Application Note

Measuring LTE Modulation Quality Over-The-Air with a Handheld Instrument

Introduction

Most major mobile carriers in the United States and many worldwide carriers are in the process of converting their networks to Long Term Evolution (LTE), the next generation of radio technologies designed to increase the capacity and speed of mobile networks. LTE utilizes multi-antenna techniques such as spatial multiplexing, beamforming, and transmit diversity to support higher data rates and improve coverage. These same multi-antenna techniques, however, create challenges for base station engineers and technicians in performing basic measurements such as modulation quality. These challenges can be circumvented by connecting the instrument directly to the transmitter, but this method has problems of its own such requiring considerable additional time and possibly having to take the transmitter off the air.

At the same time, wireless operators are being pressured to reduce costs, yet improve network quality. By making Over-the-Air (OTA) modulation quality measurements, along with Pass/Fail, Scanner, and throughput tests, LTE eNodeB performance can be quickly verified and trouble spots easily detected.

This application note presents a simpler and faster method of measuring modulation quality—making the measurement over-the-air with a handheld instrument. This method is based on the fact that control channels do not use spatial multiplexing or beamforming because they have to operate over the entire cell, including at the cell edges. Over-the-air measurements of LTE modulation quality are not intended to replace direct-connect measurements because direct-connect measurements are more accurate and comprehensive. However, over-the-air measurements are much faster and more convenient so they provide a valuable tool to help meet the challenge of delivering seamless LTE service.

