Application Note

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Applications of Remote Spectrum Monitoring

Why use remote spectrum monitors?

The use of wireless technology has grown dramatically over the past two decades. The mid-1990s put wireless into the hands of consumers for a wide variety of applications such as cellular telephony, cordless phones, and wireless audio for entertainment. The rise of the Internet and the consumer's desire to be connected to it at all times drove deployment on high-speed data communications on Wi-Fi and 3G/4G mobile networks. Consumer demand for mobile data is exponential and shows no signs of slowing – we consumed mobile data at a rate of over 10 Exabytes per month in 2014, and by 2020 this rate is projected to increase to over 70 Exabytes per month. [“Small Cells and Low Power RRH, March 2015” by Mobile Experts LLC]

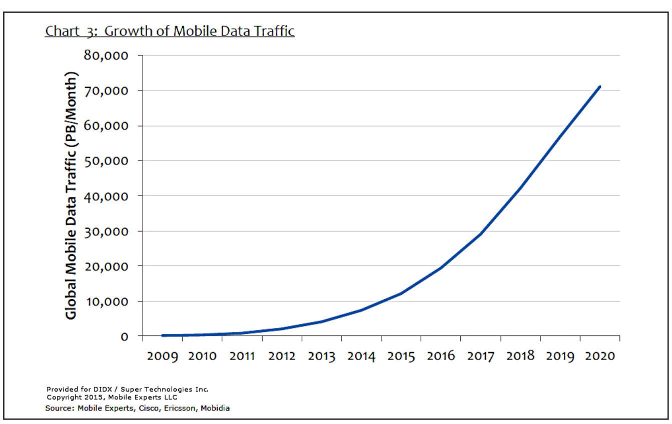

Figure 1: Global Growth of Mobile Data Traffic

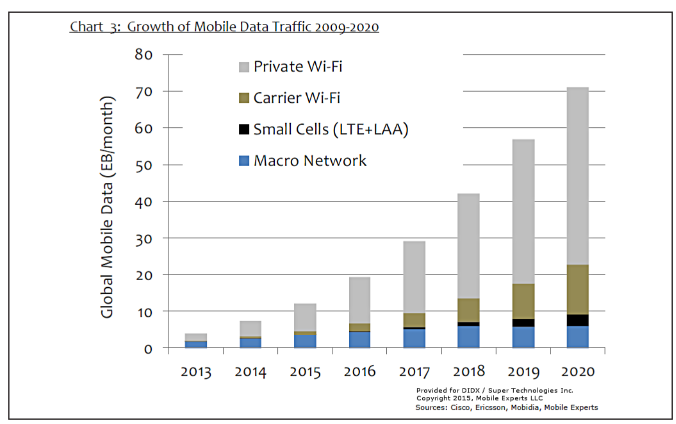

Figure 2: Types of Mobile Data Traffic

Wireless technology, once exclusively the purview of experienced technologists operating under licensing rules, is now in the hands of nearly every consumer. Driven by market pricing pressures and easy access to global markets through an online marketplace, the availability of wireless technology has gone up while the quality of wireless technology has gone down. In November 2015 the American Radio Relay League released data collected over four years of testing on hundreds of handheld radios; testing which found that radios from several manufacturers in Asia consistently failed spurious emission tests. One manufacturer, popular due to the low cost of their product, failed these tests more than 50% of the time for three of the four years, and never failed less than 36% of the time. [Source: “ARRL Laboratory Handheld Transceiver Testing” by L. Wolfgang, ARRL QST November 2015] This might seem trivial until we realize that these handheld radios are actually marketed in the US as commercial radios, and have received Grant of Equipment Authorization under Part 90 (and in some cases Part 95) of the FCC rules. Unlocking these radios is trivial, and once unlocked they can be tuned from 136 – 174 MHz and 400 – 520 MHz with ease, generating spurs at multiples well above their intended transmission frequency.

