Cost-efficient and Extensible RF Spectrum Monitoring & Management

Leveraging High-Performance Portable Analyzers, Open Software and PC Integration for Field Analysis and Remote Deployments

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Introduction

With spectrum analysis and spectrum management requirements expanding into a wide range of new and challenging arenas, the traditional standalone spectrum analyzer approach is often coming up short in its lack of adaptability for today's field-intensive applications.

In addition, the inherent high cost associated with "putting everything in one box" makes conventional analyzers a poor match for some of today's field-deployment scenarios, in which large numbers of lower cost analyzers need to be deployed to monitor remote facilities and/or signals intelligence (SIGINT).

This white paper lays out an entirely new approach to these challenges. By maximizing the capabilities of a highly portable spectrum analyzer, designed from the ground up for seamless integration with laptop PCs through an easy-to-use application programming interface (API), and an extensible open source platform, this new approach both lowers overall costs and maximizes flexibility.

Trends and Driving Factors for In-the-Field RF Spectrum Management

The requirements for high-performance spectrum analysis have already migrated well beyond the walls of traditional laboratory settings and controlled environments. Across a widening range of industry segments and specialized applications, high-end spectrum analysis has now become a "go anywhere" necessity for supporting a variety of field and remote deployment activities.

Communications Infrastructure

The global explosion of wireless devices and applications is presenting major challenges in terms of radio frequency spectrum allocation and management. Traffic and bandwidth demands are increasing while at the same time the spatial separation between devices is decreasing. With the communications and commercial wireless ecosystem becoming more crowded and diverse, the importance of being able to monitor, manage, troubleshoot, and protect RF spectrum in the field is a critical factor for success.

Accomplishing these objectives requires two different deployment scenarios for RF spectrum analysis and management systems. The first scenario involves providing field engineers/technicians with the ability to detect and analyze signals in support of installation, monitoring or troubleshooting activities.

The second scenario involves deploying lowcost remote signal monitoring systems that remain in the field and deliver data, analytics, and alerts to centralized locations. Not only do these systems need to be affordable enough for multi-unit deployments at key points in the communications infrastructure; they also need to be designed for seamless remote management, such as power cycling, system recovery and pushing out software updates without requiring a truck roll with a field technician.

Quality Assurance and Field Customer Service

The proliferation of systems that use spectrum and/or could interfere with other wireless applications makes it imperative that OEMs, installers and service staff be able to detect, analyze, diagnose, and correct any signal problems or interference issues in a variety of field environments. Portable spectrum analysis has also become important for QA testing within extended-factory ecosystems where signal performance needs to be evaluated for systems in multiple production lines and/or by QA engineers conducting vendor site visits.

Customer service and QA functions often also need the ability to stream data from remote field locations to centralized facilities for additional real-time analysis or to record streamed RF to disk on the field device for subsequent archiving and system-wide trends analysis. In QA or customer service situations, the ability to network and integrate field analyzers with backend resources can be critical for not only solving immediate problems but also for identifying emerging issues to avoid the cost of widespread corrective measures.

Government, Regulatory and Covert Spectrum Management Applications

Most countries consider wireless spectrum to be the property of the state. In fact, the International Telecommunications Union (ITU) constitution recognizes “the sovereign right of each State to regulate its telecommunication.” Government responsibilities include allocating, regulating, and monitoring the use of wireless spectrum; identifying and solving interference problems; arbitrating between spectrum users; optimizing the overall usage of available spectrum; and coordinating with other governments on cross-border spectrum issues.

In today’s increasingly crowded and globalized wireless environment, effective governmental regulation and spectrum management is both critical for international success and very difficult to accomplish. Governments actually need to have the most advanced capabilities for field-based spectrum analysis and remote deployment in order to stay ahead of the curve, to catch violators, and to resolve disputes.

