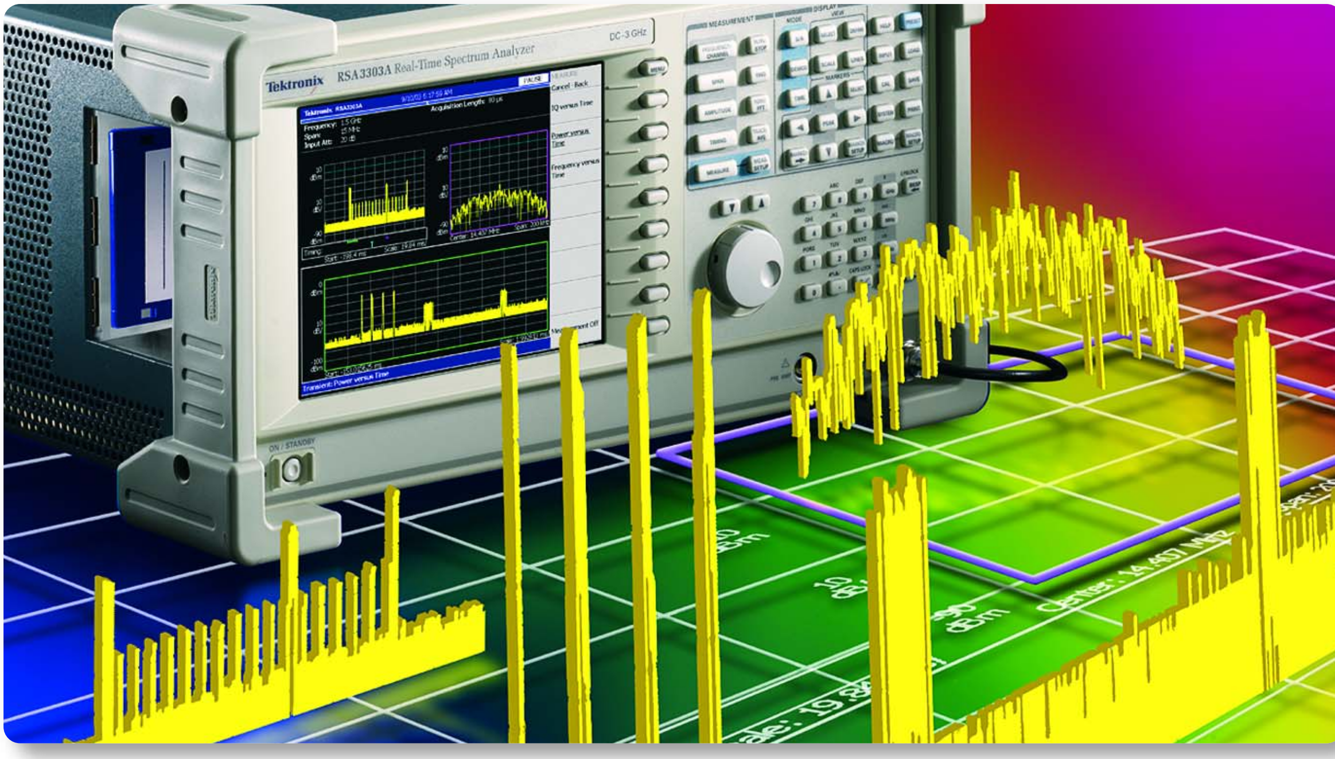
# A Matter of Time: Today's RF Signals Call for a Different Kind of Spectrum Analysis




## The nature of the RF signals is changing.

**Where once it was enough to understand frequency-domain behavior (using tools that displayed amplitude plotted across a frequency axis), another dimension, *time*, has become equally important.**

Many of today's RF signals change from one instant to the next. Some hop frequencies; others spike briefly, and then disappear; many carry complex modulation. And these activities can produce their own side-effects: random transients, interference, switching anomalies, and more.

What do all these phenomena have in common? *Time.* They all exhibit frequency-domain changes that occur in real time — sometimes microseconds, sometimes full seconds, minutes, or even longer. Time is the axis that can no longer be ignored.