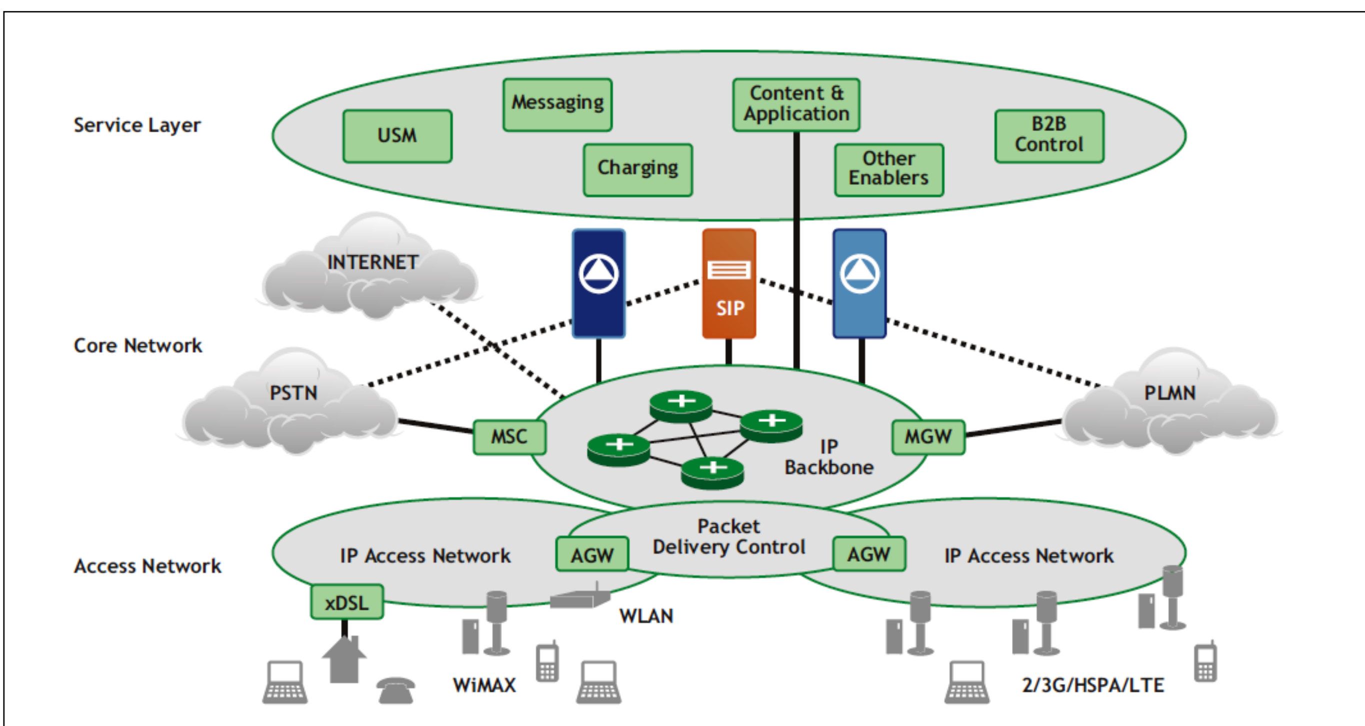

Figure 1. LTE provides mobile access to all-IP core.

LTE is a step toward the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks. The main advantages of LTE are high throughput, low latency, plug and play, an improved end-user experience and a simple architecture resulting in low operating costs. A variety of multi-antenna techniques play a key role in delivering these performance improvements. Transmit diversity uses signals that originate from two or more transmitters with identical data streams, but different coding; this helps overcome the effects of fading, which is one of the major limitations of wireless systems—especially at the cell edge where the signal strength is low. Spatial multiplexing uses multiple input multiple output (MIMO) wireless communications to transmit independent and separately encoded data signals from each of several transmit antennas. Receivers use matrix mathematics to separate the two data streams and demodulate the data. Transmitting data in multiple streams in parallel improves bandwidth but requires a relatively high signal-to-noise ratio. Beamforming uses patterns of constructive and destructive interference on the wavefront to increase and decrease the signal in specific areas, thus improving the SNR at the receiver while decreasing interference.

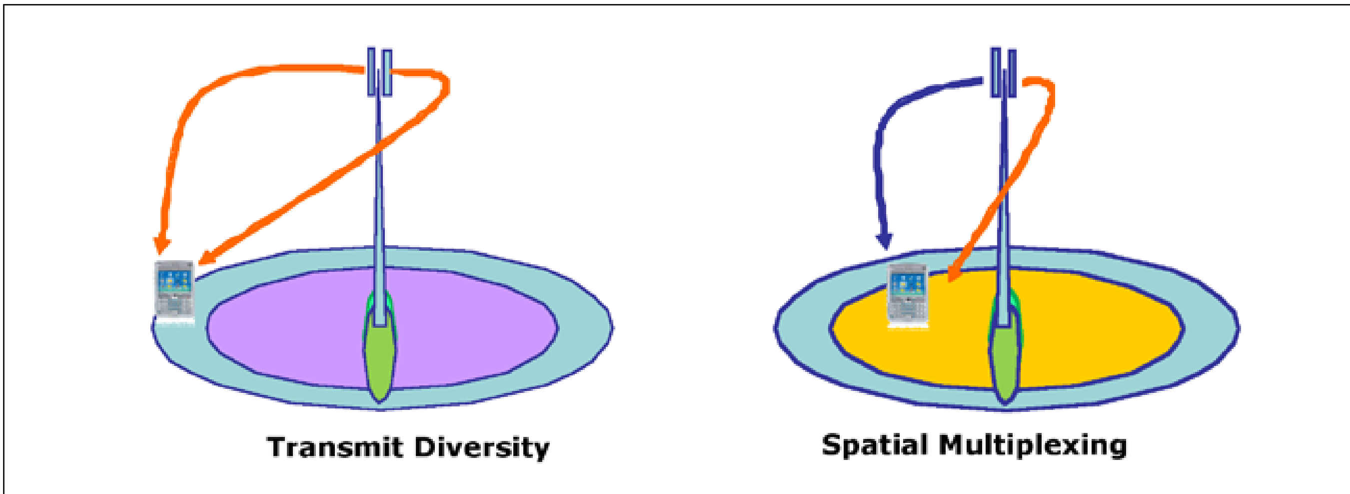

Figure 2. Transmit Diversity and Spatial Multiplexing are 2 key multi-antenna techniques.

