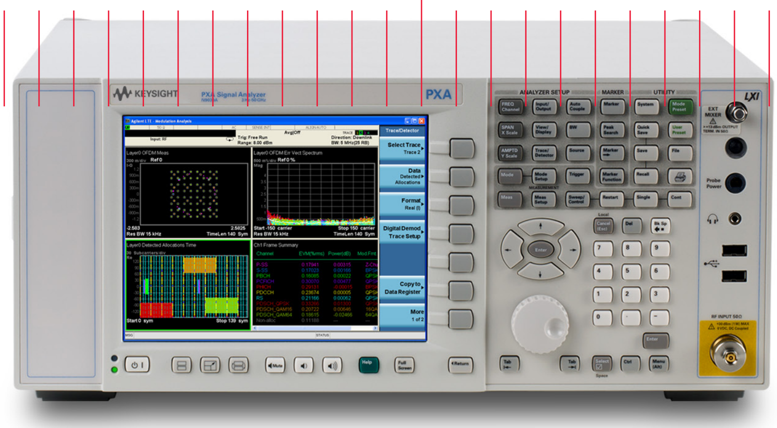
Keysight Technologies
LTE Base Station (eNB) Transmitter and Component Test

Demo Guide



Using Signal Studio software and X-Series signal analyzer measurement applications for LTE

Featured Products:

- N7624B Signal Studio for LTE FDD
- N7625B Signal Studio for LTE TDD
- N5182A MXG RF vector signal generator
- N9080A LTE FDD X-Series measurement application
- N9082A LTE TDD X-Series measurement application
- X-Series signal analyzers

KEYSIGHT TECHNOLOGIES

Introduction

FDD and TDD transmission modes

While the demonstrations in this guide focus on FDD, the procedures provided generally apply to TDD as well.

Looking for MIMO Analysis?

Please see the 89600B VSA Option BHD 3GPP LTE Self-Guided Demonstration (5989-7698EN) for MIMO product demonstrations and information.

This document describes how to evaluate key product features through demonstration and is not intended to be a User's Guide. Prior knowledge of the Keysight Technologies, Inc. products mentioned in the document is not required for these demonstrations and step-by-step instructions are provided. Please reference the appropriate Keysight User and Measurement Guides for further information regarding product operation.

The demonstrations found within this document assume basic knowledge of LTE physical layer signal characteristics. For more in-depth LTE technical information, please visit the following website:

www.keysight.com/find/lte

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Demonstration Preparation

Try before you buy!

FREE 14-day trials of Signal Studio software and X-Series measurement applications are available and provide unrestricted use of each application's features and functionality. Redeem a trial license today for your existing MXG signal generator and X-Series signal analyzer on-line at:

www.keysight.com/find/signalstudio_trial
www.keysight.com/find/x-series_trial

Equipment requirements

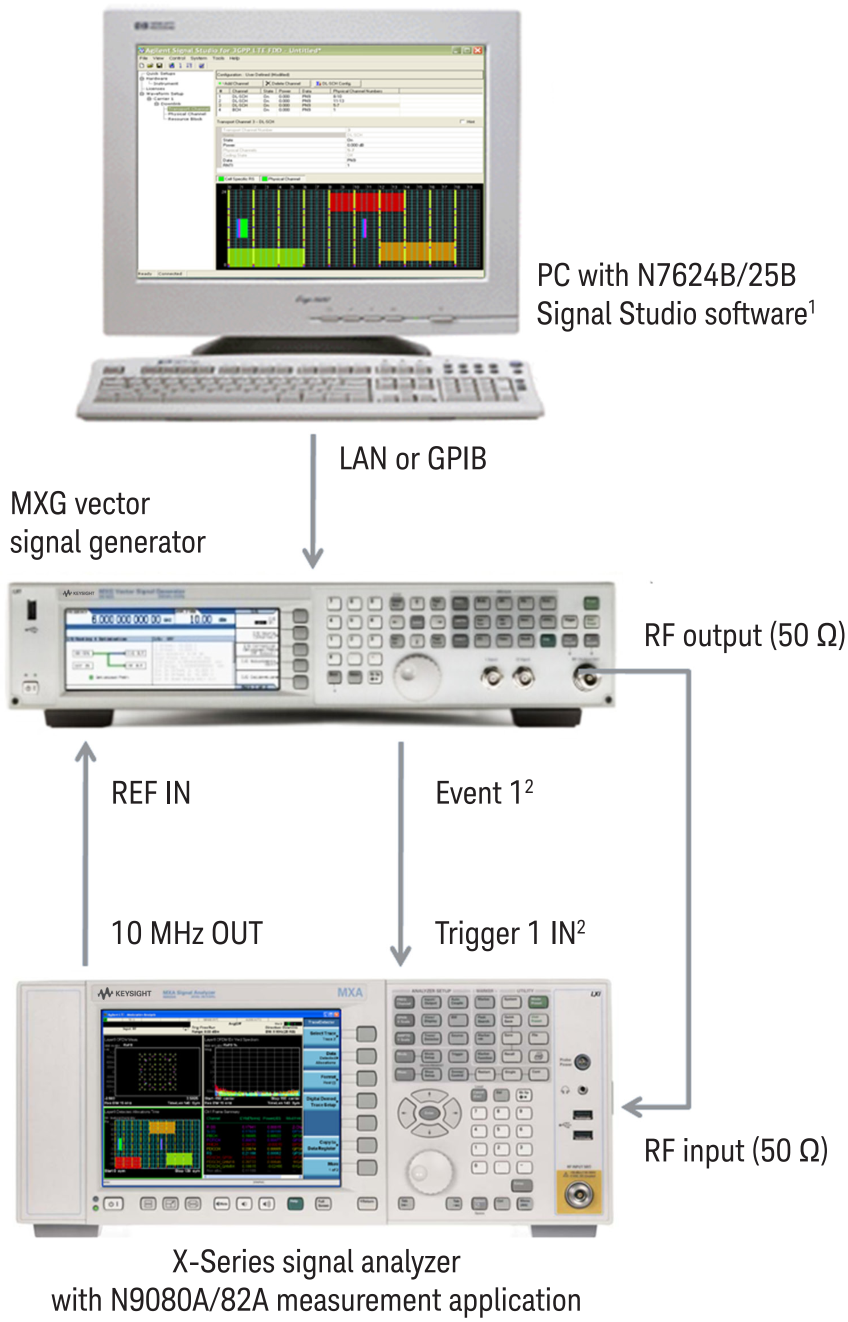
Upgrade to the latest firmware

The following instruments and software are required to perform all the demonstrations found in this guide. Note that X-Series signal analyzers differ in performance and measurement results may vary. It is strongly recommended to update instrument firmware and software to the latest versions.

MXG vector signal generator firmware: www.keysight.com/find/ss_firmware
Signal Studio software: www.keysight.com/find/signalstudio
X-Series signal analyzer firmware: www.keysight.com/find/sa_firmware

Product description	Model number	Required options	Demonstrations
MXG RF vector signal generator	N5182A (Rev. ≥ A.01.70)	≥ 503, frequency range, 3 GHz or higher	All except 3.3
		≥ 652, internal baseband generator, 60 MSa/s or higher	All except 3.3
		UNV, enhanced dynamic range (required for better ACP performance)	2.1 to 2.4, 3.3
		1EA, high output power	2.1 to 2.4
Signal Studio software for 3GPP LTE FDD	N7624B (Rev. ≥ 8.0.0.0)	3FP, to connect with MXG	All except 3.3
		HFP, basic LTE FDD	2.1 to 2.4
		SFP, advanced LTE FDD	3.2, 4.1
Signal Studio software for 3GPP LTE TDD	N7625B (Rev. ≥ 4.0.2.0)	3FP, to connect with MXG	3.3
		EFP, basic LTE TDD	3.3
		QFP, advanced LTE TDD	3.3
X-Series signal analyzer	N9030A PXA N9020A MXA N9010A EXA (FW Rev. ≥ A.06.06)	≥ 503, frequency range, 3 GHz or higher	All except 3.3
		≥ B25, analysis bandwidth, 25 MHz or higher	All except 3.3
LTE FDD measurement application	N9080A (FW Rev. ≥ A.06.06)	1FP, LTE FDD measurement application, fixed perpetual license	All except 3.3
LTE TDD measurement application	N9082A (FW Rev. ≥ A.06.06)	1FP, LTE TDD measurement application, fixed perpetual license	3.3
PC with Signal Studio software installed	Install Signal Studio software to generate and download the signal waveform into MXG signal generator via GPIB or LAN (TCP/IP). Please refer to the Signal Studio software Help for installation instructions and PC requirements. Note: the PC-based X-Series signal analyzer can also be used as the host PC for running Signal Studio software. The waveform in this case is created on the signal analyzer and then downloaded to the appropriate signal generator via LAN or GPIB.		