RF signals are evolving, and RF measurement solutions must evolve as well. Now there is a requirement for tools whose capabilities mirror the time-varying nature of today's signals. Engineers need real-time instruments that can *trigger* on unpredictable events, *capture* them seamlessly, and *analyze* accumulated data that represents the passage of time.

Consider some of the basic measurement tasks required of today's RF tools. In one form or another, these tasks span applications ranging from surveillance to physics research.

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- **Characterizing frequency drift**

  Frequency settling time and response often must be characterized to ensure that a device meets applicable standards. This requires uninterrupted capture of a signal whose frequency is constantly changing over time.

- **Detecting interference signals and their sources**

  Interference signals come and go, often as a result of switching activities inside or outside the system. By recording many discrete instances of interference plus the surrounding time, it is possible to localize the offending frequency and infer its source.

- **Finding and analyzing transient signals**

  Transient frequency changes, whether glitches or intentional transmissions, can appear unexpectedly amid steadier signals. Detection requires some means of distinguishing events of interest from everything else that is going on the observed span.

- **Capturing and analyzing channelized signals beyond baseband**

  A baseband signal is defined as one whose frequency includes an upper limit and extends down to near DC. Most present-day RF applications use signals that do not extend down to DC. These "channelized" signals, known as passband signals, may occupy a band of frequencies anywhere in the spectrum.

  Passband signals are agile and modulated, making it necessary to capture everything that occurs in the frequency band of interest over a period of time. An uninterrupted spectral record is required.

- **Analyzing digital modulation**

  Digital modulation is growing increasingly common and complex as bandwidth becomes more precious and security more important. Analyzing modulation quality and its relationship to the signal's frequency- and time-domain characteristics is a key step in wireless troubleshooting.

  Judging by this list of spectral measurement tasks, it is clear that many emerging applications call for a different kind of spectral analysis solution: a tool that captures the dimension of time along with the traditional frequency and amplitude axes.

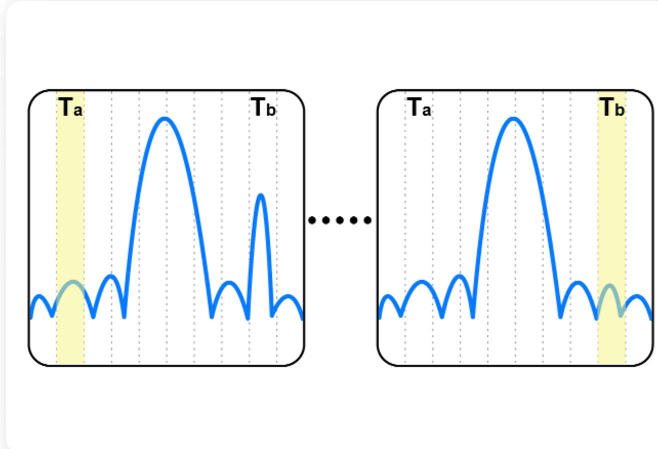



**Figure 1:** *The swept spectrum analyzer steps across a series of frequency segments, often missing important transient events that occur outside the current sweep band.*

## Three Approaches to RF Signal Analysis

Currently there are three types of RF signal analyzers available: the swept spectrum analyzer (SA), the vector signal analyzer (VSA), and the real time spectrum analyzer (RTSA).

### Swept Spectrum Analyzers: Stepping through a Band of Frequencies

The traditional swept spectrum analyzer makes amplitude vs. frequency measurements by sweeping a resolution bandwidth (RBW) filter over the frequencies of interest and recording the amplitude at each frequency point. While this method provides superior dynamic range, its disadvantage is that it only records the amplitude data in one frequency at a time. Sweeping the RBW filter over a span of frequencies takes time - on the order of seconds in some cases. A relatively stable, unchanging input signal is required.