An important specialized arena of government activities involves covert agencies that carry out SIGINT operations in the field. For these applications, spectrum analysis systems need the greatest degree of remote hardware flexibility and overall system extensibility. Depending on the deployment scenario, remote covert signal analysis systems may need to operate independently for long periods of time and respond to specific software-defined parameters that are unique to each situation. For example, a remote spectrum analysis system might need to scan for signals at certain frequencies and then begin RF recording or streaming the data only under those conditions. Some covert scenarios could even require the remote software to recognize patterns of associated frequencies, modulations, and/or signals activity to trigger actions by the remote computing platform.

RF Stream to Disk and RF Recording

The ability to continuously stream and record RF data has become a very important capability that spans all of the above applications arenas. It deserves a special mention because the implications of real-time streaming RF to disk requirements can be a very important factor when considering the extensibility of your spectrum analyzer. Depending on the spectrum characteristics and the amount of data that needs to be streamed or recorded, the remote system configuration will require very different hardware capabilities.

Real-time conditioning and digitizing of I/Q data on-the-fly can be quite challenging for the analyzer. The remote system also needs to be capable of transferring data at a high enough rate to support sustained acquisition. In addition, the amount of recorded data that needs to be stored locally dictates the size and type of mass storage drive. Requirements for continuous RF streaming of data to centralized locations also have major implications regarding the remote computing and network interface specifications. As discussed in the following section, such application-specific hardware variations can be difficult to accommodate with the conventional standalone approach to spectrum analyzer design.

Limitations of Conventional Standalone RF Spectrum Analyzers

High-Cost & Limited Extensibility

Conventional spectrum analyzers typically use a one-box design approach to provide users with complete standalone solutions. This means that they bring together within a single box all of the spectrum analysis functions using custom-programmed FPGAs, along with other supporting functions such as a CPU, display, memory, data storage and I/O interfaces. The result is a complete system with a price range that is usually in the $15,000 to $40,000 price range.

In addition to the high price point, conventional spectrum analyzers also are not generally designed for hardware extensibility. Once the original configuration has been selected, a standalone system usually does not have flexibility for adding storage, upgrading the processor, changing the network interface or making other hardware changes.

Not Designed for Portable Performance or Application Flexibility

Conventional high-performance spectrum analyzers have evolved within lab environments and therefore are inherently more suited for fixed-location deployments rather than field usage. Typical laboratory-based and fixed-testing configurations surround the high-end analyzer with dedicated computing resources and specialized software programs that optimize the end-to-end process within the controlled setting.

Achieving portability and field flexibility by starting with the traditional all-in-one design approach has always required compromises in terms of performance, features and/or usability. For example, most portable and handheld spectrum analyzers have limited preconfigured measurement options rather than being truly configurable spectrum analysis systems.

In addition, these stripped down versions of conventional standalone analyzers lack the configurability, networking, and software adaptability to support the dynamic nature of high-end field analysis and spectrum management. This is especially true for situations such as interference troubleshooting, regulatory spectrum assessments, RF streaming to disk, and specialized covert SIGINT applications.

The bottom line typically is a system that still costs more that it should because it emulates the conventional all-in-one design approach but that lacks the required performance, and extensibility to support today's demanding field analysis objectives.

Worse yet, with in-the-field spectrum management requirements continually changing and presenting new challenges, these costly, fixed-function standalone analyzers likely will have to be replaced and/or upgraded to address new communication protocols and application demands.

Signal Hound: An Open-Systems Approach to RF Spectrum Analysis

Architectural Philosophy: Optimization Instead of Duplication

By shifting the underlying architecture and design approach from putting-everything-in-one-box to instead optimizing-the-entire-system, Signal Hound has fundamentally changed the affordability and extensibility of high-performance spectrum management systems.

Using a compact high-performance spectrum analyzer that connects to a host PC through USB 3.0 and comes with an extensible spectrum analyzer software package, this open-architecture approach enables the whole system to be optimized for specific application needs.

As will be discussed in the following sections, this enables every system deployment to be

tailored for the best balance of features, performance, and cost. Just as importantly, it also enables both the hardware and the software to be upgraded and adapted for new requirements, without having to start over by replacing the whole system.