Challenge of LTE modulation quality measurements

Multi-antenna methods also increase the difficulty of basic operational and troubleshooting techniques that were much easier with the previous generation of network technology. Spatial multiplexing and beamforming provide the biggest challenges for over-the-air measurements; the dynamic nature of which multi-antenna technique is used at any given moment adds even greater complexity. With spatial multiplexing the different antennas appear to be co-channel interference to a single receiver, thus necessitating a very expensive and heavy measurement device with multiple receivers. Beamforming can also present problems because it increases or decreases the amount of power received in particular areas on a continually changing basis—making reliable measurements of the signal impossible for a passive measurement device. While transmit diversity does not present a measurement problem (because multiple antennas' signals can be recovered with a single receive channel), each Physical Downlink Shared Channel (PDSCH) used to transmit LTE data can change multi-antenna mode dynamically based on signal conditions per user. When looking at a captured signal with a measuring instrument, it's impossible to know if each resource block uses spatial multiplexing, beamforming, or transmit diversity.

Of course, you can avoid these complications by directly connecting the instrument to the transmitter. This approach provides the most thorough and accurate measurements of modulation quality so it is essential in many cases. However, there are a number of limitations associated with direct-connect measurements. It takes time to open up a shelter or building. If the transmitter has a test port then connecting to the instrument is not a problem. If there is no test port, then you have to disconnect the transmitter from the antenna which is usually difficult and time-consuming. If the site uses a Remote Radio Head (RRH) or Remote Radio Unit (RRU), then you need to gain physical access to the RF signal. This may not be difficult if the RRH/RRU is mounted inside a building or on a roof with reasonable access, but if the RRH/RRU is mounted on a tower or inaccessible roof, then you need to climb the tower or otherwise get access to the transmitter—usually a difficult and expensive process.

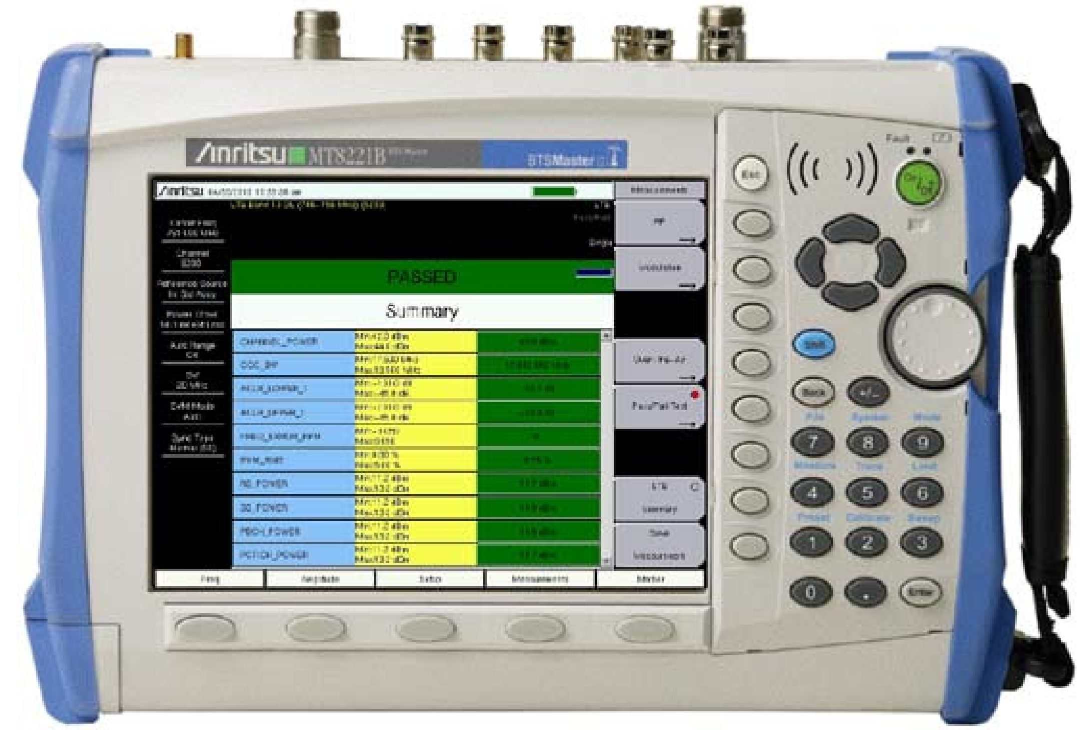

Figure 3. Anritsu BTS Master MT8221B.