If there is a rapid change in the signal, it is statistically probable that the change will be missed. As shown in Figure 1, the sweep is looking at frequency segment Ta while a momentary aberration is occurring at Tb. By the time the sweep arrives at segment Tb, the error has vanished. It does not get detected. There is no way to trigger on defined signal characteristics, nor is there a way to accumulate a record of longer-term signal behavior.

## Vector Signal Analyzers: a Special Tool for Digitally Modulated Signals

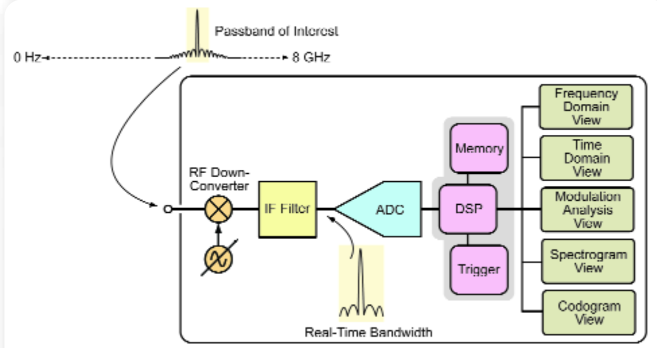
The basic swept spectrum analyzer architecture does not lend itself to capturing the details of a signal that is carrying digital modulation. The vector signal analyzer emerged to address the distinctive requirements of digitally modulated signals.

Unlike the swept SA, the VSA is optimized for modulation measurements. It captures the whole signal and any digital modulation effects occurring at one instant in time, providing fast readings of key modulation parameters such as Error Vector Magnitude. Since it is intended to complement a swept SA, the VSA's frequency-domain spectrum analysis features are not the equal of a standalone spectrum analyzer. Moreover, the VSA is not designed to trigger on, capture and analyze time-varying signals.

## RF Real-Time Spectrum Analyzers: Storing and Analyzing Frequency and Time

As time-varying signals become more common in RF applications, the need for an alternative approach to RF acquisition and analysis becomes more urgent. The real-time spectrum analyzer has emerged to solve this tough measurement problem. Formerly limited to baseband applications, the RTSA now addresses channelized signals across a broad RF range. Alone among the three spectrum analyzer architectures, the RTSA can trigger on a frequency domain event, then capture and analyze any passband signal that falls within its real-time bandwidth.

Figure 2 depicts the RTSA architecture. An integrated down-converter positions the real-time bandwidth on any passband up to the analyzer's upper limit. After filtering, the down-converted signal goes through an ADC that digitizes it, allowing triggering, capturing and analysis of the signal all at once.




▶ **Figure 2:** *Real-time spectrum analyzer architecture. The instrument captures a full passband of frequencies all at once, and the DSP supports flexible triggering and analysis features.*

Since the basic process is not one of sweeping across the RF input signal and building an image from serially-acquired frequency steps, the RTSA's digital IF architecture allows a continuous capture of "snapshots" known as frames. These frames accumulate in the memory as a seamless, continuous record of time.

The memory supports a variety of display and analysis tools including the spectrogram, which plots an entire series of frames to reveal signal changes over time. Thus the RTSA is the only RF signal analyzer that is optimized to produce a three-dimensional display: frequency, power (amplitude), and time.

What if the passband of interest exceeds the real-time bandwidth of the RTSA? In this case, the RTSA can step through a series of frequency segments, just like the swept analyzer. In doing so, each sweep captures a band of frequencies equivalent to the RTSA's real-time bandwidth. Then the instrument concatenates the frequency bands and presents a conventional frequency-domain display.

