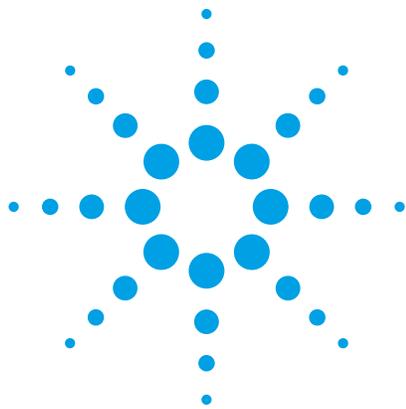


E-UTRA Base Station Transmit ON/OFF Power Measurement



Application Note



Introduction

The time domain division (TDD) mode of 3GPP LTE technology, known as LTE TDD or TD-LTE, has been accepted by major operators and most cellular equipment manufacturers. However, LTE's complex, evolved architecture introduces new challenges in designing and testing network and user equipment. One of the particular challenges for LTE TDD is strict timing and OFF power management during signal transmission.

This application note describes the LTE TDD E-UTRA base station transmit ON/OFF power measurement—also known as the power-versus-time measurement— as provided in the Agilent N9082A LTE TDD measurement application. The N9082A application runs on the following Agilent X-Series signal analyzers: PXA (N9030A), MXA (N9020A), and EXA (N9010A). According to 3GPP Technical Specification 36.141 [1], the LTE TDD transmit ON/OFF power measurement requires that the spectrum analyzer used in this measurement have an extremely high dynamic range and low noise floor. Meeting such a strict requirement is nearly impossible for spectrum and signal analyzers on the market today. To overcome this test challenge, two innovative techniques are used in the Agilent N9082A measurement application: a two-sweep method and a noise correction (NC)/noise floor extension (NFE) plus power limiter method [2]. A discussion of these methods follows.

3GPP Standard Requirements

In Section 6.4 of TS 36.141 [1], transition period and OFF power are defined and specified as follows:

- *Transmitter OFF power is defined as the mean power measured over [70 us] filtered with a square filter of bandwidth equal to the transmission bandwidth configuration of the BS (BW_{Config}) centered on the assigned channel frequency during the transmitter OFF 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 6.4.2.1-1.*
- *The transmitter transient period shall be shorter than $17 \mu s + [TT]$.*
- *The transmitter OFF power spectral density shall be less than $-85 \text{ dBm/MHz} + [TT]$.*

OFF power		$-85 \text{ dBm/MHz} + [TT]$
Max. transition period	OFF to ON	$17 \mu s + [TT]$
	ON to OFF	$17 \mu s + [TT]$