Over-the-air modulation measurements with a handheld analyzer

Making measurements over the air is much easier and faster which is always important for technicians and engineers with many responsibilities and limited time. Speed is particularly important when troubleshooting a reported problem. Anritsu has introduced LTE measurement options that enable its MT8221B BTS Master handheld base station analyzer and other instruments to perform over-the-air modulation quality measurements as well as a broad range of other LTE measurements. The new measurement options on the MT8221B accurately and easily measure all LTE bandwidths and frequencies. Besides the BTS Master MT8221B, LTE modulation quality measurements can also be performed with the Cell Master MT8212E and MT8213E, Spectrum Master MS2712E, MS2713E, MS2721B, MS2723B and MS2724B, and BTS Master MT8222A.

The MT8221B BTS Master base station analyzer was selected as the primary platform for over-the-air modulation quality measurements because it was developed specifically to support emerging 4G standards such as LTE, including 20 MHz demodulation capability. The BTS Master MT8221B is small, lightweight and battery operated, making it easy to use anywhere at a cell site. It also includes a complete suite of measurement capabilities for measuring all key aspects of base station performance, including line sweep, spectrum measurements, interference hunting, and backhaul verification. Another advantage of BTS Master handheld base station analyzers is that they are already widely used by base stations technicians and RF engineers for accurately and quickly testing and verifying the installation and the commissioning of base stations and cell sites for optimal wireless network performance. These instruments can be easily upgraded to LTE capability.

The Anritsu handheld LTE measurement suite is comprised of several options. Options 541 (LTE RF Measurements), 542 (LTE Modulation Measurements), and 543 (15 & 20 MHz LTE Bandwidths) are used to validate the performance of the complete eNodeB system and troubleshoot problems with LTE signals. These options provide a wide range of modulation quality and performance measurements. Option 546 (LTE Over-the-Air Measurements) generates measurements used for checking coverage and co-channel interference. This option adds the ability to measure EVM on over-the-air signals with transmit diversity when used in combination with option 542. Option 546 identifies up to 6 different eNodeBs with the cell ID, sector ID and group ID, and also measures the sync signal power of each sector. It then calculates the dominance, which shows the difference in the signal level between the strongest sector and other sectors.

