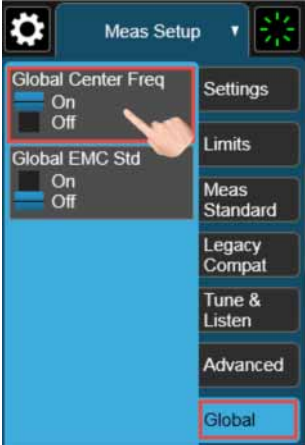
### Procedure

Step	Action	Notes
1	Preset the MXG	
2	Set up a pulse on the MXG	A pulse with 30 ms period and 30 $\mu\text{s}$ width is used at first.



### 3 Configure the instruments

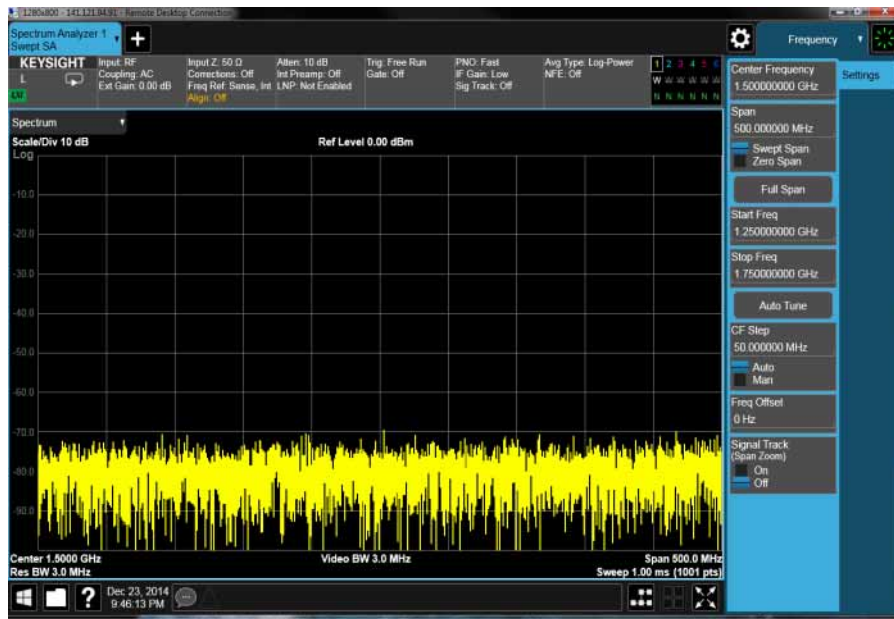


Step	Action	Notes
4 Preset the UXA	<p>a. Press the <b>Mode Preset</b> front-panel key. Or tap Mode Preset in the preset drop down list on the top right corner of the touch screen.</p>	<p>Mode Preset - Returns the current Mode to a known state. Mode Preset only presets the current Screen, it does not affect any other Screens.</p> <p>Restore Mode Defaults - Resets all of additional settings of the current mode as well as all of the Mode Preset settings.</p> <p>Restore Screen Defaults - Resets the Screen configuration to the factory default; deleting all screens, all screen names, and all screen states. A single screen will remain, set to the power-on Mode in a preset state with the default screen name.</p>
		
5 Configure the UXA	<p>a. Double tap <b>Center Frequency</b>, and enter <b>1.5, GHz</b>.</p> <p>b. Tap the hardkey drop down menu and select <b>Meas Setup</b></p> <p>c. Tap the <b>Global</b> tab and toggle the Global Center Freq to On.</p>	<p>When the Global Center Freq key is switched to On in any mode, the center frequency of the current mode is copied into the Global Center Frequency, and from then on all modes that support global settings use the Global Center Frequency.</p>
		

# Signal Detection and Analysis

## Measure a Narrow Pulse Signal

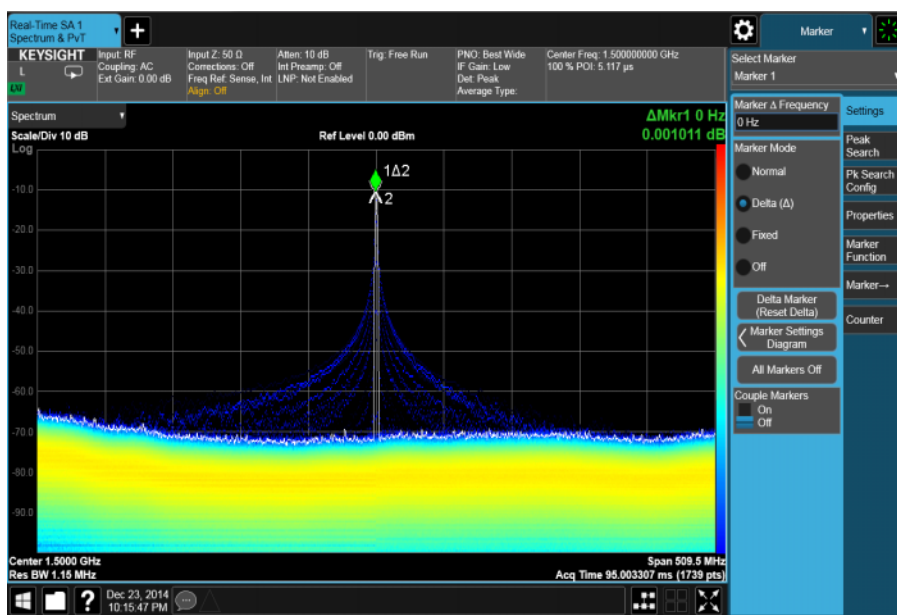
Step	Action	Notes
------	--------	-------



You may notice in the Spectrum Analyzer mode Swept SA measurement (span = 500 MHz), the small pulse signal can not be detected.

- |                            |                                                                                                                                                                                                                                                                                                                                                                      |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6 Initialize the RTSA mode | <ol style="list-style-type: none"> <li>Tap the Screen Tab drop down arrow to access the Mode/Measurement/View Selector dialog and select <b>Real Time Spectrum Analyzer, Spectrum &amp; PvT, Density</b>.</li> <li>Tap the hardkey drop down menu and select <b>Peak Search</b> then tap the <b>Settings</b> tab and select <b>Delta</b> for Marker Mode.</li> </ol> |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Since the global center frequency was set up in the previous step and the RTSA mode supports global settings, you do not need to set center frequency again.

