

SA2500 Field Spectrum Management

Application Note

Introduction

Managing the world's shared radio spectrum is a complex task involving partnerships between global treaty organizations, government agencies, military institutions, industrial producers and even amateur radio clubs. Modern advances in RF technologies have recently created explosive growth in the number of signal emitters using the shared radio spectrum, with no end in sight. Avoiding interference and quickly finding troublesome signal emitters in this crowded environment is becoming more and more difficult. To help solve these problems, Tektronix has introduced a handheld spectrum analyzer with advanced features like Digital Phosphor waveform image processor (DPX[™]) technology and Global Positioning System (GPS) referenced signal mapping. These advanced capabilities can greatly simplify spectrum surveys, locating interference sources and validating elusive breaches of signal emissions regulations. In this application note, we examine how the SA2500 general purpose handheld spectrum analyzer with DPX[™] technology simplifies the challenges of spectrum management in the field.



Introduction

Radio wave propagation characteristics vary with frequency, signal bandwidth, atmospheric conditions, and transmitter location. Conversely, the interference immunity of different receiver designs can vary greatly. These characteristics create a vexing array of technical considerations for interference-free coexistence.

Compounding the problem, a wide diversity of radio applications exists, from mobile satellite services to fixed point-to-point telecommunications, all with unique spectrum requirements. Each radio service however provides a significant economic benefit to society that warrants extraordinary care be taken for compatible coexistence. Balancing specific technical spectrum requirements with the economic benefits offered by each service, rapidly becomes a monumental task.

In the field, spectrum management thus becomes a challenging diagnostic endeavor as signal strength varies spatially with direction and distance from the transmitter. In addition, many modern digital radio signals are intermittently transmitted, making Interference issues both geographically dependent and temporally elusive. These characteristics demand a handheld spectrum analyzer with unique signal analysis capabilities.

Historically, portable spectrum analyzers left much to be desired – large bulky battery packs, lackluster rudimentary performance and few or no features designed for spectrum management. To counter these limitations, regulators would often choose an expensive van system equipped with a generator and a more useful high-end spectrum analyzer.

In recent years, some truly portable handheld spectrum analyzers have appeared in the industry that more closely fit the field spectrum management application. Even though this new breed of spectrum analyzer takes advantage of modern Liquid Crystal Display (LCD) technology and improved batteries, unfortunately it still falls short of an ideal solution.

Often designed around cellular telecommunications site turn-on and maintenance, many of the portable spectrum analyzers on the market today still lack important features and the performance needed for spectrum management roles. Slow sweep speeds, insufficient or no mapping capability, and software features of little value outside the cellular bands, make many portable spectrum analyzers on the market today



Figure 1. The Tektronix SA2500 offers handheld field portability, bench-top performance and advanced features like real-time DPX[™] technology that are ideally suited for many spectrum management applications.

a poor choice for general purpose spectrum management applications.

Tektronix' new SA2500 general purpose handheld analyzer offers solid performance with advanced real-time DPX[™] technology and many key features that overcome these traditional challenges of field spectrum management applications.

In this application note, we look at how the SA2500's features are applied to solve four common spectrum management field activities. Beginning with the process of spectrum clearing surveys prior to installing a new service, we will examine how the SA2500 addresses the challenges of finding what is already 'out there' using its unique set of spectrum monitoring features.

Next, we will review an example of signal strength mapping of a newly installed service using the integrated GPSreferenced mapping technology found in the SA2500.

Once a service has been deployed, interference from other transmitters can become a problem. Our third example looks at some analyzer features and techniques for finding interference and tracking down the source of emission.

The final example is from the regulatory agencies' point of view, examining how claims of interference, submitted by license holders, can be quickly validated prior to enforcement action.

How is radio spectrum allocated to RF services?

United Nations (UN) member countries, 192 nations representing most of the world, agree to abide by UN treaties to facilitate international law and peaceful coexistence. One such treaty is the coordination of radio spectrum usage as defined by the UN's designated agency, the International Telecommunication Union (ITU) in Geneva Switzerland.