Note: TT is the Test Tolerance

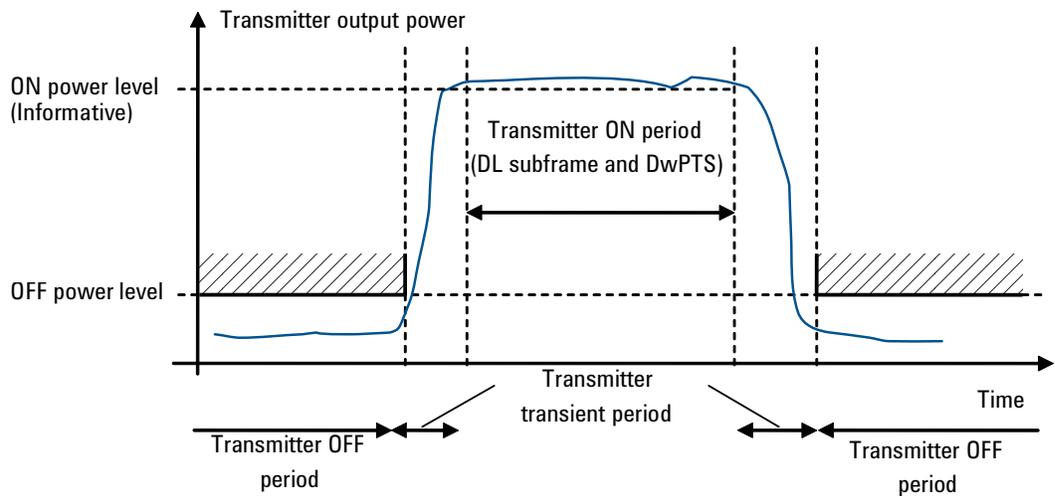


Figure 1. Illustration of the relations of transmitter ON period, transmitter OFF period and transmitter transient period (From 36.141 [1] Figure 6.4.2.1-1)

Why the Transmit On/Off Power Test is Important for TDD Systems

Benefitting from the characteristics of TDD, such as DL and UL on the same carrier frequency, the LTE TDD system can more easily accommodate new technologies such as beam forming and smart antennas and therefore achieve better spectrum efficiency. However, this benefit is achieved at the price of requiring strict burst timing and low OFF power to avoid interfering with other downlink or uplink slots. Figure 2 gives an example of how a downlink slot interferes with a uplink slot from a UE and a downlink slot from another E-UTRA base station. The transmit ON/OFF power test helps RF engineers troubleshoot E-UTRA base station power amplifier problems, including high OFF power and inappropriate ramp up/down transient period resulting from power leakage during OFF time, as well as wrong or inaccurate ON/OFF action.

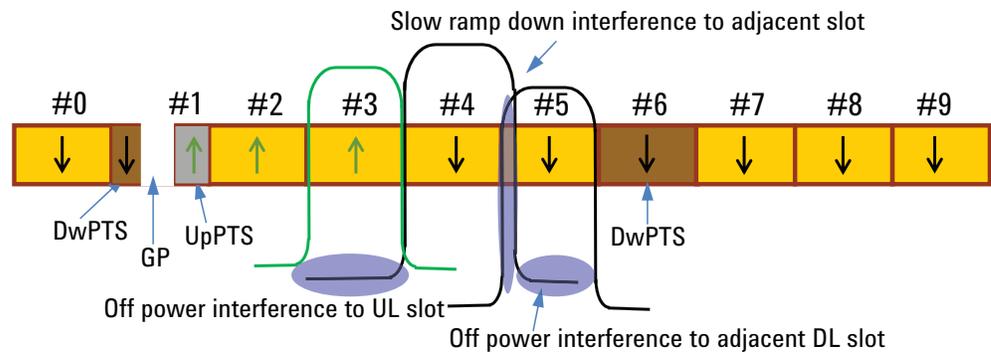


Figure 2. Illustration of OFF power and slow ramp down interference to adjacent slots

Challenges of the LTE TDD Transmit ON/OFF Power Test

The purpose of the LTE TDD transmit ON/OFF power test is to verify that the E-UTRA base station transmit OFF power and transient period fall within the limits of the minimum requirements. This test requires a spectrum analyzer with the ability to measure very high ON power and extremely low OFF power simultaneously to get the whole power-time mask. If you compare the requirements specified in TS 36.141 with even the best dynamic range and noise floor available in a spectrum analyzer, you will find that the measurement cannot be made by any existing spectrum analyzer on the market today.

Two factors that make this test so challenging will be discussed in detail below. Note that TS 36.141 requires that the transmit ON/OFF power be performed under the maximum transmit output power; i.e., 43 dBm. Therefore, all the examples used in this document will consider this most extreme case.

Challenge 1: Dynamic range

The first challenge arises from the fact that the dynamic range of a spectrum analyzer today is not sufficient to process the ON power and OFF power simultaneously, especially in the case of maximum output power. The maximum output power of an E-UTRA base station could be up to 43 dBm/BW (BW is configured as 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz), and the OFF power should be below -85 dBm/MHz, which requires that the spectrum analyzer's dynamic range be more than 126 dB ($= 43$ dBm/1.4 MHz - $(-85$ dBm/MHz + $10 \log(1.4 \text{ M}/1 \text{ M}))$). However, the best dynamic range of any spectrum analyzer on the market is only about 115 dB, which is much lower than the requirement.