Setup diagram



1. Reference Signal Studio software help for LAN or GPIB setup assistance. The PC-based X-Series signal analyzer can also be used as the host PC for running Signal Studio software. The waveform in this case is created on the signal analyzer and then downloaded to the appropriate signal generator via LAN or GPIB.
2. The Event 1-to-Trigger 1 IN connection is recommended for LTE TDD (bursted signal) demonstrations where X-Series signal analyzer LO gating functionality is required.

Component Test Demonstrations

Single-carrier adjacent channel leakage ratio (ACLR)

Introduction

Adjacent channel leakage ratio (ACLR) is a key transmitter 3GPP conformance test and an important power amplifier (PA) performance metric since this component is the main contributor of distortion in the transmit chain. The use of OFDMA for the downlink in LTE results in a signal with high peak-to-average power ratios (PAPR) (i.e. crest factor), which is a result of the independent phases of the multiple subcarriers adding constructively. This extremely stressful signal requires a PA with a large dynamic range, which presents very difficult challenges to PA designers. As a result, the signal generator and signal analyzer used during the design and characterization of the PA must have significantly better distortion peformance than the PA under test in order to minimize any uncertainity in the results.

Single carrier measurement demonstration objectives

1. Create a test signal configured for an E-UTRA test model (E-TM) using Signal Studio for 3GPP LTE software
2. Measure single carrier ACLR performance of the MXG vector signal generator using an X-Series signal analyzer with the LTE measurement application
3. Measure single carrier ACLR performance of MXG vector signal generator at higher power

Quickly create error-free test model configurations

eNB transmitter conformance tests are carried out using downlink configurations known as E-UTRA test models (E-TM). These are highly complex signals due to the flexible nature of the LTE downlink OFDMA modulation scheme. Therefore, a large number of parameters need to be fully defined, which increases the chance of errors during setup. Signal Studio software eliminates this uncertainty and deceases setup time by providing:

- Predefined setups for all three classes of E-UTRA test models (E-TM)
- Easy tree-style navigation for testing beyond standard requirements with user-defined signal configurations
- 3GPP LTE compliant signals with a first-to-market track record for updates
- Calculated CCDF graphs to investigate the effect of power ramps, modulation formats, power changes, clipping, etc.
- Comprehensive set of online documentation and embedded help

Industry best ACLR and output power performance

With the industry's best combination of high output power and distortion performance, the MXG RF vector signal generator is ideal for PA and multicarrier power amplifier (MCPA) design and production engineers who want to minimize measurement uncertainty for accurate design characterization and improved yields.

- –74 dBc (measured) ACLR performance for a 5 MHz LTE FDD single carrier
- Up to +23 dBm (specified) output power up to 3 GHz with electronic attenuator
- ≤ 1.2 ms switching speed (SCPI mode); ≤ 900 µs simultaneous frequency, amplitude, and waveform switching (List mode)

Step 1.

Create a 5 MHz LTE FDD downlink signal configured for E-TM 1.2 with Signal Studio software and an MXG vector signal generator.

NOTE: Keystrokes surrounded by [ ] indicate instrument hard keys on the instrument front panel, while key names surrounded by { } indicate soft keys located on the right edge of the display.

Signal Studio software	Software operation
Start the Signal Studio for 3GPP LTE FDD software	Start > All Programs > Keysight Signal Studio > 3GPP LTE FDD > **3GPP LTE FDD**
Connect to the MXG signal generator via GPIB or LAN (TCP/IP)	Follow the Signal Studio on-screen instructions to connect to the MXG signal generator
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GHz** Amplitude = **0 dBm** RF Output = **On**
Reconfigure the default basic LTE downlink carrier for E-TM 1.2 and 5 MHz bandwidth configuration using test model wizard NOTE: The E-TM1.2 configuration is the best setup for product performance evaluations because it simulates multiple allocations set at different power levels. This scenario results in a higher crest factor, which makes it more difficult to amplify the signal without creating additional, unwanted spectral content (i.e., adjacent channel leakage).	In the tree view, left pane of the main window, select **Downlink** under **Carrier 1**. In the right pane, click Test Model Wizard button to access a dialog box and set: System Bandwidth = **5 MHz (25RB)** Test Model Type = **E-TM 1.2** Click {**OK**} See Figure 1
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

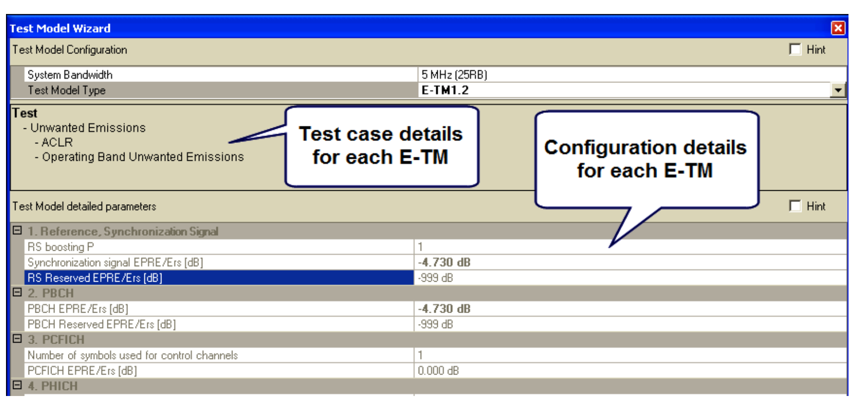


Figure 1. Signal Studio's test model wizard provides extensive information for each E-UTRA test model (E-TM) including 3GPP test use cases and related parameter details such as number of power-boosted and de-boosted physical downlink shared channels (PDSCH).

Choice of performance with measurement flexibility

When combined with the N9080A LTE FDD and/or N9082A LTE TDD measurement applications, X-Series signal analyzers offer the RF performance and measurement flexibility required for testing LTE PAs and MCPAs.

- One-button RF power measurements, such as ACLR, with pass/fail limits per 3GPP standard
- Support for E-UTRA test models (E-TMs) for transmit signal quality measurements as well as RF power measurements as defined in 3GPP TS 36.141
- Custom ACLR measurement configuration supports up to 12 carriers; choice of up to six channel offsets each with adjustable integration bandwidth, offset frequency and pass/fail limit
- –83.5 dB (nominal) LTE dynamic range (with noise correction on) when using the PXA high-performance signal analyzer

Pre-defined limit masks simplify measurement setup

The N9080A LTE FDD and N9082A LTE TDD measurement applications provide a pre-defined limit masks for both uplink (UL) and downlink (DL) measurements. These masks contain the configuration setup for carrier, offset, limit settings and LTE profile bandwidth. Pre-defined limit masks allow the user to make one-button ACLR measurements with pass/fail indication per 3GPP TS 36.141 standard without having to be an expert on measurement setup.

Optimize for increased dynamic range

One-button ACP measurement gives a very fast, usable ACLR measurement according to the LTE standard. While the results are adequate for most test needs, the analyzer dynamic range performance can be further optimized at the cost of measurement speed. The combination of the following optimization steps can improve a typical ACLR measurement by 10 dB or more from the default settings.

- Optimize the signal level at the input mixer for dynamic range
  A combination of mechanical and electronic attenuation may be used in analyzers that contain both types of attenuators. This is not necessarily the best attenuation for maximum dynamic range, and it is often possible to improve the ACLR by reducing the attenuation slightly. If the electronic attenuator is enabled, turning it off (not just setting the attenuation to 0 dB) can further improve the results.
- Turn on noise correction
  This can provide a substantial improvement in the ACLR, particularly when the distortion being measured is close to the noise floor of the analyzer. With noise correction, the analyzer takes one sweep to measure its internal noise floor, and then it subtracts that noise floor from the measurement data in subsequent sweeps.