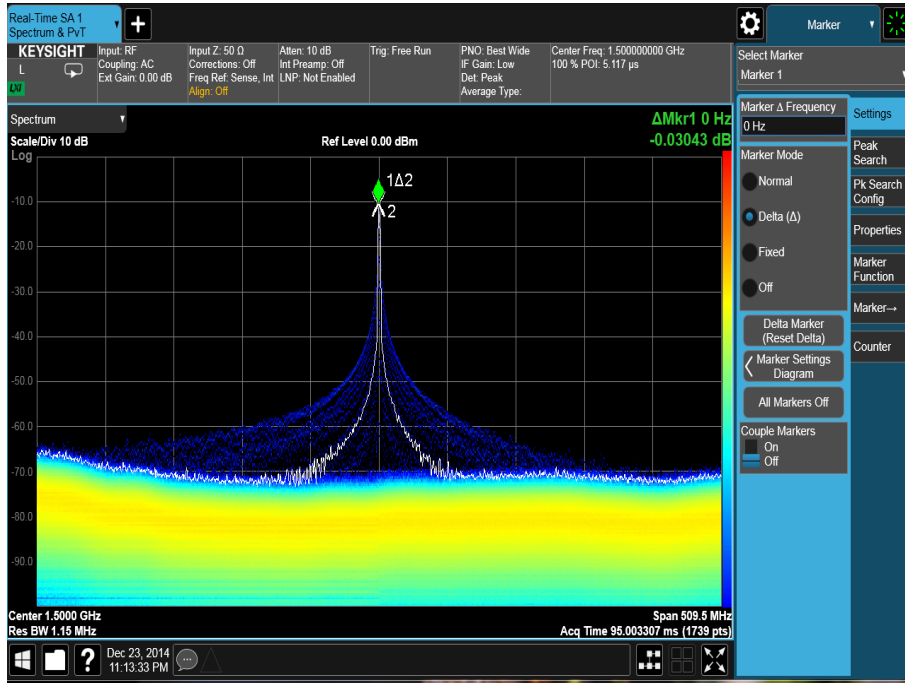


In RTSA mode, it helps to capture the small pulse with narrow width and long period.

Signal Detection and Analysis  
Measure a Narrow Pulse Signal

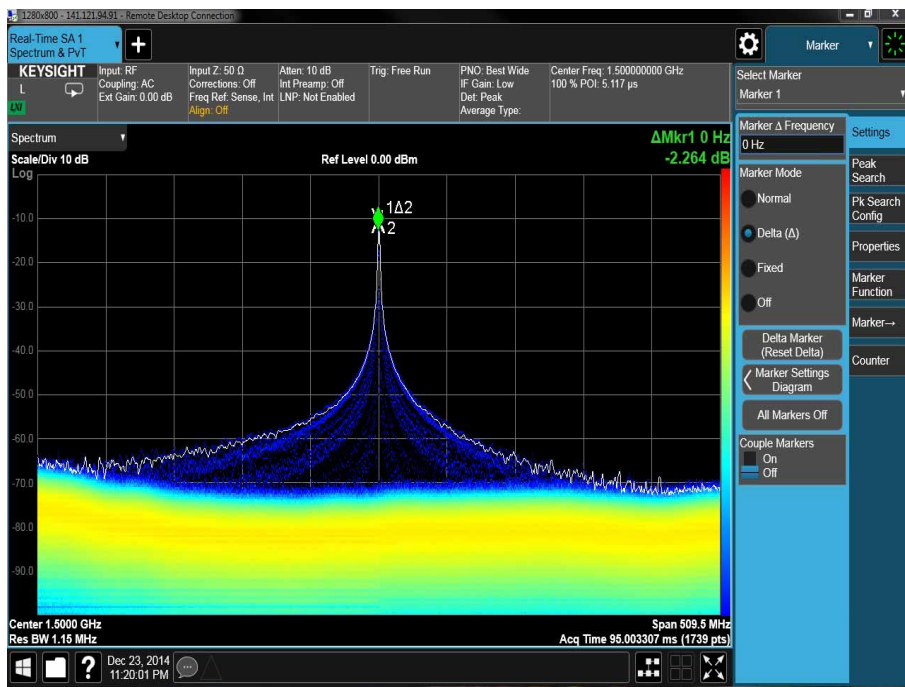
Step	Action	Notes
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7	Change the pulse width on the MXG a. Press <b>Pulse, Pulse Width, 5.117, <math>\mu</math>sec.</b>	
---	------------------------------------------------------------------------------------------------------	--



The Marker Delta remains around 0 dB on each acquisition.

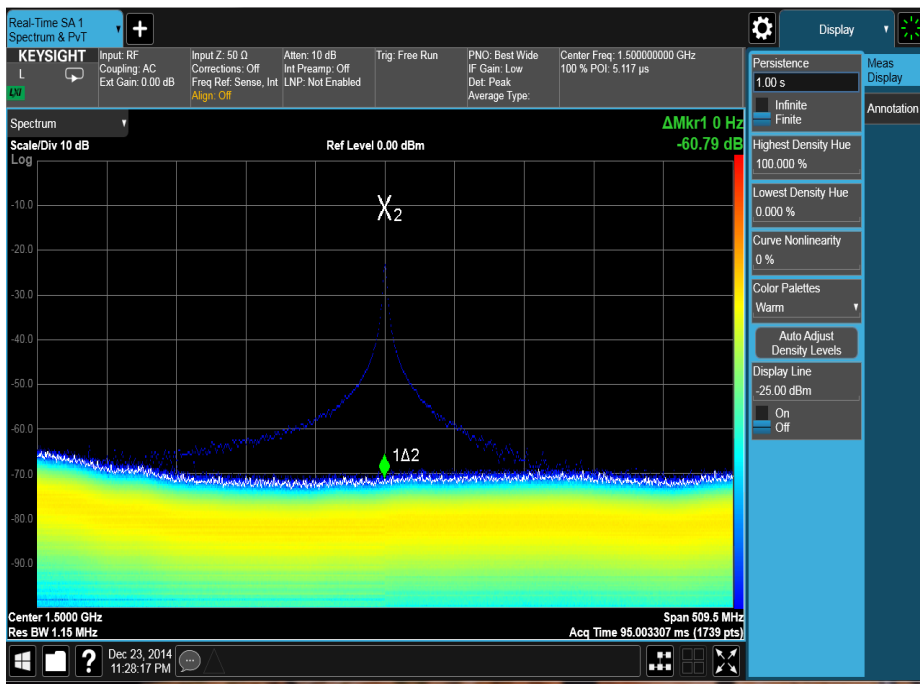
8	Change the pulse width on the MXG a. Press <b>Pulse, Pulse Width, 2, <math>\mu</math>sec.</b>	
---	--------------------------------------------------------------------------------------------------	--



Changing to a narrower pulse width will still capture the pulse, but an incorrect amplitude is being reported.