Challenge 2: Noise floor

The second challenge occurs because the noise floor of a spectrum analyzer is very close to the OFF power requirement if a high value external attenuator is used. The OFF power requirement is -85 dBm/MHz, equivalent to -145 dBm/Hz. To prevent damage to the spectrum analyzer, an external attenuator should be used between the E-UTRA base station antenna port and the RF input port of the spectrum analyzer to attenuate the 43 dBm high power signal. A 30 dBm CW signal is a typical maximum allowable input power for the spectrum analyzer. In the case of a LTE signal with a 10 dB peak-to-average ratio, the external attenuator value should be at least 20 dB to attenuate the 43 dBm signal to the safe input power of the spectrum analyzer. With this attenuation, the OFF power of the signal under test at the RF input port of the spectrum analyzer is attenuated to -165 dBm/Hz ($= -145$ dBm/Hz - 20 dB). The OFF power from an E-UTRA base station could be much lower than -85 dBm/MHz. However, the best noise floor that can be achieved from a state-of-the-art spectrum analyzer is -165 dBm/Hz to -169 dBm/Hz, which is not enough margin to measure the attenuated OFF power level.

Solutions for the Challenges

Two-sweep method

In order to meet the high dynamic range requirement of the LTE TDD transmit ON/OFF power measurement, the dynamic range of the spectrum analyzer needs to be extended in some innovative way. The Agilent N9082A LTE TDD measurement application uses what is called the “two-sweep method” to make maximum use of 3rd order distortion and noise floor performance. Figure 3 illustrates the two-sweep method using a green trace line for the first sweep and a red trace line for the second. This two-sweep method sets a threshold power level to divide the power time trace into two parts: a higher power part and a lower power part. The N9082A first sweeps the high power part with high attenuation and preamplifier OFF settings to avoid distortion introduced by spectrum analyzer front end saturation. The high attenuation setting raises the noise level, as indicated by the dashed green line, which may bury the real OFF power trace but which is not included in the first sweep. In the second sweep, the N9082A gets the lower power part trace data (below the threshold) by optimizing the settings for low level signal measurement with minimum attenuation and preamplifier on. The minimum attenuation setting may saturate the high level ON power part as indicated by the dashed red line, but this data is not used as part of the second sweep. The parts of the traces indicated by the solid color lines are stored and combined automatically by a measurement algorithm into a single trace to implement the very high dynamic range power time measurement.

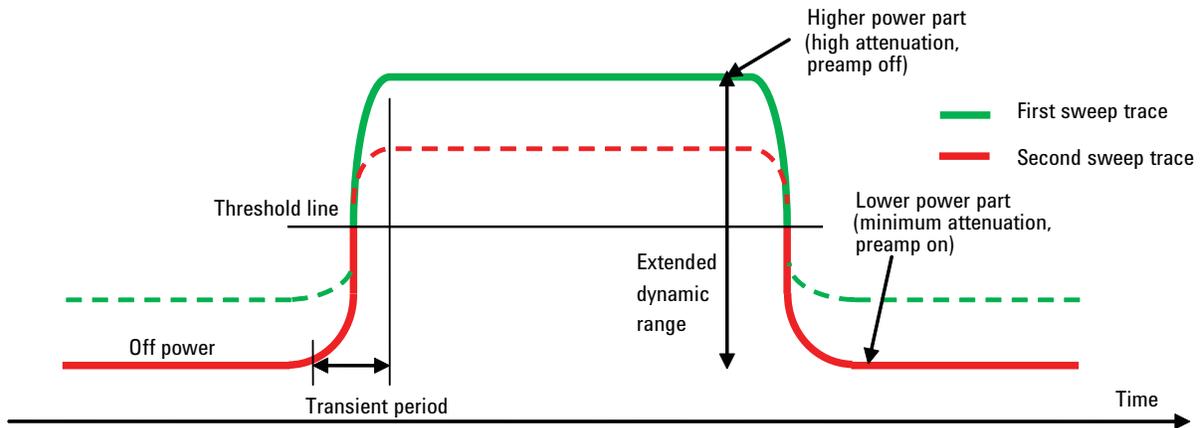


Figure 3. The two-sweep method for LTE TDD ON/OFF power measurement in the Agilent N9082A

