An Unambiguous Technique for Measuring 4G LTE Coverage Area

As today's cellular radio spectrum grows busier and busier, government agencies all over the world are rushing to allocate new frequency bands to squelch the every growing thirst for wireless data. Of course this is something that governments can do but operators rarely have the opportunity to say okay just add some cell sites at different carrier frequencies. If life could be so easy! In fact with limited spectrum, carriers are finding ways to increase LTE usable data bandwidth by underlaying small cells to offload users from their macro-cells. But crowding small cells into a serving LTE cell may create its own coverage problems which could be counter-productive and reduce available bandwidth for their users. Thus, carriers need to ensure that there is not too much cell coverage overlap by accurately characterizing the coverage reach of each cell.

New tools and metrics are needed to assess coverage of newer wireless technologies

Since the beginning of time, carriers had to address frequency re-use issues with careful RF Coverage planning and thorough testing. But as technology changed from 2G to 3G and 4G, RF planning also changed. In the early days (AMPS/GSM) coverage testing could be conducted by making simple RSSI measurements to assess quality of coverage. But as digital modulation technology evolved, RSSI measurements became less and less useful as a coverage metric. Thus, tools for coverage testing needed evolve and use new metrics to help discriminate between good, poor and bad coverage.

The tradition

The conventional signal coverage test measures RSSI (Received Signal Strength Indicator) and RSRQ (Reference Signal Received Quality) metrics. These two metrics originate from the earlier AMPS/TDMA/GSM technologies where re-use frequency planning was used and each adjacent cell or sector is strictly prohibited from using the same frequency. For technologies such as CDMA, WCDMA and LTE, the re-use frequency planning is no longer needed, and the same carrier frequency is used across all cells and sectors. These two metrics no longer apply, and the measurement results are misleading and ambiguous.

RSSI is indiscriminate and ambiguous

RSSI measures the total in-band power, and it has no ability to discriminate the signals from adjacent cells or sectors. For CDMA, different PN offsets are used for different sectors and cells. For WCDMA, different scrambling codes are used. For LTE, different cell-IDs are used. But a simple RSSI measurement does not take these mechanisms into account. You may get high RSSI readings at a cell boundary, but the actual signal coverage could be poor or even unable to service a call.

RSRP is vulnerable to in-band interference and multi-path fading

For LTE, RSRP is a metric made by the LTE mobile to help rank between the different cells as input for handover and cell reselection decisions.

The RSRP is simply the averaged RS (Reference Signal) power per resource element. The RS from each antenna port (MIMO) occupies a subset of the resource elements at symbol 0 and 4 of each timeslot. More specifically, every 6 sub-carriers of symbol 0 and 4 are used by a specific antenna port. The subset of sub-carriers to be used for each sector is determined by the cell ID number. But a subset used by one sector for RS can also be used by another sector for control or traffic channels on another sector. This is one of the problems for RSRP metric. At the sector border, you may get high RSRP number, but the actual signal coverage quality can be very bad. For the cells/sectors that employ multiple TX antenna ports (MIMO), the RSRP from each antenna port really needs to be measured and compared to assess their relative power and phase balance or imbalance to assess transmission quality. Also, multi-path fading is another real problem for using RSRP as a quality metric. The RSRP can be very low due to severe fading but the LTE RS was designed to help mitigate propagation impairments and recover faded signal, thus the coverage quality may not be impacted. Suffice it to say, the single reading of RS power alone from the default antenna port 0 cannot decisively determine the overall coverage quality thus a more precise method is needed.

Detecting PBCH Bit Errors is the ultimate solution for LTE Coverage Testing

A more direct approach is to detect bit errors of the transmit path. This can be accomplished by decoding the PBCH data bits, the measurement instrument has to function like an actual LTE phone or modem. It must synchronize to the PSS (Primary Sync Signal) and decode the PSS and SSS (Secondary Sync Signal) to obtain the cell-ID. From there, it must determine how many TX antenna ports are used and then extract all the RS signals from all the TX antenna ports to form an equalization matrix in order to decouple the signals that have been mixed up via transmit diversity layer mapping and pre-coding [1]. The same process applies to decoding the other control channels such as PDCCH and PDSCH traffic channel. If the decoded PBCH channel does not even come out right, one can be absolutely certain that the PDCCH and PDSCH channels will not work either. Regardless of power and regardless of how many sectors can be seen at a given area, a good bit-error-free PBCH channel is the simplest and also the most decisive way of determining the overall signal coverage quality for an area.

