Application Note

Measuring LTE eNodeB Output Power without Interrupting Service

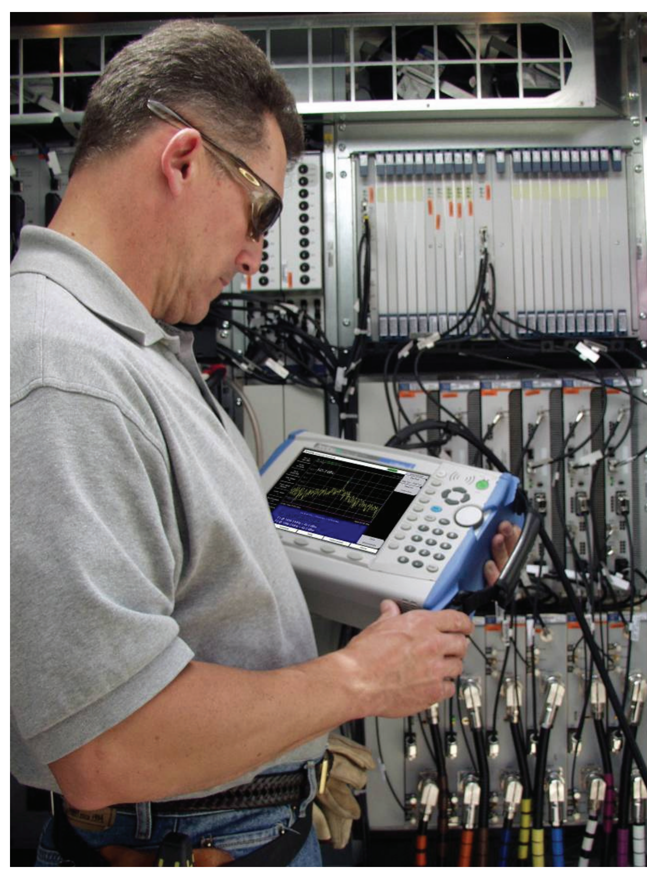
LTE eNodeB output power needs to be measured on a regular basis to provide the best possible user experience while complying with legal restrictions on maximum power output. This measurement is complicated by the fact that LTE channel output power is highly dynamic due to the use of Orthogonal Frequency-Division Multiple Access (OFDMA), adaptive modulation and coding, power control, and complex scheduling algorithms. The most accurate way to measure eNodeB output power is to put the eNodeB into a test mode and connect a power meter or spectrum analyzer to the transmitter. But operators would also like to be able to verify and set the eNodeB transmitter output power without using test modes so they don't block customer calls or lose revenue by taking the base station off the air.

This application note presents a more convenient method of measuring output power by using a handheld instrument to demodulate and measure the LTE Reference Signal (RS) power. Then it provides a simple method to estimate the maximum channel output power based on the RS power measurements. It's important to note that indirect measurement of LTE output power is not as accurate as, and is not intended to replace, direct-output power measurements. However, RS-based measurements of output power can make an important contribution to delivering seamless LTE service because they can be performed faster and without interrupting service.

Power Measurement Background

LTE takes advantage of OFDMA, a multi-carrier scheme that dynamically allocates radio resources to multiple users. OFDMA uses Orthogonal Frequency-Division Multiplexing (OFDM) to split the carrier frequency bandwidth into many small carriers, for LTE spaced at 15 kHz. Each individual subcarrier is then modulated using the BPSK, QPSK, 16-QAM or 64-QAM digital modulation formats. OFDMA assigns each user the bandwidth needed for their transmission. Unassigned subcarriers are turned off, reducing power consumption and interference. LTE uses adaptive modulation and coding to determine the modulation type and coding rate dynamically, based on the current RF channel conditions reported by the user equipment (UE).

Power control is used to set transmitter power levels to improve system capacity, coverage, voice quality and data rate. As a general rule, the eNodeB transmits with greater power to UEs that are further from the base station, while for UEs that are closer to neighboring cells less power is transmitted to minimize interference. The eNodeB scheduler the algorithms that determine resource assignments for the downlink frame. Resource assignments are defined in terms of resource blocks that occupy 1 slot in the time domain and 12 subcarriers in the frequency domain.



The resulting continual changes in output power complicate things for base station operators that need to make output power measurements on a regular basis. This is an important part of base station maintenance to ensure the actual transmit power is as expected and hasn't changed due to drift in the analog section of the transmitter. The most accurate way to measure power output is to put the eNodeB into test mode and directly connect a power meter or spectrum analyzer to the test port. The problem with this approach is the need to take the eNodeB off the air to make the measurement. This reduces the capacity of the base station which in turn can impact customer experience and reduce revenues. Some network operators schedule test mode measurements during a maintenance window – at minimum traffic periods such as at 3 AM. Using an in-service technique minimizes the need for making measurements at these inconvenient times. Of course, when a problem is reported or suspected, measurements often need to be taken immediately as well.

