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Effectively Testing 700 MHz Public Safety LTE Broadband and P25 Narrowband Networks

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In times of great emergency (such as the September 11th attacks, Hurricane Katrina, or the 2010 oil spill in the Gulf of Mexico) access to reliable, integrated communications and tactical information is absolutely critical. Unfortunately the ability to mount a coordinated inter-agency response to major threats is often hampered by the proliferation of divergent signaling standards and non-aligned spectrum planning. APCO Project 25 (commonly called "P25") digital radio systems are typically used as a solution to the voice communications aspect of this problem. However while P25 systems might effectively support mission-critical voice and low-bandwidth data applications, they fail to provide the high-speed data performance necessary to support the multimedia applications on which today's public safety agencies are increasingly relying. During the 2007 collapse of the I-35W bridge in Minneapolis, Minnesota the availability of a municipal Wi-Fi network covering the impacted area proved to be an invaluable tool for the emergency response. The 3GPP 4G Long Term Evolution (LTE) standard offers a solution to the need for wide-area broadband public safety networks, serving as the preferred broadband technology of choice for the 700 MHz public safety radio band. Now, an LTE-based network can be overlaid on the P25 Land Mobile Radio (LMR) network to deliver both the speed and low latency required to provide public safety agencies with the advanced multimedia capabilities they demand.

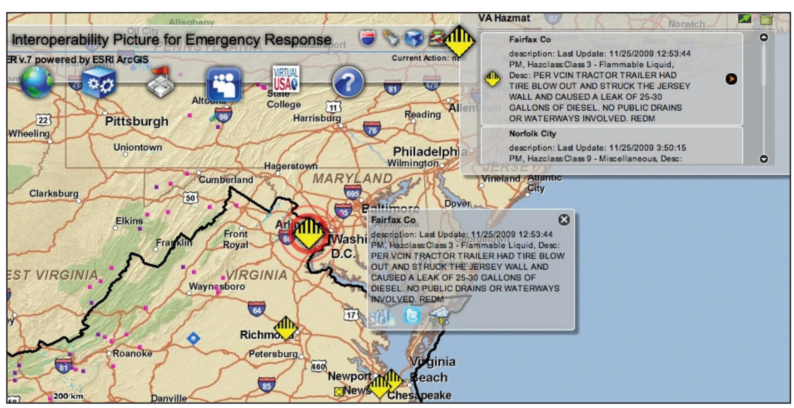
Using LTE for the 700 MHz broadband public-safety network provides public safety agencies with a number of key benefits, not the least of which is the ability to take advantage of the rapidly expanding cellular infrastructure. Additionally, public safety agencies can leverage the same functionality that consumer 4G customers enjoy, including greater economies of scale (e.g., a lower cost/bit). Of course, like the P25 standards, LTE also poses some interesting measurement challenges for installers, maintenance technicians, system technologists and site/system engineers. In this case, a key challenge is that they must verify the proper operation of, and diagnose problems for, the LTE network and the P25 digital LMR network—both of which must be quickly and cost-effectively tested in the field. Meeting these needs demands a measurement solution that offers a quick and easy handheld approach to testing both 700 MHz LTE and P25 digital LMR networks.

Next-Generation Public Safety Communication: Interoperable Broadband/ Narrowband Networks

Public safety is today undergoing a transition, from voice and low-bandwidth data applications carried on 700 MHz P25 narrowband networks to more advanced data-intensive applications supported by a 700 MHz LTE broadband network overlay. For public safety agencies, the result of combining the two networks is obvious: a unified broadband/narrowband communications infrastructure featuring the strengths of both technologies and on-going access to the continual advances being made with commercial cellular technologies and networks.

