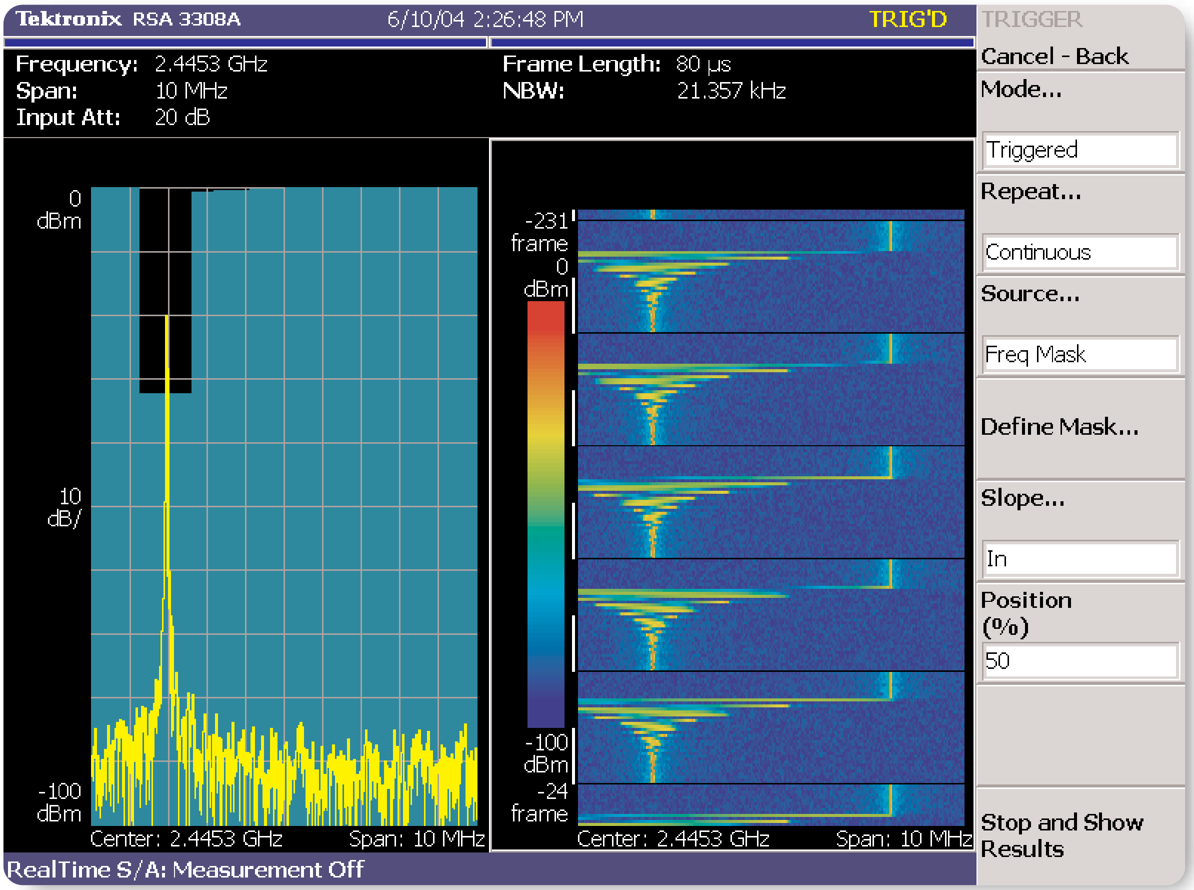
Quickly Identify Intermittent and Interfering Signals with Real-Time Spectrum Analysis



Measurement Challenges in Today's Crowded RF Spectrum

The RF spectrum is becoming increasingly crowded and busy, creating much more potential for systems and signals to interfere with each other. Not only are there more RF signals today, but typically these RF signals are much more transient and complex in nature, making it difficult for RF Engineers to identify the source of interfering signals in an operational environment.

With many of today's RF systems using techniques such as frequency hopping, pulses and digital modulation, it becomes more difficult to find, record and identify the source of the interference since the "problem signal" may only be present for a brief moment. Additionally, the signal may quickly change frequency, or may even get combined with the expected transmission causing the quality of service to be degraded.

When it comes to analyzing these signals, traditional swept spectrum analyzers struggle to provide engineers and technicians with all the information that is required to fully identify a signal. Engineers need displays showing time correlated views of the frequency, time, and modulation domains to enable them to quickly perform complete and accurate analysis of the signal.