Step 2.

Measure single carrier ACLR performance with the LTE measurement application and an X-Series signal analyzer.

NOTE: This procedure is the same when using any X-Series signal analyzer, however, performance of the instrument selected must be considered.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} = **2.14** {GHz}
Start LTE measurement application	[Mode] > {More} > **{LTE}** Note: The exact page may vary.
Set 5 MHz (25 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{5 MHz (25RB)}**
Select ACP measurement	[Meas] > **{ACP}**
Recall a preset limit mask	[Recall] > {Data (import)} > {Mask} {Open...} > open **ACP_BS** folder and select **ACP_BS_5 MHz_pairE-UTRA_CatA.mask**
Optimize for dynamic range	[Meas Setup] > {More} > {Noise Correction} = **ON** [AMPTD Y Scale] > {Attenuation} > {Enable Elec Atten OFF}> {Mech Atten} = **18 {dB}** See Figure 2 Note: For this signal power, ~18 dB of attenuation is the optimum level. The attenuation level will need to be adjusted to obtain maximum dynamic range.

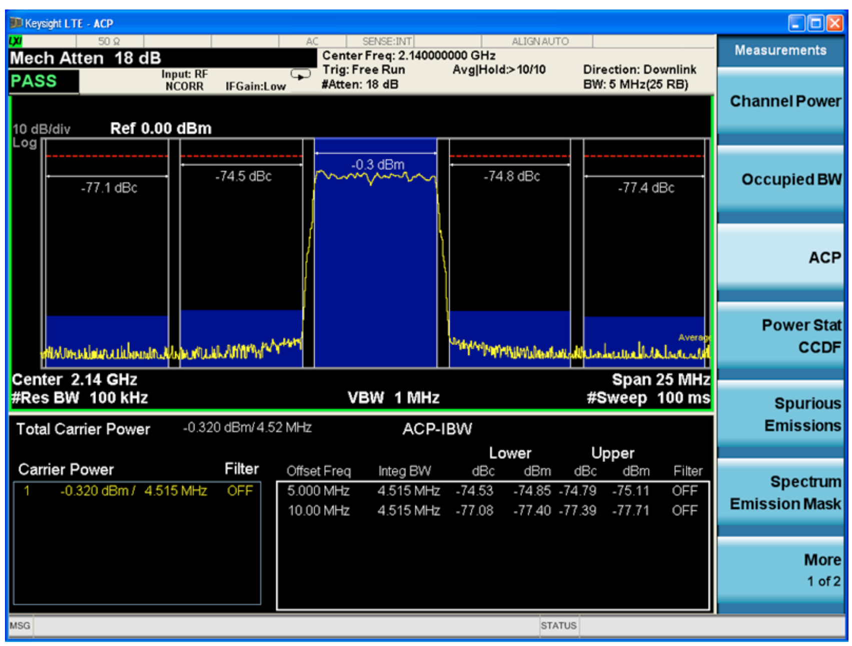


Figure 2. MXG vector signal generator industry-leading ACLR single-carrier performance of –74.5 dBc at 0 dBm measured using the PXA signal analyzer with LTE FDD measurement application.

Step 3.

Increase MXG signal generator power to +10 dBm and continue to observe industry-leading ACLR performance with excellent linearity.

Signal Studio software	Software operation
Increase MXG vector signal generator power	In the tree view, left pane of the main window, select **Instrument** under **Hardware.** In the right pane, set Amplitude = **10 dBm**
Update hardware settings	Press **Update Hardware Settings** button on the top tool bar. MXG signal generator should now be set to increased power level.

Step 4.

Adjust analyzer attenuation for increased input power.

X-Series signal analyzer	Keystrokes
Increase analyzer attenuation to compensate for increased input power	[AMPTD Y Scale] > {Attenuation} > {Mech Atten} = **22 {dB}** See Figure 3

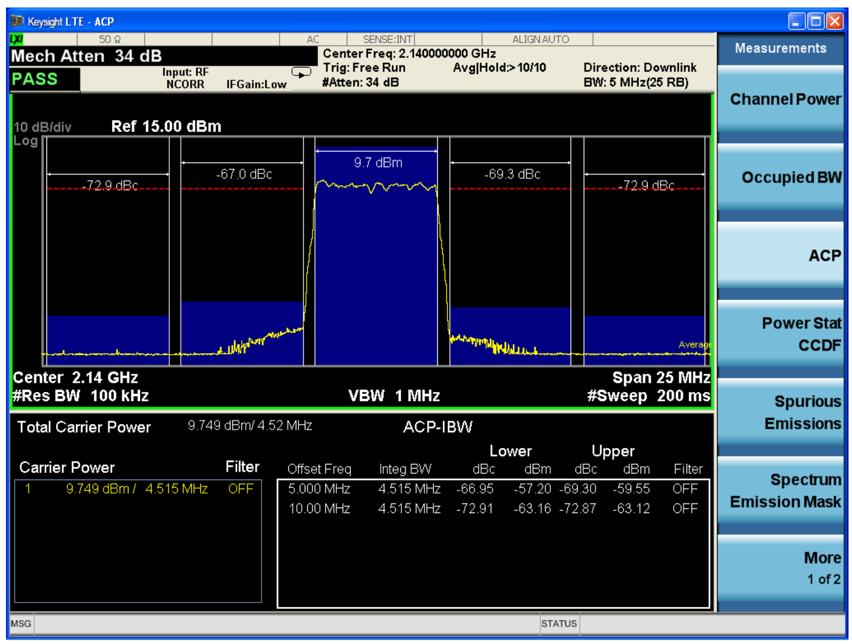


Figure 3. Continued excellent ACLR performance of –67 dBc from the MXG vector signal generator as power is significantly increased from 0 to +10 dBm. This low distortion ensures that the error contribution from the MXG during amplifier test is significantly reduced -- even at high powers.

Multi-carrier ACLR

Demonstration objectives

1. Create a multi-carrier test signal using Signal Studio for 3GPP LTE software

2. Measure ACLR performance of the MXG vector signal generator using an X-Series signal analyzer with LTE measurement application

Multi-carrier signal creation considerations

Test engineers creating multi-carrier amplifier test signals must consider the ramifications of using the same test model or similar configuration setups for each of the carriers. This approach causes carriers to add constructively producing signals with unrealistically high crest factors that are unlikely to occur during real-world operation. To avoid this issue, Signal Studio software allows parameters such as frequency offset, power, timing offset, initial phase, and filtering to be set differently for each carrier. For this multi-carrier demonstration, timing offset values were chosen to significantly reduce this effect and show the excellent MXG vector signal generator ACLR performance while simulating realistic signal conditions.

Step 1.

Create a 4-carrier LTE FDD downlink signal with Signal Studio software and an MXG vector signal generator.

Signal Studio software	Software operation
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GHz** Amplitude = **–5 dBm** RF Output = **On**
Copy existing Basic LTE FDD downlink carrier created in section 2.1 and add three more carriers to the waveform setup	In the tree view, left pane of the main window, select **Waveform Setup.** In the right pane, click  button 3 times to add 3 duplicate carriers to the list.
Set carrier frequency offsets to a 5-MHz spacing and adjust timing offsets to reduce carrier correlation	In the tree view, left pane of the main window, select each carrier and set offsets to the following: **Carrier 1:** Frequency offset to **–7.5 MHz** & Timing offset to **0** **Carrier 2:** Frequency offset to **–2.5 MHz** & Timing offset to **500** **Carrier 3:** Frequency offset to **2.5 MHz** & Timing offset to **1000** **Carrier 4:** Frequency offset to **7.5 MHz** & Timing offset to **1500** Now, the expanded tree in the left pane should show 4 carriers under **Waveform Setup** and the carrier table in **Waveform Setup** should now look like Figure 4

Signal Studio software	Software operation
Verify the generated waveform looks as good as you want before downloading it to the instrument	Press Generate Waveform button at the top tool bar. Signal Studio displays a programming bar, after the programming bar appears, click **Waveform Setup** in the left pane, then click on the Waveform button of the graph and select Spectrum from the pull-down list. You will then see a calculated graph of the 4 carriers in Signal Studio. Refer to Figure 4.
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. The MXG should now be set to correct frequency, power, and display ARB on screen.

