Using the LP Technologies LPT-3000R Remote Spectrum Analyzer in a Spectrum Monitoring System

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***Abstract*— Spectrum monitoring is integral to bandwidth management in the field of wireless and satellite communications. Currently available spectrum monitoring systems are relatively expensive and difficult to set up and maintain. An approach to providing spectrum monitoring using the LPT-3000R Remote spectrum analyzer and scripted Standard Commands for Programmable Instrument (SCPI) commands is described. This system is currently in use and has resulted in significant cost and time savings relative to commercially available SMS's.**

Keywords: spectrum monitoring, satellite, bandwidth management, carrier management, wireless, spectrum analyzer programming, RF measurement, signal detection)

INTRODUCTION

A Spectrum Management System (SMS) is an integrated set of receive antennas, spectrum analyzer(s), RF switch(es), and server/software designed to continuously monitor the status and health of discrete RF channels, or "carriers". They are used by satellite bandwidth providers to monitor the status of their proffered bandwidth, as well as by systems integrators who lease the bandwidth and offer it as part of a service. The extent of an SMS can be large. To give an example, Artel, Inc provides approximately 5 GHz of leased bandwidth services on a contract with the US Department of Defense (DoD). The contract stipulates that each carrier that is transmitted on this leased bandwidth be monitored and its status (up/down) be displayed in (near) real time. Additionally an archived record of each carrier's status must be maintained for a year. The number of carriers monitored varies, but as of this writing approaches 1000 discrete carriers on 186 transponders on 56 satellites. These satellites span the globe, with diverse downlink footprints. The SMS needed to monitor this satellite constellation is large and complex, comprising 18 sites in 10 countries around the globe. Each SMS node is sited at a satellite teleport with from 1 to 16 receive antennas, and that node communicates back to a central server and operations center at headquarters. This system was built up over nine years of the contract's life and has served the contract's requirements well. However, the individual nodes used at each of the 18 receiving antenna sites do suffer from two major limitations: they are expensive and complex, both to purchase and commission and also to maintain, license, and operate. As the architect and operator of Artel's SMS, this author has long sought a simple and inexpensive SMS that is easy to maintain. Presented here is a description of an SMS built to replace the existing system which is approximately 1/10th the cost, has no recurring license fees, and is significantly simpler to install, configure, operate, and maintain.

DESCRIPTION OF COMMERCIALLY AVAILABLE SPECTRUM MONITORING SYSTEMS

A screen capture of a spectrum analyzer with a satellite carrier is shown in figure 1. The analyzer displays power as a function of frequency. In the picture, markers 2 and 1 show that the approximate bandwidth of the signal is 37 Mhz and the carrier to noise ratio, the amount in dB above the noise floor, is approximately 11 dB. The center frequency is approximately 1190 Mhz. The basic function of an SMS is to continuously measure these values and convey them to a server for display, alarm, and archival.

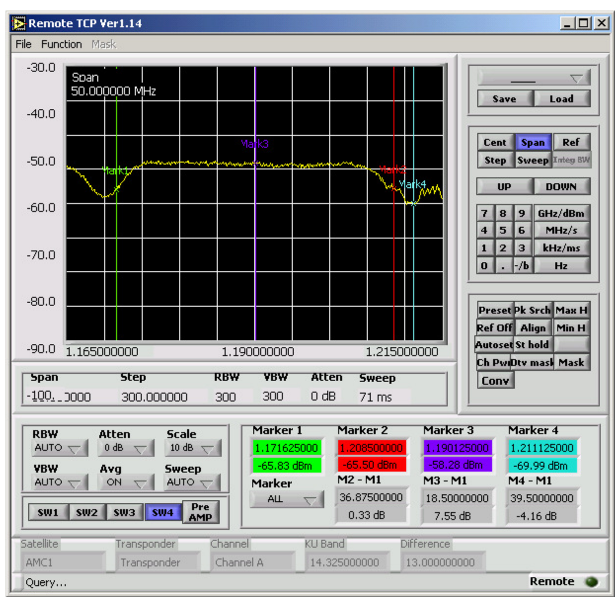

Figure 1: A Typical Carrier Measurement

A simplified diagram of an SMS is shown in figure 2. A number of antenna feeds are sent by means of an RF switch to a spectrum analyzer. The switch and spectrum analyzer are controlled by a server which, according to preset set of instructions, configures the switch and analyzer to appropriate settings to display the carrier. A measurement of the carrier's parameters (e.g. power, carrier/noise ratio, occupied bandwidth) is taken and sent to an alarm/display server which provides a user interface and also sends the measured data to a database server for archival.