In operation, this combination would comprise an integrated network of mobile devices like 50-watt P25 mobiles with hot spots located throughout cities for LTE. As a ubiquitous system, P25 would remain the lifeline for public safety agencies. LTE would then offer them real-time access to an array of high-bandwidth applications that simply cannot be supported over narrowband wireless technologies like P25. These applications include, but are not limited to:

- High-speed Internet access to network systems and other systems/services available over the public Internet, for things like email and text messaging;
- VPN access for remotely accessing authorized sites and networks (e.g., the Incident Command System (ICS), and databases/report management systems);
- Status/information Short Message Service (SMS) and Multimedia Messaging Service (MMS) messaging;
- IP-based voice communications (including interoperability with legacy and new LMR infrastructure through the use of appropriate gateways) with things like push-to-talk services, biometrics, and telemedicine;
- Automatic vehicle location;
- Digital imaging;
- Streaming video (e.g., remote monitoring, surveillance at an incident, and high-resolution two-way video conferencing); and
- Full-duplex calling to any telephone device on the Public Switched Telephone Network (PSTN) with functionality comparable to that delivered with today's cell phones.



By providing access to these types of applications, the LTE overlay will further improve communication and collaboration between different public safety agencies and first responders, increasing their response time and efficiency in the field, and improving public safety and security. And, because LTE uses standardized protocols and interfaces, users beyond the range of their home public safety network will also have the ability to maintain a connection using a local public safety 700 MHz network or a commercial wireless network.

While this public-safety transition is being driven by the industry's demand for advanced data capabilities and, in turn, an increasing need for more spectrum, its beginning stems from an action taken by the Federal Communications Commission (FCC) in 2007. That year it authorized a spectrum-channelization plan that freed spectrum in the 700 MHz band (frequencies between 698 and 806 MHz) to enable creation of a national broadband public safety network that would ensure interoperable broadband and narrowband service for public safety agencies. The plan redistributed the upper 700 MHz band and established three spectrum blocks for communications between public safety agencies (Figure 1). These blocks included: a commercial block (758-763 MHz and 788-793 MHz), known as the upper D block; a public safety broadband block (PSBB); and a public safety narrowband block (PSNB) that was awarded to the Public Safety Spectrum Trust (PSST).

This plan established the framework for overlaying a 700 MHz broadband data network on a 700 MHz P25 digital LMR network to create a single, integrated public safety network. In March 2010, the FCC took things one step further by releasing the National Broadband Plan (NBP), which made significant recommendations for improving access to broadband communications across America. The plan included a recommendation for the utilization of 10 MHz of dedicated 700 MHz spectrum in the upper D block for creation and deployment of a nationwide, interoperable public safety broadband wireless network. It further recommended that commercial technologies and infrastructure be leveraged in the network's creation to ensure its cost-effectiveness. LTE was selected as the technology of choice for this 700 MHz public safety broadband network. In February 2012 the US Congress enacted the "Jobs Act" which allocated 20 MHz of 700 MHz spectrum and US$7 billion to support creation of a nationwide LTE broadband network to be governed by the NTIA's "First Responder Network Authority" (FirstNet).