NC or NFE plus power limiter

As we discussed in Challenge 2, a signal during the OFF time could reach -165 dBm/Hz for the 20 dB external attenuator case. There are two ways to overcome this challenge: extend the noise floor of the spectrum analyzer or reduce the external attenuator value. We will talk about both possible solutions below.

The noise floor performance of a spectrum analyzer is limited by the noise introduced by the spectrum analyzer itself. This spectrum analyzer native noise can be the thermal noise of active components, the phase noise of an oscillator, and so forth. This noise can be calculated by accurate calibration of the analyzer and appropriate noise modeling, and then the noise can be subtracted from the system. The Agilent N9082A has adopted two techniques—noise correction for the PXA (N9030A), MXA (N9020A), and EXA (N9010A) and noise floor extension for the PXA (N9030A)—to perform the LTE TDD transmit ON/OFF power measurement. Noise correction has been used widely in ACPR measurement for several years. Noise floor extension is a technique introduced in Agilent's high performance PXA signal analyzer in 2009. NC or NFE can lower the spectrum analyzer noise floor by about 4 to 6 dB for LTE TDD transmit ON/OFF power measurement. With NFE or NC applied, the spectrum analyzer noise floor can be lowered to -169 dBm/Hz, which is enough margin to measure the -165 dBm/Hz OFF power signal. Figure 4 shows a setup of the LTE TDD transmit ON/OFF power measurement. The signal power level changes shown at different test points make it easy to understand how NC/NFE helps measure the OFF power.

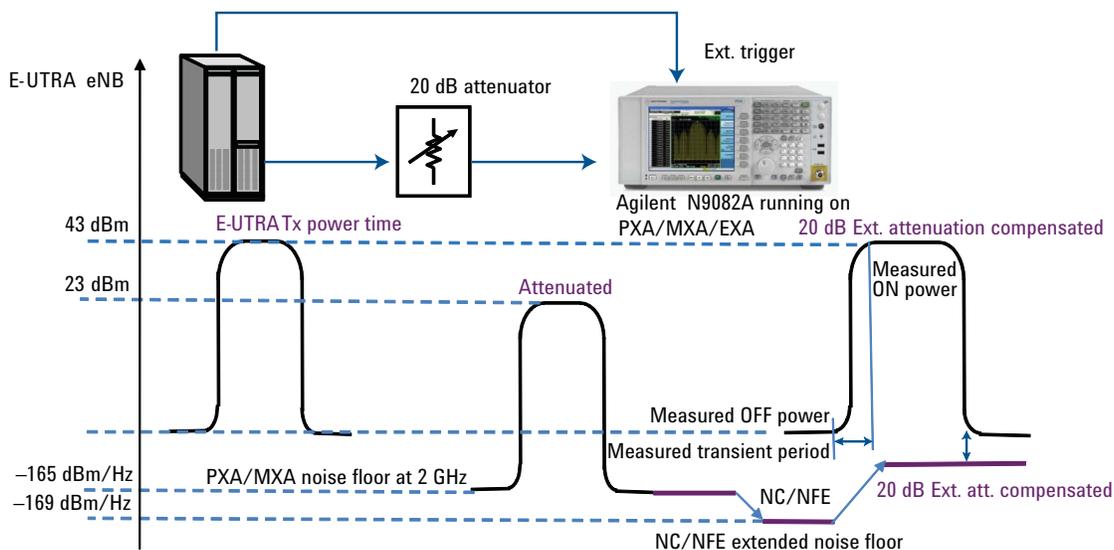


Figure 4. Test setup of LTE TDD ON/OFF power measurement with noise correction (NC) or noise floor extension (NFE) techniques

As noted previously, sometimes a noise floor of -169 dBm/MHz does not provide enough margin if the OFF power under test is lower than -85 dBm/MHz, which is achievable in current state-of-the-art E-UTRA base station designs.