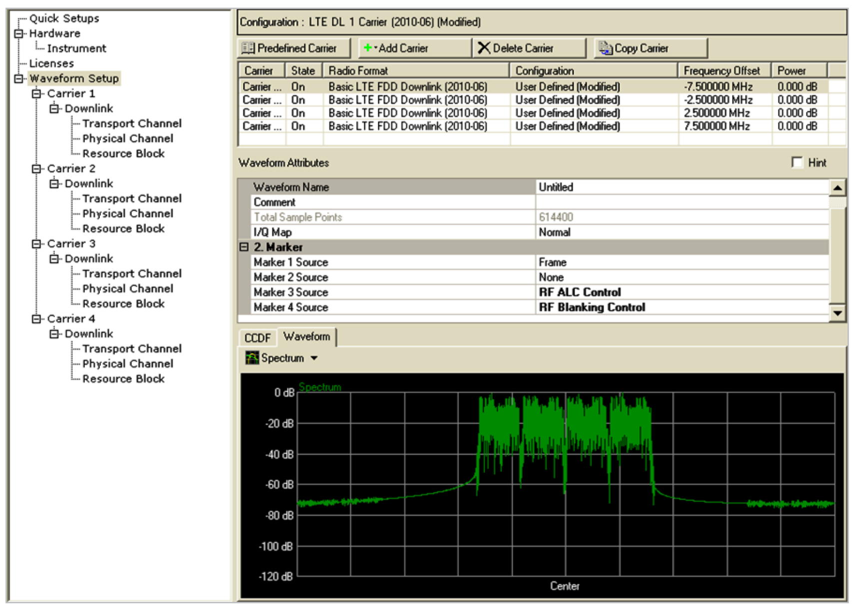


Figure 4. Signal Studio software carrier setup table and calculated graph showing four identical carriers spaced 5 MHz apart centered at the carrier frequency.

Step 2.

Measure 4-carrier ACLR performance using the LTE measurement application and an X-Series signal analyzer.

NOTE: This procedure is the same when using any X-Series signal analyzer, however, performance of the instrument selected must be considered.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} = **2.14** {GHz}
Start LTE measurement application	[Mode] > {More} > **{LTE}** Note: The exact page may vary.
Set 5 MHz (25 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{5 MHz (25RB)}**
Select ACP measurement	[Meas] > **{ACP}**
Configure ACP measurement for 4 carriers	[Meas Setup] > {Carrier Setup} {Carriers} = **4**
Optimize for dynamic range	[Meas Setup] > {More} > {Noise Correction} = **ON** [AMPTD Y Scale] > {Attenuation} > {Enable Elec Atten OFF}> {Mech Atten} = **14** {dB} See Figure 5 Note: For this signal power, ~14 dB of attenuation is the optimum level. The attenuation level may need to be adjusted to obtain maximum dynamic range.

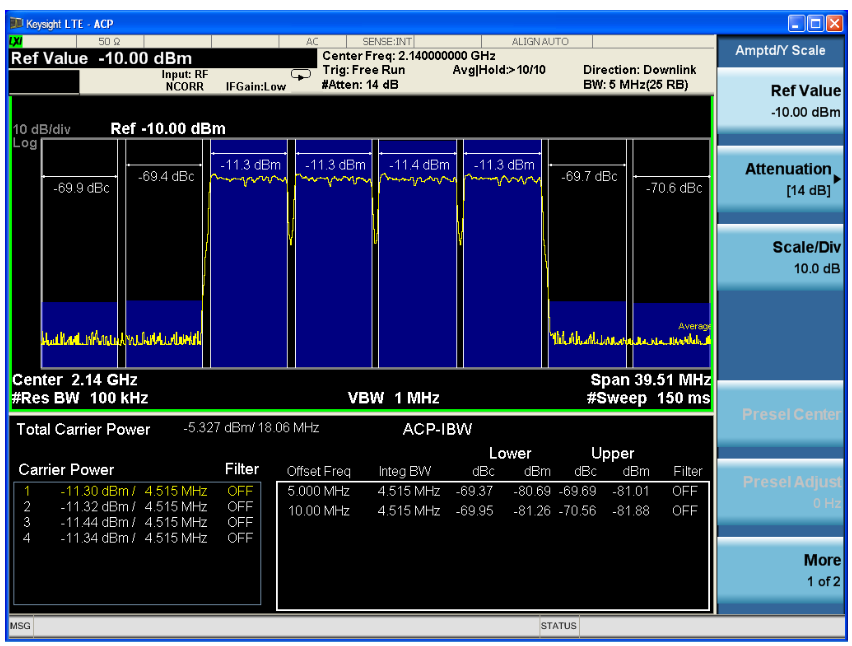


Figure 5. MXG vector signal generator industry-leading ACLR 4-carrier performance of –69.4 dBc at –5 dBm using a PXA signal analyzer with the N9080A LTE measurement application.

Multi-standard radio (MSR) ACLR

Introduction

The minimum RF characteristics for multi-standard radio (MSR) base stations were introduced with release 9 of the 3GPP standard. No longer can multi-carrier power amplifier (MCPA) designers focus on testing with one type of carrier. Now, many combinations of E-UTRA (LTE), UTRA (W-CDMA), and GSM/EDGE should be considered when characterizing MCPAs. This increased test complexity emphasizes the need for flexible test equipment capable of being adjusted easily for many different test cases.

Demonstration objectives

1. Create a multi-standard radio signal using Signal Studio for 3GPP LTE software

2. Measure multi-carrier ACLR performance of the MXG vector signal generator using the custom measurement setup of the X-Series signal analyzer with LTE measurement application

Signal Studio MSR test signal creation

Since LTE systems are expected to co-exist with W-CDMA systems, the ability to easily create MSR test signals that include both types of carriers is now essential in test signal creation. Signal Studio 3GPP LTE FDD and TDD software easily allows users to create signals containing any combination of LTE downlink/uplink and W-CDMA downlink/uplink carriers. This highly flexible multi-carrier capability provides a tremendous cost savings compared to other solutions that require purchase of additional signal generators to create MSR test signals.

Step 1.

Create an MSR LTE FDD and W-CDMA downlink signal with Signal Studio software and an MXG vector signal generator.

Signal Studio software	Software operation
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GHz** Amplitude = **-5 dBm** RF Output = **On**
Add W-CDMA carrier configured for test model 1 + 64 DPCH	In the tree view, left pane of the main window, select **Waveform Setup.** In the right pane, click [Add Carrier] button and select **Basic W-CDMA FDD Downlink** from drop-down list. In the tree view, left pane of the main window, select **Carrier 1.** In the right pane, set: Channel Configuration = **Test Model 1 + 64 DPCH**
Add second W-CDMA carrier by copying existing W-CDMA carrier	In the tree view, left pane of the main window, select **Waveform Setup.** In the right pane, select the existing **Basic W-CDMA FDD Downlink** carrier and click [Copy Carrier] button to duplicate the existing carrier and add the list.
Configure LTE downlink carrier for E-TM 1.2 and 10 MHz bandwidth using test model wizard	In the tree view, left pane of the main window, select **Downlink** under **Carrier 2.** In the right pane, click [Test Model Wizard] button to access a dialog box and set: System Bandwidth = **10 MHz (50RB)** Test Model Type = **E-TM 1.2** Click **{OK}**
Set carrier frequency offsets and adjust timing offsets to reduce carrier correlation	In the tree view, left pane of the main window, select each carrier and set: **Carrier 1 (W-CDMA 1):** Frequency offset = **2.5 MHz** Timing offset = **0** **Carrier 2 (LTE):** Frequency offset = **-5 MHz** Timing offset = **500** **Carrier 3 (W-CDMA 2):** Frequency offset = **7.5 MHz** Timing offset = **1** The expanded tree in the left pane should now show 3 carriers under **Waveform Setup** and the carrier table in **Waveform Setup** should now look like Figure 6.
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

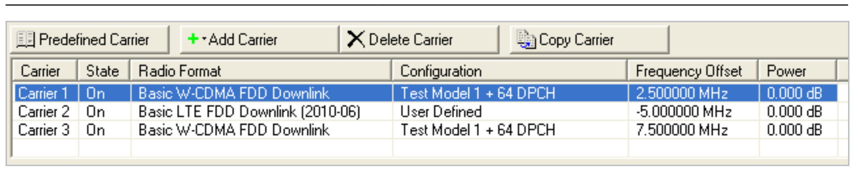


Figure 6. Carrier table found within waveform setup showing an MSR setup of two 5-MHz W-CDMA carriers and one 10-MHz LTE carrier.