Figure 3: Handheld radios from Asia often generate spurs in excess of FCC regulations

Anyone who has worked in interference hunting for cellular networks and critical infrastructure can fill a book with anecdotes about uncovering unusual and sometimes bizarre sources of interference. Wireless microphones in karaoke bars purchased overseas and imported illegally are sometimes tuned to licensed cellular frequencies. Nomadic fishermen who follow migrations around the Pacific Ocean are often heard near US shores on public safety frequencies. Young people living near airports with dreams of operating a pirate radio station can easily purchase high-powered FM transmitters that generate spurious emissions in aviation bands. Cellular jammers no larger than a handheld radio can be easily purchased outside the US and imported in carry-on luggage – ignored by overworked security screeners who are looking for guns and bombs, not radios. A major Silicon Valley company spent over two weeks attempting to locate an unusual wideband multi-carrier signal jamming an LTE network – eventually tracking the source to a test platform left energized and forgotten on a rooftop years after the company was acquired and had moved to new location.

Intended, unintended, and spurious emissions from these radios will interfere with licensed communications, and the number of possible interference sources is increasing – it's not a question of if, but when this will happen to you. The question is – how will you prepare and respond? The wireless industry has traditionally relied on technically-focused secondary schools and colleges to provide a pool of hands-on technologists who are skilled at interference hunting, but these resources are expensive and increasingly hard to hire. Remote spectrum monitoring is a great way to maximize the effectiveness of your talent pool, and should be part of your strategic response and mitigation plan.

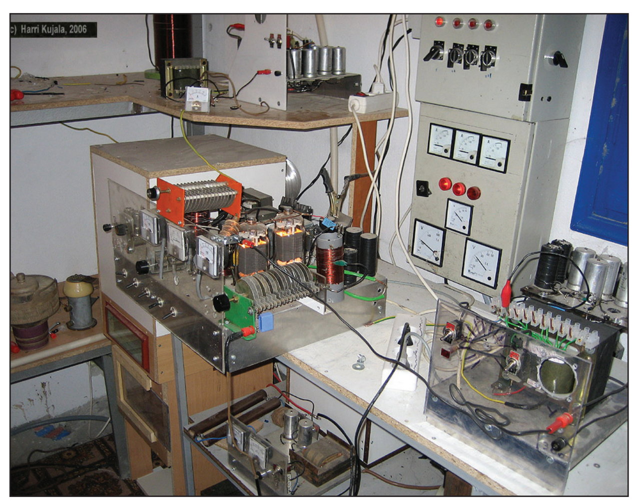

Figure 4: Pirate radio stations can be powerful, or small and harder to locate

Photo credit: H. Kujala

Use models

Deployments of remote spectrum monitoring are customizable for a wide variety of needs. Use models typically fall into one or more major categories:

- **Real-time Remote:** Time spent traveling to and from an area can exceed the time spent doing spectrum monitoring and interference location. Often the source of interference is gone by the time the engineer arrives. Real-time remote monitoring allows you to instantly be “on site” when the need arises, and for engineers to make measurements in several places at once.
- **Spectrum Recording Network:** Most interference hunting engineers work an 8am to 5pm shift but interference affecting public safety, critical communications, and cellular telephony can occur at all hours. Unusual propagation caused by fog and atmospheric temperature inversions often occurs at night, when nobody is around to make measurements. Deliberate interferers (aka “jammers”) will often operate at night or on weekends, when they can maximize effect without being detected. Spectrum recording networks allow engineers to “go back in time” and make measurements on events which occur during off-hours.
- **Alert on Event:** In cases of critical interference, or when interference from a suspected source is transient, it helps to provide engineers with an immediate alert when pre-programmed conditions are met. This is typically done by activating a limit line and generating an email or text message when the signal level exceeds or drops below the limit.
- **Location by triangulation:** By coordinating the on-board clock of at least three spectrum monitoring stations, and knowing the GPS coordinates of the stations, the location of an interference source may be automatically estimated by mathematical methods. While not providing a precise location, location estimation provides an optimized starting point for engineers when beginning their search for an interference source