Signal Detection and Analysis  
Measure a Narrow Pulse Signal

Step	Action	Notes
9	Change the pulse period on the MXG	a. Press <b>Pulse, Pulse Period, 1, sec.</b>
10	Change the UXA view	a. Tap the hardkey drop down menu and select <b>Display, Persistence</b> , and enter <b>1, s.</b>



These changes still guarantee 100% POI

11	Change the pulse width on the MXG	a. Press <b>Pulse, Pulse Width, 20, ns.</b>
12	Change the UXA filter type	a. Tap the hardkey drop down menu <b>BW, Filter Type, Rectangular.</b>

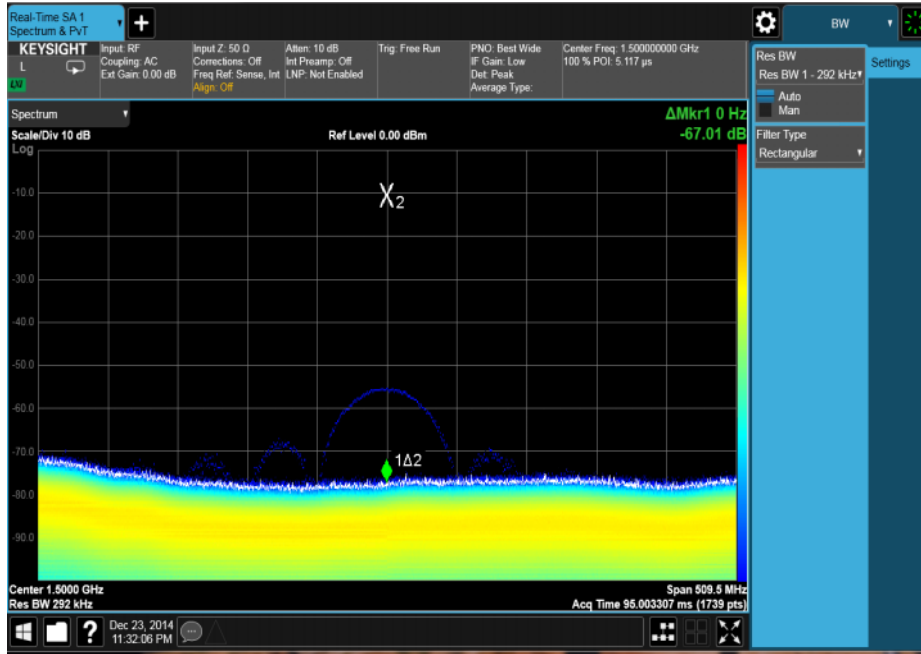
# Signal Detection and Analysis

## Measure a Narrow Pulse Signal

Step

Action

Notes



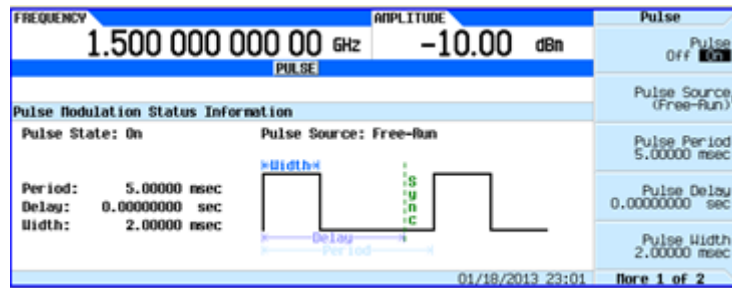
Even the narrow pulse is still captured. The Rectangular filter is used to stabilize the amplitude reading.

## Measure the Transient Signal

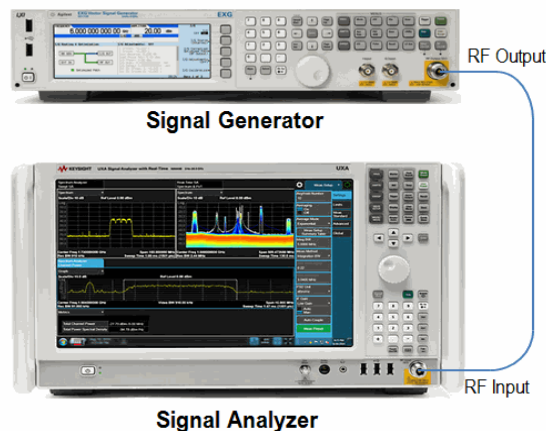
For the time/frequency/time rapidly changing signal, the Real-Time Spectrum Analyzer can help you to observe the varied signal. We will measure a AM/FM pulsed signal in this example.


### Procedure

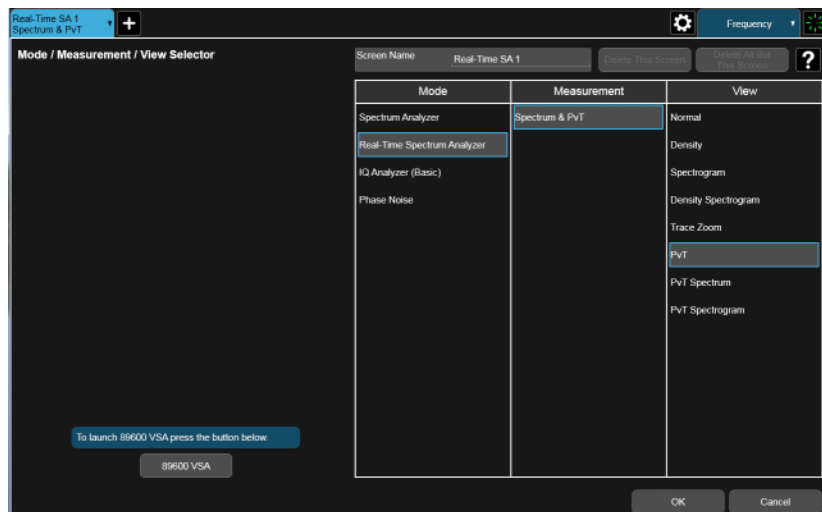
Step	Action	Notes
1	Preset the MXG	
2	Set up a pulse on the MXG	These steps set up a 5 m second pulse period with a pulse width of 2 m seconds.
	a. Press <b>FREQ, 1.5, GHz, AMPTD, -10, dBm, RF</b> to On.	
	b. Press <b>Pulse, Pulse Period, 5, msec, Pulse Width, 2, msec, Pulse</b> to On.	
	c. Press <b>AMPTD, ALC</b> to Off.	