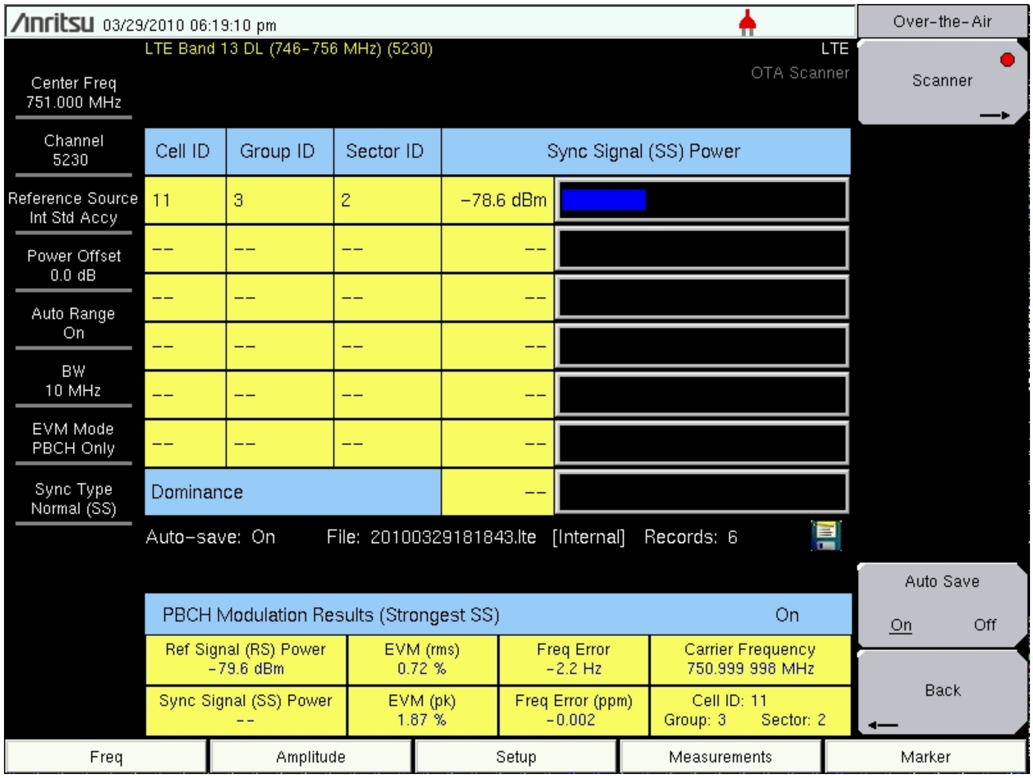

Figure 4. Option 542 LTE Over-the-Air Modulation Measurements.

How to make modulation quality measurements

Using an instrument with both Option 542 and Option 546, switch to the Over-The-Air measurement menu, select the Scanner measurement, and turn on Modulation Measurements in the sub-menu. This measures the EVM of the Physical Broadcast Channel (PBCH) which uses Transmit Diversity. Tune the instrument to the signal of interest and attach an appropriate antenna through a short cable. Next, find a “sweet spot”, a place where the signal strength of the eNodeB to be measured is high and interference, especially from other eNodeBs, is low. Option 546 is an excellent tool for finding a sweet spot because it shows the signal strength (using the LTE Sync Signal or SS), as well as dominance of one eNodeB over others. The sweet spot will be a short distance from the transmitter, and near the center of the antenna pattern. If you are too close, the antenna beam will be above you; if you are too far the signal strength will be too low, there will be too much multipath, and too much interference from adjacent transmitters. Being in the center of the sector’s transmit beam reduces the co-channel interference from adjacent sectors. The recommended approach is to start measuring several hundred feet from the antenna in the beam center, then walk or drive around to find the best available location and then mark it using GPS coordinates.

Figure 5. Performing EVM measurements with Yagi antenna.

Omnidirectional or omni antennas are much more convenient for making over-the-air measurements because of their small size. A good trade-off is to make initial measurements with the omni antenna. Then if a problem is detected, connect the larger Yagi directional antenna. Move the directional antenna around to find the best measurements; while usually this is when pointed directly at the transmit antenna, this is not always the case. If the directional antenna can be oriented so that EVM levels are reduced within the specification, this is a good indication that the transmitter is fine and any signal problems are coming from external interference.

Modulation quality specifications for LTE transmitters are 8% EVM or less at 64QAM. This limit should be used when making a direct connect measurement, with the addition of a small factor for instrument contribution. In the case of an over-the-air measurement, an even larger factor should be added to take account of the signal path. As a general rule, readings under 10% are OK. A good approach is to find a sweet spot and take an over-the-air measurement when the base station is commissioned. This will provide a benchmark value to maintain going forward.