Step 2.

Measure ACLR performance using an X-Series signal analyzer with LTE measurement application.

NOTE: This procedure is the same when using any X-Series signal analyzer, however, performance of the instrument selected must be considered.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} > **2.14** {GHz}
Start LTE measurement application	[Mode] > {More} > **{LTE}** Note: The exact page may vary.
Set to 10 MHz (50 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{10 MHz (50RB)}**
Select ACP measurement	[Meas] > **{ACP}**
Configure ACP measurement for 3 carriers	[Meas Setup] > {Carrier Setup} {Carriers} **3**
Configure LTE carrier 1	[Meas Setup] > {Carrier Setup} > {Configure Carriers} > {Carrier} = **1** {Carrier Spacing} = **10 MHz** {Meas Noise BW} = **9.015 MHz** {Method} = **IBW (Integrated BW, no RRC filtering)**
Configure W-CDMA carrier 2	[Meas Setup] > {Carrier Setup} > {Configure Carriers} > {Carrier} **2** {Carrier Spacing} = **5 MHz** {Meas Noise BW} = **3.84 MHz** {Method} = **RRC Weighted [Alpha 0.22]**
Configure W-CDMA carrier 3	[Meas Setup] > {Carrier Setup} > {Configure Carriers} > {Carrier} **3** {Carrier Spacing} = **5 MHz** {Meas Noise BW} = **3.84 MHz** {Method} = **RRC Weighted [Alpha 0.22]**
Configure offsets for carrier edge to measurement B	[Meas Setup] > {Offset/Limits} > {More 3 of 3} > {Offset Freq Define} > **{Carrier Edge To Meas BW Center}**
Configure offset A (adjacent channel)	[Meas Setup] > {Offset/Limits} > {Select Offset} > **{Offset A}** {Offset Freq} = **5 MHz**
Configure offset B (alternate channel)	[Meas Setup] > {Offset/Limits} > {Select Offset} > **{Offset B}** {Offset Freq} = **15 MHz**
Optimize for dynamic range	[Meas Setup] > {More} > **{Noise Correction ON}** [Meas Setup] > {More} > {Meas Method} **{Filtered IBW}** [AMPTD Y Scale] > {Attenuation} > {Enable Elec Atten OFF}> {Mech Atten} > **12** {dB} See Figure 7 Note: For this signal power, ~12 dB of attenuation is the optimum level. The attenuation level will need to be adjusted to obtain maximum dynamic range.

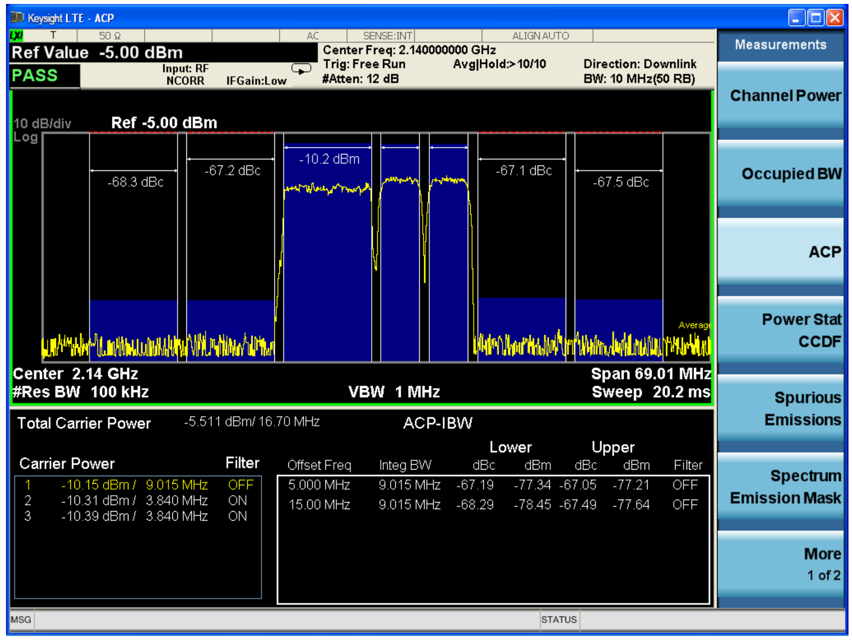


Figure 7. 3-carrier MSR test signal consisting of a 10-MHz LTE FDD and two 5-MHz W-CDMA carriers created using Signal Studio software. ACLR measurement with custom carrier and E-UTRA offsets defined using an X-Series signal analyzer with LTE FDD measurement application.

Error vector magnitude

Introduction

Error vector magnitude or EVM, also called relative constellation error (RCE), is a key modulation analysis measurement used to quantify the performance of a digital radio transmitter. A signal sent by an ideal transmitter would have all IQ constellation points precisely at the ideal locations, however, various design imperfections (such as carrier leakage, low image rejection ratio, phase noise, etc.) cause the actual constellation points to deviate from the ideal locations. In other words, an EVM measurement is a measure of 'how far' the actual measured values are from the ideal locations. This measurement needs to be made quickly and accurately and, when testing transmitter components such as a power amplifier, be accompanied by a 'clean' test signal with enough EVM performance to provide an adequate test margin for the device under test (DUT).

Demonstration objectives

1. Create a downlink signal configured for an E-UTRA test model (E-TM) using Signal Studio for 3GPP LTE software

2. Measure EVM performance of the MXG vector signal generator using an X-Series signal analyzer with LTE measurement application

3. Measure EVM performance of the MXG vector signal generator at high power

Step 1.

Create a 10 MHz LTE FDD E-TM 3.1 downlink signal with Signal Studio software and an MXG vector signal generator.

Signal Studio software	Software operation
Start the Signal Studio for 3GPP LTE FDD software	Start > All Programs > Keysight Signal Studio > 3GPP LTE FDD > 3GPP LTE FDD
Connect to the MXG signal generator via GPIB or LAN (TCP/IP)	Follow the Signal Studio on-screen instructions to connect to the MXG signal generator
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GHz** Amplitude = **–5 dBm** RF Output = **On**
Change default basic LTE downlink carrier (2010-06) to basic LTE downlink carrier (2009-12) Note: The revision of the LTE measurement application for X-Series analyzers in this demonstration guide is to support the 3GPP specification of December 2009.	In the right pane, click Delete Carrier button to delete the default carrier. Then click Add Carrier, select Basic LTE FDD Downlink (2009-12) from the pull-down list
Set selected LTE downlink carrier for E-TM 3.1 and 10 MHz system bandwidth configuration using test model wizard NOTE: The E-TM 3.1 configuration is one of four possible test models used for EVM conformance testing and is the only E-TM with all PRBs set to 64QAM, which is the highest order modulation supported.	In the tree view, left pane of the main window, select **Downlink** under **Carrier 1.** In the right pane, click button to access a dialog box and set: System Bandwidth= **10 MHz (50RB)** Test Model Type = **E-TM 3.1** Click **{OK}**
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

Step 2.

Measure EVM performance with the LTE FDD measurement application and an X-Series signal analyzer.