The ITU sets world spectrum usage policy by means of the World Radio-communications Conference (WRC) with a major conference held every 3 - 4 years. During the conference each member country and its regulatory delegates can petition the committee to alter the radio spectrum allocations for changes, usually based on new applications that will provide the most economic benefit from the spectrum.

The world's radio spectrum allocations are made based on three world regions that are loosely defined by the continental landmasses. Various service types, such as fixed, mobile, satellite, and navigation, are designated to bands across the spectrum that is administered by ITU policy.

Allocating the RF spectrum to a particular type of radio service is a complicated matter. Signal propagation characteristics of the frequency band, incumbent users, signal compatibility, region of the world and equipment costs among other technical factors must be considered. In addition to the technical considerations, the economic value to society of a proposed service is a key element to justifying any change in spectrum usage.

Once the ITU has officially adopted a radio service type, it is up to each member country's regulatory agency to enforce the policies set forth by the ITU or face possible UN sanctions. Each member country thus appoints its own regulatory commission, like the United States' Federal Communications Commission (FCC), to regulate, coordinate and enforce spectrum usage including policing interference issues internal to the country.

Spectrum Clearing Surveys

Often the first step in deploying a new radio service is surveying the existing radio spectrum for incumbent users. For example, a large hospital might wish to survey the spectrum inside the hospital before installing an Industrial Scientific & Medical (ISM) band patient monitoring system. Similarly before a Wireless Local Area Network (WLAN) paperless record keeping system is installed in a large office building, a spectrum survey might be required to ensure successful deployment. Likewise, military organizations also perform spectrum surveys prior to deployment of operations in foreign lands to determine which bands will have the least interfering signals.

Actual radio spectrum usage in these situations is dependent on many factors, ranging from regulatory allocations to market place adoption of a given RF service. All these factors influence the number of transmitter signals found in any given band and are geographically dependent. Consider for a moment that few maritime radar systems are found in high altitude mountainous regions, just as fixed point-to-point microwave backhaul radios are rarely located 30 miles out to sea. Radio service popularity also varies with time as system life cycles grow and ultimately decline becoming obsolete. Many licensed bands have reliable databases of incumbent users, but actual 'airtime' usage may be unknown. Fixed point-to-point digital data links that are 'always on' are easily predicted from databases, but Time Division Duplexed (TDD) mobile radio services can be difficult to predict. A good example of this might be a taxicab dispatch frequency, heavily used in a major city, but seldom in a rural area. The only way to reliably determine the potential for harmful interference is to survey the local radio spectrum usage.

Another motivation for spectrum surveys is that some very high-powered transmitters are actually permitted to emit signals outside of their intended band, which can cause interference with other services. Regulators recognize that filtering technology for high-powered signals is limited and some allowance must be made to gain the benefits of very high-powered transmitters. To determine actual leakage levels, the only way to precisely identify interference issues is to survey the area.

To perform a spectrum survey, a portable spectrum analyzer is usually connected to an omni-directional antenna. Unfortunately, many spectrum analyzers are designed only for testing on the bench where signal levels are much stronger than many received signals. For this reason many spectrum analyzers have a comparatively poor noise figure relative to most radio receivers. This can necessitate the addition of a Low Noise Amplifier (LNA). However, adding an external LNA preamplifier and power source can be cumbersome in the field environment.

By contrast, the SA2500's low noise floor -163 dBm/Hz is sufficiently low to eliminate the need for an external preamplifier after the antenna in most applications.

Once the SA2500 is connected directly to the antenna, the signals present can be viewed on the typical spectrum display.

The spectrum display is highly effective for finding and documenting continuously transmitting services, but not optimal for many intermittent TDD signals like 'push to talk' police and fire dispatch radios. To survey how often TDD signals are transmitting, the spectrogram is the preferred display, showing spectrum amplitude versus frequency and time.



Figure 2. The spectrum display is best suited for continuous signal emitters, while the spectrogram's additional time axis is better suited to intermittent signals. The SA2500 can display either or both at the same time as shown here.

The SA2500 not only offers a spectrogram display that is rarely found on handheld analyzers, the display's clarity is better than what many laboratory analyzers are able to achieve. Using the Discrete Fourier Transform (DFT) process, a superior sampling rate and optimum capture frame overlap give the SA2500 a spectrogram with much sharper definition than typical analyzers.

