Keysight Technologies
Overcoming LTE-A RF Test Challenges

Application Note
Introduction

The LTE-A standard is being actively updated, bringing new definitions and challenges to RF engineers configuring test systems. It can be very challenging to understand the detailed LTE specifications and then implement it in products and systems that meet the needs of real-world consumers.

The signal analyzer is a key measurement tool used to test LTE designs. These analyzers have evolved, providing greater flexibility through software capabilities such as embedded measurement applications that automate standards-compliant measurements. This application note will cover some of the recent LTE-A technical updates and possible test solutions using an easy to configure signal analyzer coupled with standards-based measurement application software. The application note also explores the possibility of implementing alternative techniques to maximize the performance of your device, while still adhering to the standard.

Testing recent LTE-A updates

With the deployment of multi-carrier (MC) and carrier aggregation (CA), E-UTRA Test Configurations (ETC), a package of test configurations, have been added to the single carrier operation condition to help designers evaluate RF standards conformance of LTE base stations. This application note covers the use of a convenient, pre-defined ETC on a signal analyzer to quickly setup accurate test configurations.

The Release 12 standard, finalized in March 2015, added several new features, including 256QAM downlink transmission. Prior to Release 12, the maximum order of modulation was 64QAM. Studies support deployment of 256QAM for improved SNR and overall throughput in femtocell implementations which have short distances between base station and user equipment. This application note covers EVM requirements for 256QAM and a proposed test configuration to meet those requirements.

LTE TDD deployment at 3.5 GHz band 42 and band 43 triggered another round of R&D investment on TD-LTE. Transmitter On/Off Power is a special TDD test item comparing to LTE FDD signal to evaluate a burst signal’s quality, which requires high dynamic range and more accurate timing to a signal analyzer.
Simplifying implementation of ETCs

Release 10 of the LTE specifications introduced carrier aggregation (CA) based on the component carriers (CC) defined in Release 8. The purpose of CA is to increase the available bandwidth to and from the user equipment (UE) by aggregating two to five CCs to create an instantaneous bandwidth of up to 100 MHz. The channel bandwidths of the aggregated carriers need not be the same and the aggregation can be contiguous or non-contiguous. The non-contiguous CCs can occupy non-adjacent channels in a single band (i.e., intra-band) or in separate bands (i.e., inter-band).

Release 10 defines extensive E-UTRA Test Configuration (ETC) conformance tests for multi-carrier (MC) and CA operation. The LTE-A base station RF conformance tests need to account for flexible spectrum allocations in MC and CA operation as the ETCs specify the signal’s spectrum allocation for all conformance tests. See 3GPP TS 36.141-4.10 for a detailed description.

ETC1: Contiguous spectrum operation

3GPP defines test configurations for MC and CA operation. ETC1 tests all base station requirements except CA occupied bandwidth, which is tested by ETC2. ETC1 is constructed on a per band basis using the following method (see Figure 1):

- Declared maximum supported base station RF bandwidth supported for contiguous spectrum operation shall be used (1);
- Select the narrowest supported carrier and place it adjacent to the lower base station RF bandwidth edge (2). Place a 5 MHz carrier adjacent to the upper base station RF bandwidth edge (3).
- For transmitter tests, select as many 5 MHz carriers that the base station supports within a band and fit in the rest of the declared maximum base station RF bandwidth. Place the carriers adjacent to each other starting from the upper base station RF bandwidth edge (4), (5), (6)
- If 5 MHz carriers are not supported by the base station, the narrowest supported channel bandwidth should be selected instead.

![Figure 1. ETC1 generation procedure.](image-url)
The N9080C/N9082C LTE/LTE-A FDD and TDD measurement applications have pre-defined ETC configurations that make measurement set-up fast and efficient. After a few measurement parameters are entered, the signal analyzer pre-populates the necessary measurement information based on the selected ETC definition (Figure 2).

![Figure 2. ETC1 preset configuration in N9080/82C LTE/LTE-A FDD and TDD measurement applications.](image)

**ETC2: Contiguous CA occupied bandwidth**

All component carrier combinations supported by the base station, which have different sum of channel bandwidth of component carrier, shall be tested. For component carrier combinations with the same sum of channel bandwidth of component carriers, only one of the component carrier combinations shall be tested.