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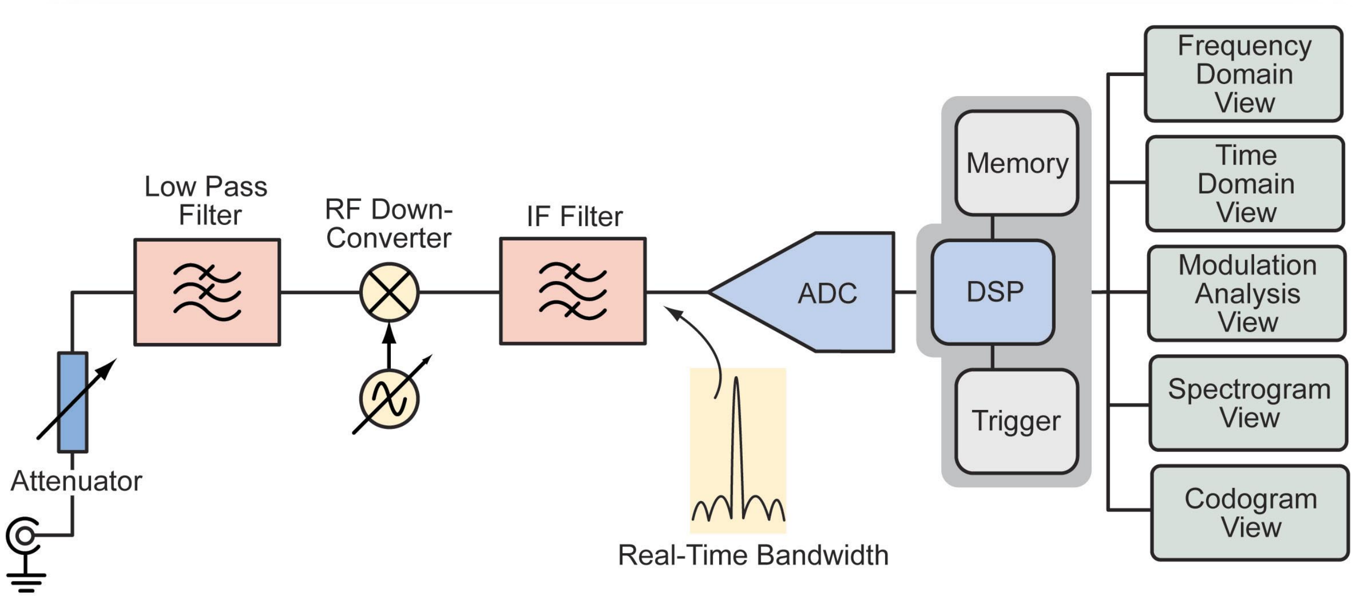


▶ **Figure 1.** *Block diagram of the Tektronix Real-Time Spectrum Analyzer.*

This tech brief will explain how the use of a Real-Time Spectrum Analyzer (RTSA) can reliably detect and characterize transient RF signals, while also greatly reducing the time taken to identify the source of the problem. A number of different examples will be used to demonstrate how the unique capabilities of a RTSA can be used in a broad range of applications where it is critical to identify intermittent and interfering signals.

Real-Time Spectrum Analysis: Trigger, Capture, Analyze

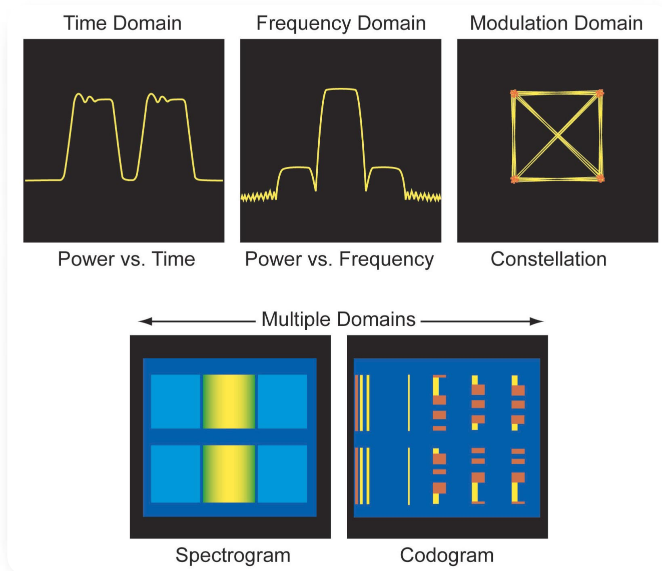
The Tektronix Real-Time Spectrum Analyzer is designed specifically to address these measurement challenges associated with transient and dynamic RF signals. The fundamental concept of real-time spectrum analysis is the ability to trigger on an RF signal, seamlessly capture it into memory, and analyze it in multiple domains. This makes it possible to reliably detect and characterize RF signals that change over time.