Sage Instruments has implemented LTE PBCH Bit Error Detection in its latest release of the UCTT 8901A advanced base station test platform. This new metric has been added to the LTE demodulation capabilities and is currently presented in the LTE Demodulation mode under submenu “Modulation” as shown in Figure 1 (circled in red).

Detecting PBCH Bit Errors using the Sage UCTT 8901A

Once the UCTT is locked onto a Cell_ID, the PBCH is continuously decoded and processed for Bit Errors. The bit error detection results are displayed as status conditions: “OK”, “Poor”, or “Bad”.

PBCH BER Results	Definition	Interpretation
OK*	Bit Error Free	Good Service Area Approx Download Data Rate > 25%
Poor	Bit Errors Present but Recoverable	Near Border or compromised location (i.e. in-building). Approx Download Rate: 25% > x > 5%
Bad	Uncorrectable Bit Errors Present (Unrecoverable)	Border area or Beyond. Approx Download Data Rate < 5%

* Indication of “OK” (Error-Free) does not imply maximum data rate.

Practical Considerations

A good PBCH (“OK”) is a necessary condition for a good PDSCH quality. And a “PBCH Bad” condition means there is no chance for a good PDSCH signal (hence no user data connection). To have high confidence in signal coverage, we suggest using PBCH Bit Error Detection to assess where coverage “is” and “is not”.

Examples – Using Sage’s UCTT 8901 and decoding PBCH to perform Bit Error Detection Coverage Testing

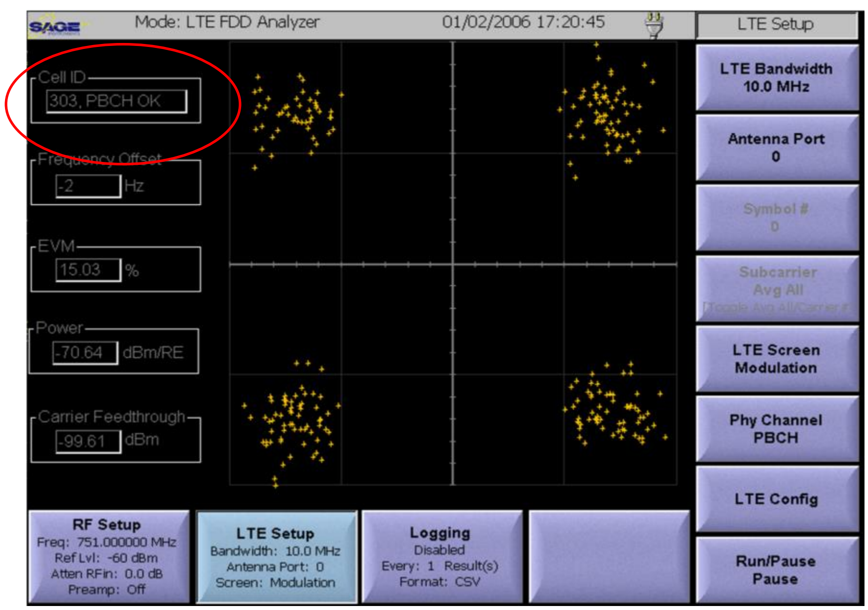

***Figure 1** Shows the PBCH constellation when the PBCH is OK (meaning no bit errors). This signal was obtained using an Omni antenna about one mile from the cell site and roughly in the center of a sector.*