NOTE: This procedure is the same when using any X-Series signal analyzer, however, performance of the instrument selected must be considered.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} > **2.14** {GHz}
Start LTE measurement application	[Mode] > **{LTE}** Note: The exact page may vary.
Set to 10 MHz (50 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{10 MHz (50RB)}**
Select modulation analysis measurement	[Meas] > {More 1 of 2} > **{Modulation Analysis}**
Optimize analyzer input level range for the given signal generator output power	[AMPTD Y Scale] > {Range} > **4** {dBm} Note: ~4 dBm is optimum for an input signal power of –5 dBm
Recall a preset E-TM 3.1 setup for a 10 MHz LTE signal	[Recall] > {Data (import)} > {EVM Setup} > {Open...} > scroll down the list and select **TM3.1-BW10MHz.evms** and click **Open**
Change the measurement interval to display the entire frame (20 slots)	[Meas Setup] > {Meas Time Setup} > {Meas Interval Slot} > **20** {Enter}
Include all active channels and signals	[Meas Setup] > {Chan Profile Setup} > {Composite Include} > **{Include All}**
Change the display to show modulation error and frame summary tables	[View/Display] > **{Preset View: Meas Summary}** See Figure 8

RE Tx power measurements provided by error summary

Downlink reference signal power is the resource element (RE) power of the downlink reference symbol. There are two types of RE transmitter (Tx) power defined in 3GPP Technical Specification 36.141:

1. RS Tx power (RSTP) is the average reference signal power for all input antenna ports for the data within a subframe. This average power is calculated by summing the powers of all resource elements occupied by RS in a subframe and dividing by the total number of resource elements in a subframe.

2. OFDM symbol Tx power (OSTP) accumulates all subcarrier powers of the 4th OFDM symbol. The 4th (out of 14 OFDM symbols within a subframe (in case of frame type 1, normal CP length)) contains exclusively PDSCH so this metric can be interpreted as an average data subcarrier power.

As shown in Figure 8, the RS and OFDM symbol Tx power results are displayed under error summary trace.

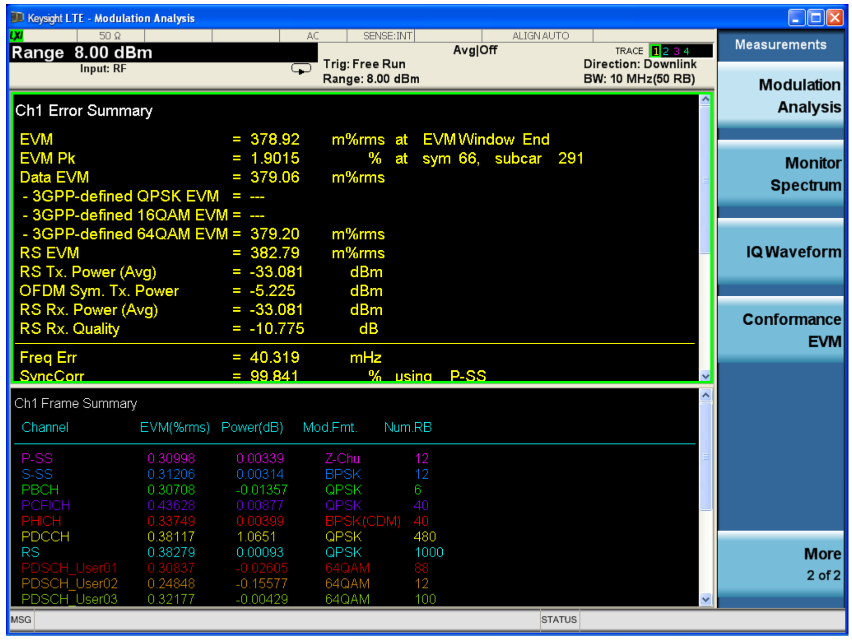


Figure 8. MXG vector signal generator EVM performance of 0.38% at –5 dBm measured using a high-performance PXA signal analyzer with the LTE FDD measurement application. Error summary trace (top): EVM, frequency error, and IQ error results. Frame summary trace (bottom): individual physical signal and channel EVM and power measurement results.

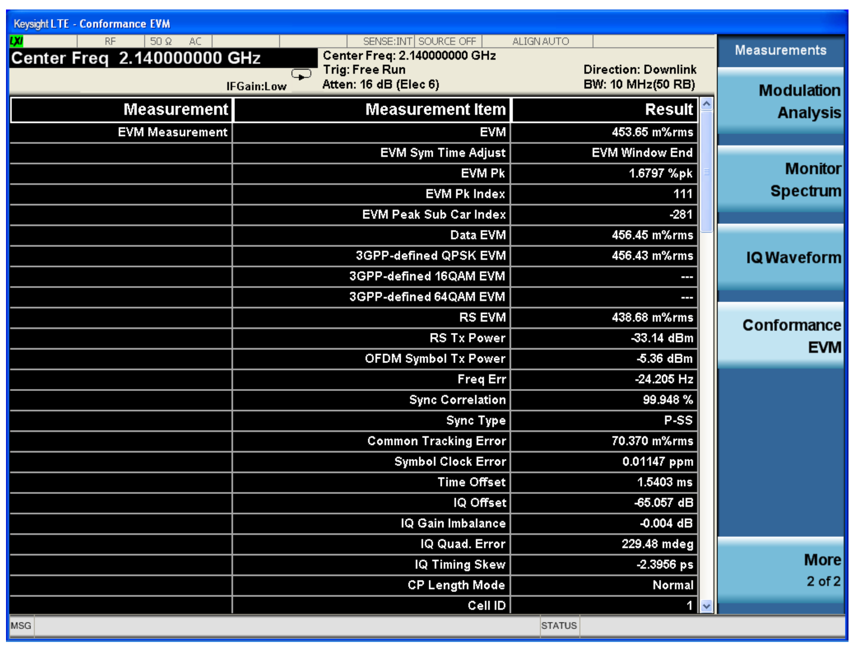


Figure 9. Conformance EVM measurement provided by the X-Series signal analyzer LTE measurement applications reduces test time for automated test equipment (ATE) production environments. Note: measurement setup with {Copy from Mod Analysis} under [Meas Setup] is required for front panel operation.

Step 3.

Now, increase MXG signal generator power to +15 dBm and continue to observe excellent EVM performance at higher output powers.

Signal Studio software	Software operation
Increase power for MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware.** In the right pane, set: Amplitude = **15 dBm**
Update hardware settings	Press Update Hardware Settings button on the top tool bar. MXG signal generator should now be set to increased power level.

Step 4.

Adjust analyzer input level for increased power to avoid clipping.

X-Series signal analyzer	Keystrokes
Optimize analyzer input level range for the given signal generator output power	[AMPTD Y Scale] > {Range} > **24** {dBm} See Figure 10

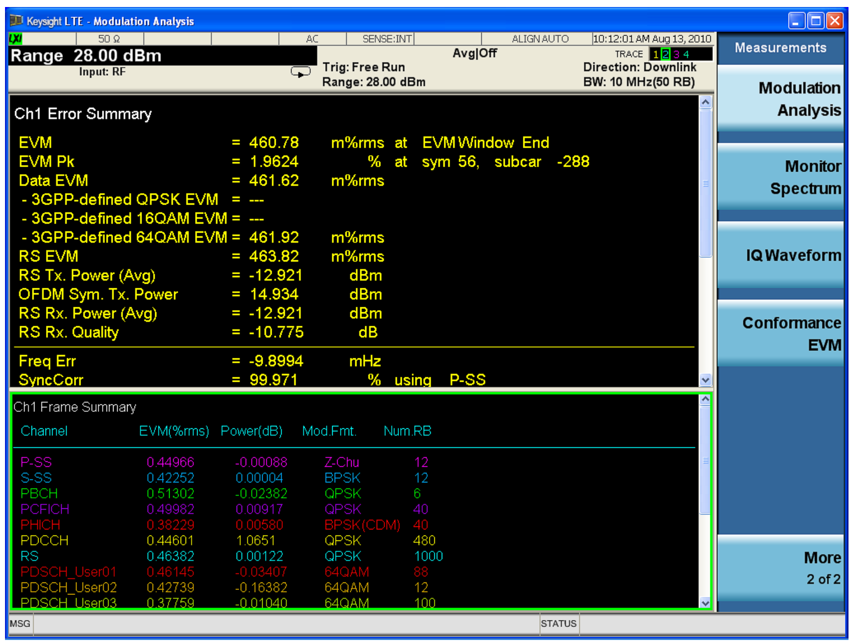


Figure 10. Continued excellent MXG vector signal generator EVM performance of 0.46% at +15 dBm output power measured using a high-performance PXA signal analyzer with the LTE FDD measurement application.

eNB Transmitter Test Demonstrations

Modulation analysis troubleshooting tools

Introduction

It is possible to analyze the structure and quality of signals in the domain for which they were designed by performing digital demodulation according to the radio specifications using a vector signal analyzer. This analysis provides a low level interoperability test and is instrumental in troubleshooting transmitter and component designs. Here are some key examples:

- Separately measure the characteristics of individual components of the signal right down to the resource element (RE) level
- Understand how modulation quality varies over time to indentify periodic or single shot effects
- Measure subtle effects of different operating conditions (average signal power, battery voltage and impedance, operating temperature, number of transmitters driven, etc.)
- Isolate the source of signal impairments
- Evaluate tradeoffs of modulation quality versus design or operational parameters (crest factor reduction or pre-distortion techniques, amplifier operating points, component choices, etc.)

