

# Comparing alternative system architectures for spectrum monitoring

This article discloses an ideal system architecture for spectrum monitoring that offers the best ability to identify unknown, short-duration signals with minimum operator attendance.

By Chris DeSalvo

Commercial companies and aerospace/defense contractors are increasingly being requested to monitor wireless signals for security and RF emitter compliance. The engineers and consultants doing this spectrum monitoring need to choose the best equipment for efficiency and productivity. Spectrum monitoring systems look at broad expanses of the frequency range for signals of interest and are sometimes called signal survey or emitter identification systems. They may also have a narrowband mode to capture signal data and to playback for analysis.

## Range management and EMI/RFI testing

Regulatory agencies and military/commercial test range managers worldwide are challenged with managing the frequency and RF airspace. If a new device with communications capability is entering or being added to their RF airspace, it must not create interfer-

ence with the existing wireless world. Many frequency bands, assigned to both civilian and government users, must be monitored along with performing many emerging tests and standards for compliance. Any change to the spectrum poses a high risk of interference, so the spectrum must be monitored and analyzed for effects from frequency reassignments.

Many aerospace/defense design and manufacturing companies find it impractical to do EMI/RFI testing in a test chamber, which can be costly to use in both equipment and staff time. Many projects get delayed because the EMI/RFI testing chamber is not available when it is needed in the project schedule. Some devices-under-test (DUT) have complex interconnections to other subsystems or the size of the device may exceed the screen room's physical space. If testing in the open airspace, the spectrum monitoring system must be able to store a typical baseline RF environment, then compare the RF environment when the device is under test. Engineers need to analyze

intermittent, short-duration signals and make appropriate design changes if the DUT caused interference.

## Measurement challenges

The RF and microwave wireless spectrum gets more crowded and complex every year. It is an ever-increasing challenge to monitor this spectrum considering the rapid growth of wireless, satellite, and point-to-point communication devices in the last decade. Plus, these wireless communication technologies continue to increase in complexity and sophistication. Engineers and consultants are asked to hunt RF interference in this crowded and complex spectrum.

If you have a-priori information on the emitters you want to track, e.g., approximate frequency and amplitude, traditional spectrum analysis techniques and equipment will work extremely well for tracking these signals. As an example, spectrum analyzers (SA) are excellent tools to monitor signals when testing an electronic device in design, verification or production. The signal frequency and amplitudes are in a narrowband, so you can easily set the analyzer to monitor and measure that signal. But, if you do not control the RF/microwave airspace you want to monitor and you have little information about the signals you want to find, the RF spectrum-monitoring task is a discovery process, not a test process. You discover signals of interest with spectrum monitoring because many wireless signals vary in power, duration, and bandwidth. Some of the complex interactions between systems may actually be harmonics of known emitters; translated into frequencies where they become unwanted interferers. There are thousands, even tens of thousands, of irrelevant signals that you need to ignore to capture data on your signals of interest.

## Spectrum analyzers

A system with very fast wideband search would be able to measure signals that are present for less than a second. To find small signals close to large signals or to find small

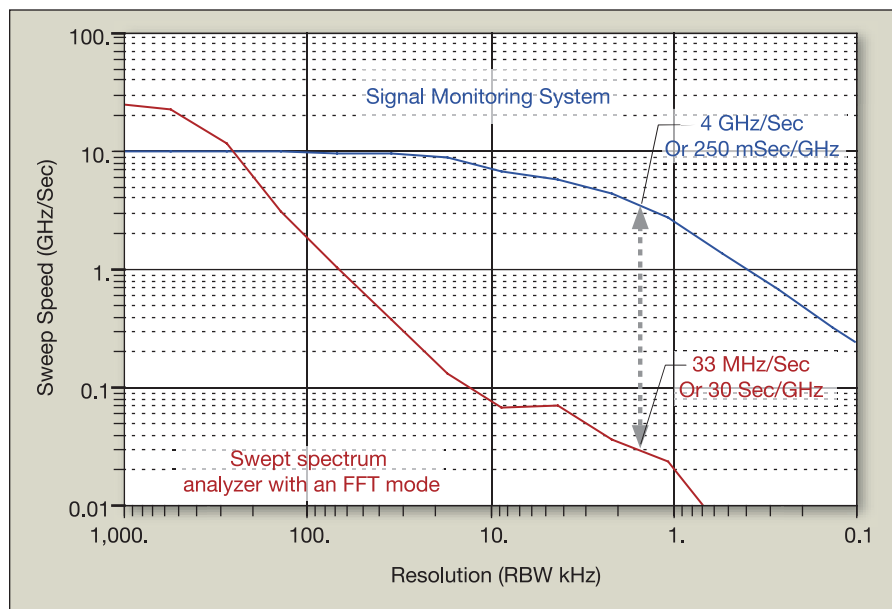
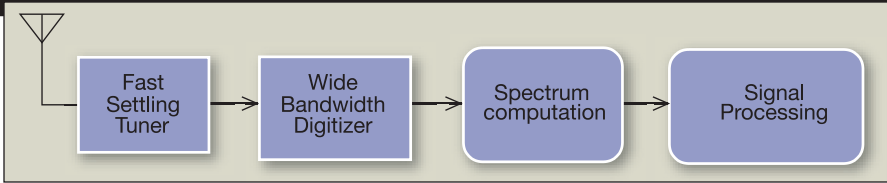