Therefore, we must change the test setup by adding a power limiter, which provides more test margin to reduce the external attenuator value—for example, to 10 dB. However, this solution measures OFF power correctly only if the transient period and ON power measurements are not considered. As depicted in Figure 5, the transient period and ON power are measured incorrectly with some unknown part due to the limiter power cut. Agilent recommends using the N9356B power limiter (0 to 18 GHz) with maximum input power of 6 W, limiting threshold of 25 dBm, low insertion loss of < 1.75 dB, and fast turn on time of < 100 ps.

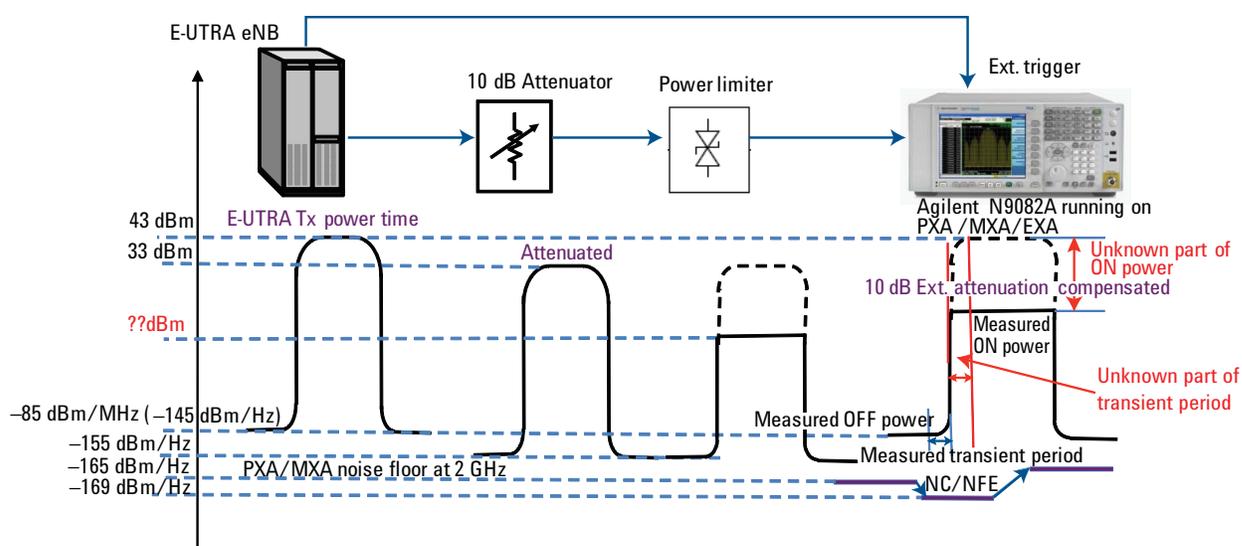


Figure 5 Test setup of LTE TDD ON/OFF power measurement with power limiter

For the LTE TDD transmit ON/OFF power measurement, Agilent suggests that you choose the measurement setup in Figure 4 for a standards-compliant transient period test if you are already confident in the OFF power performance of the E-UTRA base station, and choose the measurement setup in Figure 5 for an OFF power test only with enough margin.

How NC and NFE Work

Noise correction and noise floor extension are similar techniques in that they characterize spectrum analyzer native noise and subtract it from the signal under test. They differ, however, in the way they measure the noise. Noise correction measures spectrum analyzer noise before each measurement of the signal under test. In contrast, noise floor extension measures the spectrum analyzer's native noise during factory calibration and stores the appropriately modeled noise data before the spectrum analyzer is shipped. Then, before making a signal measurement, the analyzer just needs to read back from the stored information the data that is appropriate for the current spectrum analyzer parameters and environment. Noise floor extension takes less time during a signal measurement than does noise correction. More detailed information about NFE theory and application is discussed in [2].