### 3 Configure the instruments



Step	Action	Notes
4 Preset the UXA	<p>a. Press the <b>Mode Preset</b> key on the front panel. Or tap Mode Preset in preset drop down list on the top right corner of the touch screen.</p> 	<p>Mode Preset - Returns the current Mode to a known state. Mode Preset only presets the current Screen, it does not affect any other Screens.</p> <p>Restore Mode Defaults - Resets all of additional settings of the current mode as well as all of the Mode Preset settings.</p> <p>Restore Screen Defaults - Resets the Screen configuration to the factory default; deleting all screens, all screen names, and all screen states. A single screen will remain, set to the power-on Mode in a preset state with the default screen name.</p>
5 Select the Real-time mode	<p>a. Tap the Screen Tab drop down arrow to access the Mode/Measurement/View Selector dialog and select <b>Real Time Spectrum Analyzer, Spectrum &amp; PvT, PvT</b>.</p>	



- b. Double tap **Center Frequency**, and enter **1.5, GHz**.

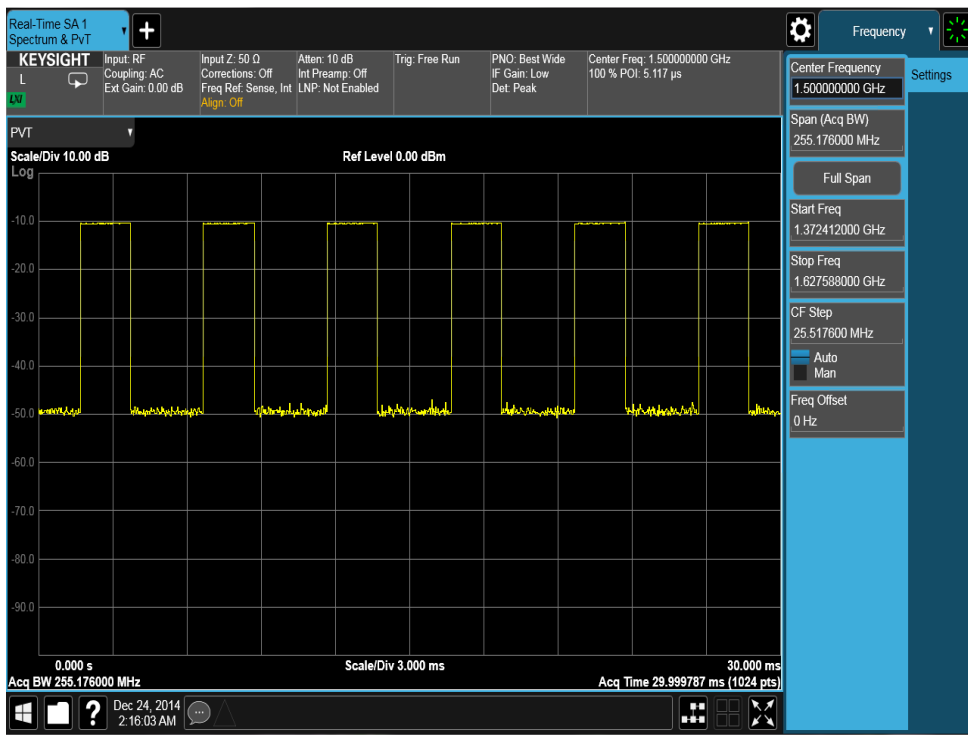
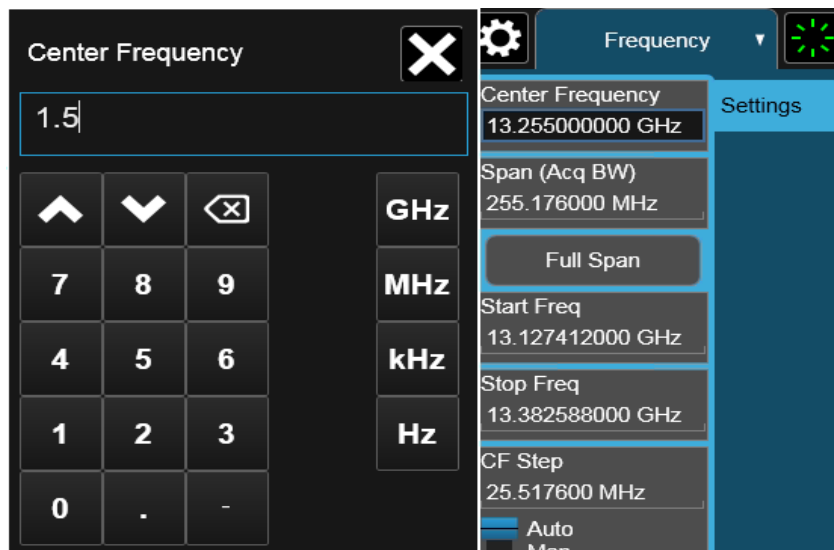


