Increasing the probability of intercepting signals of interest

While the interception of radio traffic is a mission-critical capability, the volume of RF signals in a given environment can potentially overwhelm the resources devoted to the analysis of captured data. Using signal-analysis techniques implemented in software, it is possible to reduce the entire mission workload by analyzing monitored RF signals to record and study only signals of interest.

By Chris DeSalvo

Effective signal monitoring of wireless signals requires high-speed hardware with high resolution. This type of hardware can provide a range of signals in a given spectrum, including intermittent or short-duration signals from push-to-talk devices. If all of these signals were to be recorded, most of them would not be of interest. Plus, the amount of data available for capture would be so huge that the system design would be extraordinarily expensive. The sophisticated software driving this specialized hardware is mostly responsible for filtering and detecting only signals of interest. Advanced methods for signal detection can efficiently and exclusively capture data on only wireless signals that are of interest. With more software tools available, efficiency increases by eliminating extraneous signals. Most advanced signal-detection software involves programming or compiling code, and sometimes, that software resides in the DSP. Reconfiguring using a visual dialog box, allow customized signal detectors to be created without the need for advanced programming.

Signal-detector software

A universal signal detector is a concept that is implemented in software. It is used with a specialized set of high-speed and high-resolution search hardware that can capture short-duration intermittent signals. A universal signal detector should have many optional methods to sift through the crowded spectrum of signals and only provide signals of interest. Universal signal-detection techniques, including bandwidth filters, frequency plans, wideband detectors, and narrowband confirmers could be used individually or combined to make more powerful and selective solutions. You should be able to create or “learn” new signal detection methods from replaying captured signal files.

The universal signal detection concept has two major applications. Sometimes, the mission involves surveying and logging the types of signals that exist in an unknown RF environment. A frequency range of interest would be set up and the signal’s development engineer would hunt for unknown emitters with different setups and begin to understand the signals in the RF environment. This type of discovery for specific signals may provide insights that can be used in other missions. The second application is when the signal of interest can be described in technical terms or can be played back from a capture file. Then a signal-detection algorithm can be created to look for this particular signal. Detecting emerging or complex signals can be a complicated task, which is well suited for a universal signal detector that provides flexibility in tools and settings.

Designing for universal signal detection

Systems with universal signal detectors first monitor and scan the energy of the spectrum. This spectrum of energy contains many signals. It is only when a signal appears above a threshold level that a signal detector is invoked. It is the signal-detector algorithms and methods that will determine whether this signal is of interest. In a simple example, a signal-detection method should easily differentiate an FSK signal with a large modulation index versus a CW signal. Unsophisticated systems might simply start recording those signals once they have exceeded the spectrum energy threshold limits, requiring the developer or reviewer to invest substantial time to correctly interpret these two signals as components from a single source.

Signal detectors should operate with separate development and run modes for maximizing efficiency for the developer and the operator.

Figure 1. The use of GUI tools such as this dialog box, allow customized signal detectors to be created without the need for advanced programming.

Figure 2. Universal signal detector components (blue) are added to the other components within a wideband search engine.
In the development or design mode, you would select various methods of filtering, signal parameters, modulation and other parameters. In run or monitor mode, signal detectors could be added “on-the-fly,” or from a library of detectors that was previously created.

A signal development or design environment should create and test effective signal detectors without using advanced programming. Using dialog boxes (Figure 1), pull-down menus and easy selections, it should be possible to create a new signal detector or modify an existing one. Signal development engineers need not spend time learning compilers and detailed programming to capture signals of interest. The design mode for these systems should be protected from operators and only signal developers should access these windows. Once signal detectors have been designed, they should only be accessible to operators in a run mode. This will reduce the chance of someone corrupting a signal detector that may have been learned from numerous replayed capture files. The operator could access and load the signal detector from a library that the developer has created. Alternatively, the mission setup may already load numerous detectors and begin the search for signals. In run mode, an operator could monitor the performance of the signal detections or make adjustments to it if this degree of freedom is provided in the detector.

It is also desirable for the signal detector to be integrated with other software in the same system. For example, a software tool that detects voice signals should be compatible with the universal signal detector.

**Supporting multiple signal-detection techniques**

A universal signal detector should incorporate multiple techniques for detecting signals rather than responding solely to signals that exceed a particular threshold level. When properly designed, a signal detector would combine multiple energy-detection schemes that correspond to the signals of interest. Good techniques for signal detection are shown in Figure 2.