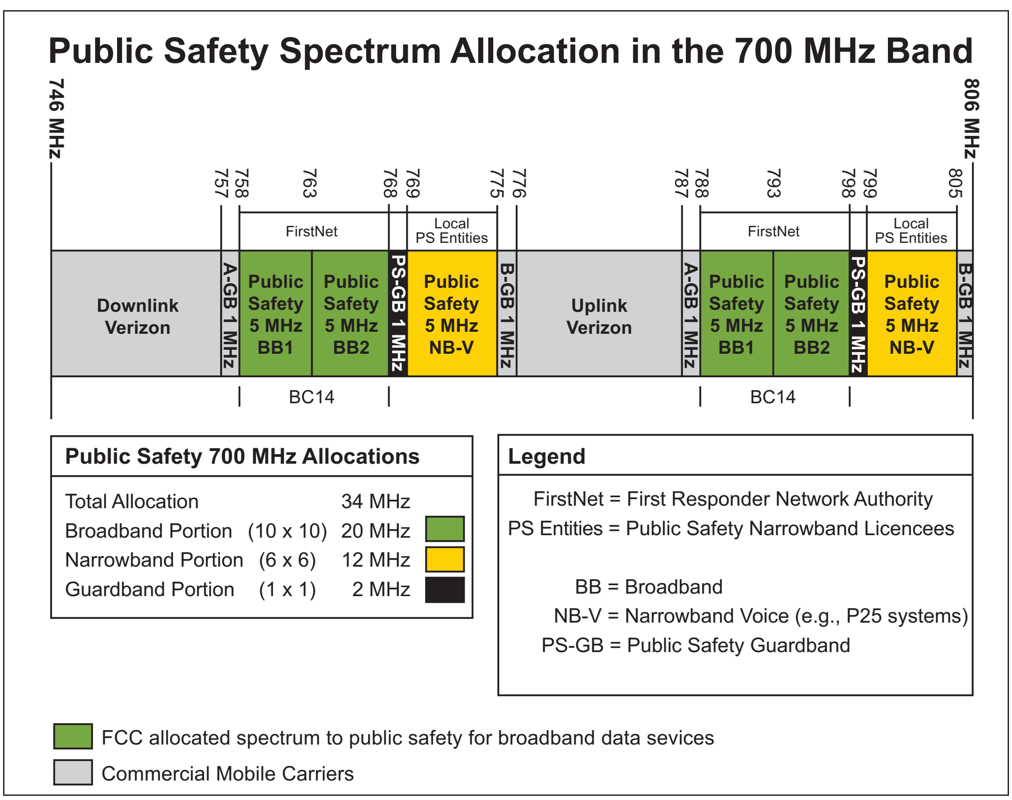


Figure 1. By redistributing the 700 MHz band, the FCC addressed public safety needs for a nationwide wireless broadband network that could provide public access to modern technologies like LTE. The FirstNet allocation will provide nationwide broadband resources to public safety in times of emergency.

700 MHz LTE Technology Overview

LTE's functionality makes it highly attractive for the 700 MHz public safety broadband network. Considered a 4G technology, it supports mixed data, voice, video, and messaging traffic. LTE is characterized by downlink peak data rates of over 50 Mbps and an uplink rate of over 25 Mbps with a 10 MHz channel bandwidth, and multiple antenna configuration.

The key advantages often associated with LTE include: 10x lower cost per bit, high throughput, low latency, scalable bandwidth capacity, support for both frequency division duplexing (FDD) and time division duplexing (TDD) in the same platform, an improved end-user experience, a simple IP network architecture resulting in low operating costs, and backwards compatibility with older network technology (e.g., GSM and UMTS). In addition, LTE can be organized using a cellular configuration to optimize capacity for point-to-point data traffic flows and access to centralized databases.

To deliver on its promise of improved throughput and coverage, LTE relies on advanced technologies like Orthogonal Frequency-Division Multiple Access (OFDMA) and Multiple Input Multiple Output (MIMO) smart antenna technology. OFDMA allows multiple access on the same channel and can therefore accommodate many users in the same channel at the same time. MIMO uses multiple antennas at both the transmitter and receiver to improve communication performance by either increasing the coverage or the user data throughput.

Capacity Concerns

The issue of network capacity is perhaps one of the biggest concerns when it comes to the public safety network. Will the 700 MHz public safety spectrum be able to provide the capacity and performance necessary for day-to-day communications and serious emergency situations? In the Spring of 2011 field tests were performed on the San Francisco Bay Area UASI (Urban Area Security Initiative) LTE test bed to determine network performance under heavy traffic loading. (Andrew Seybold Inc., *http://bit.ly/seybold_lte*) Results showed that at least a 10x10 allocation would be required to support real-world usage scenarios. Given proper site deployment and intelligent control of when and the how user equipment accesses the network, it's likely that the FirstNet allocation will support most (if not all) public safety usage scenarios.

