Application Note

Practical eNodeB Transmitter Measurements for LTE and TD-LTE Systems Using MIMO

Introduction

The use of multiple input multiple output (MIMO) severely complicates the process of measuring eNodeB power and modulation quality in LTE systems. The difficulties include the fact that spectrum analyzers have just one receiver, while two or more receivers are needed for complete demodulation of data channels with spatial multiplexing. Connecting directly to a transmitter is not necessarily the solution, since “precoding” causes direct-connect measurements to appear as if they have spatial multiplexing—even though only one transmitter is being measured. However, measuring the LTE control channels can provide an excellent quick health indication.

When this health check shows a problem, then it usually makes sense to bring down the eNodeB and use a 3GPP Test Model signal for a more thorough evaluation. This application note explains how to troubleshoot an eNodeB using a spectrum analyzer with LTE over-the-air (OTA) measurements.

MIMO creates measurement complications

MIMO involves the use of multiple antennas operating on the same frequency for both the transmitter and receiver. This improves performance without adding bandwidth or transmit power. MIMO in LTE can exist in three forms, each of which presents different challenges from an eNodeB measurement perspective. Beamforming is the simplest case from a measurement perspective, where measurements can be performed by a single receiver without any additional processing. Transmit diversity is also relatively simple from a measurement perspective since it requires only a single receiver and a bit of extra processing on the received signal.

Spatial multiplexing and precoding (which is often used with spatial multiplexing) complicate over-the-air and even direct-connect measurements by acting like strong co-channel interference. This causes a high EVM reading even when the transmitter is performing perfectly. Most LTE systems use spatial multiplexing for some users when channel conditions are appropriate, typically when that user is fairly close to the eNodeB. This creates complications for technicians and engineers because it’s almost always preferable and often essential to make eNodeB measurements without taking it off the air. Making traditional EVM measurements while the eNodeB is operating would require some method of having MIMO turned off. Even if this was possible, it would reduce network capacity and coverage. While a solution to this problem is to measure during the “maintenance window” (often 2 AM to 3 AM), it may be difficult to find a technician or engineer available at this time. In addition, when a problem is reported or suspected, testing often needs to be performed immediately.

Connecting directly to the transmitter is especially difficult when remote radio heads or units (RRHs or RRUs) are used, due to the difficulties in gaining access to the transmitters. While this may not be a problem if the RRH or RRU is mounted inside a building or on an accessible roof, if the RRH or RRU is mounted on a tower or inaccessible roof, connecting to the transmitter can be difficult. This would require climbing the tower or otherwise getting access to the transmitter, often a difficult and expensive process. Direct-connect measurements are also affected by precoding, which adds signal outputs from each path into each antenna. The result is that when precoding is occurring, direct connect measurements appear to have spatial multiplexing, creating the same problem as over-the-air measurements.

Even base stations that do not use an RRH or RRU can save time by measuring eNodeB performance over the air. For example, an eNodeB may be suspect due to a report of dropped calls in the area. Then technicians and engineers can determine with an over-the-air measurement whether or not the transmitter is working properly, in much less time than would be required to connect an instrument to the transmitter. Over-the-air measurements also increase the confidence that the entire transmitter-feedline-antenna system is working properly.

Once it is determined if the eNodeB is working properly or not, effort can be focused on solving the real problem- either eNodeB repairs or addressing interference problems.

Health checks based on control signals

In most cases, field measurements do not require perfect accuracy such as would be needed to characterize an eNodeB during its development. Instead the goal is to identify the existence of a problem without bringing down the eNodeB. If it is determined that there is a problem with the eNodeB, then it can be brought down and a test signal can be used for a more thorough evaluation. This type of good-but-not-perfect measurement can be obtained by measuring control signals. These signals do not use spatial multiplexing or precoding, because they need to work at the cell edge — where these advanced methods cannot be used due to interference by adjacent cells.