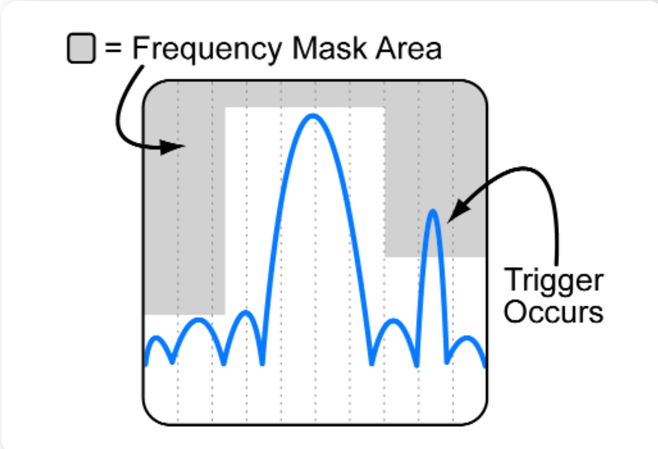



**Figure 3:** *Frequency Mask Trigger setup concept. When the signal's amplitude penetrates the gray mask area, the trigger occurs. Note that amplitude levels may differ across the chosen passband.*

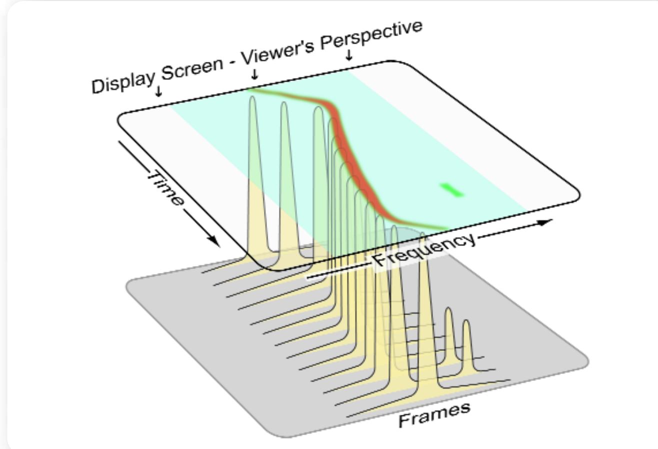



**Figure 4:** *The spectrogram brings out accurate information about the signal's amplitude and frequency over time.*

## RTSA Triggering, Capture, and Analysis in Balance

The RTSA offers unmatched synergy between triggering, capture, and analysis features. This balance is essential for dealing with today's complex RF signals: powerful triggering enables qualified capture; seamless capture and memory enable storage of a continuous time record; extensive analysis tools provide correlated views of frequency, time and modulation.

### Triggering in the Frequency Domain

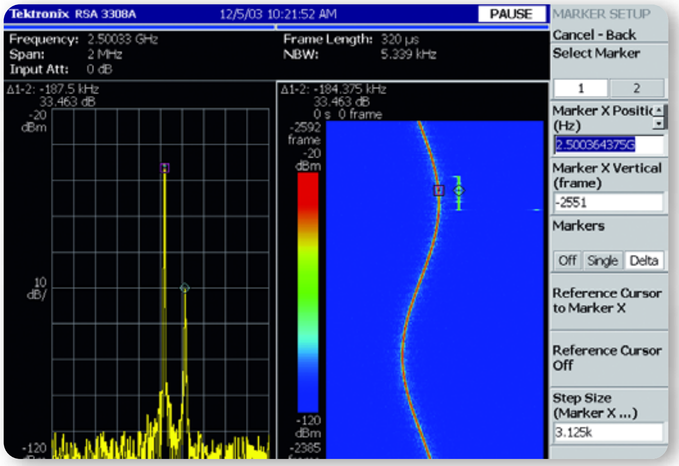
Powerful triggering has long been the missing ingredient in traditional swept spectrum analyzers. The RTSA is the first mainstream spectrum analyzer to offer frequency-domain triggers and other useful modes in addition to simple free run or external triggers. The Frequency Mask Trigger allows the user to set up both amplitude and frequency conditions for an acquisition.

Consider the transient in Figure 3. Unlike the swept SA, the RTSA is able to capture a glitch anywhere in the span, anytime. The Frequency Mask Trigger can be set to ignore the "normal" signal frequencies, ignore low-level aberrations, and trigger only when an anomaly exceeds a specific power level. Figure 3, a simplified view, shows how the Frequency Mask Trigger definition is imposed on the span.