Performance

The first requirement for any spectrum analyzer is the ability to handle the required frequency range, resolution bandwidths, sweep speed, and precision needed to perform the target measurement and analysis tasks. Fall short on this baseline requirement and nothing else matters.

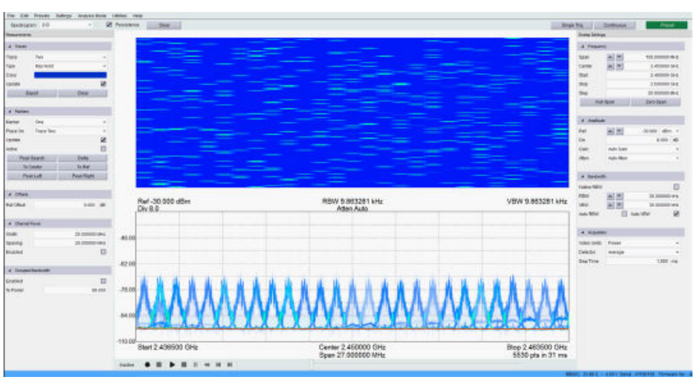
Now in its second generation, the Signal Hound BB-series has already proven up to the task in real-world operational settings, with the first-gen BB60A having been very well received. The new BB60C product version goes even further: improving SFDR by 20dB, flattening the noise floor, extending the operating temperature range (now -40°C to +65°C), and expanding the streaming I/Q bandwidth to make it selectable from 250 kHz to 27 MHz. The BB60C provides an instantaneous bandwidth of 27 MHz and sweep speeds of 24 GHz/sec.

Gapless spectrum coverage is achieved for the entire 27 MHz of Instantaneous Bandwidth (IBW) by using 75 percent overlapping Fast Fourier Transforms (FFT). This means that

BB60C SPECIFICATIONS SUMMARY	
Frequency Range	9 kHz to 6 GHz
Streaming Digitized I/Q	25 kHz up to 27 MHz of selectable, amplitude corrected, IF bandwidth
Resolution Bandwidths (RBW)	10 Hz to 10 MHz
Sweep Speed (RBW ≥10 kHz)	24 GHz/sec
Displayed Average Noise Level (DANL)	-158 dBm/Hz + 1.1 dB/GHz (>10 MHz)
Residual Responses: Ref Level ≤ -50 dBm, 0 dB Atten	-106 dBm (>500 kHz)
Spurious Mixer Responses: (ref level -50 to +10 dBm (any 5dB increment) and input signal 10 dB below reference level	-50 dBc
Operating Temperature, ambient	32°F to 149°F (0°C to +65°C) Standard -40°F to 149°F (-40°C to +65°C) Option-1

every digitized sample will be included in 4 FFTs. In this mode, any signal inside the IBW of sufficient amplitude, regardless of duration, will show up in the display. For maximum displayed amplitude, a signal must be present for one entire FFT. For a 631 kHz resolution bandwidth, this works out to about 4 microseconds, but even a 1 microsecond pulse will be attenuated by only 2 to 3 dB.

This makes the system a good choice for difficult field spectrum management applications, such as intermittent interference hunting. A traditional spectrum analyzer will only display interference if it occurs within the RBW being measured, making interference difficult to identify and quantify. A real-time spectrum analyzer like the BB60C processes thousands of RBWs simultaneously (in parallel), making the task of interference hunting easy. Identifying and analyzing frequency hopping spread spectrum signals can pose a challenge for a traditional spectrum analyzer, which will only catch a small fraction of hops. The BB60C's ability to simultaneously stream the entire 902 to 928 MHz ISM band, or sweep from 2400 to 2475 MHz in about 4 ms, greatly simplifies this process. This can be seen in the following picture of a Bluetooth signal being received by a BB60C.