Bandwidth and frequency are fundamental parameters for detecting off-the-air signals of interest. So, a signal detector algorithm would have bandwidth filtering and frequency plans after identifying a potential signal that exceeded an energy threshold level. Bandwidth filtering can be used to filter out energy detections that have a narrower or wider bandwidth than expected in the signals of interest. The hardware search engine and energy threshold settings may also be limiting the bandwidth of signals that get to the signal detectors. Frequency plans can be as simple as identifying the two frequency points in a band or more complex with multiple bands or specific frequencies.

In addition to the frequency and bandwidth methods, a wideband detector technique also operates on the frequency-domain results of each sweep. When energy is detected in the frequency spectrum and the bandwidth selected, that portion of the frequency spectrum can be processed by one or more wideband detectors. A wideband detector discriminates potential signals of interest by comparing the resulting spectrum to the wideband detectors you created. This is a manner of filtering using a view of the spectrum data.

Common methods of wideband detection are using peaks, shapes or simple limit lines. Each method depends on the spectral characteristics of a signal of interest. The shape method would be used for signals with a steady and distinctive shape, such as a two-level FSK signal. For signals with pronounced and evenly spaced peaks, such as four-level (or greater) FSK, peak wideband detection is best. Limit lines have been used with signals that have a steady-spectral part (or parts) plus a less-steady part. With some North American digital cellular signals a wideband detector could be designed with narrow limits on the sides and wider limits in the center. If the signal’s amplitude changes or the signal is near the noise level, the limit-lines method is not a good choice.

All of the detected signal information is generally stored in an energy database. These detected signals can be automatically recorded, their frequencies can be added to a frequency list, and signal data can be used to trigger other system tasks.

**Modulation recognition increases probability of intercept**

One more aspect of an advanced signal detector should be to verify that the energy captured by the wideband detector has the correct modulation parameters. This narrowband confirmation operates on time-domain data collected from a narrow frequency band. To use a narrowband confirmation, the search engine should have optional narrowband-processing hardware channels for the simultaneous capture of signals of interest. Modulation recognition and demodulation algorithms can then confirm if the signals have characteristics of potential interest. Figure 3 illustrates how this capability can be added to the...
universal signal detector block diagram.

A small time delay would allow all of the signal information to be processed, even if the system takes some time to decide if the signal should be recorded. Then, narrowband time-domain data is compared against user-specified signal parameters, such as modulation format, symbol rate, bandwidth and frequency spacing to determine if the detected signal qualifies as a signal of interest. If the signal matches the specified parameters, the signal information should be logged into a signal database. It may be desirable to record or set signal alarms to do various tasks such as entering the confirmed signal frequencies into a frequency list.

Narrowband channels should be dynamic and change recordings of signals that meet the universal signal detector criteria. Each channel should be tasked and released based on criteria set by the signal’s developer. A recording channel might be released after a certain amount of time, regardless of whether the signal has terminated. In addition to time, a channel might be released if the signal-to-noise ratio (SNR) or power level falls below a minimum threshold during that time period. Using the power level as a decision parameter may be unreliable in environments where the noise floor is not stable. The channel should be released if the narrowband confirmation in the signal detector is not detecting the specified modulation.

**Flexibility for complex signals**

For the ultimate capability to find signals that change modulation type or have different modulation modes, each universal signal detector should have multiple narrowband confirmers. For example, some pager signals have different valid protocols, such as 1600 baud and 3200 baud symbol rates. Some signals may have a preamble and a payload requiring advanced signal-detection methods. Shown in Figure 4, the modulated preamble might contain control information for the signal and the payload contains the voice data that is to be transmitted. Many times, these complex signals undergo an additional stage of modulation, such as FM, prior to RF transmission.

In this example, multiple wideband detectors and multiple narrowband confirmers in the signal detector would be able to detect this complex signal of interest. All of the mentioned universal signal-detection techniques should be provided as selectable options for the equipment operator. For example, narrowband confirmation may not be necessary if the wideband detector can be designed with an acceptable probability of intercept.

**Software enhances effectiveness**

A universal signal detector is ideal for intercepting specific signals, complex signals or surveying the RF environment because it has the power and flexibility to make signal development engineers more efficient and effective. A high-speed and high-resolution search engine provides the spectral and time data on intermittent, short-duration signals. That search engine is combined with sophisticated universal signal-detection software tools that sort and sift through the spectral and time data to record only the signals of interest. The previously discussed concepts have been implemented in the Agilent E3238S signal intercept and detection solutions. New software options USD and MR1 have the capabilities of universal signal detection with narrowband confirmation.

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Chris DeSalvo is a product marketing engineer for the signal networks division of Agilent Technologies. He has a B.S. in electrical engineering from the University of Pittsburgh. In his career with Agilent, he has been responsible for technical marketing of basic instruments, automotive electronics test systems, mobile handset testers, phase noise systems and most recently, spectrum monitoring solutions.