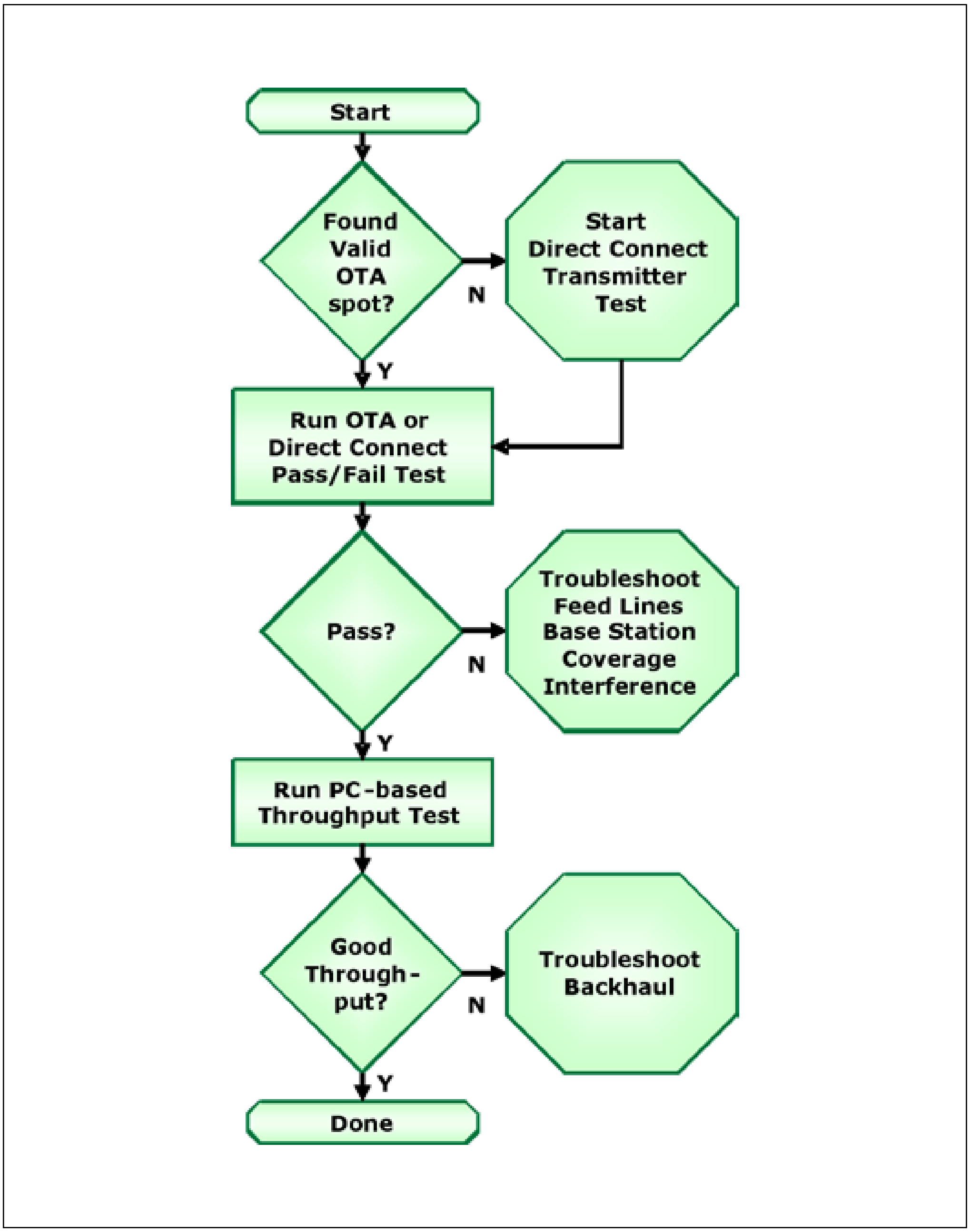

Figure 6. One quick test – OTA Pass/Fail – checks health of cell site.

Conclusion

The ability to make over-the-air modulation quality measurements with a handheld instrument can substantially improve troubleshooting efficiency. This is especially true for cases with inaccessible Remote Radio Heads/Units, but can also be used for quick verification of transmitter quality in traditional installations. When OTA modulation quality tests are combined with the BTS Master's LTE Pass Fail and OTA Scanner tests, as well as a simple throughput test using a PC with wireless modem, technicians can have high confidence in the entire base station. This includes the transmitter & receiver, antennas & transmission lines, backhaul, and co-channel interference. These quick tests provide a simple method to help ensure optimal network performance, with minimal time spent. When trouble spots are found, the Anritsu BTS Master also has all of the needed tools for troubleshooting the problem, so the correct fix can be made. Finding faults early has the added benefit that repairs can be scheduled at a convenient time, rather that under emergency conditions.

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