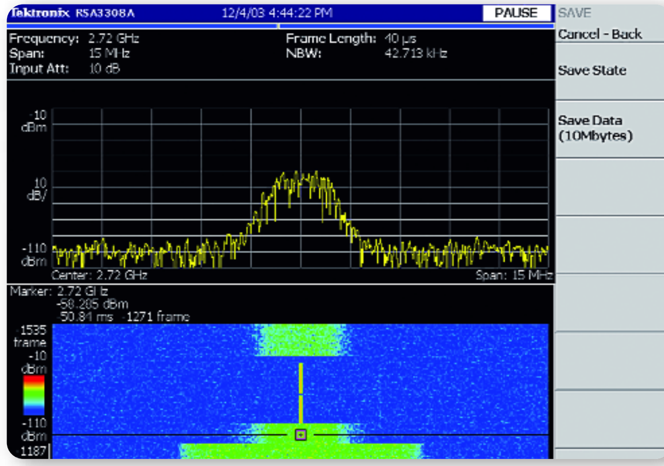
### Acquiring Signals and Events in Real Time

Upon encountering the trigger event, the RTSA acquisition proceeds with its seamless, continuous acquisition unless instructed to do otherwise. The acquisitions accumulate potentially thousands of frames per second, depending on the chosen measurement span.

These frames accumulate in a dedicated memory within the RTSA. This deep (up to 256M) memory supports spectrograms and many other analysis tools. Figure 4 summarizes the relationship between stored frames and the spectrogram.




▶ **Figure 5:** *RTSA frequency domain and spectrogram views. Here the RTSA has captured a pair of amplitude peaks in some frames. In the spectrogram, amplitude is denoted by color. The thread of orange through the spectrogram’s left trace indicates higher amplitude peaks than those in the right trace. The frequency domain view (depicting a single frame that equates to the cursor placement in the spectrogram) confirms this.*




▶ **Figure 6:** *In this dual-domain view, the cursor rests on an individual frame in the spectrogram. The frequency domain view (the upper window) displays this exact frame.*

Looking downward from the viewer’s perspective toward the display screen, a succession of full-span frames contains the underlying information for the spectrogram. The light blue area indicates the full width of the span. The trace color signifies amplitude; here the green trace’s curvature indicates a shift in frequency. The red trace documents transients in some of the frames. A real-world screen shot illustrating the concept is shown in Figure 5. In this case the two amplitude peaks appear in every frame, producing a spectrogram with two solid traces side-by-side.

## Analyzing Results: Capture Once, Measure Twice... or More

Once stored, the signal information is available to support analysis in the frequency, time, or modulation domains. Importantly, each of these domains is time-correlated. When the cursor selects a point on the spectrogram, the appropriate frame appears in the frequency-domain view as shown in Figure 6. Similarly, points on the EVM constellation diagram have their equivalents on the spectrogram. This allows the user to expand the analysis from one domain to another and improve the detailed view of the captured signals.

## RTSA Application Areas

The unique capabilities of the RTSA technology embrace a wide range of applications. Following are a few examples:

### RFID Product Development

Radio Frequency Identification (RFID) product developers are designing systems in which transmitters send modulated RF signals to receiving "tags" that reflect energy and identify the receiver. Swept spectrum analyzers cannot reliably record dynamic signals and offer no way to seamlessly capture complete RFID transactions, making it difficult to localize the origin of any errors that might arise.

Using its powerful triggering capabilities, the RTSA triggers on events such as the charging pulses of an RFID reader. It can store both the reader stimulus and the tag response. This enables analysis of the full transaction in both the frequency and the time domains. The instrument's AM and FM demodulation features provide the tools to examine the tag response in great detail.

### Surveillance

Spectrum monitoring for military and regulatory purposes is often a search for the unexpected and unpredictable. Against a backdrop of noise and routine traffic, the signals of interest may be intermittent, long-term periodic, "bursty," or frequency-hopping. In contrast, most spectrum analyzers require a stable, unchanging signal to capture a full trace reliably.

The RTSA's frequency domain trigger allows the user to focus on the signal of interest only. Seamless long-term capture—more than an hour at certain spans—helps detect unpredictable events. The resulting data can be analyzed in the time, frequency, and modulation domains. In addition, the spectrogram view summarizes the frequency activity over time.