Let’s look at several different measurement alternatives. The PDSCH (Physical Downlink Shared Channel) is used to send user data to mobile devices or UEs (User Equipment). The PBCH (Physical Broadcast Channel) sends system identification and access control parameters to the UEs. The 3GPP defined modulation quality (EVM) measurements focus on the PDSCH, and thus measuring the PDSCH provides the best measurement. However since precoding is often used on the PDSCH, EVM measurements on live traffic can be much higher than expected. On the other hand, measuring the PBCH provides a reasonably good indication of transmitter health, and since the PBCH is not subject to precoding this measurement can always be used on live traffic. Figure 1 shows how a signal appears to have a very poor EVM of 28% when measured on the PDSCH (due to precoding), but Figure 2 shows how the same signal shows a much lower EVM (< 1%) when the PBCH is measured. In both measurements the instrument was directly connected to one transmitter.

While the PBCH never uses spatial multiplexing, it often does have transmit diversity encoding. This means that when making over-the-air measurements, the spectrum analyzer needs to have transmit diversity decoding for the EVM measurement. This is included in the Anritsu LTE Modulation Quality measurement options — 542 for LTE and 552 for TD-LTE. The instrument automatically detects when transmit diversity decoding is required.

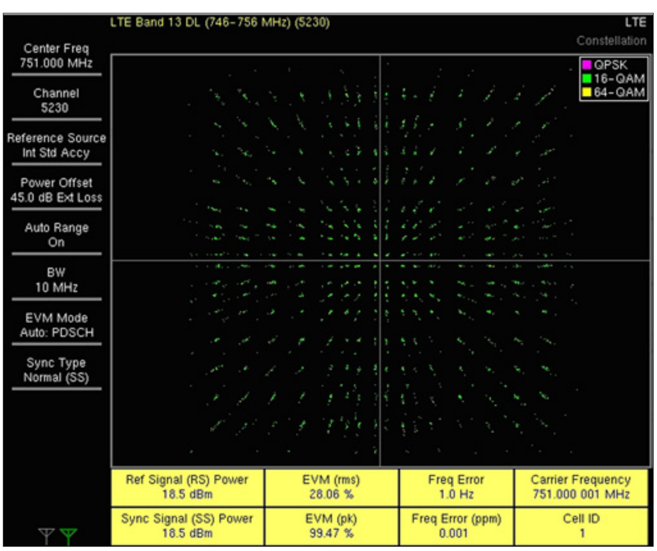

Figure 1: Measuring the PDSCH on live traffic with precoding shows very poor EVM.

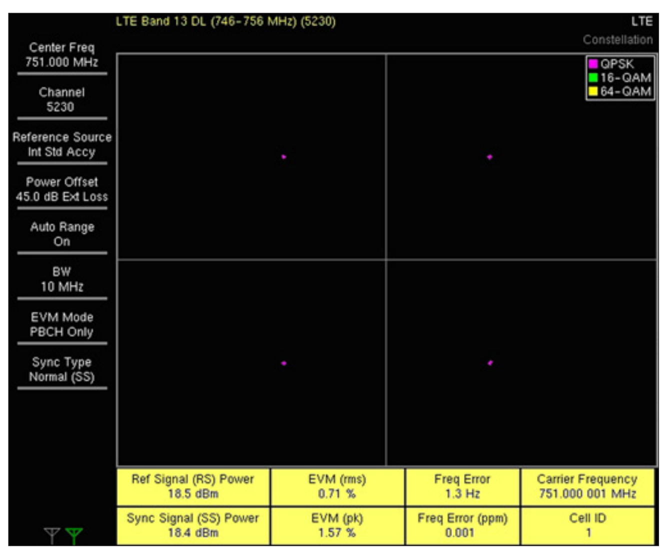

Figure 2: The same signal as Figure 1 measured using the PBCH provides a more useful EVM reading.

Finding a Sweet Spot

The first step in taking an over-the-air measurement is finding a sweet spot where the eNodeB to be measured is highly dominant. Begin looking for the sweet spot by making measurements on the ground approximately 500 yards from the antenna, with a line-of-sight to the antenna if possible. Move around to find the spot with the least amount of co-channel interference from adjacent sectors—using the over-the-air Scanner or Tx Test measurement you should see only one cell ID, or at least very high dominance (>20 dB if possible). Directional antennas can be used if needed to help isolate the signal to be measured, if necessary. Once you have found a sweet spot, it is a good idea to make note of where it is so you can easily re-use it when you return to that site.