Signal Detection and Analysis  
Measure the Transient Signal

Step

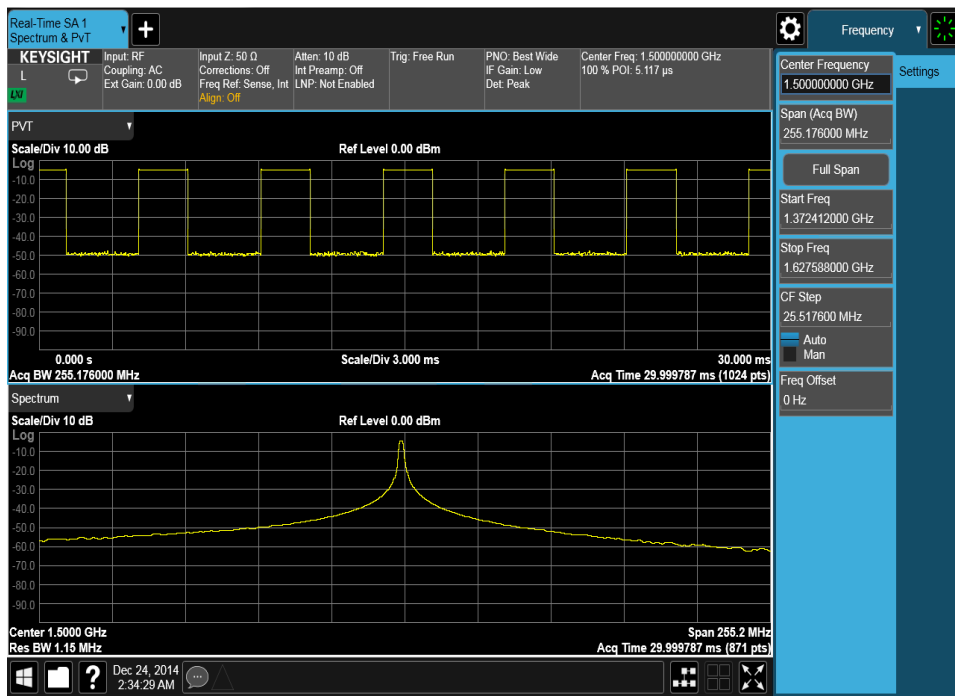
Action

Notes



This signal provides 6 stable pulses on the display without any triggering since the acquisition time of 30 ms is 6 times the pulse period of 5 ms and this is a real-time view of power versus time.

Step	Action	Notes
6	<p>Add AM and FM to the pulse signal on the MXG</p> <p>a. Press <b>AMPTD, ALC to On.</b></p> <p>b. Press <b>FM, FM Source, Func Gen 1, FM Dev, 8, MHz, More, Setup FM Source, FM Rate, 0.3, Hz, Return, Return, FM Off On to On.</b></p> <p>c. Press <b>AM, AM Source, Func Gen 2, AM Depth, 90, %, More, Setup AM Source, AM Rate, 0.4, Hz, Return, Return, AM Off On to On.</b></p>	
7	<p>Change to the spectrum view on the UXA</p> <p>a. Tap the Screen Tab drop down arrow to access the Mode/Measurement/View Selector dialog and select <b>Real Time Spectrum Analyzer, Spectrum &amp; PvT, PvT Spectrum.</b></p>	



This view shows a combination of two different displays. The top window shows the Power vs. Time trace and the bottom window shows the Spectrum trace. In the bottom window, the horizontal axis represents frequency and the vertical axis represents amplitude.

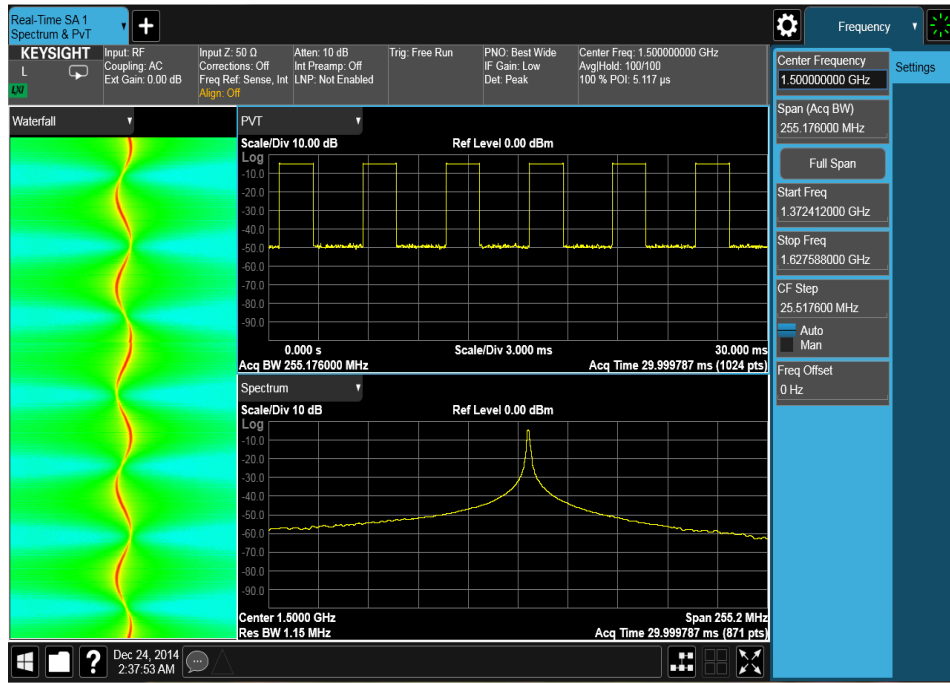
8	<p>Change to spectrogram view on the UXA</p> <p>a. Tap the Screen Tab drop down menu to access the Mode/Measurement/View Selector dialog and select <b>Real Time Spectrum Analyzer, Spectrum &amp; PvT, PvT Spectrogram</b></p>	
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Signal Detection and Analysis  
Measure the Transient Signal

Step

Action

Notes



This view adds a Spectrogram trace to the left of the dual window. See **“Spectrogram” on page 21** for more information.

9 Change the FM rate on the MXG

a. Press **FM, More, Setup FM Source, FM Rate, 1, Hz.**

10 Change the span and spectrogram view on the UX

a. Tap the hardkey drop down menu and select **Frequency** then **Span**, and enter **40, MHz.**  
b. Tap the hardkey drop down menu and select **Display, Color Adjust, Auto Adjust Hue Position.**

This sets the Ref Hue Position to the highest amplitude value found in the Spectrogram and sets the Bottom Hue Position to the lowest amplitude value found in the Spectrogram to enable you to focus on the signal of interest. See **“Spectrogram” on page 21** for more information.

