Introduction to LTE Base Station RF Conformance Testing

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Operator acceptance testing is yet another step in the process and includes more user-centric tests.

Table 1. Base station RF transmitter characteristics tests

36.141 subclause	Test case
6.2	Base station output power
6.3.1	Resource element (RE) power control dynamic range
6.3.2	Total power dynamic range
6.4.1	Transmitter OFF power
6.4.2	Transmitter transient period
6.5.1	Frequency error
6.5.2	Error vector magnitude (EVM)
6.5.3	Time alignment between transmitter branches
6.5.4	Downlink reference signal power
6.6.1	Occupied bandwidth
6.6.2	Adjacent channel leakage power ratio (ACLR)
6.6.3	Operating band unwanted emissions
6.6.4	Transmitter spurious emissions
6.7	Transmitter intermodulation

[1]

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Table 1. Base station RF transmitter characteristics tests.

The successful deployment of 3GPP Long Term Evolution (LTE) depends in large part on the compatibility and effective interworking of the system's different elements. Conformance testing ensures that these elements meet a minimum level of performance as defined in the 3GPP specifications. For LTE base stations, the conformance tests focus on RF test methods and conformance requirements for base stations operating in FDD or TDD mode.

The complex and flexible LTE air interface supports many options for modulation format (QPSK, 16QAM and 64QAM), frequency bands (FDD and TDD), resource allocations, and mobility. As a result, the number of RF configuration permutations that can be tested is enormous. In selecting the configurations for the LTE RF conformance tests, considerable effort was made by 3GPP to identify those combinations of parameters that represent the most difficult operating conditions so that when a product passes the tests, the design engineer can be reasonably confident that the device will perform satisfactorily in many more combinations than those explicitly tested.

Structure of the Base Station Conformance Tests

The base station RF conformance tests follows a standard format that includes the title; the definition of the parameter under consideration and applicability of the test to all or a subset of equipment; minimum conformance requirement with reference to the subclause of the 3GPP core specification that defines the minimum requirement; and the test purpose.

Table 2. Base station RF receiver characteristics tests

36.141 subclause	Test case
7.2	Reference sensitivity level
7.3	Dynamic range
7.4	In-channel selectivity
7.5	Adjacent channel selectivity (ACS) and narrow-band blocking
7.6	Blocking
7.7	Receiver spurious emissions
7.8	Receiver intermodulation

[2]

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Table 2. Base station RF receiver characteristics tests.

Although the test purpose may seem obvious from the title of the test, a product may sometimes appear to fail a test for reasons that have nothing to do with the test purpose. Sometimes tests generate intermediate results that could be meaningful to other tests. Nevertheless, only the specific items listed in the test purpose determine the pass/fail result of a conformance test. A clearly written test purpose helps clarify what is and what is not important, especially when additional minimum requirements that are not to be tested get copied from the core specifications to the minimum conformance requirements subclause.

Base station conformance testing for LTE is similar to UMTS except for those areas of testing affected by the change to using an Orthogonal Frequency Division Multiple Access (OFDMA) modulation scheme. The base station RF conformance tests are defined in 3GPP Technical Specification 36.141 [1] and are based on the core specification TS 36.104 [2]. There are three main categories of conformance tests: transmitter characteristics, receiver characteristics and performance requirements.

Transmitter Characteristics

Table 1 lists the transmitter characteristics test cases defined in the conformance test specification. These tests follow very closely the pattern from UMTS with differences mainly due to the use of OFDMA . The test for time alignment between the transmitter branches is particularly important to LTE because of the widespread use of transmit diversity, spatial multiplexing, and beamsteering. A time alignment of 65 ns is required, as is the case in UMTS, which specifies ¼ of a chip (65 ns).

The downlink reference signal power test (TS 36.141 subclause 6.5.4) is the equivalent of the primary Common Pilot Channel (CPICH) power accuracy test from UMTS.

Receiver Characteristics

Table 3. Base station RF performance tests

36.141 subclause	Test case
8.2.1	Performance requirements of PUSCH in multipath fading conditions
8.2.2	Performance requirements for UL timing adjustment
8.2.3	Performance requirements for HARQ-ACK multiplexed on PUSCH
8.2.4	Performance requirements for High Speed Train conditions
8.3.1	ACK missed detection requirements for PUCCH format 1a
8.3.2	CQI missed detection for PUCCH format 2
8.3.3	ACK missed detection requirements for multi-user PUCCH format 1a
8.4.1	PRACH false alarm probability and missed detection

[3]

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Table 3. Base station RF performance tests.

The receiver characteristics conformance test cases are listed in Table 2. Of note is the in-channel selectivity test (subclause 7.4). Unique to OFDMA, it tests the receiver's ability to maintain a particular throughput on an allocation on one side of the DC subcarrier when a larger signal is present on the opposite side. This test checks for IQ distortion in the receiver and is the reverse of a UE transmitter IQ image requirement for in-band emissions.

Performance Requirements

Table 3 lists the base station performance test cases currently defined in TS 36.141. Note that these represent only some of the requirements given in TS 36.104 subclause 8.

Downlink Test Models

Table 4. E-UTRA Test Model mapping to test cases

E-TM	Notes	Test case
E-TM1.1	Maximum power tests	Output power, occupied bandwidth, ACLR, operating band unwanted emissions, transmitter spurious emissions, transmitter intermodulation, reference signal absolute accuracy
E-TM1.2	Includes power boosting and de-boosting	ACLR, operating band unwanted emissions
E-TM2	Minimum power tests	Total power dynamic range (lower OFDM symbol power limit at min power), EVM of single 64QAM PRB allocation (at min power), frequency error (at min power)
E-TM3.1		Total power dynamic range (upper OFDM symbol power limit at max power with all 64QAM PRBs allocated), frequency error, EVM for 64QAM (at max power)
E-TM3.2	Includes power boosting and de-boosting	Frequency error, EVM for 16QAM
E-TM3.3	Includes power boosting and de-boosting	Frequency error, EVM for QPSK

[4]

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Table 4. E-UTRA Test Model mapping to test cases.