Example of Finding a Sweet Spot

Figure 3 shows poor dominance so it is not a sweet spot. The measurement shows poor EVM; however, the problem is mostly likely due to the location of the instrument rather than the transmitter. In Figure 4, we are getting warmer – dominance is higher but still not ideal. The EVM is at a marginal level. In Figure 5 we have found a truly sweet spot. The adjacent sector has disappeared from the instrument display, and the primary signal has achieved complete dominance. EVM now is at very low levels. It’s important to remember that the high EVM readings in Figures 3 and 4 were due to co-channel interference rather than a transmitter problem.

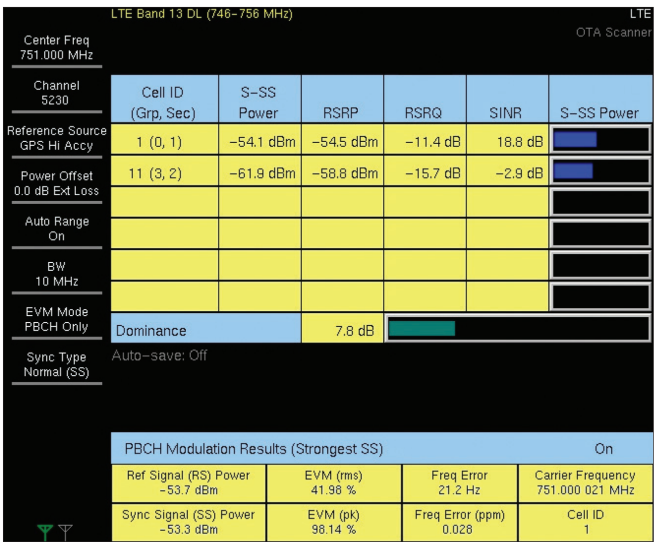

Figure 3: Poor dominance and a resulting poor EVM shows this is not a sweet spot.

Figure 5: This is truly a sweet spot and it shows excellent EVM.

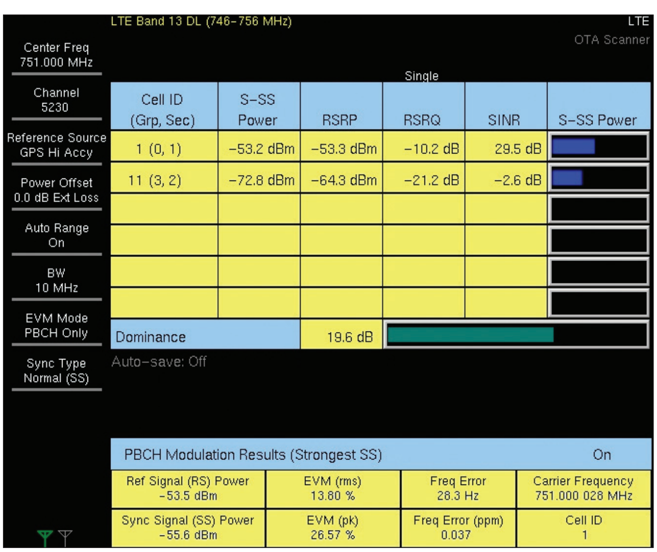

Figure 4: This is almost a sweet spot – dominance is higher and EVM is lower.

Over-the-Air Measurements

Once a sweet spot is found, use the Tx Test measurement to verify that the eNodeB transmitters are working correctly. The measurement shows a full range of measurements needed for OTA verification, including co-channel interference from adjacent cells, relative RS (Reference Signal) power so that you know all MIMO transmitters are working correctly, and modulation quality measurements, especially frequency error and EVM.

While you are at the sweep spot, it's a good practice to also make a throughput test using a UE. The throughput test complements the EVM measurement by verifying that the backhaul and the baseband signal processing part of the radio are working properly.