Setting Up the LTE TDD Transmit On/Off Power Test

The LTE TDD transmit ON/OFF power measurement is made using the test setup depicted in Figure 4 or Figure 5. A frame synchronization trigger from the E-UTRA base station is needed to connect to the spectrum analyzer to get the wanted time slots to measure. In the following examples, Agilent's N9082A LTE TDD measurement application running on an Agilent X-Series signal analyzer is used to make the measurement. To ensure the success of the measurement, several parameters need to be set appropriately. These are the center frequency, information bandwidth (Info BW), downlink and uplink (DL/UL) allocation configuration, and special subframe length configuration. Because the two-sweep method has been adopted in the Agilent application software, the transmit ON/OFF power measurement is made in single-sweep (non-continuous) mode only. NC or NFE can be turned on and the power limiter can be used if you want to test OFF power levels lower than -85 dBm/MHz. The measurement results in Figure 6 show the power versus time graph and OFF power, ramp up/down period, and mean power for an E-TM1.1 test signal. A table of average power and slot width for each slot are also shown at the bottom of the screen. The pass/fail indicator at the upper left corner of the screen gives you the general pass/fail result at a glance.

The transmit ON/OFF power measurement of the Agilent N9082A provides more advanced functions for R&D engineers. Figure 7 zooms in on a trace of the power ramp up period for further troubleshooting. Zooming in on a trace can be accomplished easily by changing the Ref Value and Scale/Div of the X-axis, and it is a useful function for helping identify the root cause of ON/OFF power measurement failures.