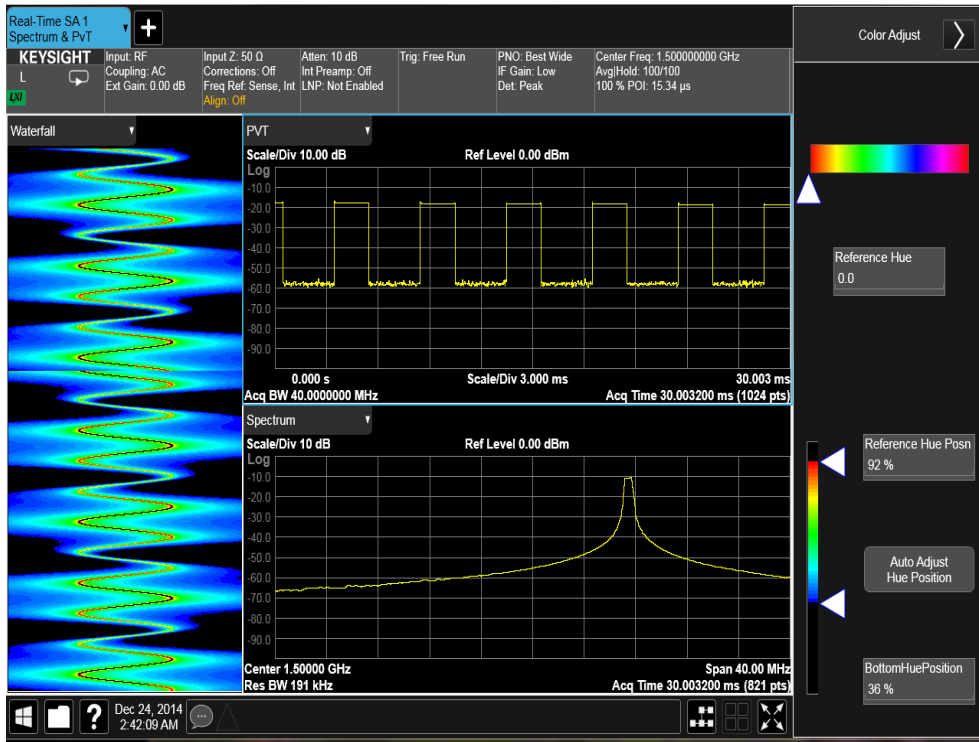
# Signal Detection and Analysis

## Measure the Transient Signal

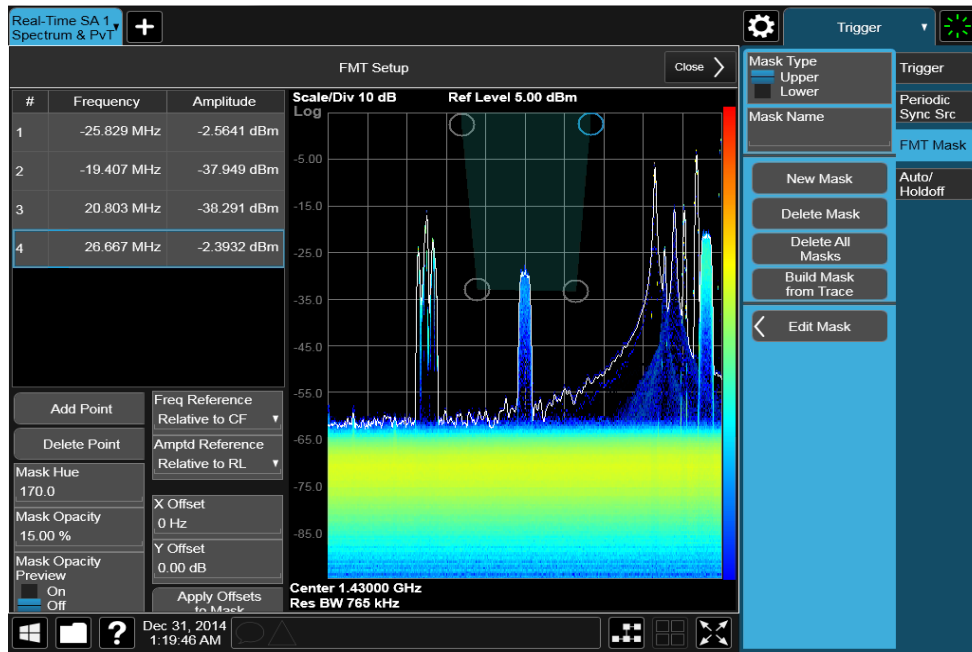
Step

Action

Notes



## FMT Setup Details



### Navigate

When you enter the FMT Editor, you can move through the table to edit the desired point. You can edit the table of values (highlighted in blue).

### Frequency

Selects the frequency value of the current row for editing.

### Amplitude

Selects the amplitude value of the current row for editing.

### Add Point

This inserts a point (frequency and amplitude values that form the mask anchor points) below the current point. The new point is a copy of the current point and becomes the current point. The new point is not yet entered into the underlying table, and the data in the row is displayed in light gray. When you select the terminating unit, the new point is entered in the table.

### Delete Point

This will immediately delete the currently selected point, whether or not that point is being edited, and select Navigate as the active function. The point following the currently selected point (or the point preceding if there are no points following) will be selected.

## Freq/Amptd Reference

Specify that the selected mask is relative to either the center frequency or the reference level.

**Relative to CF** - Chooses whether the mask frequency points are coupled to the instrument center frequency, or whether the frequency points are expressed as an offset from the instrument center frequency.

For example, assume the analyzer center frequency is at 1 GHz. If Relative to CF is "Off", entering a mask point with a frequency coordinate of 300 MHz displays the mask point at 300 MHz, and the mask point will not change frequency if the center frequency changes. If Relative to CF is "On", entering mask point with a frequency coordinate of 300 MHz displays the mask point at CF + 300 MHz, or 1.3 GHz. Furthermore, if the center frequency changes to 2 GHz, the mask point will be displayed at CF + 300 MHz, or 2.3 GHz.

It is possible to change this setting after a mask point has been entered. When changing from On to Off or vice-versa, the frequency values in the mask table change so that the mask points remains in the same position for the current frequency settings of the analyzer.

**Relative to RL** - Chooses whether the mask amplitude points are coupled to the instrument reference level, and whether the amplitude points are expressed as an offset from the instrument reference level.

For example, assume you have a mask, and the reference level at -10 dBm. If Relative to RL is "Off", entering a mask point with an amplitude coordinate of -20 dBm displays the mask point at -20 dBm, and the mask point will not change amplitude if the reference level amplitude changes. If Relative to RL is "On", entering a mask point with an amplitude coordinate of -20 dB displays the mask point at RL - 20 dB, or -30 dBm. Furthermore, if the reference level amplitude changes to -30 dBm, the mask point will be displayed at RL - 20 dB, or -50 dBm.

It is possible to change this setting after a mask point has been entered. When changing from On to Off or vice-versa, the amplitude values in the mask table change so that the mask points remains in the same position for the current reference level settings of the analyzer.