Troubleshooting swapped sector problems

Now let's look at how we can use this method to identify specific problems starting with swapped sectors, the situation where transmitters for sector e.g. Alpha are instead connected to antennas for sector e.g. Beta.

The measurements for this depend on the type of transmitter used. Some eNodeBs transmit the Sync Signal on all Transmitters, other eNodeBs transmit the Sync Signal on only the first transmitter.

In either case, the first step is to find an OTA sweet spot (as mentioned earlier). This provides the best position for determining what's going on with the transmitters, feedlines, and antennas. Below are shown a number of measurements in different cases, starting with having the sync signal on 1 transmitter.

Figure 6 shows a case where the scanner does not find a Cell ID and the "sync signal not found" message appears even though channel power is above -60 dBm and the spectrum looks fine. For the single-transmitter sync signal, this tells us that the antenna that should be radiating the sync signal is instead radiating another sector's transmitter with no sync.

For the multiple-transmitter sync signal, this measurement would indicate a more serious problem, since neither transmitter is working correctly.

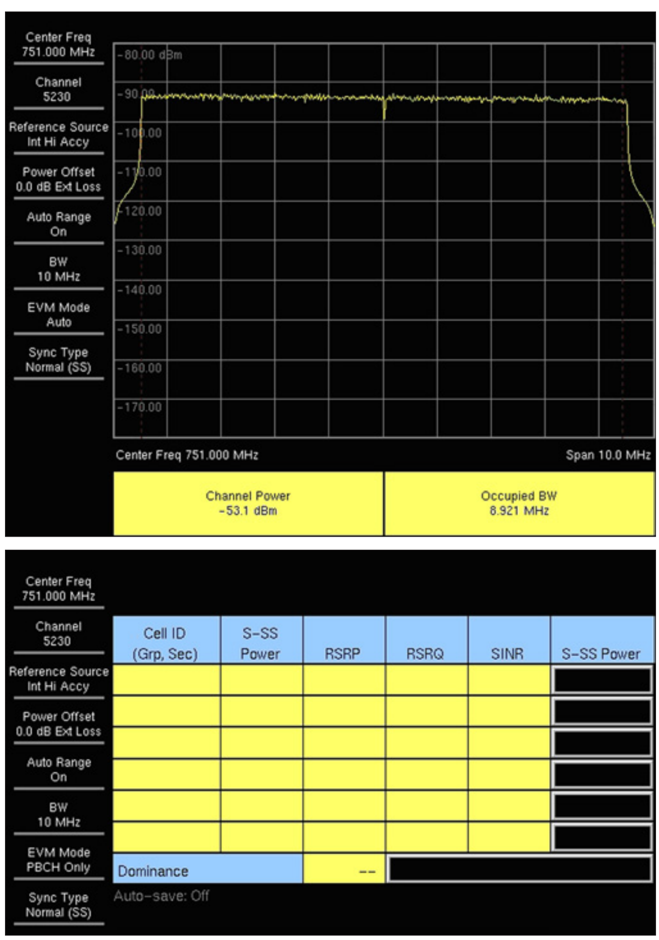

Figure 6: There's plenty of power but no Cell ID.

Figure 7 also shows the case where we have plenty of power, in this case sync signal power of greater than -80 dBm. In this case there are two large Cell IDs, however, so we are not in a sweet spot. This indicates that there are two transmitters in the sector with different sync signals. If this is the “sweetest” spot we can find, this indicates one of several possible problems, including a bad antenna in an adjacent sector (with a poor radiation pattern) or a large nearby reflector. If those aren’t the case, then we know that one of the MIMO antennas is radiating the signal from the wrong sector—in this case one with a sync signal. For eNodeBs with no sync on one transmitter, you know exactly which transmitter is causing the problem. For eNodeBs with sync on both transmitters, you can tell which transmitter is which sector is swapped by the unexpected cell ID, and can often tell which transmitter is swapped by looking at the Delta Power graph in the OTA Tx Test measurement (see Figure 8).