Figure 1 shows a typical simplified block diagram of the RTSA architecture. The RF front-end can be tuned across the entire frequency range of the instrument, and it down-converts the input signal to a fixed IF that is related to the maximum real-time bandwidth of the RTSA. The signal is then filtered, digitized by the ADC, and passed to the DSP engine that manages the instrument's triggering, memory, and analysis functions. The RTSA is optimized to deliver real-time triggering, seamless signal capture, and time-correlated multi-domain analysis.

For measurement spans less than or equal to the real-time bandwidth of the RTSA, this architecture provides the ability to trigger on signals in the time or frequency domain and then seamlessly capture the input signal with no gaps in time by digitizing the IF signal and storing the time-contiguous samples in memory. Then, signals can be analyzed using the wide variety of time-correlated views available in the RTSA, as illustrated in Figure 2.

Once a specific RF signal has been detected, acquired, and stored, the RTSA provides the ability to make frequency domain measurements, time domain measurements, and modulation domain measurements. Since all of these results are computed from the same underlying set of time domain sample data, the RTSA makes it possible to correlate behavior between domains and understand how frequency, time, and modulation events are related based on a common time reference.

This allows thorough characterization of transient and dynamic RF signals that are difficult or impossible to capture and analyze using a swept spectrum analyzer or a vector signal analyzer, which is especially useful for applications requiring transient signal characterization such as system integration, device troubleshooting, and spectral monitoring.

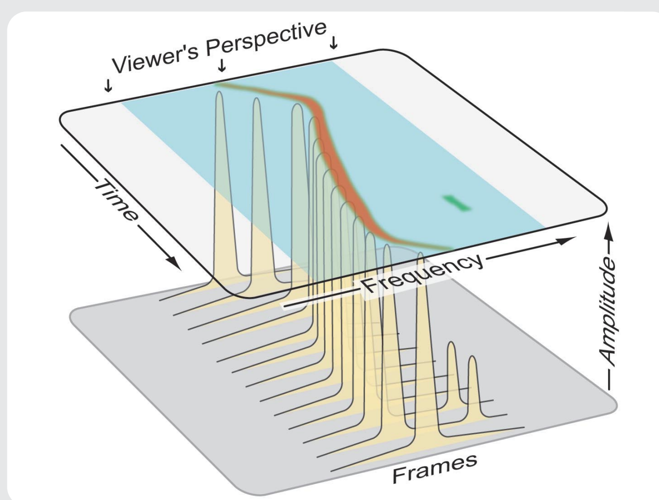


▶ **Figure 2.** *A few examples of time-correlated measurements available on the RTSA.*

Finding Signals in Crowded Spectrum

One of keys to quickly identifying the source of an interfering signal is the ability to capture the desired signal the moment it appears. This can be especially difficult if the desired signal is intermittent, unstable or located in a crowded portion of the RF spectrum. The main difficulty in finding intermittent signals is caused by their unpredictability. Seconds, minutes or hours can pass before the event occurs. When it does occur, it may not happen again for a very long time, so you have to be sure that your spectrum analyzer is ready and able to capture this signal. With their sweeping architecture and lack of sophisticated triggers, it is extremely difficult to use traditional swept spectrum analyzer to capture an intermittent signal.

The Tektronix RSA offers several powerful tools to view signal characteristics in the time, frequency, and modulation domains. By seamless capturing RF signals into memory and then using DSP techniques to process the sampled data, the RSA can reliably show how RF signals change over time. The spectrogram, shown in Figure 3, in an important display that provides an intuitive representation of how a signal changes in the frequency domain over time. This enables engineers to confidently make measurements on bursted, transient, and frequency hopping signals, as described later in this document.