## Offsets

**X Offset** - Offsets all the frequency points in the mask by the specified frequency.

**Y Offsets** - Offsets all the amplitude points in the mask by the specified amplitude.

**Apply Offsets to Mask** - Apply X and Y offsets to the selected mask.

## Mask Color

**Mask Hue** - This parameter allows you to adjust the Hue of the Mask.

**Mask Opacity** - This parameter allows you to adjust the Opacity of the mask.

**Mask Opacity Preview** - Displays the Mask Opacity that will be used.

## Mask Type

This selection enables you to select either an upper or lower mask type.

## Mask Name

Provides a description of up to 60 characters by which you can easily identify the limit. This will be stored in the exported file and can be displayed in the active function area to be displayed in a screen capture.

## New Mask

Clears any existing mask and creates a new mask of 4 points. Two points will be at  $20\% \pm$  the Center frequency and at the Reference Level. The other two points will be at  $10\% \pm$  Center Frequency and  $20\%$  below the Reference Level.

When selected the following warning message will appear:

```
"This will delete all the points in the current mask,  
Are you sure you want to do this?"
```

```
Press Enter to proceed or ESC to Cancel"
```

## Delete Mask

This key/selection deletes the currently selected mask.

When selected the following warning message appears:

```
"This will delete all the points in the current mask,  
Are you sure you want to do this?"
```

```
Press Enter to proceed or ESC to Cancel"
```

## Delete All Masks

This key/selection deletes both the upper and lower masks.

When selected the following warning message appears:

```
"This will delete all the points in both the masks  
Are you sure you want to do this?"
```

```
Press Enter to proceed or ESC to Cancel"
```

## Build Mask from Trace

This enables you to generate a mask from the trace displayed in the FMT setup view. The points generated will provide a rough outline of the current trace, with a maximum of 20 points.

Signal Detection and Analysis  
FMT Setup Details

The mask points generated by Build Mask from Trace can use X and Y offset to adjust the mask position.



## Trigger Setup Details

### Trigger Criteria

This parameter is used to define the event that will cause a trigger to occur. The events are ways that the signal interacts with the frequency mask. The data captured by RTSA is generated using multiple FFTs. The Trigger Criteria selection determines which FFTs are used in the data generation.

Enter	A trigger will occur when a signal enters the frequency mask area. The trigger event will not happen again until the signal leaves the mask and re-enters.
Leave	A trigger will occur when a signal leaves the frequency mask. This requires a signal to be present in the mask area.
Inside	A trigger event will occur when a signal is in the mask area and will continue to trigger until the signal is no longer in the mask area.
Outside	A trigger event will occur when the signal is not in the mask area and will continue to trigger until the signal is in the mask area.
Enter - Leave	A trigger will occur when a signal enters the frequency mask area then leaves it.
Leave - Enter	A trigger will occur when a signal re-enters the frequency mask area after leaving it.

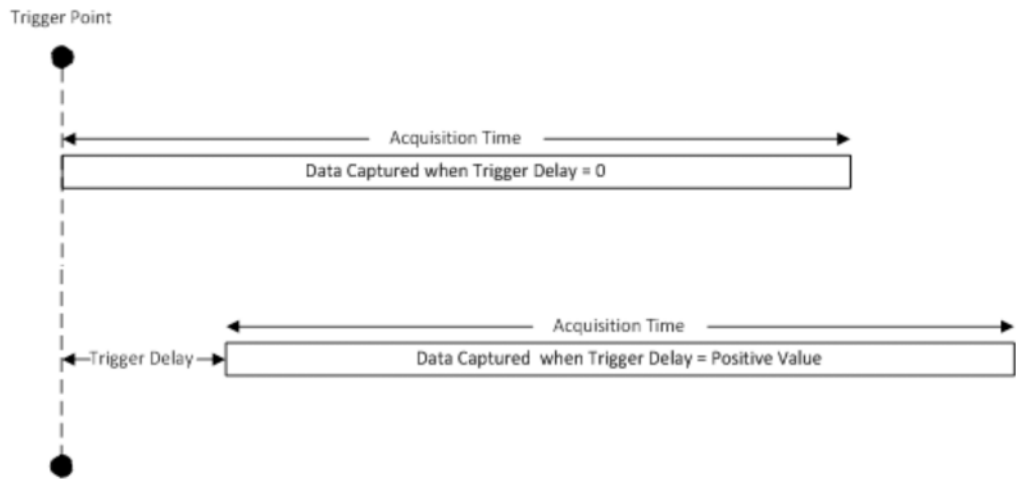
### Trigger Mask

This parameter is used to select which Mask to be used for triggering; Upper, Lower, or Both.

### Trig Delay

Controls a time delay during which the analyzer will wait to begin a sweep after meeting the trigger criteria.

### Trig Delay Diagram



### #of Acquisitions /Trigger

This specifies how many acquisitions worth of data to return for each satisfied trigger. This is most useful with Spectrogram when you have short Acquisition Times, yet you want more than 1 Spectrogram scan for every triggered result. If the number of acquisitions per trigger is 20 and the Acquisition Time is 30 msec, then you will get 600 msec ( $20 * 30$  msec) worth of data after the trigger condition has been met.

## Save Data

### Saving Spectrogram Data

You can save the results of up to 10,000 successive, gap-free sweeps in Spectrogram mode. Each sweep contains 821 points of amplitude results representing all the data measured during the interval defined by the Acquisition setting. The spectrogram engine continues collecting new data while saving the data and if the save time is less than the collection time to fill all traces, then it is possible to continually save files with no loss of data.

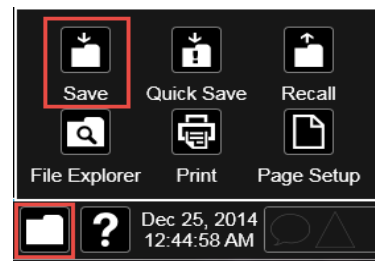
For example, if you set an acquisition time to 100 ms, it takes about >16 minutes to fill the 10,000 traces. Saving all 10,000 traces to the internal drive on a UXA takes about 12 seconds. While saving the file, the spectrogram continues running, with no loss of acquisitions every 100 ms.