![Figure 3. ETC2 preset configuration in N9080/82C LTE/LTE-A FDD and TDD measurement applications.](image)
ETC3: Non-contiguous spectrum operation

ETC3 tests all base station requirements except CA occupied bandwidth, for non-contiguous spectrum operation.

ETC3 is constructed on a per band basis using the following method:

- The RF bandwidth shall be maximum supported RF bandwidth for non-contiguous spectrum operation (1). The RF bandwidth consists of one sub-block gap (2) and two sub-blocks (3), (4) located at the edges of the declared maximum supported RF bandwidth.
- For transmitter tests, place a 5 MHz carrier adjacent to the upper edge of the RF bandwidth (5) and a 5 MHz carrier adjacent to the lower edge of the RF bandwidth (6). If 5 MHz E-UTRA carriers are not supported by the base station, the narrowest supported channel bandwidth shall be selected instead.
- The sub-block edges adjacent to the sub-block gap shall be determined using the specified $F_{offset}$ for the carrier adjacent to the sub-block gap.

![Figure 4. ETC3 generation procedure](image1)

![Figure 5. ETC3 preset configuration in N9080/82C LTE/LTE-A FDD and TDD measurement applications.](image2)
ETC4 and ETC5

ETC4 tests multi-band operation considering the maximum supported number of carriers. Each band shall be considered as an independent band and the carrier placement in each band shall be according to ETC1.

ETC5 tests multi-band operation aspects considering higher PSD cases with a reduced number of carriers and non-contiguous operation (if supported) in multi-band mode. Each band shall be considered as an independent band and the carrier placement in each band shall be according to ETC3.

ETC4 and ETC5 are defined for multi-band test configurations. The implementation and configuration of these tests can be handled by ETC1 and ETC3, and so these will not be covered in this application note.
Characterizing downlink 256QAM

Demand for higher data throughput and greater efficiency continues to grow, especially in areas that have high-density cellular networks. Downlink 256QAM is the most recent modulation type defined in release 12 of the LTE-A standard. It is designed to help maximize data throughput in areas with limited wireless spectrum. However, higher order modulation is always challenging to implement in a wireless communication system. Two test models E-TM 2a and E-TM 3.1a with 256QAM PDSCH are defined for base station transmitter test.

CMCC, one of the major operators in China, started the 4th round of TD-LTE base station and small cell bidding in December 2015 and requested downlink 256QAM as a mandatory RF test item. The EVM requirement for CMCC’s 256QAM downlink is less than 3.5%, stricter than its requirement for 64QAM (5%).

When using the N9080C/82C LTE/LTE-A measurement application with the UXA signal analyzer, the EVM floor for downlink 256QAM is less than 0.2%, and less than 0.4% when using the PXA signal analyzer. This leaves a substantial margin for a device under 256QAM test.

![Multi-measurement with 256QAM analysis in N9080C LTE/LTE-A FDD measurement application.](image)

In carrier aggregation tests for LTE-Advanced signal analysis, contiguous or non-contiguous component carriers which are part of an aggregated transmission bandwidth, should be tested in a single measurement. The N9080C/N9082C LTE FDD and TDD measurement applications provide tests and display configurations supporting up to 5 CCs with same or different modulation types sequentially or simultaneously. Additionally, it displays the measurement traces in customized layout, and saves the layout for future recall.
Switching between sequential and simultaneous, the signal analyzer can capture all CCs in one acquisition and test the signals simultaneously. Figure 7 illustrates a simultaneous measurement for a non-contiguous CA with three CCs. Each CC has different bandwidth and ETM configuration. The LTE application captures and analyzes the three CCs all together.

Figure 7. Simultaneous modulation analysis of three CCs makes it possible to view spectrum and constellation data together.
Supporting diversity on TDD 3.5 GHz band

LTE TDD transmitter ON/OFF power measurements are defined in 3GPP TS36.141-6.4. There are two test items, transmitter off power and transmitter transient period, both requiring high dynamic range and more accurate timing to a signal analyzer. See the application note, E-UTRA Base Station Transmit ON/OFF Power Measurement, literature number 5990-5989EN, for more information on how to address dynamic range test challenges for these measurements with X-Series signal analyzers.

Transmitter OFF power

Transmitter OFF power is defined as:

- The mean power measured over 70 μs filtered with a square filter of bandwidth equal to the transmission bandwidth configuration of the base station (BWConfig) centered on the assigned channel frequency during the transmitter OFF period.