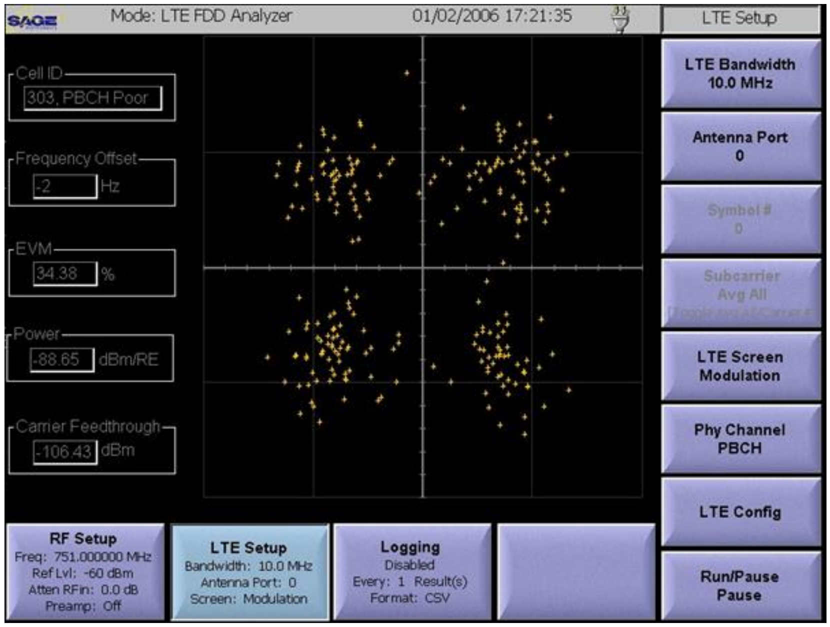

Figure 2 *Shows the PBCH Poor condition (meaning there are bits errors, but still correctible, marginal performance). This signal was obtained using an Omni antenna at an indoor location about ½ mile from cell site..*

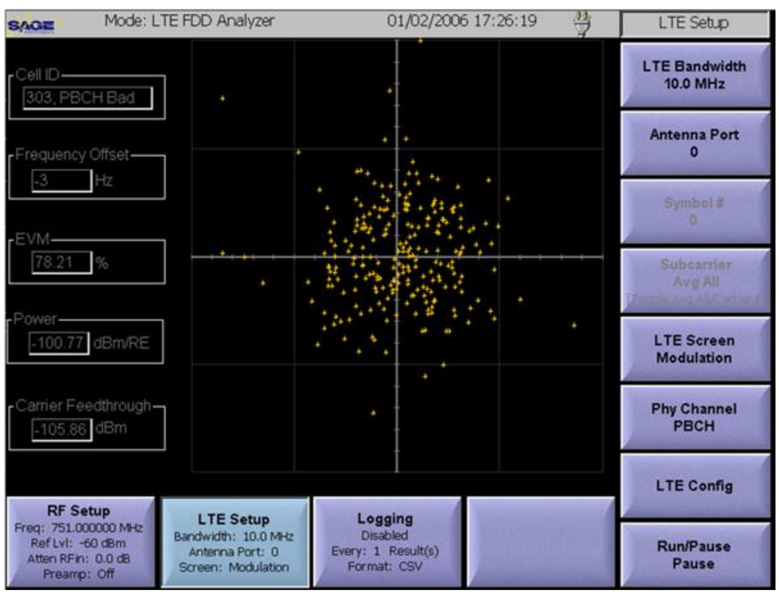

Figure 3 *Shows PBCH bad Condition (meaning there are uncorrectable bit errors). This signal was obtained using an Omni antenna about 3 miles away from the serving macro-cell.*

Practical Applications for PBCH Bit Error Detection Test

- LTE Cell Coverage Area Assessment
- In-Building Coverage Quality
- Troubleshooting Poor Coverage Areas

Future Applications

- LTE Bit Error Coverage Mapping utilizing GPS for location capture.
- Indoor LTE Bit Error Coverage Mapping utilizing indoor building maps to capture location.

Other useful metrics for troubleshooting LTE Coverage issues:

- Multi-path measurement – LTE Submenu screen that graphically displays multi-path to assist with diagnosing coverage problems
- MIMO Scanner – LTE Submenu screen that displays the performance of each serving MIMO antenna port without requiring connection
- Cell_ID Scanner – LTE Submenu screen that displays all visible serving Cell-ID's and their Sync Power to help assess border areas.

References

[1] 3GPP TS 36.211, "Physical Channels and Modulation."

[2] 3GPP TS 36.212, "Multiplexing and channel coding."

[3] SGPP TS 36.141, "Base Station conformance testing."

[4] SGPP TS 36.104, "Base Station radio transmission and reception."