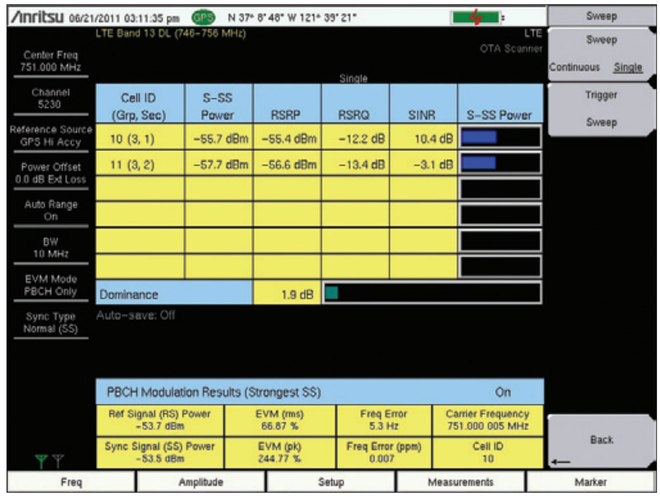

Figure 7: There’s plenty of power but we can’t find a sweet spot.

Figure 8 shows the case where sync signal power is again higher than -80 dBm but the PBCH has a high EVM reading— greater than 20%. For eNodeBs with single-transmitter sync signal, this indicates that either there is a bad transmitter or the signal without sync has been swapped with another transmitter without sync. In the later case, the co-channel interference caused by the wrong transmitter radiating into the sector is responsible for the high EVM reading—but you don’t see a 2nd cell ID, because there is no sync signal to be able to measure the cell ID.

Figure 8 also shows that the Tx Test measurement can help to indicate that only one transmitter is working. In this case you can see the first transmitter is working as the left bar graph is much higher in the RS Power (All Antennas) display.

For the case where the sync signal is on all transmitters, figure 8 would indicate either a broken transmitter, or strong interference.

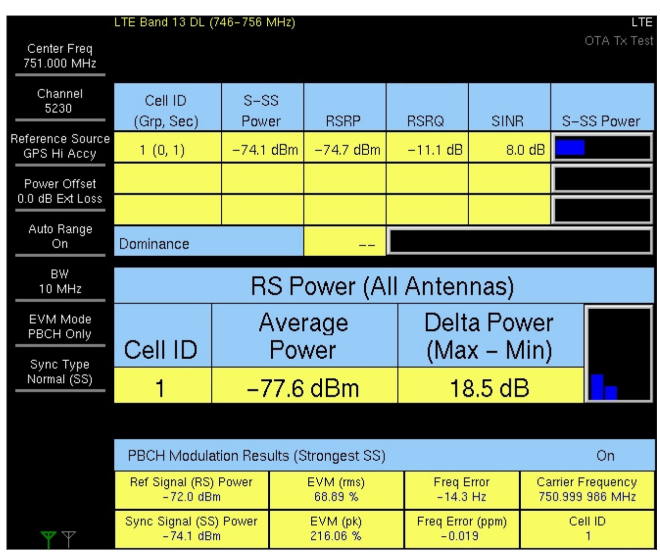

Figure 8: Plenty of power and high dominance but a very high PBCH EVM reading.

When these eNodeB problems are corrected, we get a reading like Figure 9 with high dominance and a low EVM reading, ideally below 10%. However we still don’t have a comprehensive answer to the question of “is MIMO working properly”, since we could have a transmitter completely off, and still get good EVM measurements. This is the purpose of the Tx Test measurement.

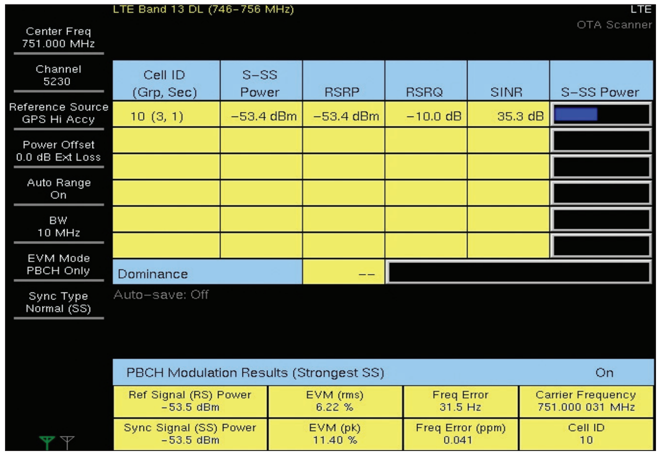

Figure 9: This reading looks great – high dominance and a low OTA EVM.

