The Role of Time-Domain in the Digital RF World

By Darren McCarthy

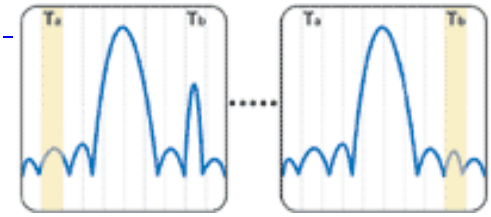
Many emerging applications call for a highly-capable RF analysis tool that captures the dimension of time along with the traditional frequency and amplitude axes. Many of today's RF signals change from one instant to the next. Some hop frequencies, others spike briefly, and then disappear. Many can have complex modulation that can dynamically change in an instant. 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. Time is the axis that can no longer be ignored.

In this article, the basic measurement tasks required of RF tools are explored in order to establish the critical nature of time in digital RF. This leads to a review and comparison of approaches to signal discovery, triggering, capture and analysis.

RF Transmission classes

The digital RF revolution has introduced an unprecedented number of useful devices while lowering their cost and power consumption. Whole communications systems are



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integrated in monolithic silicon. The proliferation of information being transmitted over an increasingly scarce spectrum has driven a need for ever higher data rates per unit bandwidth and for complex communications protocols that allow the peaceful co-existence between RF devices and systems. A key goal of communications protocols is to reliably transmit a packet of data in as little bandwidth as possible over as short a time as possible while minimizing interference. While not designed for communications, radar systems have similar objectives of spectral efficiency and minimum interference with the added goals of security and detection avoidance. This has led to several classes of RF transmissions, including:

&#149Transmissions that turn on only for the brief time it takes to transmit a unit of data, releasing the spectrum for other use as soon as the data is sent. In many cases the timing of these short transmissions is unknown and random.

&#149Systems that share the same spectrum at the same time as in ultra-wide-band (UWB) and code division multiple access (CDMA). &#149Cognitive radios (CR) adjust frequency, modulation and power in response to the spectrum environment at a particular point in time and location and can build upon prior knowledge. &#149Shared package: Multiple RF devices inside a single package. &#149Shared silicon: RF devices sharing the same silicon as digital CPUs with clock rates in the GHz range.

RF Measurement Challenges

Now let’s consider some of the basic measurement tasks required of today's RF tools in order to allow designers to achieve their goals. In one form or another, these tasks are common in the various classes of RF transmissions and span applications ranging from surveillance to physics research.

&#149***Characterizing frequency drift*&#151** Frequency settling time and response often must be characterized to ensure that a device meets functional and operational needs. This requires uninterrupted capture of a signal whose frequency is constantly changing over time . &#149***Detecting interference signals and their sources***&#151 Interference signals come and go, often as a result of switching activities inside or outside the system from intentional or unintentional sources. By recording many discrete instances of interference plus the surrounding time, it is possible to localize the offending frequency and infer its source. &#149***Finding and analyzing transient signals***&#151 Transient frequency changes, whether glitches or intentional transmissions, can appear unexpectedly amid steadier and even higher level signals. Detection requires some means of distinguishing events of interest from everything else that is going on the observed span. &#149***Capturing and analyzing channelized signals beyond baseband***&#151 Baseband signals are often upconverted to a specific channelized band of operation called a passband. Passband signals can be 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 so the spectrum, time, and modulation characteristics of the signal can be explored. &#149***Analyzing adaptive digital modulation***&#151 Adaptive 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 during transitions. Often, testing is required to go beyond standards, especially as implementation is not defined. In reviewing this list of RF measurement tasks, it is clear that many emerging applications call for a highly capable RF analysis solution: a tool that captures the dimension of time along with the traditional frequency and amplitude axes.

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). Below we take a closer look at each its ability to meet emerging digital RF design requirements.

Swept Spectrum Analyzers

The traditional swept spectrum analyzer makes amplitude vs. frequency

measurements by sweeping a resolution bandwidth (RBW) filter over the frequencies of interest. The disadvantage is that it only records the amplitude data in one frequency at a time. A relatively stable, unchanging input signal is required. Figure 1, the sweep is looking at frequency segment at time Ta while a momentary aberration is occurring at a higher frequency. By the time the sweep arrives at the higher frequency segment, at time Tb, the aberration 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

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 and stores a record into memory. This process is also a limitation as the capture cannot be triggered by a frequency defined event.

RF Real-Time Spectrum Analyzers

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. 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.

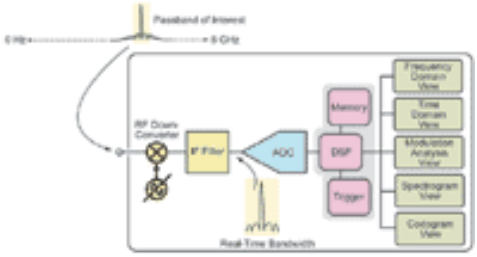
Figure 2 depicts the RTSA architecture. An integrated down-converter positions the real-time bandwidth on any passband up to the analyzer's upper limit. After filtering, the down-converted signal goes through an ADC that digitizes it. This allows real-time triggering of frequency domain events, capturing of the signals into memory, and multi-domain analysis of the time, frequency, and modulation-domains.

The RTSA's digital IF architecture allows a continuous capture of a signal over time. Once triggered on a frequency defined event, the signal is then stored in the memory as a seamless, continuous record of time.

The RTSA is the only RF signal analyzer that is optimized to produce a three-dimensional display: frequency, power (amplitude), and time.

Shedding Light on Problems

Recognizing that a problem exists is the first step to resolving it. Problems specific to digital RF are often discovered indirectly. Transients in one device may cause increased



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bit error rates in another. Radars may occasionally provide inaccurate target information due to self-jamming or susceptance to transient interference. Thermal or electrical memory effects in a power amplifier may cause lost data and momentary interference with adjacent channels. The execution of a computationally intensive software subroutine may cause power supply voltage variations that affect the quality of RF transmissions.

To enable RF designers to discover problems, Tektronix has developed digital phosphor or DPX&#153 technology to emulate variable persistence CRTs. The implementation of digital phosphor spectrum analysis used in Tektronix Real-Time Spectrum Analyzers combines display processing with dedicated DSP hardware that perform frequency transforms several orders of magnitude faster than traditional spectrum analyzers. At almost 50,000 trace updates per second, the DPX technology has about 100,000% more spectrum updates than a traditional swept spectrum analyzer.

The information from each transform is combined in the DPX engine generating displays at a full motion rate. This engine includes statistical persistence processing that allows full-motion viewing of signal behavior over time. It also makes weak signals interspersed amid strong ones instantly visible and highlights infrequent short-duration events. Persistence adjustments allow the user to optimize display characteristics for varying signal conditions, from a live RF view of dynamic signals to the discovery of single occurrences. This sheds light on signal behavior that was not viewable with traditional spectrum analyzers or vector signal analyzers. Other Real-Time Spectrum Analyzer features provide means to trigger on signal behavior, capture those signals in memory and analyze them in the time, frequency and modulation domains

Summary

As RF signals become more complex and less predictable, designers need to understand time-varying signal behavior ranging from frequency hopping to EMI transients. While a number of instruments are available for RF measurements, only the RTSA offers the triggering, capture and analysis features needed to all designers to go forward with emerging trends in RF design.

About the Author

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