Some TDD signals can present an even more difficult challenge as their transmit duration is very infrequent and extremely short. Wireless car entry signals, for example, may only transmit for a few hundred milliseconds once or twice a day. Until recently, finding such signals as part of a band survey was very difficult.





The SA2500 is the only battery-operated handheld analyzer to offer true real-time DPX capability that can reliably find such rare intermittent signal emissions. DPX is ideal when the user just cannot afford to miss even the shortest transmissions. For example, a military peace-keeping operation in a forward area might find it critical to mission success to find intentionally elusive signals. DPX is an indispensable tool for discovering these sources and will be covered in more detail later in this application note.

The general purpose SA2500 also offers integrated georeferenced signal mapping capability that facilitates signal surveys before deployment as well as signal strength mapping after deployment to document signal environments. In the next section, we look at how both existing and new service signal levels can be mapped in a region.

Signal Strength Mapping

Mapping received signal strength is an important element for many radio services. Broadcast operators use signal strength maps to show where potential market advertising coverage exists. Signal coverage is an important element to selling advertising 'air' time. Optimizing RF radiation patterns to maximize signal coverage and audience is a critical element of radio station success. Similarly for emergency service radio links like police, fire and Emergency Medical Service (EMS) dispatchers, the radio experts who design and maintain these systems understand that signal coverage is a critical element to service quality and safe operations.

Mapping signal strength to determine area coverage has always been a bit of a challenge. Portable receivers with builtin signal strength indicators are notoriously inaccurate, lacking measurement standard traceability. This can create all kinds of problems in reliably predicting radio performance from such uncalibrated signal strength measurement maps.

Even though accurate handheld spectrum analyzers have existed for many years, most lack the necessary Displayed Average Noise Level (DANL) performance to accurately measure low narrow band receive signal levels near typical radio thresholds. The SA2500 offers outstanding DANL performance in a handheld ruggedized instrument.

Recording spectrum measurements on GPS maps can be set up in a variety of ways on the SA2500. The most basic method of assigning a spectrum measurement to the GPS map is to tap on the map display touch screen to record a measurement point, which reveals a small icon of the spectrum found at the measurement location. The measurement recorded is also saved in a tabular database including latitude and longitude of measurement points along with the data samples for detailed analysis.



Figure 4. A public utility's transmitter signal strength is mapped in a remote canyon using the automatic distance interval between measurements plotted on a topographic map.

To generate a signal strength map of a particular service channel, the spectrum display is set to the channel of interest. A channel power measurement can then be turned on to accurately display the signal strength.

The Resolution BandWidth (RBW) can also be set very narrow so the noise floor is far below the signal level; however, some prefer to adjust the RBW so the noise floor shown on screen is at the same level as the receiver threshold. Unlike other handheld swept frequency analyzers, the SA2500 streamlines this process with its continuously variable DFT based RBW. Simply adjust the resolution bandwidth until the noise floor on screen is equal to the manufacturer's published receiver threshold level.

Mapping the signal strength by visiting a variety of locations and initiating a measurement by tapping the touch sensitive screen is a quick and easy way to build up the actual picture of signal strength. Since the SA2500 allows importing of a wide variety of map types, data can be easily overlaid on the type of map best suited for the application. Emergency service dispatch signals can be plotted on topographic maps, naval operations on maritime charts and broadcast radio on city street maps.



Figure 5. Time interval signal mapping greatly simplifies in-building surveys where GPS signals may not reach.

Signal strength mapping on the SA2500 can also be set to record automatically based on a distance interval measured by the GPS receiver. For instance, a measurement can be automatically taken and plotted on the map at every mile (or km). Such distance interval measurements greatly simplify airborne and shipboard surveys of large areas. Simply enter mapping mode by tapping or clicking on the icon, then set the 'Measure By' selection to 'Distance' and enter a measurement interval.

Measurements can also be taken at set time intervals, by setting the 'Measure By' selection to 'Time'. Time interval mode automatically maps spectrum measurements and can be useful for walk-around signal strength characterizations. For example, a floor plan of a large airport can be downloaded to the SA2500. Then, a starting point can be selected on the map and at regular time intervals a new signal strength spectrum will be recorded as the surveyor walks through the airport, finally tapping on the ending point. This method is ideal for in-building surveys where GPS signals may not be reliable.