Demonstration objectives

1. Create a user-defined LTE FDD downlink signal using Signal Studio software
2. Observe the available modulation analysis traces with the X-Series signal analyzer LTE measurement application
3. Simulate an eNB transmitter impairment using Signal Studio software
4. Change trace to observe simulated error in time domain
5. Turn on marker coupling to observe errors across different measurments, traces, and domains

Step 1.

Create a user-defined 5 MHz LTE FDD signal with three downlink shared transport channels (DL-SCH) using Signal Studio software and an MXG vector signal generator.

Signal Studio software	Software operation
Start the Signal Studio for 3GPP LTE FDD software	Start > All Programs > Keysight Signal Studio > 3GPP LTE FDD > **3GPP LTE FDD**
Connect to the MXG signal generator via GPIB or LAN (TCP/IP)	Follow the Signal Studio on-screen instructions to connect to the MXG signal generator
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GHz** Amplitude = **–5 dBm** RF Output = **On**
Edit the default downlink shared transport channel (DL-SCH)	In the tree view, left pane of the main window, select **Transport Channel** under **Downlink.** Select **DL-SCH** in the table and click the DL-SCH Config. button to access a dialog box and set: Subframe = **0-2** Modulation Type = **QPSK** Resource Block = **0-5**
Add and edit a 2nd downlink shared transport channel (DL-SCH)	In the tree view, left pane of the main window, select **Transport Channel** under **Downlink.** Click Add Channel button and select **DL-SCH** and set: Subframe = **4-6** Modulation Type = **16 QAM** Resource Block = **18-23**
Add and edit a 3rd downlink shared transport channel (DL-SCH)	In the tree view, left pane of the main window, select **Transport Channel** under **Downlink.** Click Add Channel button and select **DL-SCH** and set: Subframe = **6-8** Modulation Type = **64 QAM** Resource Block = **2-7** See Figure 11
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

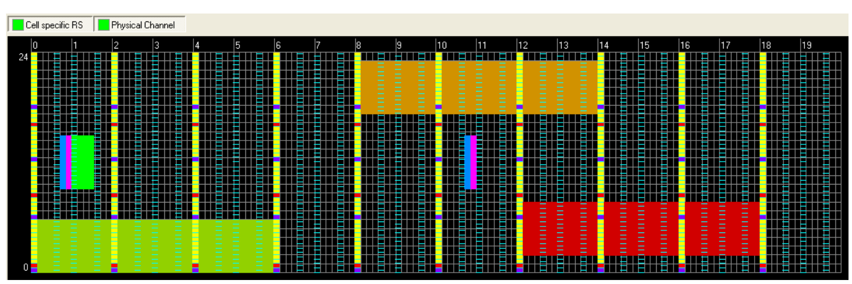


Figure 11. Calculated graph provided by Signal Studio for 3GPP LTE software showing resource block mapping for a 3 DL-SCH user-defined signal configuration. Resource blocks (subcarriers/frequency) on the vertical axis and slots (time) on the horizontal axis for a single frame (20 slots). Note: Place your mouse pointer over any occupied resoure element for configuration details.

Step 2.

Observe the measured resource block mapping with the detected allocation trace of the X-Series signal analyzer LTE measurement application.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} = **2.14** {GHz}
Start LTE measurement application	[Mode] > **{LTE}** Note: The exact page may vary.
Set to 5 MHz (25 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{5 MHz (25RB)}**
Select modulation analysis measurement	[Meas] > {More 1 of 2} > **{Modulation Analysis}**
Adjust analyzer input level range for the given signal generator output power	[AMPTD Y Scale] > {Range} > **4** {dBm}
Change the measurement interval to display the entire frame (20 slots)	[Meas Setup] > {Meas Time Setup} > {Meas Interval Slot} > **20** {Enter}
Include all active channels and signals	[Meas Setup] > {Chan Profile Setup} > {Composite Include} > **{Include All}**
Set PHICH allocation to 1/6	[Meas Setup] > {Chan Profile Setup} > {More 3 of 3} > {Edit Control Channels...}. Set **PHICH Allocation = 1/6** {OK} Note: Auto detection requires that the PHICH allocation value is carried on a fully coded PBCH. This is not true for a Signal Studio Basic LTE Downlink Carrier used for this demonstration and the reason why it needs to be manually adjusted.
Change trace 2 to detected allocation	[Trace/Detector] > {Select Trace} > {Trace 2} > {Data} > {Demod} > **{Detected Allocations}**
Change trace 4 to frame summary	[Trace/Detector] > {Select Trace} > {Trace 4} > {Data} > {Tables} > **{Frame Summary}** See Figure 12

Easily discover with color

Color is used in X-Series measurement applications to great effect, highlighting aspects of the complex LTE signal structure for the purposes of identifying and isolating specific signal impariments and channel effects. Each physical channel and signal is given a unique color that is used in other traces for helping identify the root causes of impairments.

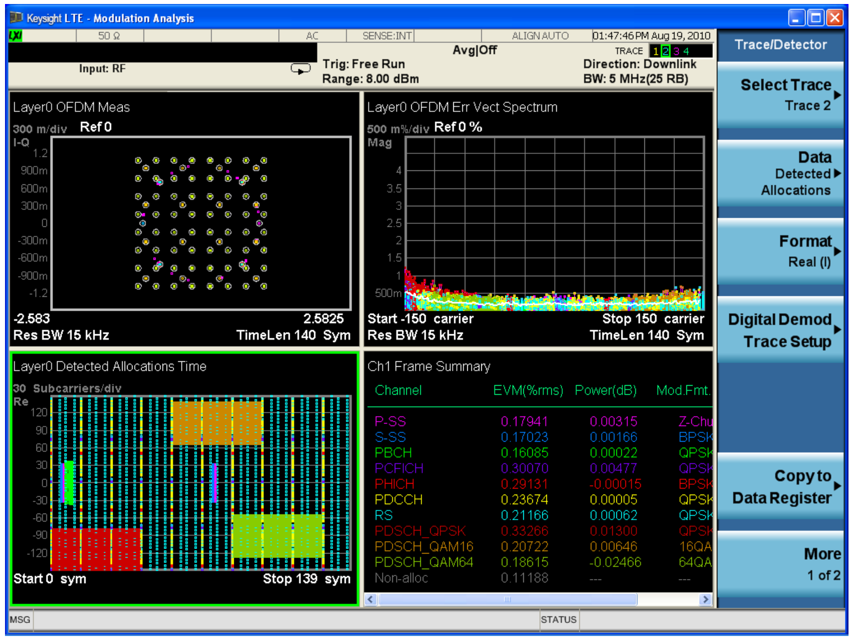


Figure 12. Modulation analysis measurement traces for a user-defined LTE FDD downlink test signal measured using an X-Series signal analyzer with the LTE FDD measurement application. For further clarity, you can deselect some of the channels and signals to see a less-populated allocation under [Meas Setup] > {Chan Profile Setup}.

We will now take a closer look at each measurement trace.

Frame summary (lower right) displays the summary of all active channels including the EVM for each channel, their relative power, modulation format used, and number of resource blocks occupied by each active channel. Note that each channel and signal has a unique color. This same color is used throughout other traces making the frame summary trace not only a great first-level troubleshooting tool, but also a legend for the other traces. Note: In order to view the "number of occupied RB" column, select the frame summary trace and change the display layout to single: [View/Display] > {Layout} > {Single}.

Detected allocations time (lower left) displays subcarriers on the vertical axis and symbols on the horizontal axis. This trace is a quick way to get an overall view the LTE signal allocations. In this example, the measured trace matches the calculated graph provided by Signal Studio software during signal creation (see Figure 11). Each point on the grid represents a single resource element (1 subcarrier x 1 symbol). Only channels and signals that are selected under the channel profile setup key are displayed. Note that the reference signal and physical channel colors match the colors in the frame summary trace.