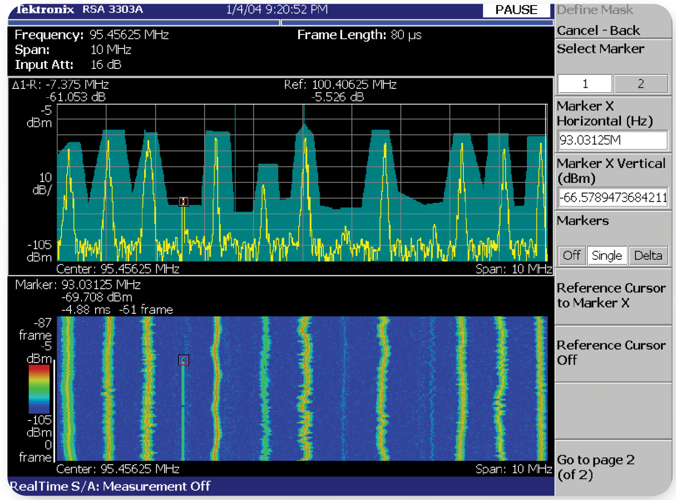
▶ **Figure 3.** *The spectrogram display: horizontal axis is frequency, vertical axis is time, and amplitude is represented by color.*

To solve this problem, Tektronix RSAs incorporate frequency domain triggering capability that ensures that they start seamlessly recording the whole frequency band of interest as soon as an interfering signal appears in the spectrum. This seamless capture ensures that there are no breaks in the time record so that a complete and accurate analysis of spectrum over time can be made.

A Frequency Mask can be built in the frequency domain to selectively exclude specific regions that are not of interest or that may contain existing large transmissions. The purpose of the mask is to look for signals that “break” into or out of the mask area. This triggering function ensures that only “unexpected” signals are captured into the memory, while larger known signals are ignored. All this can be achieved without the need for external filters.

In the example shown in Figure 4, a 10 MHz section of the FM Radio band is being monitored as there is a problem with an intermittent, low level interfering signal. This frequency band is crowded with many high level signals that are close together, making it difficult to find any interfering signal. However, with the use of Frequency Mask Trigger all the known FM broadcasts can be masked out, leaving the RSA free to look for the interfering signal. Looking at the frequency domain view, top section of Figure 4, any RF signal that crosses into the black area of the screen will trigger the analyzer, causing it to capture a seamless time record of the whole 10 MHz spectrum into memory.

In addition to the Frequency Domain view in Figure 4, there is a Spectrogram display that shows changes in Power and Frequency over time. These two views are linked: selecting any point in the Spectrogram will result in the Frequency Domain view updating to show the Frequency vs. power response for that exact moment in time. In this case, the RSA is showing the exact moment that the interfering signal broke into the mask area and triggered the instrument.



▶ **Figure 4.** *The Spectrogram shows the power and frequency changes over time, while the instantaneous frequency spectrum view provides a detailed insight into the moment the interfering signal appears.*

The level-only triggers that are common in swept spectrum analyzers work well in clear spectrum or in frequency bands where the desired signal has the highest power level. With today’s crowded spectrum, there is less chance that your intermittent signal is in a clear segment of the spectrum or the dominant signal in any band. Because the level-only trigger function senses only level and is not frequency selective, it therefore can not reliably detect events at a specific frequency. If the desired intermittent signal is weak in comparison to larger near-by continuous transmissions, a level-only trigger will not detect its presence.

A further limitation of the level-only trigger and the swept spectrum analyzer architecture is that there is no way to capture events before the trigger condition is met, therefore only post event analysis can take place. In today’s RF environment, traditional trigger functions like level-only triggers are no longer suitable in most applications that involve spectrum monitoring.

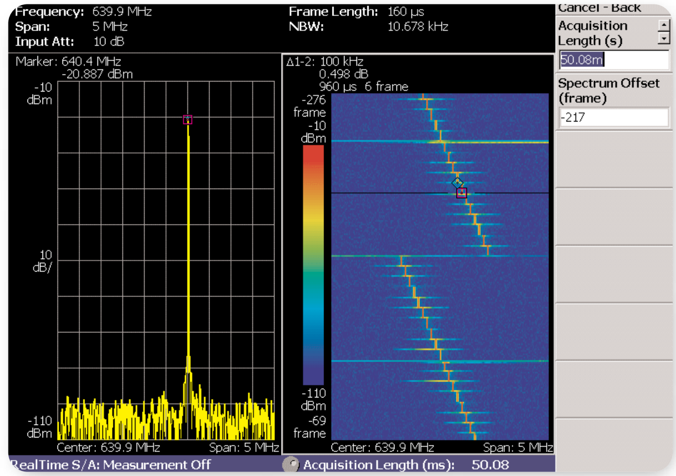
With seamless real-time capture and multi-domain analysis capability, engineers can quickly and easily extract information about the signal of interest. The powerful ability to view power and frequency changes over time in the Spectrogram display ensures that the engineers have a complete understanding of the signal of interest.