Measuring power with a handheld instrument

Power fluctuations make it impossible to directly measure maximum power while the eNodeB is in service. Power measurements of the RS, which UEs use for downlink channel estimation, can provide surprisingly accurate proxy measurements. This is because RS power is a static value that closely correlates to maximum channel output power. This raises two questions, how do we measure RS power, and how to use it to determine maximum channel output power? Anritsu has introduced LTE measurement options that enable its MT8221B BTS Master handheld base station analyzers and other instruments to measure RS power, as well as perform a broad range of other LTE measurements. Besides the BTS Master MT8221B, LTE modulation quality measurements can also be performed with the BTS Master MT8222A, MT8222B, Spectrum Master MS2712E, MS2713E, MS2721B, MS2722C, MS2723C, MS2724C, MS2725C, and MS2726C as well as Cell Master MT8212E and MT8213E.

The MT8221B BTS Master base station analyzer was selected as the primary platform for LTE measurements in the field because it was developed specifically to support emerging 4G standards such as LTE – including 20 MHz demodulation capability. The BTS Master MT8221B, figure 1, is small, lightweight and battery operated, making it easy to use anywhere at a cell site. It also optionally 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.

You can use these instruments to measure RS Power by using the LTE Option 542 for bandwidths of 10 MHz and smaller and, in addition, Option 543 for 15 and 20 MHz LTE bandwidths. For TD-LTE, use option 552 for bandwidths up to 10 MHz; option 543 again provides for the wider bandwidths. Options 542 also provides a number of other modulation measurements, including a graphical view of the different active modulation formats in the LTE signal, error vector magnitude (EVM) measurements, pass fail measurements, frequency & frequency error, cell ID, and power measurements of the Primary and Secondary Synchronizing (P-SS and S-SS) channel, Physical Broadcast Channel (PBCH) and Physical Control Format Indicator Channel (PCFICH). Pass/Fail limits can be set up for all of these.

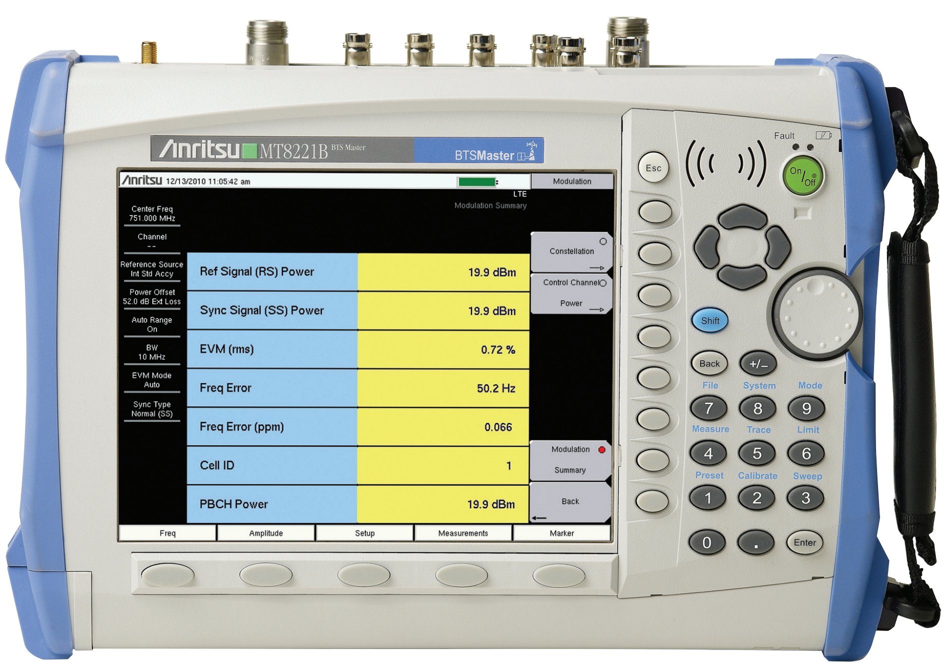


Figure 1: Anritsu BTS Master MT8221B.

Inferring Total Output Power from RS Power

Now we'll address the question of how to convert RS measurements to maximum output power measurements. We'll start with the simple case of using a test signal, so we can get perspective on what the measurements mean.

The RS power measurement is defined as the average power of all of the subcarriers used for RS. Across a 10 MHz channel there are 50 Resource Blocks with 12 subcarriers each; therefore there are a total of 600 Resource Elements per symbol. Two of the subcarriers in selected symbols in each Resource Block are used for RS from each transmitter. This gives a total of 100 RS Resource Elements in those symbols. When all the Resource Blocks are occupied and the referenceSignalPower is set to the nominal value, the RS subcarriers are at the same power level as the other subcarriers. Test signals use the nominal value for RS power, which is why we are starting with that case.[1]

Then the RS power per subcarrier and symbol, called Energy per Resource Element (EPRE) in the standard, is 10*log10(subcarriers) below the maximum total output power (assuming all subcarriers are at the same power level). This means that RS is 27.78 dB below the maximum channel power for a 10 MHz LTE channel bandwidth. Note that power control normally is used for live traffic so one would rarely if ever see the maximum output power from the transmitter unless a test signal is used. Table 1 shows the relationship between RS power and maximum output power for the various LTE bandwidths, again with referenceSignalPower set to the nominal value.