The SA2500 offers traceable general-purpose signal strength GPS-referenced mapping for a wide variety of applications, ensuring that signal coverage is accurately known and antenna patterns are adjusted for maximum benefit.

Once a system is deployed and the radiation pattern is optimized, the next spectrum management challenge typically comes in the form of finding an interfering signal from a new and unknown transmitting source.

Finding Interference

With many spectrum analyzers, finding the source of RF link interference can be a substantial challenge. Typically, continuous interference is found by looking in the band of the victim receiver for a signal that does not belong there. Seeing the interference on the spectrum analyzer display, however, is often merely the start of a long process of determining where the signal is coming from and removing the interference, not at all the solution to the problem.

Often, simply looking at the signal on a spectrum display is not enough to identify interfering transmitters. Even if the modulation type is apparent, the location and owner of the actual transmitting source may not be. To physically find the source of interfering emissions, some form of signal Direction Finding (DF) capability is needed. Most spectrum analyzers offer nothing to aid the user in quickly finding the offending transmitter.

Dedicated radio DF equipment, used to physically locate transmitters, varies significantly in capability and cost. Sophisticated DF systems designed for military or surveillance applications are usually far too expensive for most operators and many regulatory agencies.

The SA2500's GPS mapping feature solves these problems with signal direction mapping tools that work in conjunction with a built-in signal strength indicator and an external directional antenna to physically locate sources of interference. In effect this provides a very low cost DF capability.



Figure 6. Using a directional antenna and the SA2500's bar graph with audio tones, the direction of strongest signal reception (usually the direction to the transmitter) can quickly be determined.

The signal strength meter can be turned on by entering the spectrum display and choosing 'RF Measure' pane. Then, select 'Signal Strength' from the pull down menu and un-mute the audio indicator.

With the SA2500's audio un-muted, the peak signal strength is easily found by sweeping a directional antenna across the horizon. The SA2500 indicates signal strength with both a bar graph and an audio tone. The audio tone varies its pitch based on received signal level, using a distinctive warble designed to make finding the highest pitch or power level easy without having to look at the analyzer. This allows the operator to remain visually focused on where the antenna is pointing for faster recognition of the interferer's transmitting antenna.



Figure 7. Using a directional antenna, vectors can be drawn on the map manually to gain perspective on where the transmitter is located. A radio tower obscured from the road by trees is easily found by comparing pointing vectors.

Once the direction to the transmitter is known, the GPS map display can be tapped and a line dragged in the direction of the interfering signal. The SA2500 will record the spectrum icon on the map along with a manually drawn arrow pointing towards the transmitter.

Two or three measurements taken at different points plotted on the map with pointing vectors attached identifies where the vectors intersect, and thus the physical location of the interfering transmitter. For a distant interferer with a relatively small antenna, or a mobile emitter that is moving, this process of pinpointing the emitter's location may need to be repeated.

With the interfering transmitter identified, harmful emissions can be more accurately characterized up close, prior to initiating a discussion with the owner of the interfering source or filing a dispute claim.

The SA2500 makes documentation of interfering signals easy with a variety of file and screen capture exports modes. Signal captures can be saved to a file by choosing 'Save Results' under the 'File' menu. Saving to a file allows playback and further analysis. Simple screen captures can also be accomplished with Virtual CE for Tektronix Products, via either a USB or LAN connection. Virtual CE for Tektronix Products allows remote viewing and control of the SA2500 instrument with a standard Personal Computer (PC) and can be downloaded at no charge from the Tektronix website.

Recording an interfering signal with accurate location information can greatly aid in resolving the problem. Presenting clear and compelling evidence greatly improves mediation efforts. If formal regulatory channels are sought, clear evidence is extremely helpful for regulatory authorities to do their job. The SA2500's mapped spectrum measurement makes documenting the problem quick and easy.