LTE can provide more capacity (Mbps) per MHz of spectrum in any given cell than earlier technologies. As LTE evolves and incorporates even newer technological advances, further improvements are expected. And, by employing LTE for its 700 MHz broadband network, the public safety community will see increases in spectral and other operating efficiencies, as well as cost, much more quickly. That's because as a commercial technology, LTE will advance faster than a technology developed for a niche market. Additionally, these LTE network upgrades will mean plenty of room for expansion and growth of the 700 MHz public safety broadband network.

LTE also holds promise for the priority access and roaming (onto commercial networks) scheme recommended by the NBP to accommodate large capacity spikes during time of worst-case emergency. It allows network operators to assign different priority levels to different users or services, essentially restricting use of network resources by low-priority users. In addition, Internet Protocol and LTE technologies make it possible to prioritize traffic in a way that enables capacity to be transferred to the highest and best use.

One issue that has the ability to negatively impact network capacity is interference; a problem that serves to underscore the importance of appropriate measurement instrumentation. Interference can be problematic to P25 LMR networks because it can block distant users. In contrast, LTE employs techniques like Inter-Cell Interference Coordination (ICIC) to improve performance at cell edges by reducing interference. Because of this, the potential for interference problems in LTE systems is greatly reduced.

P25 Technology Overview

The P25 standards address the public safety's need for greater spectrum efficiency by defining digital codec standards that reduce channel size from 25 kHz today, to 12.5 kHz in P25 Phase 1, and in Phase 2 to 6.25 kHz equivalent (12.5 kHz channel w/ 2-slot TDMA). In addition to more efficient spectrum use, the P25 standards enable public safety radio networks to deliver voice access in less than 1.3 seconds from button press. They also provide reliable, simultaneous voice communications to 100's of responders in each talkgroup (assigned groups on a trunked radio system), and support direct mode communication when the local infrastructure is down or users are out of network coverage.

P25 standards define the interfaces, operation, and capabilities of any P25-compliant radio system. P25 radios communicate in analog mode with legacy radios and in either digital or analog mode with other P25 radios. This backward compatibility with existing analog radio systems allows P25 users to gradually transition to digital while continuing to use analog equipment. An open interface to the RF Subsystem, included in P25 radios, facilitates interlinking of different vendors' systems.

When operating in digital mode, P25 radio systems can be either conventional or trunked. Conventional systems employ a relatively simple geographically-fixed infrastructure (e.g., a repeater network) that serves to repeat radio calls from one frequency or channel to another. System operation is user controlled. In contrast, the management of a trunked system's operation, including call routing and channel allocation, is automatic (Figure 2). A group of traffic channels are automatically shared among a large group of users in a talkgroup. As users request access, a controller in the infrastructure assigns the calls to specific traffic channels. This control channel is unique to every city and state, and is set by technicians. Each public safety organization manages its own channel. P25 digital trunked systems can be optimized for low-latency, mission-critical wide area group calls using standard multicast and simulcast configurations.