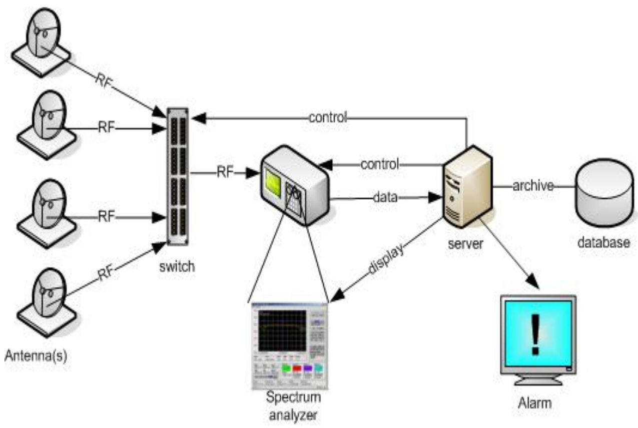

Figure 2: Basic Spectrum Monitor System

In practice, a single SMS site is not sufficient to monitor the signals of a large constellation of satellites. The SMS must be located in the footprint of the monitored transponder, and (usually) multiple nodes are required. For example, in the example cited in this paper, 18 sites around the world are used to monitor all required signals. Integration of multiple sites requires that an additional retrieval/display/alarm/archive layer be added to the simplified picture. Carrier state information is extracted from the remote site via a scripted query and a separate manager is used to display the information and archive it at a central facility (HQ). This layer can be created or integrated from commercially available management software, or can be provided from the SMS software itself.

LIMITATIONS OF COMMERCIALLY AVAILABLE SMS'S

Operationally Complex: A fundamental complexity of commercially available SMS's is that addition or modification of a given carrier always requires two operations: First, local configuration (either on site or via remote client) and then configuration of the retrieval/display/alarm/archive script for use at HQ. We shall see that in the SMS described by this paper, a single set of scripts at the HQ accomplishes both the monitoring and the display/archive function, and this results in a much simpler and easier to operate system.

Physically Complex: The author uses two competing vendor's commercial SMS's: An older "legacy" system that uses a standard Agilent spectrum analyzer and a newer SMS, that uses a proprietary digital signal processor (DSP)-based system. The older system requires 5 physical connections between four pieces of equipment; the newer one requires 7 connections between 5 pieces of equipment, all with their own settings and drivers to be exactly configured. This complexity is exacerbated when one considers that many SMS sites are in remote parts of the world, depending on the location of the satellite downlink footprint. Ideally one could ship a SMS to an independent teleport operator and have him make the connection to the receive antenna and to the communications links (IP or leased line). In practice the physical complexity of commercially available SMS's has required a knowledgeable operator to travel to the remote site for installation. This complexity also complicates troubleshooting site failures remotely.

Single point of failure: As a consequence of the fact that monitoring instructions are configured and maintained locally, if the server fails or has to be swapped out for some reason, configuration information is lost and carriers have to be rebuilt manually. It is possible of course to use independent methods to backup configuration settings, but these methods also add to cost of operational complexity.

Large: With the monitor and keyboard, each commercial system takes up approx. 1/3 to ½ rack space (16 to 24 Rack Units, or RU's) in the remote site—this can be expensive when co-location space is at a premium and the operator of the SMS is paying by the rack unit (1.75").

Vulnerable: Both commercially available SMS's described here use Windows operating systems, which are prone to viruses. It is possible of course to guard against infection and compromise using constant antivirus updates and system patches, but this maintenance adds to the headache and cost of maintaining the system.

Expensive: The expense of commercially available systems is manifested three ways: Initial purchase (approx $40k); recurring licensing (10-15% of purchase price, per year); and indirect costs associated with co-location fees and the maintenance described above. Costs that must also be accounted are travel, shipping, and customs duties for the initial installation.