The base station transmitter conformance tests are carried out using downlink configurations known as E-UTRA Test Models (E-TM). This concept has been inherited from UMTS although any similarity stops there. The highly flexible nature of the downlink OFDMA modulation scheme means that a large number of parameters are required to fully define any signal. An inspection of the definition of the E-TM in 36.141 subclause 6.1.1 clearly shows how much more complex the LTE signal structure has become.

Three distinct classes of test models are defined: E-TM1, E-TM2, and E-TM3. The first and third classes have further subclasses. All test models share the following attributes:

• Defined for a single antenna port, single code word, single layer with no precoding
•Duration of one frame (10 ms)
• Normal cyclic prefix
•Localized virtual resource blocks, no intra-subframe hopping for PDSCH
•Cell-specific reference signals only; no use of UE-specific reference signals

Table 5. FRC parameters for performance requirements (64QAM 5/6) from TS 36.141 Table A.5-1

Reference channel	A5-1	A5-2	A5-3	A5-4	A5-5	A5-6	A5-7
Allocated resource blocks	1	6	15	25	50	75	100
DFT-OFDM Symbols per subframe	12	12	12	12	12	12	12
Modulation	64QAM	64QAM	64QAM	64QAM	64QAM	64QAM	64QAM
Code rate	5/6	5/6	5/6	5/6	5/6	5/6	5/6
Payload size (bits)	712	4392	11064	18336	36696	55056	75376
Transport block CRC (bits)	24	24	24	24	24	24	24
Code block CRC size (bits)	0	0	24	24	24	24	24
Number of code blocks – C	1	1	2	3	6	9	13
Coded block size including 12 bits	2220	13260	16716	18444	18444	18444	17484
Total number of bits per sub-frame	864	5184	12960	21600	43200	64800	86400
Total symbols per sub-frame	144	864	2160	3600	7200	10800	14400

[5]

click to enlarge
Table 5. FRC parameters for performance requirements (64QAM 5/6) from TS 36.141 Table A.5-1.

The data content of the PDSCH is generated from a sequence of zeros scrambled using a length-31 Gold code according to TS 36.211 [3], as are the reference signals and the primary and secondary synchronization signals. The physical channels PBCH, PCFICH, PHICH and PDCCH all have detailed definitions. For each E-TM every physical signal and physical channel is allocated into the channel at a specific power relative to the reference signal power. There are six different mappings for each E-TM to take account of the six different channel bandwidths. For those E-TMs that employ power boosting or de-boosting, an additional table specifies for which resolution bandwidths the power boosting/de-boosting applies as a function of the channel bandwidth.

Each E-TM is defined for specific use according to Table 4.

An example of E-TM3.3 is shown in Figure 1. This signal was generated using the Agilent Signal Studio signal creation software and analyzed using the Agilent 89601A Vector Signal Analyzer software. Amplitude clipping was added to the signal to emphasize the impact this type of distortion has on EVM vs. time across the subframe. This can be seen in the top right trace.

Uplink Fixed Reference Channels

The LTE base station receiver and performance tests are carried out using uplink Fixed Reference Channels (FRCs) in a manner similar to UMTS. The base station FRC is similar in concept to the reference measurement channels used for UE testing. In most cases they are single-ended signals that can be generated in a signal generator without the need for any real time feedback.

The 64QAM example shown in Table 5 uses a code rate of 5/6, which is intended for testing the highest throughput requirements. For the 100 RB case of A5-7, there are 86,400 bits per 1 ms subframe indicating a maximum throughput of 86.4 Mbps. The base station performance requirements measured under fading conditions will be based on reaching a percentage of the maximum throughput under particular conditions. An example from TS 36.141 Table 8.2.1.5-6 demonstrates that a two channel eNB receiver operating in a pedestrian A channel with 5 Hz Doppler is required to reach 70% of the A5-7 FRC maximum throughput when the SNR is above 19.7 dB.

Conformance Testing Necessary but not Sufficient

For any standards-based technology, the goal of conformance testing is to ensure that all devicesbase station and user equipmentmeet a minimum level of performance. Although the lists of conformance tests may seem large, other kinds of testing are still needed. For example, a more thorough investigation of performance margins is important since conformance testing gives a pass/fail result with no indication of how close the product is to a particular limit. LTE conformance tests are primarily designed to ensure that the network's underlying transport mechanisms are in place to carry end-user services, so at a higher level applications will need to be tested. Operator acceptance testing is yet another step in the process and includes more user-centric tests. Thus conformance testing is an important and essential step towards the successful deployment of a new system, but it is by no means the beginning or end of the test process.

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References
[1]3GPP TS 36.141 V8.4.0 (2009-09) Base Station (BS) Conformance Testing
[2]3GPP TS 36.104 8.7.0 (2009-09) Base Station (BS) Radio Transmission and Reception
[3]3GPP TS 36.211 V8.7.0 (2009-05) Physical Channels and Modulation

Links:
[1] http://www.wirelessdesignmag.com/sites/wirelessdesignmag.com/files/legacyimages/0912/Agi_table1_lrg.jpg
[2] http://www.wirelessdesignmag.com/sites/wirelessdesignmag.com/files/legacyimages/0912/Agi_table2_lrg.jpg
[3] http://www.wirelessdesignmag.com/sites/wirelessdesignmag.com/files/legacyimages/0912/Agi_table3_lrg.jpg
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