Technical Requirements

Effective remote spectrum monitoring solutions should have the following characteristics:

- **Fast Sweep:** Ideally at least 20 MHz instantaneous FFT bandwidth to allow nearly real-time sweeps across a wide spectrum.
- **Quiet Receiver:** Spectrum monitors will often be located at high-level sites with good coverage over an area, but because they’re high-level they tend to receive a lot of RF energy from sources within line-of-sight. Also, most high-level sites are already home to transmitters and repeaters for a variety of communications users. Spectrum monitors must have low spurious response to RF inputs.
- **Stable Platform:** After being sited at remote locations, it’s important that remote spectrum monitors provide good uptime and be resilient to firmware stability issues. A good spectrum monitor should always have a default “golden version” firmware to which it can revert if a newer version of the firmware fails. The default firmware should always be able to connect to the network and accept firmware updates from an authorized remote user.
- **Management Software:** Remote spectrum monitors need a unified management system capable of allowing users to control and analyze numerous monitoring nodes at a distance. The management software provides the ability to easily see the status of nodes, their map location, and whether they’re violating any pre-set limit conditions.
- **Rugged:** Remote monitoring locations are often hostile environments. Precipitation, temperature extremes, and dust are common in equipment vaults and rack enclosures. In some cases it’s preferable to locate the equipment outside on a tower.
- **Remote Controllable via Ethernet/LTE Modem:** With monitors potentially being deployed tens or even hundreds of kilometers from the control center, it is imperative that they can be controlled by Ethernet or wireless modems and remain operational under all types of conditions. Look for instruments that have capabilities for remote power cycling, automated system recovery protocols and firmware updates “pushed” to the monitor remotely.

Applications

The potential uses for a remote spectrum monitoring system are numerous, and each deployment can be flexibly configured to meet needs. Some examples of applications and use cases are:

- **Remote spectrum recording:** Typically this is done when a system user complains of interference from an unknown source. In public safety and critical communications users might complain of broken reception (especially in digital voice systems), warbling or squealing (analog heterodyne from co-channel signals), or sporadic interference at certain times of the day or night. Recordings can be correlated with time and location estimation reports from users to determine likely sources and facilitate “spectrum fingerprint” analysis.
- **Spectrum clearing:** In an effort to maximize spectrum use efficiency regulators in many countries have implemented re-banding rules which require users to vacate spectrum and transition to other frequencies. For example: In the US the 600 MHz frequencies formerly occupied by analog television broadcast will be auctioned to mobile telephony carriers, but the rules for this auction are complex and not all broadcasters will be vacating their channels. This means that carriers who want to bid on spectrum will need to monitor and analyze the performance of their bidding targets to determine if interference from co-channel broadcasters might occur during periods of unusual propagation. Also, there are a large number of wireless microphones in use which operate on the 600 MHz band, and not everyone will know they have to stop using them after the auctions are complete.
- **Enforcement & rule-making:** Government regulatory agencies benefit from remote spectrum monitoring because it allows manpower to be effectively multiplied over a wider area and at times when engineers are not normally on duty. Direct savings are realized through reduced time when engineers are on travel, avoiding unnecessary travel, and focusing travel on times and locations where interference is more likely to occur. Prior to rule-making regulatory agencies can use remote spectrum monitoring to analyze and understand real-world scenarios in bands where new services are to be targeted.