DESIRED SPECTRUM MONITORING SYSTEM

The "ideal" SMS can be described in terms of the opposite of the limitations described above. It would be small in size, easy to configure, easy to maintain, not susceptible to Windows based viruses, and centrally managed. If a remote unit failed, one should be able to configure an IP address on a replacement unit and ship it out that afternoon. And it should cost a lot less than commercially available SMS's. Following is a description of a combination of a commercially available spectrum analyzer and a set of SCPI scripts that approaches this ideal. This paper describes a process of scripting SCPI commands from a central location to any number of remote LPR-3000R analyzers. This process addresses the fundamental limitations of current commercially available SMS's. Because that scripting can be accomplished at the central HQ and sent out to a remote spectrum analyzer, local configuration is avoided, installation is made vastly simpler, and backup of configuration script is easier. Because the remote unit is a single unit integrated with an RF switch, installation and co-location costs are drastically reduced.

BASIC EXPLANATION

Refer to figure 3. An LP Technologies LPT-3000R remote spectrum analyzer is sited at the remote viewing site. This site is located within the receive footprints of the satellite transponders to be monitored. The frequency response of the analyzer is 9 khz to 3 Ghz. Therefore, in order to monitor downlink signals of C band (4 GHz) or Ku band (11-12 GHz), the down-linked signal is first converted to L-band using a down converter. The LPT-3000R has an embedded switch that allows physical connection of 4 inputs. This embedded switch greatly simplifies its employment as an SMS, as only one set of commands needs to be scripted to provide continuous carrier monitoring where more than one RF input is required to be monitored.

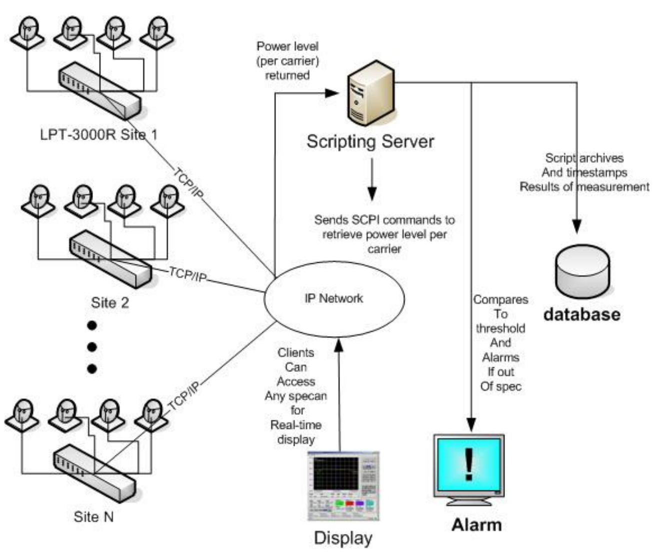

FIGURE 3: SIMPLE SMS USING SCRIPTED SCPI QUERIES

An SMS must provide 2 basic functions: it must allow real-time interaction with the spectrum analyzer to perform ad-hoc 'spectrum snapshots'; and it must routinely sample a designated portion of bandwidth for the presence/absence of a carrier and display or alarm accordingly. The first function is accomplished using a graphical user interface provided with the LPT-3000R. This allows remote communication/control of the unit with all settings expected of a standard spectrum analyzer—center frequency, span, reference level, resolution bandwidth, etc. In addition, the GUI allows selection of the switch position (1 through 4).

An embedded Ethernet TCP/IP port affords communication to the LPT-3000R. Continuous monitoring of RF carriers is accomplished by sending SCPI (Standard Commands for Programmable Instruments) commands to the LPT via this port. SCPI is a standardized set of commands used to set spectrum analyzer parameters and to return measurements from them, in this case power level. In this application, in order to return the power level of a carrier, the following SCPI commands are sent:

Command:	**Function**
:switch 1	(sets switch position)
:freq:center MHz	(sets center frequency of LPT)
:**freq:span** MHz	(sets span)
:band MHz/kHz/Hz	(sets resolution bandwidth)
:band:vid MHz/kHz/Hz	(sets video bandwidth)
:marker:x MHz	(sets marker frequency to center of specan)
:marker y?	(returns power level of marker)

The returned power level is an excellent indicator of whether the carrier is up or down. Typically, depending on carrier power and the size of the receive antenna, this power measurement will be 6 to 15 dB higher than the noise floor adjacent to the carrier.

A simple text based client reads these scripted SCPI commands and sends them to the LPT. The marker power query (**:marker y?**) returns a numeric result, which the client inputs into a text file (temp.txt). The SCPI commands are scripted into a continuous loop, so that this text file is constantly refreshed with a current power reading. In order to monitor multiple carriers, a script is written to run each set of SCPI commands in series, outputting the retrieved power level into a unique folder for each carrier. The scripting language used is not important. This author used a version of visual basic but any simple scripting language will probably work.