Figure 1. RF sweep speed vs. resolution. Spectrum monitoring systems sweep 100 times faster than spectrum analyzers with the same resolution to find more short-duration, intermittent signals.



**Figure 2. High-speed survey system architecture. The system and components are optimized for simultaneous fast spectrum search and high resolution.**

signals near to the noise floor, you need a system with high resolution. Conventional spectrum analyzers are constrained and can't provide both high-speed search and high resolution. If you set the frequency span and the resolution bandwidth, the analyzer determines the sweep time. The resolution bandwidth filter settling time follows device physics and, therefore, determines this sweep speed. Equipment used for spectrum monitoring uses a different architecture that sweeps the frequency spectrum orders of magnitude faster. Typical sweep speed vs. resolution for a high-performance conventional spectrum analyzer and a spectrum monitoring system are shown in Figure 1.

Let's use a typical example of monitoring a 1 GHz spectrum with a 2 kHz resolution bandwidth to see most signals in that frequency span. A conventional spectrum analyzer set to these criteria would sweep the spectrum every five minutes. So, many short-duration signals would not be seen. In contrast, a system designed for spectrum monitoring set up using the same capture criteria would only take 250 milliseconds for each spectrum scan; thereby allowing users to discover many more unknown short-duration signals. Many new high-performance spectrum analyzers have a Fast Fourier Transform (FFT) mode so they can speed up the sweep times at low-resolution bandwidths. Even these enhanced spectrum analyzers would take 30 seconds to scan this spectrum. In the world of interactive push-to-talk radios and wireless Internet traffic, a complete conversation could occur in that 30 seconds.

### Ideal spectrum monitoring system

An ideal spectrum monitoring architecture combines FFT with high-speed stepped local oscillators (LOs) to rapidly revisit the spectrum. At each step, the system processes the equivalent of many swept resolution bandwidth filters in parallel using a powerful FFT engine. The component blocks of the architecture shown in Figure 2 are optimized for the spectral search application. An antenna connects to the system via the tuner's RF input. The tuner, which downconverts the signals to IF, has a very short settling time so frequency steps occur very fast. The wide

IF bandwidth output of the tuner is matched to the input bandwidth of the ADC to reduce the number of frequency steps required for covering the spectrum. The digitizer must also have a high dynamic range, digital filter and re-sample capability to accurately digitize all of the signals in each frequency step. This front-end of the system is sending large amounts of spectrum data to the processing components. To avoid data processing bottlenecks in the system, the digital architecture must have high-speed I/O and significant embedded signal processing power. Connections between the digitizer and processing components must use ultrafast digital I/O infrastructure, such as a fiber-optic front-panel data port. Multiple digital signal processors (DSP) working in parallel compute the spectrum information from raw time data including the base FFT analysis. For example, six processors can successfully compute spectrum data for the system front-end and maintain full analysis of spectrum data at up to 10 GHz/sec sweep rates.

Typical spectrum monitoring systems have additional signal processing used to process energy data into signal content. The discovery process of identifying and recording data on signals of interest should be an automated task. Many hours of time can be spent sorting and identifying signals, only to find they are irrelevant to the current task. An ideal system for spectrum monitoring automates spectrum monitoring using energy detection thresholds, alarms, and task scheduling as well as interfaces to hand-off receivers and other processing, including direction-finding subsystems.

### Narrowband signal capture

In addition to looking at the broadband spectrum, some newer spectrum monitoring solutions offer additional narrowband chan-

