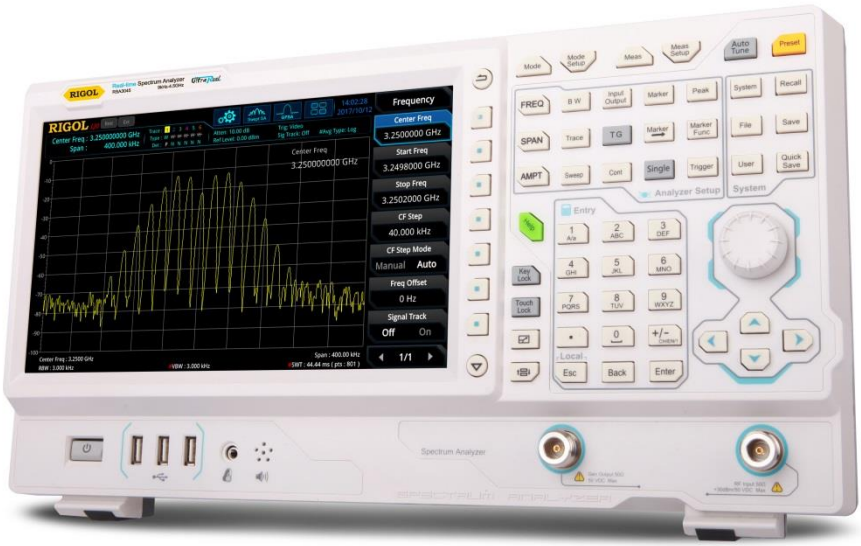
Interactive Debugging in Multi-Domain Environments

The continued expansion of the Internet of Things and the accompanying RF integration challenges means that designers benefit from versatility across disciplines. A single product routinely combines RF, digital, and analog design elements. Ultimately, this means engineers need to debug systems that include both RF and embedded subsystems interactively. Design issues can be seen in embedded signals, RF signals, or radiated emissions while the root cause of the issues may be in any of those sections or in the mechanical design. To address complex debugging issues with flexibility and value, RIGOL combines the latest Real-Time Spectrum Analysis with embedded debugging in Multi-Domain systems.

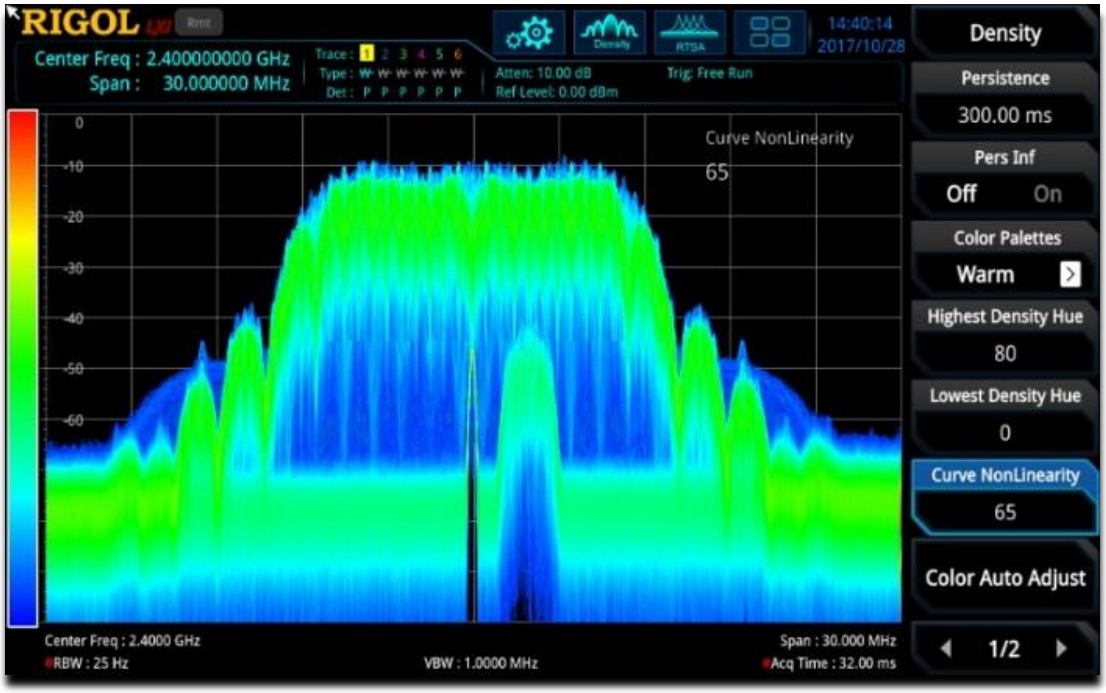
RIGOL's multi-domain analysis combines the power of our new Real-Time Spectrum Analyzers with our high-performance oscilloscopes to make investigating, correlating, and analyzing signals easier than with traditional instrumentation. Unlike many of the basic Real-Time Spectrum Analyzers on the market today, RIGOL's RSA series all have a combination of hardware triggering and IF output designed to work with an oscilloscope for advanced multi-domain analysis.