The chief advantage of this technique is that because the LPT-3000R is responding to simple SCPI commands and queries, it is very easy to run these commands from a central HQ and not locally at the remote receiving site. This accomplished one of the chief design goals—all the "brains" of the system are back at the central HQ. If a remote unit fails, all that is required to restore operations is to set the desired IP address and ship a replacement unit out. The set of SCPI commands is easily edited and saved for backup purposes.

As described so far, this system will not produce a visual display of current carrier power level; it will merely produce a set of unique folders, one per carrier, each with a temporary file with a power reading. In order to create a true SMS, this must be coupled with software that reads this text file and displays status, and takes some sort of action if the reading is out of spec. This is a common function provided by most network management applications. The author currently uses Ipswitch's "WhatsUp Gold" (WUG) Network monitoring software tool for this purpose, but many others will also work. WUG was selected for its low cost and ease with which a visual basic script can be created that reads the temp.txt file and associates that value with a carrier icon. When the reading is in spec the icon is green, it turns red when out of spec and a host of actions—email, pager, text alert--can be initiated when an out of spec conditions occurs. WUG also stores the result of the measurement in an SQL database, for archiving, and displays both the current state end archived results via a web server—thus, the information is readily available to all customers. Hence the complete SMS as described by this paper consists of an LPT-3000R remote spectrum analyzer at the remote site and a scripting server at the central site that executes the stored SCPI scripts.

Limitations

There are two limitations, relative to commercial SMS's. The first is that technically, this process does not produce a true power reading of the carrier itself. A true power reading would aggregate power measurements over the span of bandwidth covered by the carrier. This process "merely" returns a power reading of a marker set to a specific frequency. However, this difference is largely semantic – in practice, measuring power from a marker set to the center of the carrier returned a very faithful indicator of whether the carrier is up or down. If necessary, it would be possible to construct a set of SCPI commands that returns true carrier power.

The second limitation is that because commands are sent serially across TCP/IP, a larger time is required to complete a measurement relative to commercial SMS's controlled at the remote site. This imposes an inverse relationship between timeliness of the measurement and the number of carriers that can be monitored. For instance, assuming a typical power measurement takes 6 seconds to complete (a typical measurement across the internet in the US), the number of carriers that can be monitored in a 5-minute span is 300/6 = 50. In the DoD contract mentioned at the beginning of this article, the stipulated maximum time-lateness of a measurement is 15 minutes, so for a site with 6 seconds per measurement a maximum of 150 carriers can be monitored. In practice 150 carriers at one site is a large number, and in the authors experience only 1 of 18 operational sites is more than 150 carriers monitored. A simple solution is to put multiple LPT's at a site. Alternatively the scripted queries could be performed by a server locally, which would reduce measurement time owing to less transit time per SCPI command. However this would obviate some of the other advantages of this approach.

Extensibility and Applications

The context of this paper had been in monitoring communications satellite carriers, but its applicability extends to any case where a portion of the RF spectrum must be continuously monitored for activity. For example, it could be used to monitor for Wi-Fi (wireless Ethernet) transmission. An omni L-band antenna would be connected to an LPT, and series of SCPI commands could be scripted to sample power across the 14 allowed Wi-Fi bands. The relatively low cost and small footprint of the LPT would allow a set of them to be deployed over a large area to detect and report transmissions. This would be very useful for security purposes, where a continuous measurement for illicit transmissions was required. In general it is expected that this approach will be useful for any case where a low cost, continuous RF spectrum monitoring system is required.

Future Development

It is anticipated that while the level of effort and technical expertise required is not overly burdensome, not all users would like to delve so deeply into the specific text-based scripting described in this paper. Therefore, the author envisions a Graphical User Interface (GUI) which would simplify the operations described in this paper. Such an application would have all the benefits of the approach described here, with the additional benefit that it would be simple enough that tier 1 NOC operators could configure and measure carriers, and retrieve archived measurements. It is anticipated that this GUI application would be much simpler and inexpensive than any current SMS on the market today.

About the Author

Hank Rausch is a retired Navy Commander from the US Navy Submarine Force. He is a graduate of Stanford University and UCLA. He has worked in the commercial satellite communications industry since 2000 and currently operates a worldwide satellite communications monitoring network. He has published papers on satellite jamming and submarine communications.