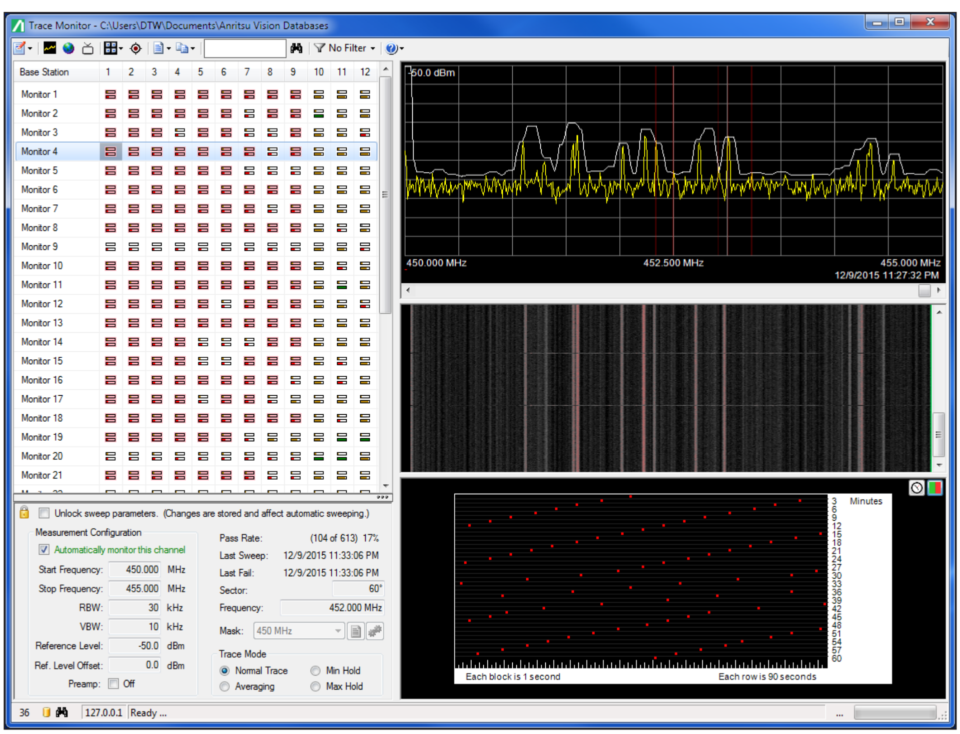

Figure 5: Anritsu Trace Monitor provides multi-station monitoring, spectrogram, and limits

- **Interference hunting:** Interference to mobile telephony can cause subscriber frustration leading to “churn” – where a subscriber switches to another carrier. Mobile telephony is replacing traditional wireline telephony for some subscribers – hence interference to mobile telephony can be potentially life-threatening if calls for police, fire, or EMS do not go through. Intentional and unintentional interference to aviation, maritime operations, critical infrastructure, and public safety creates a potentially life-threatening scenario that must be quickly addressed. Resources for this kind of work are expensive, and the work is time-consuming. Understanding the sources of interference, determining if the interference occurs at specific times of the day, and obtaining location estimates for interference sources is critical to maximizing limited engineering resources.
- **Airport monitoring for interference:** Aviation communications in the area of busy metropolitan airports is especially critical, because the tight timing and coordination of air traffic patterns and runway activity leaves little margin for error. Monitoring for interference in adjacent channels/bands is critical to determine if immediate action is needed.
- **Sports venue monitoring:** Communications are a critical component of American Football. The NFL employs large numbers of engineers and professional volunteers to ensure that coaches, referees, and medical teams can communicate during games. Stadium security, concessions, parking, and cleaning crews also rely on communications to ensure fans can enjoy a clean and safe event. With the massive adoption of wireless devices by consumers, NFL communication engineers and volunteers have an increasingly difficult task of ensuring that interference does not occur. Remote spectrum monitors help multiply resources and provide a dashboard of all radio activity within a sports venue so the efforts of engineers and volunteers can be focused efficiently.
- **Tracking illegal phones in correctional facilities:** Contraband cell phones are a growing problem in correctional facilities. Inmates use them to coordinate crimes outside prisons, to threaten and intimidate witnesses and their families, and to coordinate assaults on other inmates. Spectrum monitoring with real-time alerts and location estimation lets correctional officers and prison officials know that illegal phone use is occurring, and helps them focus efforts efficiently during search and seizure actions.