Affordability

The second key goal of this new architectural approach is providing a level of overall system affordability that breaks through the cost barriers posed by conventional one-box systems, thereby creating new opportunities for wider field usage and enabling cost-efficient remote deployments.

By connecting the BB60C to a PC for handling the signal processing functions, this modular approach eliminates the need for a large portion of the costs (and markups) associated with conventional standalone analyzers. Traditional system designs rely on custom-programmed FPGAs to handle signal processing within the analyzer itself, which significantly drives up the cost. With FPGAs powerful enough to handle the required processing tasks costing from $250-$1000 each and marked up by at least 400%, this approach can add $4000 to the price of a standalone analyzer. Additional system cost is incurred for the peripheral hardware such as a display, power supply, computer processor, keypad, and internal memory. On top of the system costs, manufacturers also need to amortize the high cost of skilled FPGA programmers to develop, support, and update the signal processing algorithms.

All of these factors drive the price of a conventional spectrum analyzer up into the $15,000-$40,000 range, which still needs to be interfaced with a computer to perform and report automated measurement tasks. In contrast, the Signal Hound approach starts at less than $3,000 including the compiled API and open-source spectrum analyzer software. Just connect it to an appropriately configured Windows PC, which also hosts the application software, and the complete system is ready for deployment.

Usability and Portability

The compact BB60C is designed for portability with a net weight of only 1.1 lbs. (0.50 kg) and dimensions of 8.63” x 3.19” x 1.19” (219mm x 81mm x 30mm). Because the unit draws its power from the PC over the USB 3.0 connection, there is no external power supply or power cabling, thereby minimizing space requirements and eliminating the need to keep track of accessories.

The unit is designed for flexibility of deployment along with the associated PC, with typical scenarios ranging from packaging them together in an IP67 type weatherproof enclosure for outside mounting on a pole or roof, to deploying the PC and BB60C in an attic, crawlspace or wiring closet inside a building. For use by a roving field technician, the system can be packaged together in a rugged briefcase type enclosure for quick set up and operation at any location or simply Velcroed to the back of a laptop or tablet.

Connectivity

The system is connected to the network and backend resources through the PC’s Ethernet interface, which supports the full range of communications, data uploads, software updates, and other system management tasks. By pairing the BB60C with any Intel vPro-enabled PC, from a high performance desktop to an ultra-compact NUC, the entire system can be managed remotely, including the ability to turn it on and initiate operations. The Intel vPro technology keeps the Ethernet port powered on – even when the PC is shut down – thereby allowing the following functions to be executed over the network:

- Remotely power cycle the PC – On or Off
- Remotely manage software updates (including restart operations)
- Remotely perform system recovery if the PC or BB60C crashes or locks up

Extensibility

One of the most significant game-changers in the Signal Hound approach is the tight integration of an open-source Windows-based spectrum analyzer software application. This enables the engineer to immediately begin using all of the BB60C’s functionality.

The integrated software supports traditional controls such as frequency span/center/start/stop, resolution bandwidth, video bandwidth, reference level, configurable traces and markers. Using OpenGL to leverage the PC’s GPU acceleration, the software supports rich display features such as 2D and 3D spectrogram plots and a real-time color persistence display format to enhance the user experience and simplify signal identification.

By incorporating a rich compiled API and an open source spectrum analyzer software application, this approach also enables users to extend the system’s capabilities by writing their own functions and integrating them tightly with the spectrum analyzer. The fully documented API is written in C/C++ and supports capabilities such as setting record-on-event triggers, real-time analysis and streaming I/Q data. Programmers can either customize the existing open-source application or develop a targeted application from scratch.

Real-World Benefits and Use Cases

Customer experiences have shown that the benefits of the modular Signal Hound approach generally fall into two major categories: 1) lowering out-of-the-box cost and 2) extending capabilities beyond what was previously possible. Many customers are enjoying both benefits.