### Component Characterization: Phase Lock Loop Settling Time

Phase lock loop (PLL) devices are often used to stabilize clock frequencies in digital computing and communication devices. PLLs help cellular phones, for example, recover after switching frequencies to check for available base stations. Industry standards place limits on the time it takes to settle after a switching sequence. During this time, the frequency is constantly changing.

Real-time spectrum analyzers acquire continuously and store the results in a local memory with seconds' worth of capacity. RTSA spectrograms can profile the settling characteristics of a PLL and provide a graphic view of frequency activity vs. time.

### Wireless Design: Digitally Modulated Signals

Wireless standards such as GSM encompass networks operating at any one of several frequency ranges. The networks transport complex frequency-hopping, digitally-modulated signals that must be evaluated for conformance with specified tolerances for Error Vector Magnitude and more.

The RTSA includes built-in tools such as standard-specific measurements and constellation diagrams to aid designers in judging digital modulation quality. Because it seamlessly and continuously captures the input signal, the RTSA will detect modulation details and frequency hops as well as any aberrations. The RTSA's capture span can be placed at any point within its RF frequency range, accommodating all prevailing wireless standards and their variants.

### Electronics Design: Digitally Modulated Signals

Electronic products ranging from keyless entry devices to medical electronics and even wireless toys are using more and more RF communication. In addition to conducting the traditional RF measurements as part of the design process, engineers now must test the modulation quality of general-purpose digital modulation schemes such as QPSK, 64QAM and 256QAM. The modulation must meet specifications to ensure interoperability among related products.

The RTSA's spectrum analysis features handle all of the basic RF measurements such as occupied bandwidth, carrier frequency and channel power. Again using stored data (rather than re-sampling the signal for every measurement), the RTSA's built-in digital modulation tools can analyze modulation quality and display a constellation diagram. Stored information provides a complete picture of the signal, even if it appears only briefly.

The table on the next page presents a further sampling of RTSA applications.

## RTSA features match the requirements of applications in a variety of RF fields.

| | RFID Design and Manufacturing | Signal Intelligence and Surveillance | Physics and Electronics Research | EMI Diagnostics | Component Design and Manufacturing | Radar Measurements | Low Frequency Analysis | Mobile/Cellular Device and Systems Design and Manufacturing and Network Operations | Consumer, Medical and other Electronics Design and Manufacturing |
|---|---|---|---|---|---|---|---|---|---|
| **Trigger** | | | | | | | | | |
| Freq Mask Trigger | • | • | • | • | • | • | • | • | |
| Power (Span Bandwidth) Trigger | • | • | • | • | | | • | | |
| Continuous Repeated Trigger | | • | | • | | | | | |
| Level (Full Bandwidth) Trigger | | • | | | | | | | |
| **Capture** | | | | | | | | | |
| Seamless Time Record Capture | • | • | • | • | • | • | • | • | • |
| Wide Real-time Bandwidth | | • | • | • | | • | | • | |
| Deep Memory | | • | | | | | • | • | |
| Separate I and Q signal capture | | | | | | | | • | • |
| **Analyze** | | | | | | | | | |
| Spectrum Analysis | • | • | • | • | • | • | • | • | • |
| Correlated Multi-domain analysis | • | • | • | • | • | • | • | • | • |
| Spectrogram | | • | • | • | • | • | • | • | |
| Analog Modulation Analysis | • | • | | • | • | • | | | • |
| Digital Modulation Analysis | | • | | | • | • | | • | • |
| Time Domain Analysis | • | | • | • | | • | | | |
| Code Domain Analysis | | | | | | | | • | |

The RTSA delivers unique solutions and advantages for designers working with RF signals of all kinds. As signals become more complex and less predictable, only the RTSA offers the triggering, capture and analysis features to help designers understand time-varying signal behavior ranging from frequency hopping to EMI transients. The RTSA is the solution that can go forward with emerging trends in RF design.

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