Bandwidth	Number of Resource Blocks	Maximum total output power / RS EPRE (dB)
1.4 MHz	6	18.57
3 MHz	15	22.55
5 MHz	25	24.77
10 MHz	50	27.78
15 MHz	75	29.54
20 MHz	100	30.79

Table 1: Total output power as a function of RS power, for nominal RS power settings.

Also note that referenceSignalPower can be adjusted in many base stations. This will change the relationship between total output power and RS power. The referenceSignalPower is not adjusted dynamically, but rather only when the base station is taken out of service. For a particular base station setup, the relationship between the RS power and total power will be constant for a particular RS power setting.

A good technique is to first measure both actual transmitter power and the RS power using the out-of-service measurement – with a test signal that has all subcarriers turned on. This reduces the uncertainty of the measurement, and verifies that the RS power level is as expected. Measure the base station output power at the physical antenna port or at a coupler output with a known coupling factor, using a calibrated spectrum analyzer or a power meter.

Next measure the RS power level at a the same test point with a BTS Master with the appropriate LTE option. Then if the RS power level is measured at some future date, deviations from this measured value are a good indication that the maximum power will deviated by the same amount (in dB).

The RS power measurement shows the average power of the resource elements that carry RS. This is the same as the eNodeB measurement called Reference Signal Transmit Power, or RSTP. RS Power is also similar to, but not identical with, the UE measurement called Reference Signal Received Power (RSRP); the later uses a method to reject co-channel interference.

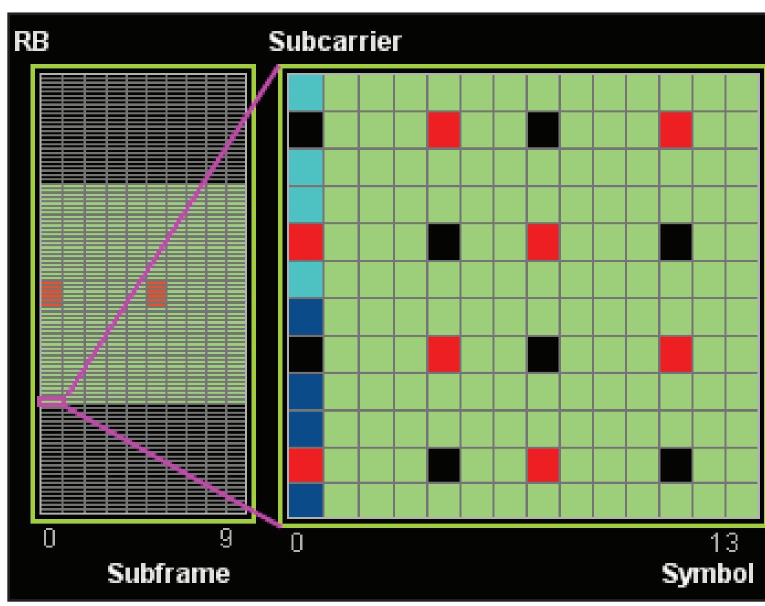


Figure 2: Reference Signals (red) take up just a few subcarrier and symbol locations in each resource block.

1. Note that referenceSignalPower is also called Reference-signal-power in the LTE standards documents.

The eNodeB, however, often reports power in a different way – the maximum power of the RS. This is the same value that a power meter would report if only the RS was present. You can see both measurement values at once, in both dBm and Watts, using the Table display mode in the Control Channel Power measurement. See figure 3.

In summary, RS power measurements provide a fast and convenient way to indirectly measure LTE maximum output power using a handheld instrument and without taking the eNodeB out of service.

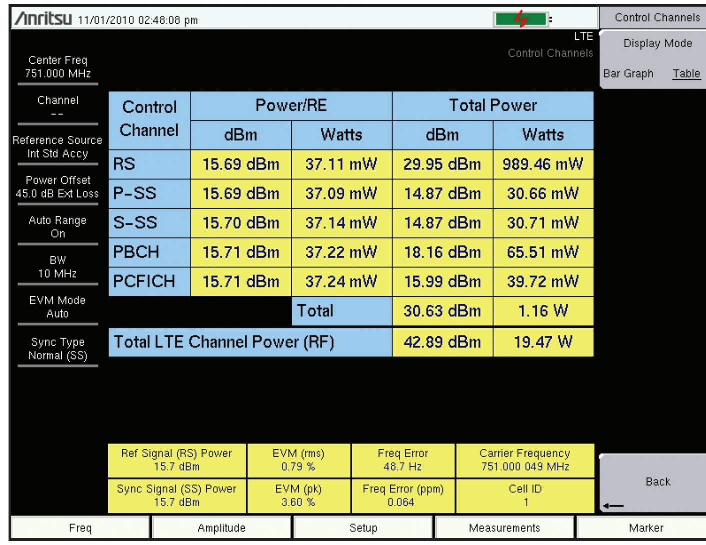


Figure 3: The Table display mode for the Control Channel Power measurement shows both EPRE and total power for each control channel.

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