Lowering the Out-of-the-Box Cost for Spectrum Analysis

For many companies, the opportunity to reduce their cost-per-analyzer by a factor of 5x to 10x is reason enough to make the switch. At $3K plus the PC cost for a complete system vs. $15-$40K for just the standalone conventional analyzer, the capital expenditure and ROI math are very compelling. In fact, some companies have calculated that instead of adding one more standalone analyzer, for the same expenditure, they could refit their entire lab or production floor with BB60C units. As a bonus, they get the ROI upside of being able to future-proof the new units through software upgrades and modifying the PC configurations whenever needed (disk size, network interface speeds, etc.).

For remotely deployed scenarios, the lower cost is an enabling factor that makes it possible to put remote systems in the field where the cost of standalone analyzers was simply too prohibitive. This means that communications service providers can cost-effectively push high-end embedded spectrum management further out into their infrastructures, thereby eliminating the cost and time delays involved with ad hoc truck-roll technician trips, while simultaneously improving service reliability and customer satisfaction.

Expanding Spectrum Analysis Capabilities Beyond the Box

The other way that this new open-systems approach breaks-out-of-the-box is by providing a highly extensible platform for creating custom-tailored spectrum analysis applications. Companies with specialized applications can easily extend the basic analysis software that comes with the product to address their unique requirements. Since the APIs are fully documented and programmable in C/C++, virtually any set of custom functions can be created, deployed, and maintained by programmers who are familiar with these industry-standard software methods.

Extensibility is very important in today's rapidly changing wireless communications environment, where companies need to remotely deploy solutions that can then be adapted to address new requirements simply by remote updates of the software.

Software customization is also a critical factor for creating specialized spectrum analysis functions, such as field-deployed covert SIGINT platforms and governmental regulatory monitoring systems. In these cases, the spectrum analysis applications often need to incorporate complex algorithms to detect, analyze, and "chase" signals of particular interest, which calls for sophisticated software running on the remote computer that is tightly integrated with the spectrum analysis functionality.

The Bottom Line

Today's complex globally dispersed and highly diverse signals management requirements can no longer be adequately addressed by yesterday's conventional fixed-functionality spectrum analyzers. Spectrum management applications have already left the lab and, in the process, have left traditional lab equipment behind. These applications require a new approach to spectrum analysis system design.

The new approach, as embodied in the Signal Hound BB-series, is designed to optimize the front-end spectrum analysis and RF streaming functionality in a manner that supports cost-effective integration with a standard Windows PC environment to provide an affordable out-of-the-box complete solution. This enables virtually any existing spectrum management application to be migrated to these new platforms at a small fraction of the cost of traditional spectrum analyzers.

The Signal Hound® company started as Test Equipment Plus (TEP) in 1996 with the belief that providing quality used test equipment, at affordable prices to every customer, would drive growth and foster loyal customers. It did. Then in 2006, TEP expanded their focus by designing and manufacturing a color LCD display retrofit kit to answer the need for CRTs that were no longer available for the aging HP® 8566A, 8566B, 8568A, and 8568B spectrum analyzers. TEP also began offering a repair service for HP/Agilent® step attenuators. In 2007 TEP designed and began manufacturing another color LCD display retrofit kit to support the HP/Agilent 8560 series spectrum analyzers. At the same time, TEP also decided to play to their strengths, and began offering test equipment repair services for Agilent spectrum analyzers, network analyzers, and signal generators. The repair segment of TEP is now recognized in the RF and microwave test equipment industry as a world class operation.

The LCD kits were so well received that in 2009, TEP decided to design a compact, lightweight, and inexpensive spectrum analyzer. The goal was to provide an economical spectrum analyzer with unparalleled value compared to anything else on the market. TEP achieved that goal with the USB-SA44 spectrum analyzer which was introduced in February 2010, marking the birth of the Signal Hound line of test equipment. In April of 2014, Test Equipment Plus began officially doing business as Signal Hound. Signal Hound's latest innovation is the Signal Hound BB60C spectrum analyzer, introduced June 2014, which is an enhanced version of its well-received predecessor, the BB60A.