The SA2500 also offers signal strength readings in either dBm from the antenna or field strength readings in $dB\mu V/m$. Depending on the allocated uses of the band, field strength readings sometimes fit the regulatory rule structure best, and can be found under the 'RF Measure' tab, pull-down menu 'Field Strength.'

In our final example, we look at how a regulatory agency can use the SA2500's unique handheld DPX[™] capability to rapidly validate interference claims prior to taking enforcement actions.

Mitigating Interference Claims

Before taking enforcement action, regulatory authorities may need to validate an interference claim to assure the data was correctly taken. It is important that the regulatory authorities have capable equipment so they can validate claims of interference efficiently.

We are all familiar with the interference that occurs when driving too close to a competing broadcast radio tower while listening to a distant station. The nearby transmitter overpowers the desired distant signal, producing easily recognizable interference. In recent years the nature of interference problems has changed somewhat from this common example. With the proliferation of digital data links, interference issues have evolved into a different problem and discovery scenario. With voice traffic over an RF link, like our broadcast radio example, interference issues are more easily detected. For example, to detect an interference problem, a cellular carrier might count dropped calls in an area previously determined to have good signal coverage from an earlier signal strength survey.

However, for the more general digital link carrying data, interference can have two very different types of effects.

The packet switched type data link just tends to slow down the data transfer performance with intermittent interference, even though the link might still be useable. Take for example a Wireless Local Area Network (WLAN) operating near a microwave oven. These two devices share the same frequency band. The WLAN can only continue to transmit while the microwave oven is operating between each half cycle of the 60 Hz (or 50 Hz) power, when the microwave oven's magnetron tube is not emitting energy. Thus, when the oven is running, the WLAN data rate throughput is cut in half from interfering signal leakage. This type of interference scenario tends to be reported differently from the more obvious 'dropped call,' leading to a more insidious dissatisfaction with the service. This problem is becoming common in unlicensed user coordinated bands.

The full duplex continuously transmitting Frequency Division Duplexed (FDD) digital data link also presents a different challenge when confronted with an intermittent interfering source. Unlike voice traffic, if digital data is corrupted, files may become unreadable. Some high speed data links, such as fixed point-to-point radios used to control remote dams and power plants, depend on ultra low Bit Error Rates (BER) of 10-12 or less. Even a brief moment of interference can hopelessly corrupt critical data.

In either case, intermittent interfering sources can create troublesome interference problems with brief interruptions of modern digital data links. The challenge from the regulator's perspective is validating very brief, sometimes rare intermittent interfering events, quickly and reliably. Finding such an intermittent source of RF interference with a modern digital data link is a different problem from the easily captured Continuous Wave (CW) interferer.



Figure 8. Unlike conventional spectrum analyzers, real-time DPX[™] displays can capture even very short transient spectrum events. DPX[™] does not have the long periods between sweeps of the resolution bandwidth filter that are blind to the input signal. Consequently DPX[™] doesn't miss short transient interference events.

A digital data link can be badly disrupted by a very short burst of RF energy. Frame errors, or even synchronization loss, can occur that are easy to measure digitally, but difficult to correlate to RF interference events.

Short RF bursts of energy are usually difficult to detect with conventional spectrum analyzers because of their slow sweep time and significant retrace blanking time, leaves large amounts of time between spectrum samples unanalyzed. The conventional swept tuned spectrum analyzer sweeps a narrow crystal filter across the band to detect signal power levels. Thus, many popular portable spectrum analyzers provide only an occasional 'snap-shot' of what the spectrum is doing. For the regulatory authority pressed to find and validate interference problems quickly, the short signal duration interferer can pose a significant problem that requires a much different kind of spectrum analysis tool.

The SA2500 is fundamentally different from all other handheld spectrum analyzers as it has true real-time capability.

Using DPX, the SA2500 processes 2,500 spectrums per second and captures all events equal or greater than 500 μ s in duration with a 100% probability of intercept (POI).



Figure 9. Like other display and measurement modes, the real-time DPX[™] display can be entered by selecting the DPX[™] icon.

DPX[™] mode is entered by selecting the measurement display icon under the 'View' menu or using the display button.

Using a statistical process to show much more information than a typical peak signal level detection process, DPX[™] engine on the SA2500 accumulates the rate of occurrence that energy is found at each pixel in the display. This gives the users an unparalleled insight into the behavior of intermittent signals.