To save a the Real-time Spectrum Analyzer Spectrogram results data in .csv format:

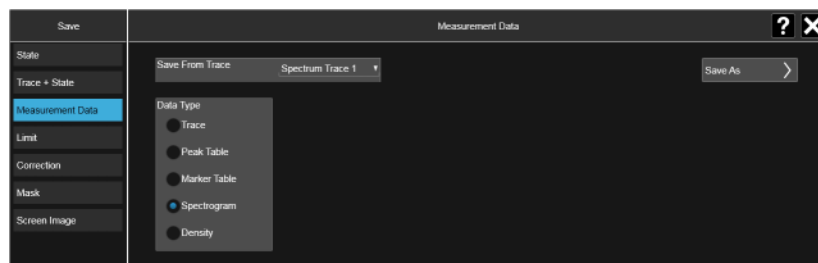
#### Step

#### Notes

1 Tap the File icon and select **Save**



2 Tap **Measurement Data, Spectrogram**



3 Tap **Save As**

The Save As dialog box enables you to name the files and select where you want to save the data.

4 Tap **Save**

To save subsequent files, press **Quick Save** and the files will be saved with the same name but with sequential numbering.

Signal Detection and Analysis

Save Data

In the saved data file, each individual line, beginning with Data1 represents one slice of the spectrogram. Data1 represents the most recent acquisition and the last Data(N), represents the oldest, or first trace record in the file.

The second column in the trace data is a time stamp and each individual row represents all the data captured during that particular time interval. All 821 frequency points are listed (the data goes all the way to column "AEQ" in the Excel spreadsheet). Refer to the following example graphic.

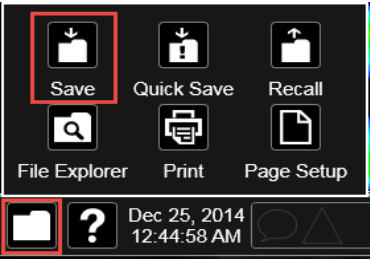
	A	B	C	D	E	F
1	MeasResult					
2	Real Time SA					
3	A.15.00_R0063	N9040B				
4	526 ALV B25 B2X B40 B5X CR3 CRP EA		1			
5	Segment		0			
6	Result Type	Spectrogram				
7	Measurement Type	Spectrum				
8	Number of Points		821			
9	Pvt Number of Points		1024			
10	Acquisition Time		0.03000024			
11	Start Frequency		1495000000			
12	Stop Frequency		1505000000			
13	Average Count		100			
14	Average Type	Voltage				
15	RBW		47838.57657			
16	RBW Filter	Gaussian				
17	RBW Filter BW	3dB				
18	Trigger Source	Free				
19	Trigger Level		1.2			
20	Trigger Slope	Positive				
21	Trigger Delay		0			
44	...					
45	DATA					
46	Frequency (Hz)		1.5E+09	1.5E+09	1.5E+09	1.5E+09
47	DATA0	NaN	-87.4727	-87.3202	-86.7485	-86.285
48	DATA1		2.97038269	-87.4727	-87.3202	-86.7485
49	DATA2		2.940376282	-65.5912	-65.5138	-65.4372
50	DATA3		2.910377502	-18.6017	-17.274	-17.5993
51	DATA4		2.880371094	-77.0446	-77.2923	-77.3401
52	DATA5		2.850372314	-87.7282	-87.0363	-86.7485
53	DATA6		2.820365906	-26.6022	-25.2755	-25.5999
54	DATA7		2.790359497	-18.5998	-17.2729	-17.5987
55	DATA8		2.760360718	-69.1951	-69.2087	-69.2447

## Saving Density Data

The Density result file has the same data as the other Meas Results files with the additional data: #FFT's, Sample Rate and Acquisition Time.

The format of the data listed under DATA, is a series of frequency and amplitude points with the value at each point representing the density percentage, in the range 0-1. Therefore, a frequency and amplitude point that is hit 50% of the time during an acquisition will be represented by 0.5. The location of the frequency and amplitude point within the bitmap will correspond to the row and column point in the .csv file.

To save a the Real-time Spectrum Analyzer Density results data in .csv format:

Step	Notes
1. Tap <b>File</b> icon and select <b>Save</b>	
5 Tap <b>Measurement Data, Density</b>	
6 Tap <b>Save As</b>	The Save As dialog box enables you to name the files and select where you want to save the data.
7 Tap <b>Save</b>	To save subsequent files, press <b>Quick Save</b> and the files will be saved with the same name but with sequential numbering.

In the saved data file, the header data is listed first. The format of the data will be a series of frequency and amplitude points with the value at each point representing the density percentage, in the range 0-1. Therefore, a frequency/amplitude point that is hit 50% of the time during an acquisition will be represented by 0.5. The location of the frequency/amplitude point within the bitmap will correspond to the row/column point in the .csv file. Refer to the following example graphic.

Signal Detection and Analysis  
Save Data

	A	B	C	D	E	F	G
1	Trace						
2	Real Time SA						
3	A.15.00_R0063	N9040B					
4	526 ALV B25 B2X B40 B5X CR3 CRP EA3 EMC E	1					
5	Scale Per Div	10					
6	Segment	0					
7	Result Type	Density					
8	Measurement Type	Spectrum					
9	Number of Points	1739					
10	Pvt Number of Points	1024					
11	Acquisition Time	0.095003307					
12	Start Frequency	1245263675					
13	Stop Frequency	1754736325					
14	Average Count	1					
15	Average Type	Voltage					
16	RBW	1148125.838					
17	RBW Filter	Gaussian					
18	RBW Filter BW	3dB					
19	Trigger Source	Free					
20	Trigger Level	1.2					
21	Trigger Slope	Positive					
22	Trigger Delay	0					
44	...						
45	DATA						
46	Freq/Ampl	1245263675 Hz	124555681	124584994	124614308	124643622	124672936
47	-100 dBm	0.000431143	0.000431	0.000287	0.000503	0.000323	0.000216
48	-99.55556 dBm	0.000395214	0.000395	0.000503	0.00079	0.000395	0.000539
49	-99.11111 dBm	0.000574857	0.000539	0.000647	0.000539	0.000503	0.000719
50	-98.66666 dBm	0.0007545	0.000683	0.000898	0.000575	0.000719	0.000683
51	-98.22222 dBm	0.000215571	0.00018	0.000144	0.000287	0.000252	0.000252
52	-97.77778 dBm	0.000431143	0.000862	0.000826	0.000826	0.000755	0.000503
53	-97.33334 dBm	0.000862286	0.000683	0.000683	0.000611	0.000539	0.000539
54	-96.88889 dBm	0.001149714	0.001186	0.001437	0.001293	0.00079	0.001222



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