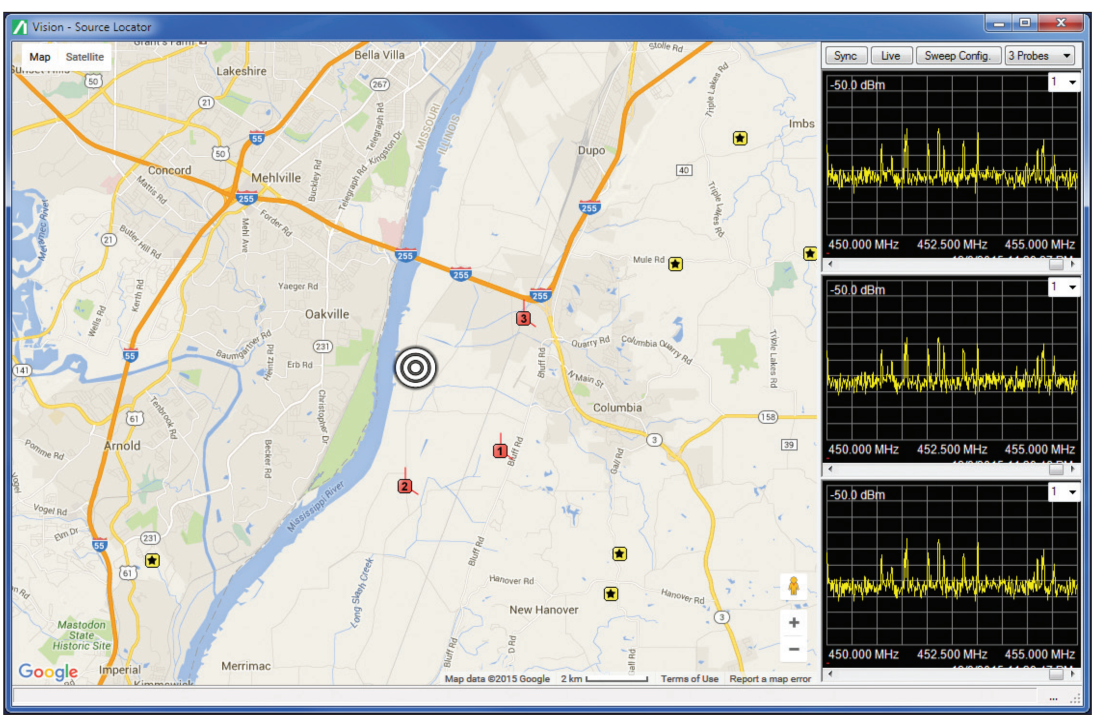

Figure 6: Anritsu Trace Monitor provides multi-station monitoring, spectrogram, and limits

Remote Spectrum Monitoring

With the rapid expansion of wireless communications, the need for robust networks relatively free of interference continues to grow. Capacity can be degraded by the presence of illegal or unlicensed signals that interfere with legitimate transmissions. These signals can be periodic or present at different frequencies over time, making the discovery and removal of these sources of interference a significant challenge.

Spectrum monitoring can also serve to enforce compliance with government regulations. Police, fire fighters, air traffic control, railroads using positive train control, military and emergency services must all have access to communications free of impediments and distortion. Compliance with spectrum regulations is often enforced by spectrum monitoring.

Anritsu offers several models of remote spectrum monitoring products. These include:

MS27101A

Figure 7. MS27101A

The MS27010A is designed for applications such as white space monitoring, harm claim threshold detection, in building interference monitoring, positive train control and research/university applications. Housed in a half-rack enclosure, the MS27101A is the ideal solution for spectrum monitoring where a single RF In (for a single antenna) is required. It is designed to operate in an indoor environment only. Typically these spectrum monitors are positioned in a permanent or semi-permanent location for radio surveillance and monitoring. The MS27101A can also be positioned as benchtop units in lab environments. Government regulators often use indoor monitors for monitoring spectrum usage. In areas where certain frequencies are under-utilized, the spectrum can be re-purposed for other applications. Alternatively, little used spectrum can be shared with other applications using cognitive radio techniques. Research is ongoing in many universities and labs throughout the world for new cognitive radio algorithms. This monitor contains one RF IN port and runs on a DC voltage of 12 VDC.