Analyzing the Spectrogram shows that this signal switches on at 93.03125 MHz with a power level of -69.7 dBm. There is no power ramp and the signal has good frequency stability (there is no horizontal movement in the green line that represents this interfering signal). However, interesting enough, the signal appears to briefly stop transmitting, shown by the small gap in the line. This may indicate that the interfering signal is pulsed or that the source has some start up power instabilities.

Characterizing Frequency Hopping Transmitters

The task of characterizing frequency agile or hopping transmitters can be challenging, especially in environments where transmitters do not follow a simple repeating pattern. In such cases, it is critical that the interactions between the power, frequency and timing parameters are accurately understood. Traditional swept spectrum analyzers cannot provide timing information, making it extremely difficult to characterize frequency agile or hopping transmitters with a single piece of test equipment. However, the development of RSAs enable one single spectrum analyzer to perform correlated multi-domain analysis on a single transmission, thus reducing total test time and measurement uncertainty.

In the example below, a 640 MHz frequency agile transmitter performs a stepped, sweep across a 2 MHz span. The spectrogram in Figure 5 makes it easy to identify the pattern of the transmitter; however that is only part of the story. The quality of the signal has to be analyzed, meaning along with the traditional RF measurements, time varying effects such as switching transients, spectral splatter and settling time have to be measured. The ability of the RSA to capture a seamless record of a span of RF frequencies, allows engineers to analyze the signal at any point in time. In this example, the Spectrogram clearly shows the spectral splatter that is generated during the middle section of the sweep. Viewing the relationship between the change in frequency and power over time enables engineers to quickly identify potential problems or source of interference.

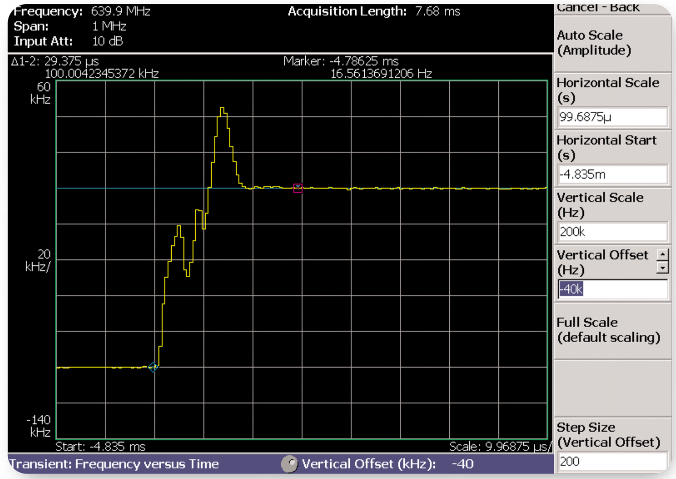


▶ **Figure 5.** *Right side image: Spectrogram of 640 MHz frequency agile hopping transmitter. Hopping pattern of discrete steps with spectrum splatter in between is clearly visible. Left side display shows spectrum of signal correlated to the same time as the marker position on the right side spectrogram.*

When a transmitter changes from one frequency to another, one of the most important characteristics is the frequency settling time. From an operations point of view, it can cause quality problems, while from a monitoring perspective it can reveal unique characteristics that can lead to the identification of an individual transmitter. The multi-domain capabilities within the RSA mean the frequency settling time of any hop can be analyzed without having to recapture another signal or use a second piece of test equipment.

Changing into the time domain mode of the RSA enables the switching transient (frequency vs. time) of a particular hop to be analyzed. The frequency vs. time display in Figure 6 shows that the frequency change is not a smooth linear change, but in fact, for a short period of time the transmitter frequency appears to ring. This may have been caused by the PLL within the transmitter having lost "lock" during the frequency hop. The delta markers on the top left display measure the settling time as 30 µsec and the frequency change as 100 kHz.