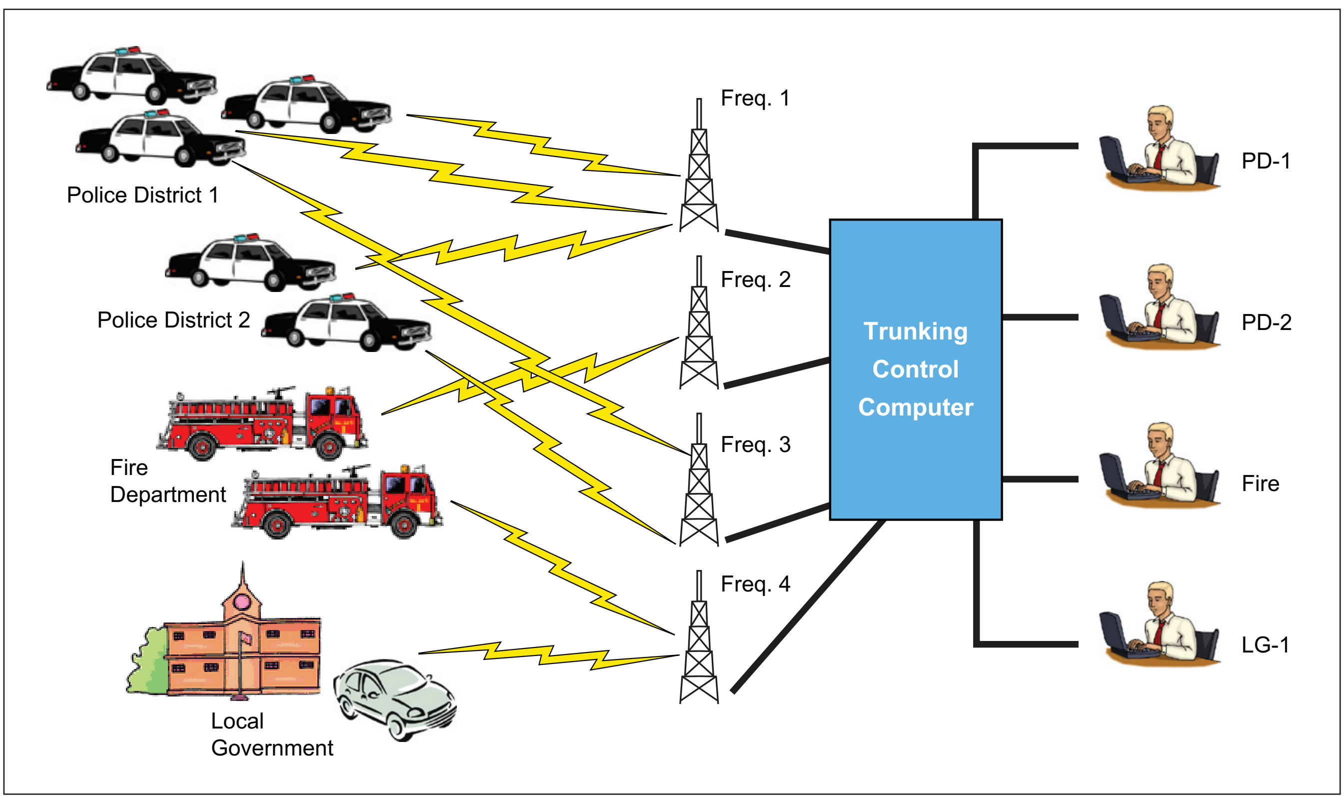


Figure 2. With trunked P25 radio systems, a limited number of channels are shared among a large number of users.

Testing the 700 MHz Public Safety LTE/P25 LMR Network

Despite the benefits of augmenting a 700 MHz P25 LMR network with a 700 MHz LTE data network, verifying the proper operation of associated base stations and mobile devices in the field, and then diagnosing problems when an issue is found, is a challenging task. By its very nature, LTE is a highly complex technology, made all the more so by its variable channel bandwidths and use of both MIMO and OFDMA to support high data rates. And, corrections and additions are still being made. Additionally, with digital communications systems like P25, multipath and fading can degrade signal quality and in turn, communications, even when the signal strength is adequate. Handheld test equipment that can deal with both the complexity of testing LTE networks and mapping bit error rate (BER) and modulation fidelity of P25 networks is critical to providing technicians and engineers that install and maintain public safety communications systems with confidence that these networks will work as expected. Unfortunately such measurements often require a number of different tools, all of which must be carried into the field.

The Anritsu S412E LMR Master is the industry's first and only battery-powered Land Mobile Radio (LMR) field analyzer, capable of testing both 700 MHz LTE broadband and P25 LMR narrowband networks (Figure 3). It accomplishes this by combining many of the tools needed to install, maintain and certify LTE and P25 systems in a single instrument with a single user interface, including: a 2-port vector network analyzer (500 kHz to 1.6 GHz), spectrum analyzer (100 kHz to 1.6 GHz), LMR signal generator (500 kHz to 1.6 GHz), and internal power meter (10 MHz to 1.6 GHz). Users can then select from optional features like an interference analyzer, coverage mapping (indoor and outdoor), and an internal GPS receiver. The spectrum and vector network analyzer frequency range can be optionally extended to 6 GHz. With such functionality, this compact, handheld multi-function analyzer significantly reduces the number of different tools technicians and engineers need to verify operation of wireless network infrastructure and to diagnose problems in the field.