Figure 10. The Real-time DPX[™] display easily captures a Wireless Local Area Network (WLAN) signal (red) being interfered with by a microwave oven (blue) that shares the same frequency band. Fortunately the microwave oven goes off 60 times per second, so the WLAN user's data link is only slowed down.

DPX[™] on the SA2500 can be adjusted to have variable or infinite persistence by selecting the 'More' button at the bottom of the 'DPX[™] Spectrum' tab. This brings up a dialog box that allows customization of the display under the 'Bitmap' tab. Next, with the analyzer set to infinite dot persistence, the SA2500 will then stare at the spectrum and detect any interference event that has a duration equal or greater than 500 µs with 100% POI.

This feature is essential for validating claims of intermittent interference events that would be difficult to ever capture on traditional swept tuned portable analyzers or DFT based analyzers lacking real-time DPX[™] capability.



Figure 11. DPX[™] can capture intermittent interferers with amazing reliability like this very short wireless motion detector alarm interfering with the smaller signals just to the left of the strong motion detector signal.

It is important to note that true DPX[™] capability is based on very fast Digital Signal Processing (DSP) and dedicated high speed digitizing capability. Some analyzers provide a display which gives a similar look to DPX[™] but lacks the real-time capability. Instead, these imitation products work on a short recording of the signal environment. Since the signal capture time of these instruments is limited by the available memory, large gaps in time between data records go unanalyzed. The result is that these imitation products cannot detect short 500 µs events with a 100% POI. Unlike the SA2500, these products cannot stare at the spectrum for hours, days or weeks to look for the rare but significant effects of powerful, pulsed type interferers. For example, a 1 MW Doppler radar used for tracking tornados might only be tuned seasonally and operated for a few hours as storms appear and dissipate. Such radars can have disastrous effects on high quality fixed point-topoint radios used to coordinate emergency services during severe weather disasters. Finding such interference sources is not very practical with swept tuned spectrum analyzers that are blind to the spectrum most of the time. Nor can vector signal analyzers that only use a few seconds of recorded spectrum data for their displays reliably capture such events. It is essential to have true continuous real-time DPX[™] spectrum display capability that can capture every interference for months.

DPX[™] capability revolutionizes the efficiency with which regulatory professionals can find and validate interference claims.

Conclusion

Managing the shared RF spectrum takes a partnership between manufacturers, users and regulatory agencies. The general purpose field portable spectrum analyzer has been the tool of choice for the application for many years. Unfortunately, most portable spectrum analyzers have been far less than optimal for the task. Bulky battery packs, short run times, inputs designed for strong laboratory signals and designs focused on cellular site maintenance have been less than ideal. Introduction of the Tektronix SA2500 now adds a solidly performing handheld general-purpose spectrum analyzer with the features to efficiently perform the radio spectrum management task. The SA2500's low noise preamplifier, sound DANL and allday battery life offer solid fundamentals. However, its unique features are what make it an easy choice for the spectrum management professional. Crystal clear spectrograms make pre-deployment surveys fast and easy when determining what incumbents are using the radio spectrum, just as integrated GPS-referenced mapping and field strength measurements in volts/meter or dBm expedite post deployment antenna pattern adjustment and signal strength mapping.

When interference does arise, with a directional antenna and the GPSreferenced mapping capability, the SA2500 signal strength indicator offers an inexpensive DF capability that can physically locate the interfering emitter quickly. The SA2500 also makes documenting the findings a simple matter with a variety of export and PC control options.

Even difficult to find intermittent interference can be rapidly discovered and documented using the SA2500's unique real-time DPX[™] display and infinite persistence. As the only handheld real-time spectrum analyzer with true DPX[™] capability in the market, the SA2500 can detect a 500 µs spectrum event with a 100% probability over a period of months, making it ideal for regulatory validation applications.

Beyond emerging as the only handheld spectrum analyzer with realtime DPX[™] and bench-top performance, the SA2500 offers innovative capabilities that are ideal for spectrum management in the field. Consider an onsite demonstration from your Tektronix representative today.

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For Further Information

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