With all this information about hopping pattern, RF performance, spectral splatter and settling time available from a single shot capture of the signal, the benefits of a true multi-domain instrument that can seamlessly capture a time record of the a span of frequency into memory are priceless in environments where time varying RF signals have to be characterized.

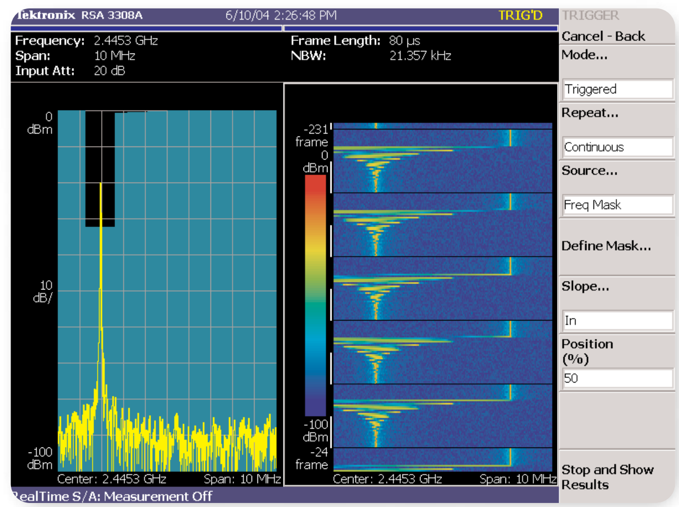


▶ **Figure 6.** *Switching transient (frequency vs. time) of hopping transmitter shown in Figure 5. Markers show 100 kHz frequency step with transient settling out in 30 µsec.*

Detecting and Capturing Intermittent Signals

When characterizing an unknown transient signal some questions that typically need to be answered are: "How often does this signal appear?" and "Does the signal look the same each time it appears?" The signal may appear once every hour or even once per day, but only last for a fraction of second, so how can you be sure? The only way to truly answer that question is by continually monitoring the spectrum of interest and capturing every event into memory. Traditionally this was done with specialized, high end monitoring equipment that would continually record the spectrum. This method is expensive and not particularly efficient, since the vast majority of the recorded data would contain information that was useless.

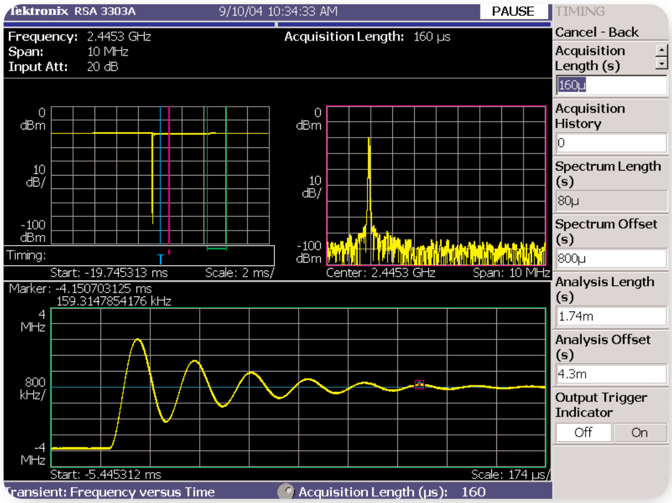
RSAs make this task much more affordable and efficient. By employing a continuous trigger mode, the RSA triggers can be set to capture the signal every time the "trigger" condition is met. Once triggered the analyzer will capture the spectrum activity for a small amount of time (determined by the operator), then will rearm itself and await the next trigger. The next time



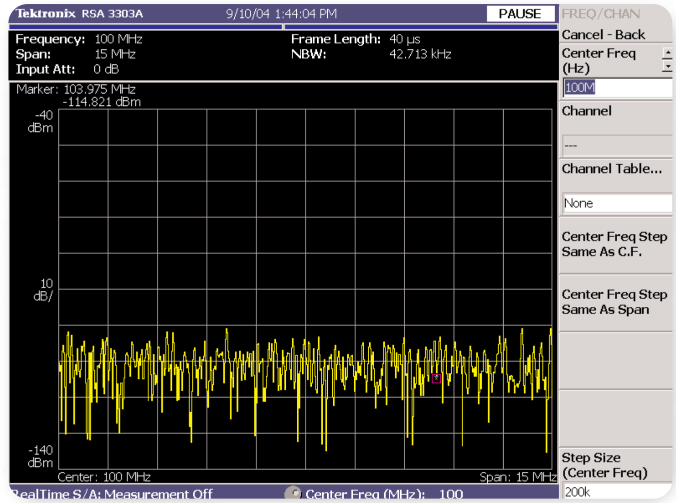
▶ **Figure 7.** *A series of frequency hops are captured into memory and each individual hop can be analyzed independently.*

the signal of interest appears the RSA triggers and captures again, but this time it appends the information into the memory along with a time stamp. This capability makes efficient use of the capture memory in the RSA, ensuring that it is filled with only relevant information.