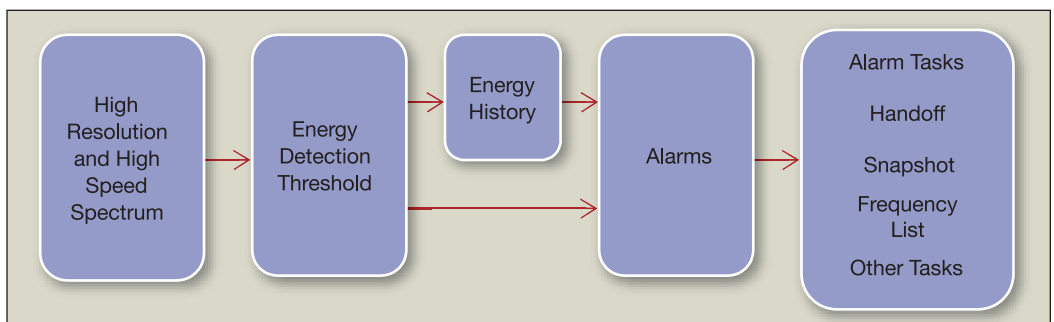
nels. These narrowband channels are likely implemented as software-defined radio channels to capture and record signals for further analysis. Many signal survey systems are used to identify signals and hand the specific signal frequency off to these new digital recorders and radios. In some systems, the narrowband handoff receiver includes traditional low-cost radio receivers that simply demodulate the audio signal. In other cases, spectrum analyzers and vector signal analyzers are used as further analysis tools for the narrowband signals. In all of these cases, the narrowband receiver is fixed or locked on a frequency range during the capture and analysis of signal data.

A few spectrum-monitoring systems have multiple narrowband receivers set at adjacent frequency spans to monitor a wide spectrum. The frequency spans can be pre-set in the range of the signals of interest or set in an automatic mode to cover most of the wideband spectrum. The narrowband data for these multiple receivers is later compiled in a computer. Multiple high-performance, narrowband receivers while providing real-time coverage in their narrow span usually results in expensive system architecture for spectrum monitoring. This is especially true if wide frequency spans are required, and the narrowband receiver needs to replicate the ADC components multiple times in the system.

### Transforming data into information

A system searching the RF/microwave spectrum can generate a huge amount of data. Each scan of the spectrum can be millions of points of data. Generally, when engineers are monitoring a spectrum, many data points are irrelevant or not important to the current measurement job. An ideal spectrum monitoring system will have numerous tools to reduce spectrum data into only the signals of interest. The time and/or frequency data will be captured on the signals of interest for real-time analysis or post processing.

Instead of a frequency or time-domain view of signals in the spectrum, like spectrum



**Figure 3. Automation and data transformation. Spectrum monitoring systems process energy using thresholds, alarms and tasks to streamline and automate the data collection.**

analyzers or oscilloscopes, an ideal spectrum monitoring solution considers the energy in the spectrum. With an energy-based view of the spectrum, a new set of tools is used to reduce the spectrum data into signals of interest. The data captured on the signals of interest is the information that engineers want. Here are two examples of this filtering or data-reduction process. If energy exceeds a noise or environmental threshold, then the monitoring equipment should trigger a task to gather detailed data on one signal. A second example could be if a signal appears above

the threshold four times, then hand it off to a narrowband receiver for signal capture and analysis. As shown in Figure 3, an ideal spectrum monitoring system would have these types of capabilities to reduce spectrum data into only signals of interest.

Alarms and alarm tasks allow the ideal spectrum monitoring system to automate data gathering and more specifically define signals of interest. This includes the ability to ignore certain signals, once they are analyzed and determined irrelevant. Creating an totally unattended system operation saves money

by reducing the number of operators.

### **Capturing and analyzing signal of interest**

Once an intermittent, short-duration signal is determined interesting to study, data is captured for a period of time, and then the signal is analyzed. An ideal spectrum monitoring system will have real-time tools for reviewing the signals and more powerful analysis tools for processing the signal data files. Typically, the narrowband signal capture is used and time data or frequency data files are stored on a disk. Some systems will allow operators to listen to signals during the scan and signal filtering process, so they can determine signals of interest in real time.

Many different tools are available for analyzing the captured signal data files. Some simple tools perform demodulation on the signal data files and allow you to listen to the record to determine if they are voice, fax or other non-voice. Many powerful stand-alone signal analysis software packages perform baseband I/Q analysis, analog and digital demodulation. With many new and complex digital signals, more powerful signal analysis tools are used to demodulate the narrowband and broadband digital communication signals.

### **Conclusion**

The ideal spectrum monitoring architecture discussed has been considered in the design of the Agilent E3238S family of signal-monitoring solutions. The family has wide bandwidth, high-speed search and high resolution providing an optimum tool to hunt unknown wireless emitters. The ultrafast search speed on a wide spectrum will find more intermittent short-duration signals in a wide span. The high resolution with fast search can find signals near to other large signals and low-level signals close to noise. It has integrated software tools to transform spectrum data into those signals of interest. A narrowband processing option can gather details on those signals. Captured signal files can be analyzed real time or stored for later analysis. Engineers and consultants using this system can understand the RF airspace and take action on non-compliant transmitters. **DE**

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Chris DeSalvo is a product marketing engineer for the instrument systems business in Agilent Technologies. He has a BS in Electrical Engineering from the University of Pittsburgh, Pa. In his extensive career with Agilent, Chris has done technical marketing on basic instruments, automotive electronics test systems, mobile handset testers, phase noise systems, and most recently spectrum monitoring solutions.