1 - RIGOL's Real-Time Spectrum Analyzer (RSA3000)

Investigate

Identifying issues starts with capturing and verifying signals either in the time domain or RF domain. One of the advantages of this multiple instrument approach is how easy it is to view signals in either time or across spectrum. When symptoms appear in the RF transmissions use Real-Time to monitor the frequency band of interest using seamless capture to investigate transient events. Extend this analysis into the time domain with Power vs Time view or by monitoring the IF signal on an oscilloscope. Deep memory and waveform recording verify signals as they change on longer time scales. First, let's discuss the new RF domain views available in Real-Time analysis. One of the most important is the Density view. Density view highlights transient signals that are difficult to capture using other techniques by visualizing probability of occurrence in color. As shown in Figure 2, Density view makes it possible to differentiate signals even when one is obscured by the spectrum of the other signal. With Frequency on the X axis and Power on the Y axis, the color shows how often the power in that frequency is at that level with yellow and red being more consistently at that level and bluer hues showing infrequent signal levels.

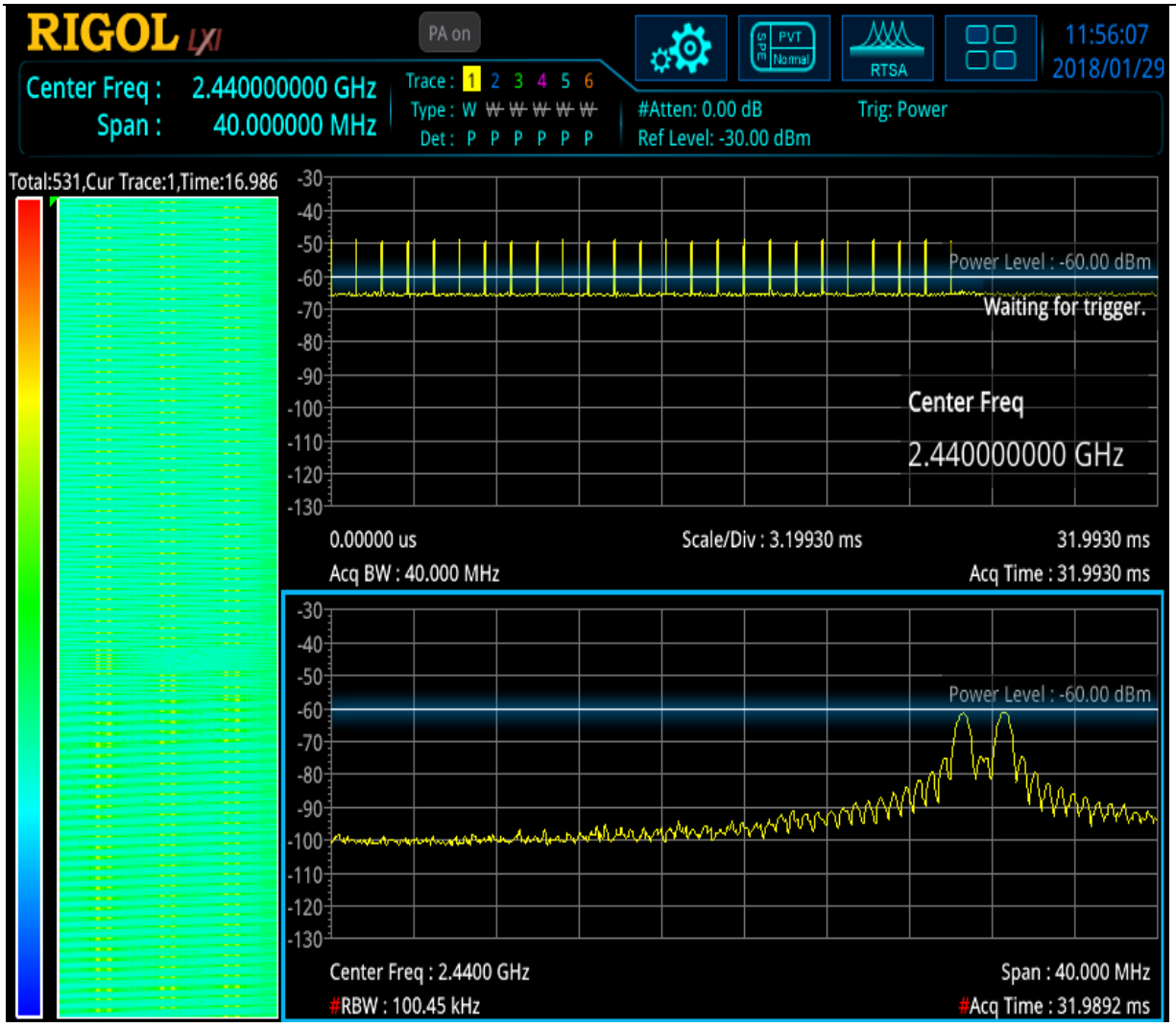


2 - Density view of a hidden signal artifact