Figure 3. The Anritsu LMR Master is the ideal solution for Public Safety System technicians and engineers testing the RF performance of LTE and P25 radios in the 700 MHz band.

For 700 MHz networks, the LMR Master features a family of optional LTE measurement capabilities that can be used for FDD LTE test on the downlink. An RF quality analyzer, for example, can be used to make a range of RF measurements, including channel spectrum (channel power and occupied bandwidth), reference signal power, and spectral emission mask (Figure 4). Understanding how the LTE resources are being utilized over time is critical; modulation displays such as Power vs. Resource Block are used to confirm signal level, utilization, and other critical parameters (Figure 5). The LMR Master also supports Over-the-Air (OTA) scanner measurements for measuring LTE DL coverage quality, including six sync power levels and dominance greater than 10 dB (Figure 6). The OTA scanner validates sectors present in a given location.

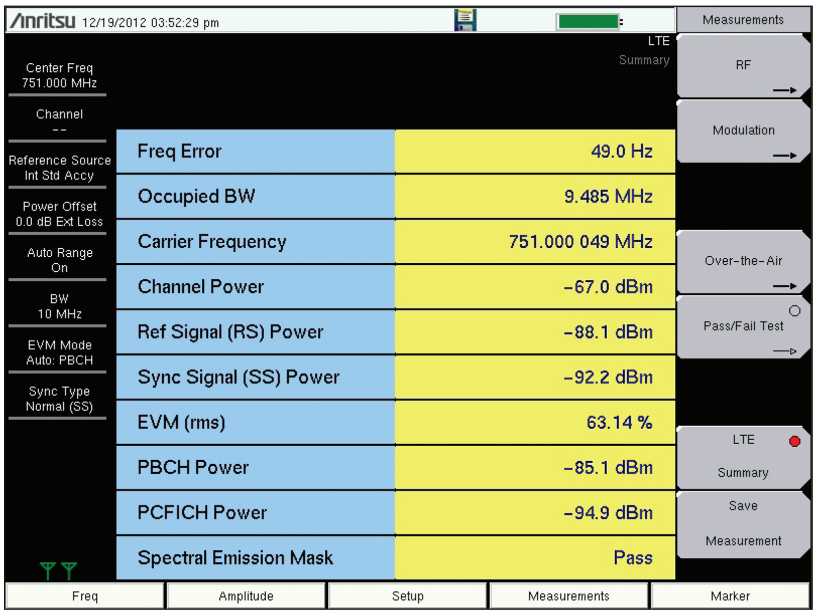


Figure 4. The S412E's RF quality analyzer can be used to perform RF measurements. The analyzer provides the user with an RF measurement summary, shown here, which summarizes all measurement results.

Figure 5. Power vs Resource Block (PvRB) is a critical measure of LTE modulation quality which shows the power level in each resource block as the subframes progress in time. The measurement shown here is made with the LMR Master's LTE Analyzer. Erratic or low PvRB can be caused by a number of factors including distortion in the channel cards or a fault in the power amplifier, filter, or antenna system. Such faults can lead to dropped calls, low data rate, low sector capacity, and blocked calls.