For base stations supporting intra-band contiguous CA, the transmitter OFF power is defined as:

- The mean power measured over 70 μs filtered with a square filter of bandwidth equal to the Aggregated Channel Bandwidth BWChannel_CA centred on (Fedge_high+Fedge_low)/2 during the transmitter OFF period.
Transmitter transient period

The transmitter transient period is the time period during which the transmitter is changing from the OFF period to the ON period or vice versa. The transmitter transient period is illustrated in Figure 11.

The N9082C LTE/LTE-A TDD measurement application provides 70 μs averaged off power calculation through all entire OFF power period and reports it as 70 μs RMS trace. As shown in Figure 10, the blue trace is the calculated 70 μs RMS power trace, while yellow trace is the limit line.

Figure 10. 70 μs RMS trace for transmitter OFF power test.
Different definitions are provided for the relationship between the expected Tx Burst boundary and the Tx transient period in the 3GPP TS36.141 (base station case) and TS36.521-1 (user equipment case). This application note only covers downlink for base station test.

For the base station transmitter transient period test, interpretations of two critical methods can significantly impact the test results.

1. Determining slot boundaries

Traditional timing reference for determining each slot boundary is based on the timing of measured burst ramp up and ramp down, with auto timing adjustments in the measurement software. The yellow lines in Figure 12 illustrate the auto adjusted timing using the traditional method.
However, the accuracy of the traditional timing reference method has been questioned, as illustrated in Figure 13.

By using traditional timing reference method, burst timing is adjusted based on the measured ramp up and ramp down edge timings (orange lines). Even if the measured burst (red trace) is delayed from the expected timing (green trace), it may pass the burst after an auto timing adjustment, which is expected to fail.

Thus, an external trigger is expected to be an absolute reference of burst boundary.

The N9082C LTE/LTE-A TDD measurement application supports the traditional timing reference method and the external trigger reference method by enabling the engineer to turn off the Auto Timing Adjustment.

2. Calculating ramp up and ramp down periods

The 3GPP definition of Transient Period comes from the previously determined burst (slot) boundary to the point of the specified OFF power limit:

-83 dBm/MHz (f ≤ 3 GHz) or -82.5 dBm/MHz (3 GHz < f ≤ 4.2 GHz).

Using the burst boundary determined by traditional timing reference method, the ramp up and ramp down periods are measured based on the Ramp Up/Down Start/End Level (dB) parameter settings. This definition is commonly used in the wireless industry as the ramp up/down period. (Figure 14, arrow a)

Using the burst boundary determined by using an external trigger, the off power limit point is as same that determined by the traditional method and both are aligned with 3GPP definition. However, the two different burst boundary points result in different transient period lengths.
Arrow (b) in Figure 14 illustrates the Transient Period result using an external trigger.

Arrow (c) shows the specified limit of the Transient Period of 17 μs.

In N9082C LTE/LTE-A TDD measurement application, you may turn the Auto Timing Adjustment on or off to switch the Transient Period test from method (a) to method (b).

Figures 15 and 16 illustrate a test executed using the N9082C LTE/LTE-A TDD measurement application. In Figure 15, the Auto Timing Adjustment is on. The ramp up start level is used to determine the burst boundary, and test result is 177 ns. In Figure 16, Auto Timing Adjustment is off. The external trigger (white line on the burst left) is used to determine the burst boundary, and test result is 1.68 μs.
Figure 15. Traditional approach is used to measure the LTE TDD transmitter transient period.

Figure 16. External trigger approach is used to measure LTE TDD transmitter transient period.
Conclusion

While a standards-compliant test solution is helpful to quickly design and test products for LTE, a flexible software application gives you the ability to test your devices using alternative approaches, particularly when the standard definition is ambiguous.

The X-Series measurement applications - N9080C LTE/LTE-A FDD and N9082C LTE/LTE-A TDD - designed for the multi-touch X-Series signal analyzer provides an easy-to-use touch screen user interface, well-designed configuration layout and enhanced capabilities, to help you overcome LTE/LTE-A test challenges and help reduce test complexity.

References

Literature

N9080C/N9082C LTE/LTE-A Measurement App, Multi-Touch – Technical Overview, literature number 5992-1305EN

Characterization of LTE Devices Made Simple – Application Brief, literature number 5992-1361EN

E-UTRA Base Station Transmit ON/OFF Power Measurement - Application Note, literature number 5990-5989EN

Product web pages

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