Using the Real-Time visualization modes we can capture any RF errors and investigate how they change over time. As a debugging tool, RIGOL's RSA enables viewing time in 3 distinct modes. We just talked about the first: Density, which shows time as probability of occurrence. Spectrogram shows a history of power across the spectrum and Power vs. Time shows the timing of power changes from microseconds to seconds.

3 - RSA Density & Spectrogram

While Density shows how often each signal is active along the spectrum, the Spectrogram shows the sequencing of these signals over longer time periods. Figure 3 shows a hopping FSK modulated signal that we need to characterize. With the addition of the spectrogram we can now easily identify the hopping algorithm and channel spacing over time. Markers can be used on the Spectrogram display to calculate the timing between transmissions. For fast, transient events like these the Power vs. Time display can be used to provide additional signal characteristics.



4 - RSA Power vs. Time

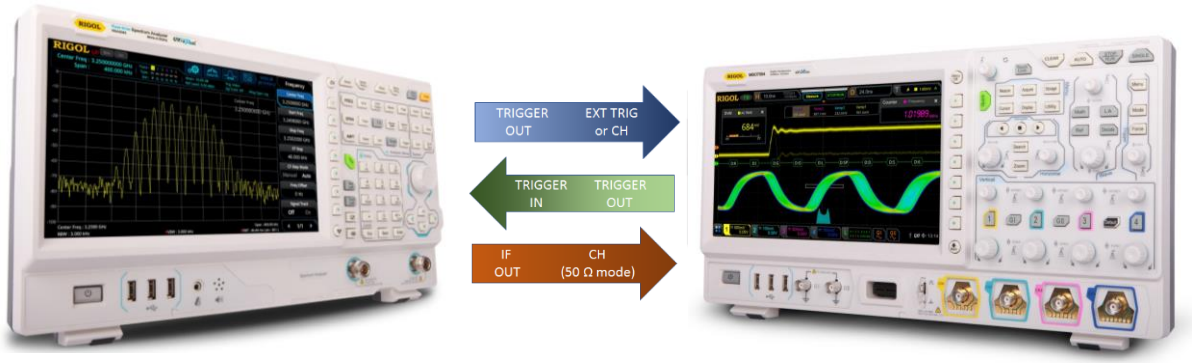
Figure 4 shows the same signal with the addition of the Power vs. Time display in the top right. In that panel, we can see the 1 ms repetition rate of this transmission. The spectrogram (on the left) shows the same hopping sequence and the spectrum in the bottom panel shows the latest capture of the FSK pulse. This capture is triggering when it detects a power level of at least -60 dBm.

The individual pulses shown in Figure 4 are too short to measure. To zoom in on this pulse width, connect the scope to the IF Output. This makes it possible to view the precise timing of the RF pulse and see it in context of other signals.