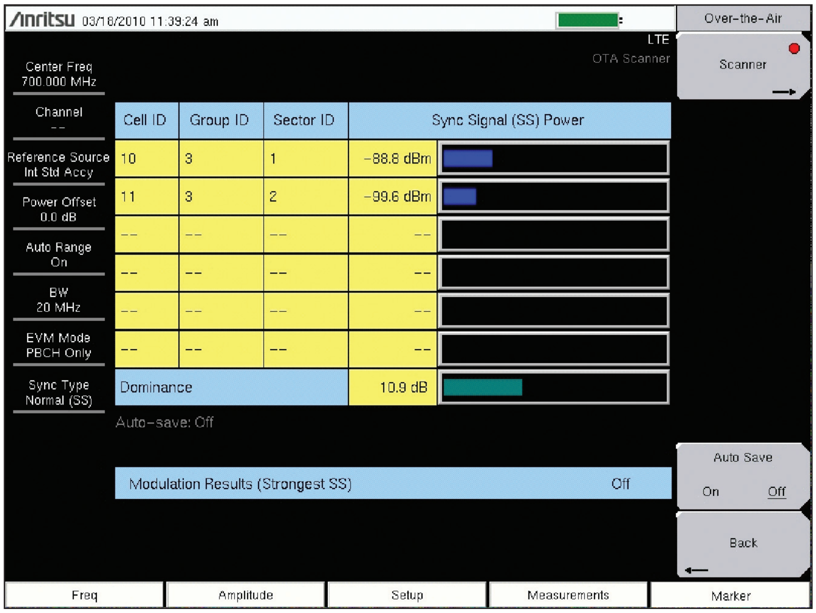


Figure 6. The LTE synchronization signal scanner test, shown here, is performed during OTA measurements. The synchronization signal power tells the engineer which sectors are present at the current location. Too many strong sectors create frequency avoidance that can diminish capacity and lead to low data rate.

OTA measurements allow the site technician or RF engineer to spot-check the LTE transmitter's coverage and signal quality without taking the cell site off-line. If the results are ambiguous, a direct connection to the base station can be established to check the signal quality and transmitter power. A range of measurements can then be performed to help troubleshoot and detect subtle characteristics of the device under test (base station), such as whether or not the signal to the base station is correct. Possible measurements include Adjacent Channel Power Ratio (ACPR) and EVM.

The LMR Master also features an LTE Pass/Fail mode that can be used to set up common test limits, or sets of limits, for each instrument. This mode is especially crucial for identifying the inconsistent settings between base stations, which can lead to inconsistent network behavior.

The information obtained from each of these LTE-related measurements is essential to ensuring accurate power settings, low out-of-channel emissions, and good signal quality—all attributes that help create a low dropped call rate, a low blocked call rate, and, in turn, a good user experience for public safety agencies.

For P25 networks, the S412E LMR Master supports an optional P25 transmitter analyzer (including P25 signal generation) and P25 BER coverage mapping (Figure 7). Using these options, the LMR Master is able to measure most of the components of the P25 system (e.g., the antenna, cable, and transmitter duplexer combiner), as well as P25 control channels (Figure 8). The S412E LMR Master also uniquely has the ability to perform first layer protocol analysis on P25 trunked systems.