MS27102A

Figure 8. MS27102A

The MS27102A is rated to IP67 standards for outdoor deployment. It is dust tight (no ingress of dust) as well as water resistant. This involves testing the monitor for immersion into as much as 1 meter of water for durations of up to 30 minutes. Each port on the unit is ruggedized and weatherized. Ports include power, RF Input, Gbit Ethernet and GPS antenna. See figure 8 for port positioning. With an operating temperature range from –40 ºC to +55 ºC, a rugged weatherized case and splash proof design, the MS27102A works in the most extreme weather conditions with guaranteed performance anywhere and anytime. Key applications include the following:

- Radio surveillance and monitoring
- Detection of illegal or unlicensed transmitters, including AM/FM and cellular broadcasts
- Coverage measurements
- Spectrum occupancy and frequency band clearing
- Fast and efficient detection and elimination of interference sources
- Monitor jails/prisons for illegal broadcasts
- Security at military facilities, national borders, utilities, airports and other sensitive sites
- Spectrum monitoring associated with lab RF testing
- Government regulators enforcing spectrum policies

MS27103A

The MS27103A (fig 9) provides 12 RF Input ports as a standard configuration. This model is typically used with 3 sector BTS architecture, with multiple carriers per sector. A high speed switch is placed in the monitor to provide measurement capability for each RF input. This electronic switch can move from port to port in approximately 300 ns. A greater than 30 dB isolation is provided between each RF Input port to assure the integrity of the measurement.

Figure 9. MS27103A 12 RF input ports.

Option 424 allows the MS27103A to be upgraded to 24 RF Input ports. This option is optimal for 6 sector BTS operation or other applications where access to a large number of antennas and frequency bands is required. The monitor operates with either a 220V/110V AC source or –48 VDC supply. The MS27103A is environmentally friendly, typically consuming less than 11 Watts. Key applications include the following:

- Network interference monitoring
- Geo-location of interference signals
- Maintain history of spectrum activity
- Set power threshold levels to automatically generate alarms
- Generate records of interference events for potential legal action

Vision (MX280001A) Spectrum Application Software

Vision™ software (MX280001A) is optionally available for use with the MS27101A hardware platform. Vison software provides complete command and control of all spectrum monitoring monitors deployed in the field. Vision operates on Windows based PCs/servers, communicating with the MS27101A via Gigabit Ethernet. Alternatively, a USB cellular modem can be used for communications.

Figure 10. MX280001A Spectrum Application software.

The Vision™ software platform works with Anritsu's spectrum monitoring hardware to automate the process of collecting measurement data, providing useful information about network health and use of the spectrum. Using multiple hardware monitors covering a wide geographical area, Vision presents a comprehensive picture of spectral activity to assist users in monitoring the spectrum for unusual activity.

Vision software facilitates a variety of applications used for spectrum monitoring systems. One important application includes determining the presence of interferers in a network which can degrade communications services. Cellular operators in particular are vulnerable to such interference that manifests itself in slower data rates and dropped calls. In most cases, network performance is compromised on the uplink frequency bands (communication from the mobile unit to the base station). However, network quality of service can also be impacted by interference on the downlink channels. This type of interference can be prevalent at the cell periphery where the power levels of the interference signals approximate those transmitted by the base station itself.

Another important application for Vision software is the detection of illegal or unlicensed broadcast signals. Illegal broadcasters may set up AM/FM, cellular or other types of transmissions which must be identified and ultimately located. By using spectrum monitors, unlicensed broadcasts can be tracked, processed and stored in a database for further examination and potential use in legal proceedings.

Conclusion

Remote spectrum monitoring plays a critical role in how governmental, regulatory and commercial enterprises deal with interference within the licensed spectrum. Knowing the tools available to them helps entities make an informed decision when selecting a solution for their particular application.

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