Whether focused on emissions or transmissions in RF space, one of the challenges for any of these issues is when the root cause ends up being an emission or signal from a different section of the device. This is when signal correlation becomes important to interactive debugging.

Correlate

Once bugs are located it is often necessary to correlate embedded signals or serial data packets with RF signals to find the root cause. There are three ways the RSA and an Oscilloscope, such as the RIGOL 7000 Series, can be used together to correlate these signals.



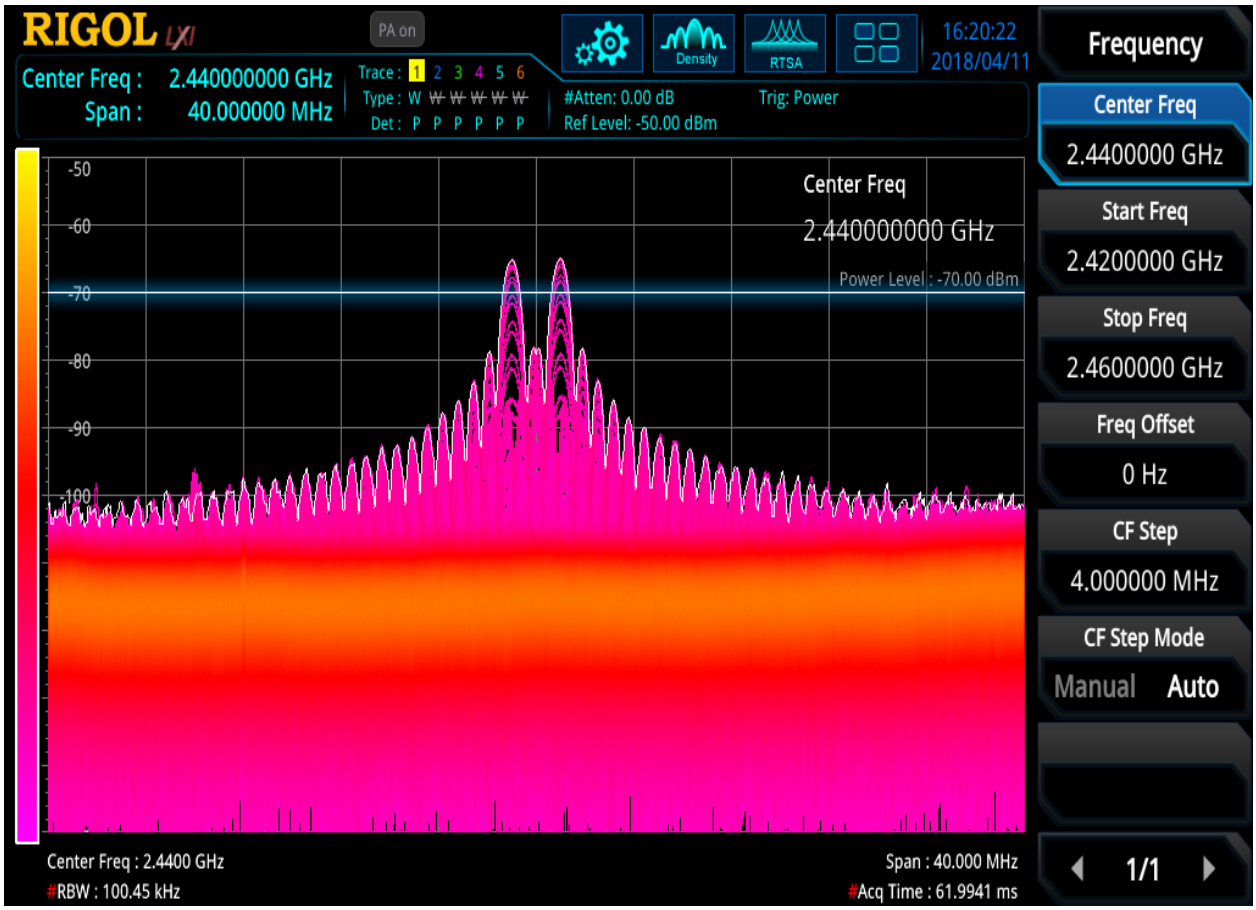
5 - Instrument Connections for Multi-Domain Debugging