The signal in Figure 7 shows a 2448.38 MHz signal that hops to 2442.24 MHz. We are only interested in characterizing the hop. We want to know if each hop



▶ **Figure 8.** *The detailed, time correlated multi-domain view enables in-depth analysis of each individual frequency hop.*



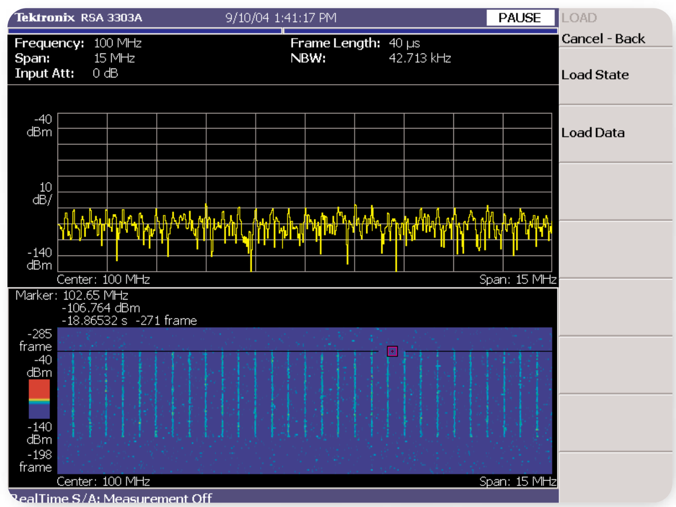
▶ **Figure 9.** *With the traditional frequency domain view there appears to be nothing of interest in the spectrum.*

is the same and how often these hops occur. The right hand side of Figure 7 shows a spectrogram that contains 5 occurrences of the hop that were captured over a long period of time*1. The instrument can be left unattended to capture these signals, leaving engineers and operators free to concentrate on more pressing issues.

Once there is enough information stored into memory, each individual event can be independently analyzed so that all aspects of the frequency hop can be characterized. The Real-Time Spectrum Analyzers' ability to show time correlated multi-domain views enable the changes in power and frequency to be fully analyzed. Figure 8 shows Multi-Domain View of one hop, power vs. time (top left), power vs. frequency (top right) and frequency vs. time (bottom half).

Identifying Low Level, Spread Spectrum Signals

In many cases, problem signals are so low they disappear into the noise floor of the spectrum analyzer, making them extremely difficult and time consuming to find. With a traditional swept spectrum analyzer, it is not possible to achieve a low noise floor while quickly scanning a wide span of frequencies, making the task of finding low level signals very tedious. Additionally, there is no way to see changes in the signal over time.



▶ **Figure 10.** *With the Spectrogram the spread spectrum signal is clearly visible.*

The unique capabilities of the RSA enable signals that are embedded in the noise floor to be easily identified. Figure 9 shows a traditional frequency domain view of 15 MHz span of spectrum. There appears to be no signal present, however, when the spectrogram is activated, it becomes clear that a spread spectrum signal is present in Figure 10. The real-time seamless capture of a span of frequencies enables the analyzer to quickly and accurately capture a time record of these low level signals, while the multi-domain views make the identification of signals and signal patterns extremely quick and easy.

*1 The horizontal black lines show the breaks in memory capture.

Summary

In an operational environment where engineers are making "off air" measurements in an attempt to identify and characterize interfering signals or rogue transmitters, only Real-Time Spectrum Analyzers offer the triggering, capture and analysis capabilities that allow interfering signals to be quickly identified.

The unique triggering capabilities ensure that any change in the spectrum will be captured. Real-Time seamless capture stores signal shot events into memory, allowing complete analysis of the signal without the need to recapture the event. Multi-domain analysis provides powerful insight into the complex relationships between the time, frequency and modulation domains.

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