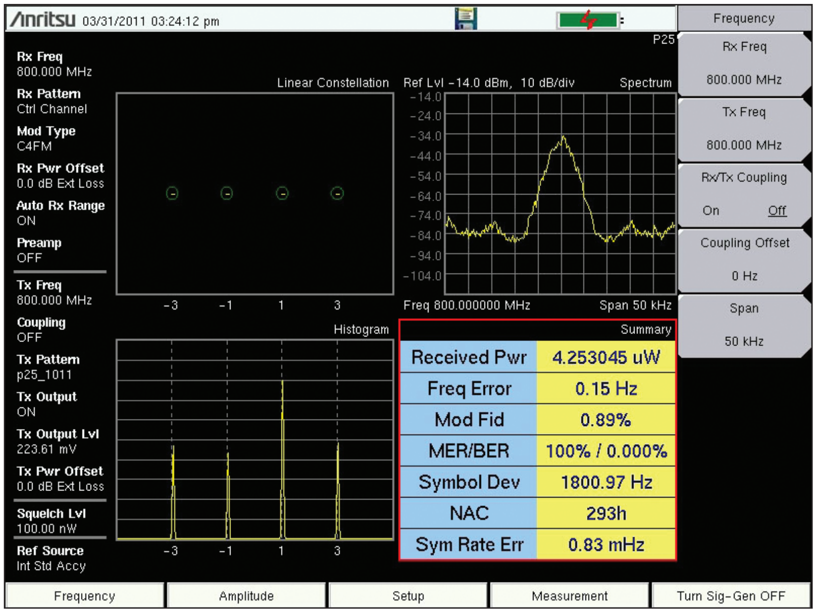


Figure 7. The optional P25 analyzer supports measurement of conventional and trunked Phase 1 P25 systems and includes a signal generator to support receiver sensitivity tests. The P25 BER coverage mapping option allows in-service testing of P25 systems on voice and control channel traffic, plus out-of-service testing with PN9 and 1011 Hz patterns.

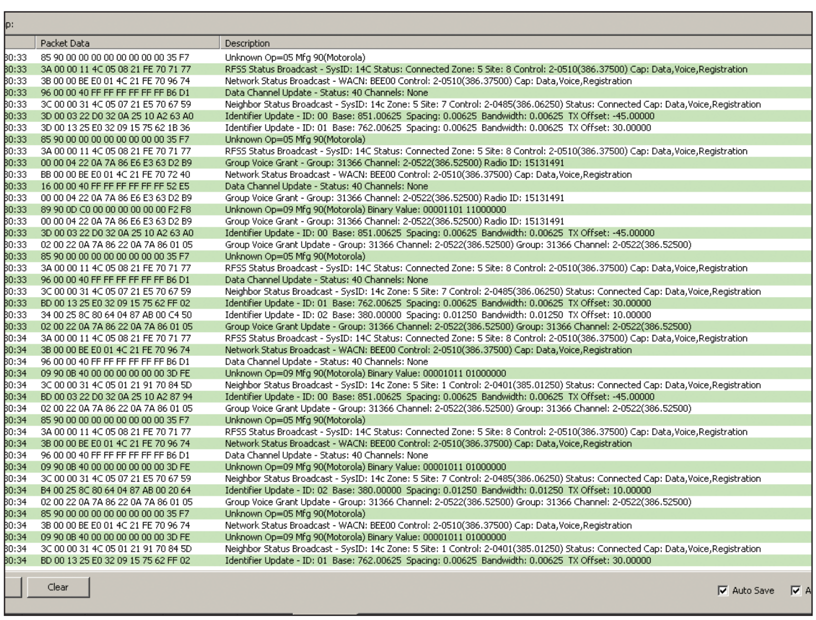


Figure 8. LMR Master measures P25 control channels and displays decoded control-channel messages.

Pairing the S412E LMR Master with Anritsu's MT9090A Network Master results in a complete suite for testing the backhaul. The MT9090A is a palm-size modular platform with a high-resolution indoor/outdoor display, excellent optical performance, innovative features, and expandable modular design that helps technicians and RF engineers quickly and cost-effectively isolate network problems. Users can interchange different modules to configure the MT9090A as an optical fault locator, CWDM optical channel analyzer, or 10/100/1000MB Ethernet tester (Figure 9).

Figure 9. The modular design of the MT9090A Network Master enables technicians/RF engineers to quickly, easily, and cost-effectively locate optical faults, analyze optical channels during installation/maintenance of CWDM networks, test Gigabit Ethernet, or install/troubleshoot Ethernet communication lines.

Summary

Next-generation public safety communications will be defined by a ubiquitous 700 MHz P25 LMR network overlaid with a 700 MHz LTE broadband network. Ensuring these networks are properly installed and maintained is critical to ensuring mission-critical public safety communication and keeping the public safe. The Anritsu S412E LMR Master is the only solution on the market today that provides a quick, easy, and cost-effective means of verifying the operation of both 700 MHz P25 narrowband and LTE broadband networks, and when necessary, diagnosing problems. With the need for spectrum and advanced data capabilities increasing in public safety, such capabilities are essential to the successful deployment and operation of a nationwide 4G wireless public safety network overlay to the P25 LMR networks.

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