For all three methods, connect the instruments as shown in figure 5. This makes all of our interactive debugging methods possible. The RSA trigger out is connected to either the external input or a standard channel. The Oscilloscope's trigger output is connected to the RSA trigger input. Finally, the IF output is connected to a 500 MHz scope channel in 50 Ω mode. Now we can set up the instruments from the front panel to trigger together in 3 different ways. The first method involves triggering on the oscilloscope itself. With the RSA in Real-Time mode you can now select a view and trigger on the scope channel connected to the RSA IF Output. The scope can be set to trigger on RF power changes. These changes are correlated with the other signals captured by the scope for analysis. The IF Output downconverts the center frequency of the Real-Time display to 430 MHz making the data easy to analyze on a 500 MHz scope. Use this triggering method to select a trigger from any embedded signals on the mixed signal oscilloscope or from the IF output channel on the oscilloscope. View and analyze time correlated signals looking for causal patterns on the scope.

The second method improves detailed analysis by ensuring both instrument pause together. This would be to also trigger the RSA from the scope's trigger output. Now, the RSA will trigger with the scope making correlated visualization of the spectrum possible whenever the scope identifies a trigger event. Basic visualization of the spectrum can also be done with the FFT Math function on the oscilloscope in this mode. This method is ideal for viewing signals where there are complex time correlated events as well as RF signal patterns that are best viewed on the analyzer as well.

For more complex RF signals, we can use the third triggering method. This takes advantage of the Real-Time capabilities to trigger on the power level or specific values within the spectrum. Here we set the RSA trigger mode to Power or Frequency Mask Trigger, enable the RSA's trigger out, and use this signal to trigger the scope. Now, you can view the status of embedded, power, and serial signals at the time of a RF event or EMI emission. The Power Trigger being used to capture a FSK pulse is shown in figure 6 and the resulting pulse and trigger is shown on the scope in figure 7. In this mode, both instruments will trigger together only when power is detected in the 2.4 GHz band at or above -70 dBm.

Having investigated potential bugs and correlated signals across the relevant sections of our device we can now analyze changes and improvements to solve the problem.



6 - RSA Frequency Mask Trigger

7 - 7000 Series scope showing IF output from the RSA while triggering on the RSA trigger out externally