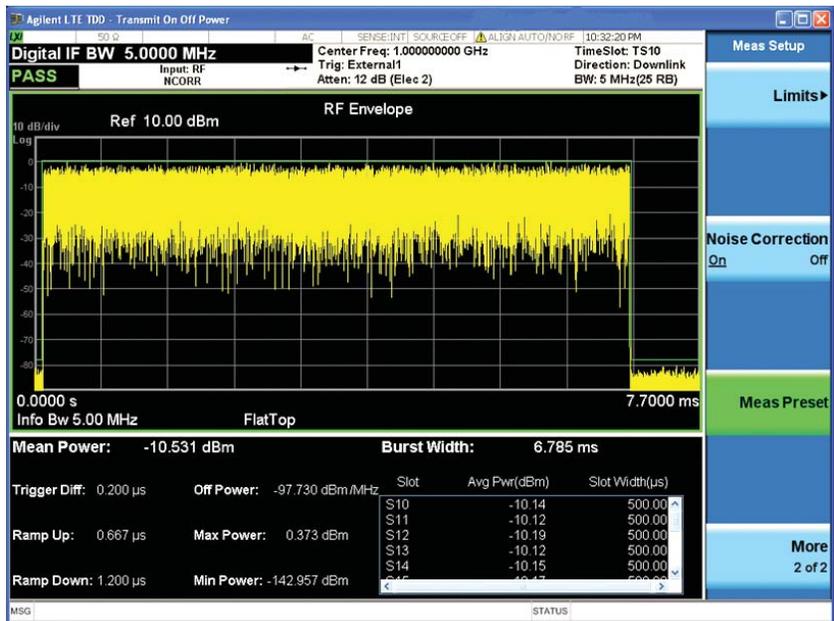


Figure 6. Example of LTE TDD transmit ON/OFF power measurement results

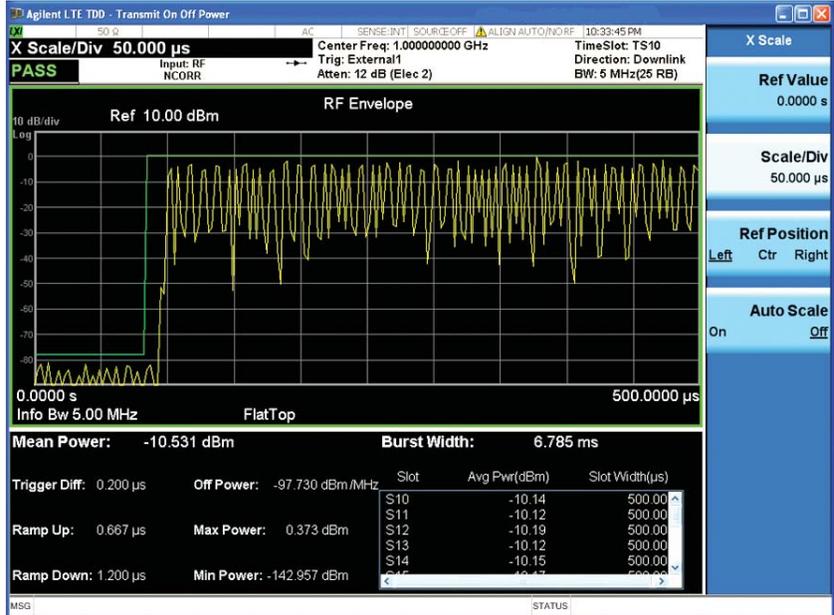


Figure 7. Zoomed-in power ramp up period

Conclusions

Standards-compliant LTE TDD ON/OFF power measurement is invaluable for RF engineers developing E-UTRA base station systems. However, because of spectrum analyzer dynamic range and noise floor limitations, this test is difficult to perform without using the two-sweep method and NC/NFE techniques adopted by the Agilent N9082A LTE TDD measurement application.

The Agilent application software running on an Agilent X-Series spectrum analyzer gives you an excellent solution for making the standards-compliant LTE TDD ON/OFF power measurement and for advanced troubleshooting as well.

Acronyms

3GPP	3 rd Generation Partnership Project
CW	Continuous waveform
DL	Downlink
E-TM	E-UTRA test model
E-UTRA	Evolved-UMTS terrestrial radio access
LTE	Long term evolution
NC	Noise correction
NFE	Noise floor extension
TDD	Time domain division
TD-LTE	Time division-long term evolution
UL	Uplink

References

- [1] 3GPP TS 36.141 V8.5.0 (2009-12), Base Station (BS) Conformance Testing
- [2] *Using Noise Floor Extension in the PXA Signal Analyzer*, Agilent literature number 5990-5340EN

More Information

For more information about the 3GPP, visit the 3GPP home page
www.3gpp.org

3GPP Series 36 (LTE) specifications
www.3gpp.org/ftp/Specs/archive/36_series

For more information about Agilent design and test products for LTE visit
www.agilent.com/find/lte

Agilent LTE application notes and technical overviews:

3GPP Long Term Evolution: System Overview, Product Development, and Test Challenges: 5989-8139EN

LTE Component Test: 5990-5149EN

MIMO in LTE Operation and Measurement—Excerpts on LTE Test: 5990-4760EN

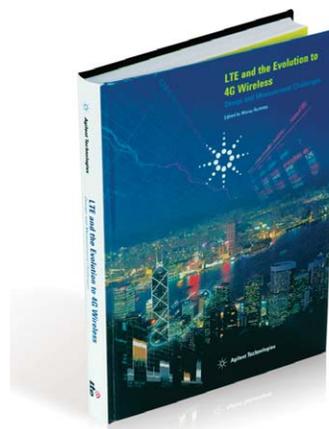
MIMO Performance and Condition Number in LTE Test: 5990-4759EN

N9080A & N9082A LTE Modulation Analysis Measurement Application Technical Overview: 5989-6537EN

Measuring ACLR Performance in LTE Transmitters: 5990-5089EN

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Revised: October 1, 2009

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Printed in USA, June 22, 2010
5990-5989EN



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