Diagnosing transmitter failures

Now let's look at how we can troubleshoot the situation where one or more transmitters have failed, is not connected, or the feedline-antenna system has high loss or has failed. This problem can be identified by looking at the Reference Signal which is carried on different subcarriers for each MIMO transmitter. In the example shown in Figure 10, there is only one Cell ID and the EVM is reasonable, so we know the cables are not swapped. But the big difference in the RS power levels indicates that one transmitter is not getting to the antenna. In Figure 11, the problem has been fixed and the RS power levels are now consistent.

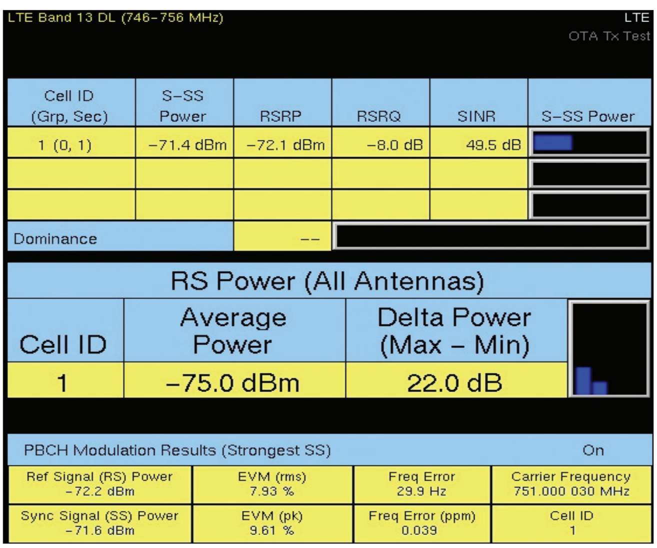

Figure 10: RS power delta is large indicating the second transmitter is missing

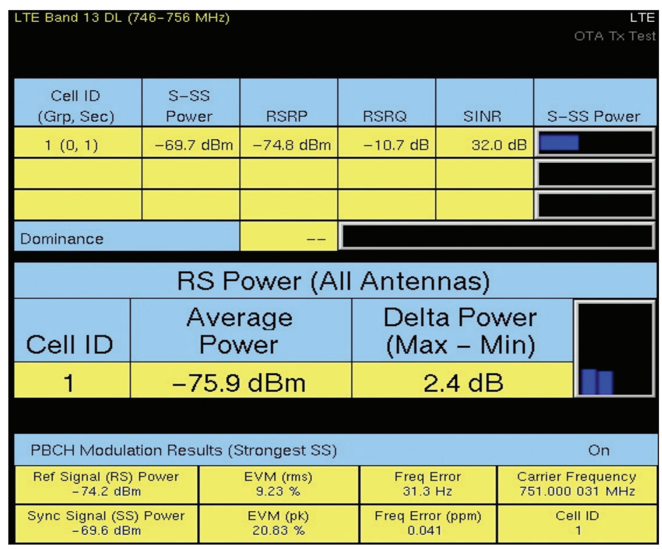

Figure 11: Everything looks fine in this measurement.

Conclusion

In conclusion, MIMO and Remote Radio Heads complicate LTE eNodeB transmitter measurements, but these complications can be overcome by measuring the LTE control channel signals. When combined with a throughput check, the Anritsu LTE Measurement Suite, and especially the Tx Test measurement, provides an excellent tool for ensuring that LTE MIMO systems are working properly, even while operating with live traffic. This reduces the time and cost required for troubleshooting while reducing service disruptions.

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