Analyze

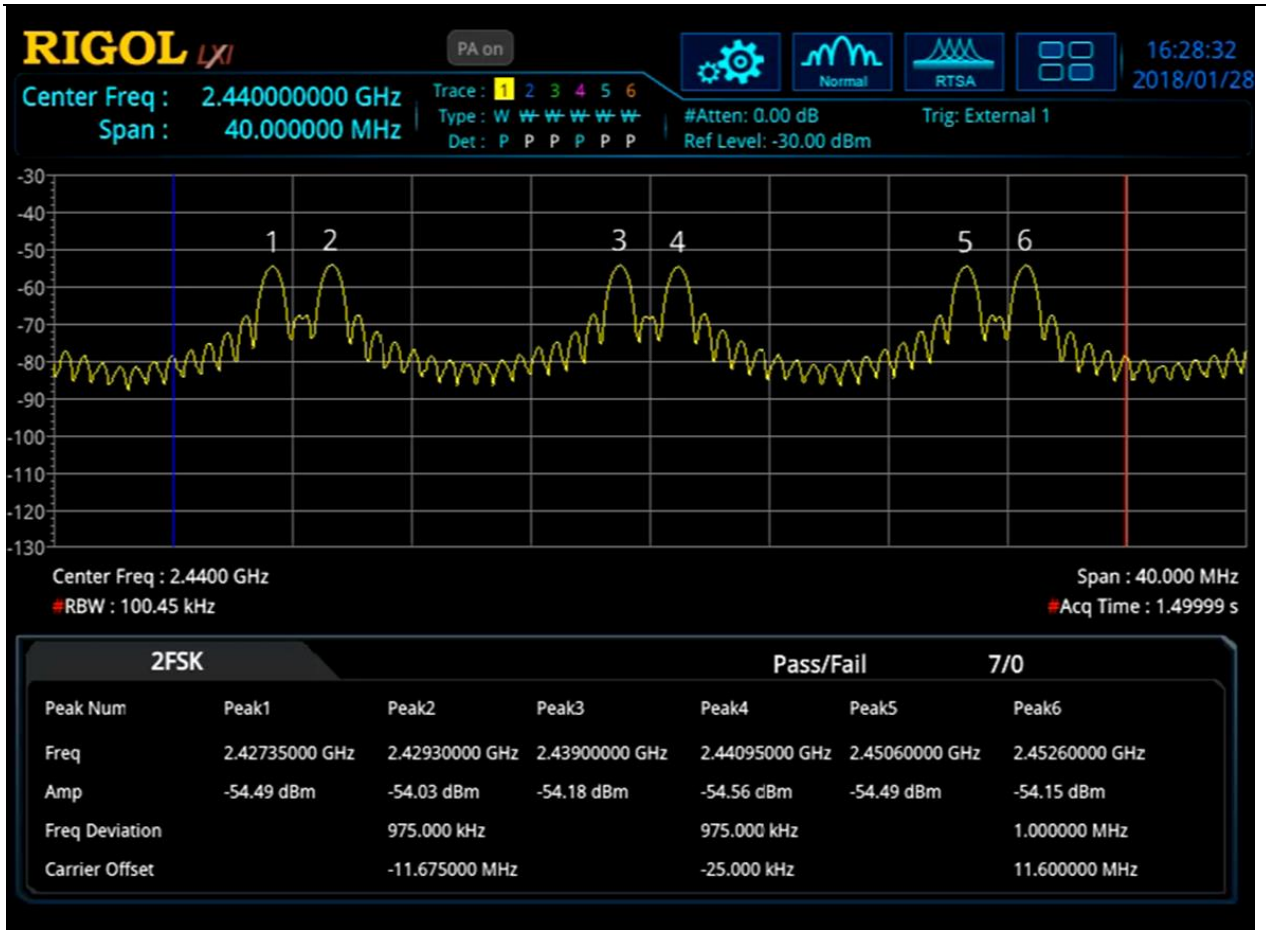
Now that we have identified errors and correlated embedded and RF signals, we can further analyze signals in a series. With a deep memory scope like the 7000 Series, you can use the long record length to view the time before and after an RF event to find root cause of any errors. This time based analysis is critical since many of the causes are not instantaneous but are a result of a previous event. Programmable components like FPGAs hide many of these errors. One way to debug and verify their performance is to monitor changes over time in a continuous dataset to locate the logic or state error.

RIGOL's Waveform Record mode is another powerful tool for multi-domain analysis. Record mode makes it possible to capture a sequence of thousands of trigger events. Then playback or analyze these frames using pass/fail masks or a point by point RMS difference analysis. Comparing occurrences of errors and establishing a common cause is critical to ultimately fixing the underlying issue.

In figure 8 we are capturing the IF pulse (channel 1) shown near the bottom of the main display as well as its FFT in purple. Here we have detected errant pulses in the 2FSK series and have located the related embedded signal that is the root cause. Using record mode we can easily see channel 3 correlates with RF power. Once we solve the issues we have found, we use the RSA for verification of the overall modulation scheme versus the design specifications.

8 - 7000 Series Scope capture shows glitch in center of RF pulse while recording trigger events

To do this evaluation we use the Real-Time Spectrum Analyzer's included 2FSK signal analysis package. Once we have solved all of the embedded issues causing the pulse interruptions we can activate the 2FSK mode in the analyzer and characterize each channel level and frequency to make sure it is within the error budget. Figure 9 shows the results of the analysis on the improved hopping FSK signal.



9 – 2FSK Analysis on the RSA3000 Spectrum Analyzer

Conclusion

The RSA Series Real-Time Spectrum Analyzers from RIGOL are configured to make it easy to bring real-time visualization to multi-domain debugging. Used with a RIGOL MSO7054 Oscilloscope the RSA bridges the gap between RF and embedded signals making true multi-domain analysis possible. Multi-Domain analysis includes time correlated RF and embedded signals, configurable triggering across signal types, and adds real-time visualization of the RF signals. RIGOL's Multi-Domain analysis is available at significant savings to a single, new instrument with multi-domain capabilities that would still limit how you can visualize the complex RF signals in real-time. These capabilities make the RSA Series an important part of Multi-Domain analysis. RIGOL brings value to debugging applications in RF and embedded projects by saving engineers both time and money.

For more information about RIGOL's Real Time Analysis solutions go to:
http://www.rigolna.com/product-tour/

Learn about all our products at www.rigolna.com