Error vector spectrum (upper right) displays EVM as a function of sub-carrier (frequency). The RMS error value for a given sub-carrier is shown in white. The value of analyzing EVM in this domain is to determine if there are frequency-specific elements in any observed error.

OFDM measurement (upper left) shows the complete composite constellation diagram. Note that the colors in the constellation points match the colors in the frame summary trace. From this trace it should be immediately apparent whether the signal analyzer has successfully synchronized to and demodulated the signal correctly. If the pattern is unstable or just shows noise, then synchronization has not been achieved and a check of the demodulation setup and signal quality is required. Note: you can zoom in for more clarity by double-clicking the trace.

Use EVM to discover root cause of problems

Error vector magnitude measurements can provide a great deal of insight into the performance of digital communications transmitters and receivers. Primarily a measure of signal quality, EVM provides both a simple, quantitative figure-of-merit for a digitally modulated signal, and a far-reaching methodology for uncovering and attacking the underlying causes of signal impairments and distortion. With the proper tools such as an X-Series signal analyzer equipped with one of the many available measurement applications, EVM and related measurements can pinpoint exactly the type of degradations present in a signal and even help identify their root cause.

Step 3.

Now, simulate an eNB transmitter impairment by increasing the physical broadcast channel (PBCH) power to 0.25 dB using the Signal Studio software and observe what happens to the EVM results.

Signal Studio software	Software operation
Increase PBCH power	In the tree view, left pane of the main window, select **Physical Channel** under **Downlink.** In the right pane, select **PBCH** and set power = **0.25 dB**
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

Step 4.

Change trace 1 to EVM error versus time (symbols) to also observe the simulated PBCH impairment in the time domain.

X-Series signal analyzer	Keystrokes
Change trace 1 to error vector time	[Trace/Detector] > {Select Trace} > {Trace 1} > {Data} > {Demod Error} > **{Error Vector Time}** See Figure 13

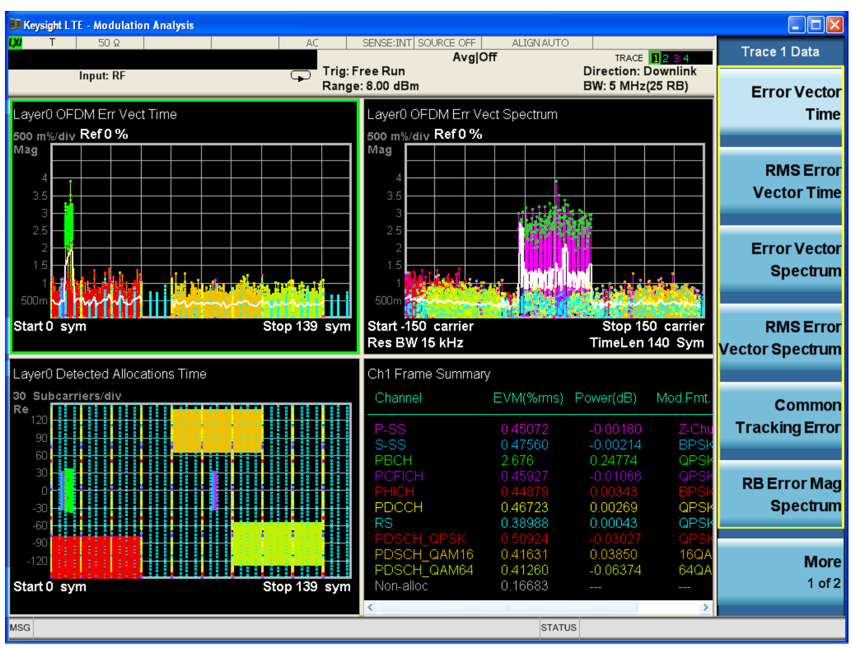


Figure 13. Simulated PBCH impairment causes degraded EVM on the center subcarriers. This error can be easily identified in the error vector time (upper left) trace (symbols 7-10) and the center subcarriers of error vector spectrum (upper right) trace. The total PBCH EVM (2.86%) and channel power (0.25 dB) can be found in the frame summary (lower right). Note that the green color assigned to the PBCH is found in all four traces.

Coupling markers across domains

One of the most powerful tools in demodulation analysis is the coupling of markers across different measurments, traces, and domains. This tool is particularly effective for analyzing LTE signals, which can have a high symbol content (i.e. large number of symbols per frame) and a larger number of different signal elements (channels, reference signals, OFDM subcarriers, etc.). Coupled markers allow the user to understand the identity and characteristics of a symbol simultaneously in time, frequency, power and constellation. To make this analysis even more specific, coupled markers can be combined with the selection or de-selection of individual LTE physical signals and physical channels for display and analysis.

Step 5.

Change trace 4 and turn on marker coupling.

X-Series signal analyzer	Keystrokes
Change trace 4 to OFDM measure	[Trace/Detector] > {Select Trace} > {Trace 4} > {Data} > {Demod} > {IQ Meas}
Turn on markers on for each trace	[Marker] > {Select Marker} > {Marker 1} > {Normal} > {Properties} > {Marker Trace} > **{Trace 1}** Follow the same process to place Markers 2, 3, and 4 on Traces 2, 3, and 4 respectively.
Couple the four markers	[Marker] > {More 1 of 2} > **{Couple Markers: On}**
Put the measurement in single sweep	[Single]
Perform a peak search on trace 1	Marker] > {Select Marker} > **{Marker 1};** Select **[Peak Search]** Note: The markers in all the other display will show the same point in time but provide different error views.
Turn on marker table	[Marker] > {More 1 of 2} > **{Marker Table: On}** See Figure 14

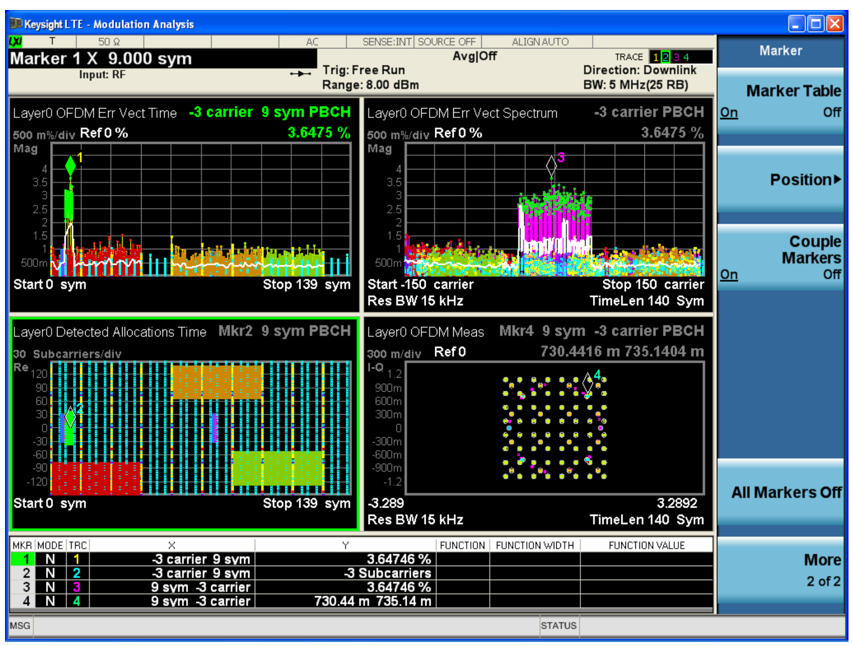


Figure 14. Marker coupling across different measurments, traces, and domains. A peak seach was pe-formed in trace 1 (upper left) and markers in the other traces now show results for the same point (symbol #9 in this example), but for different measurements. The marker table at the bottom provides the results for all four markers.

Even more troubleshooting tools

Similar to the 89601B VSA LTE application, one of the greatest strengths of the X-Series LTE measurement applications is the wide variety of error analyis traces to select from when troubleshooting your LTE design. The following are a few more examples for the signal created in step 1 (Figure 11). These traces are available under [Trace/Detector] > {Data} > {Demod Error} for each trace selected.

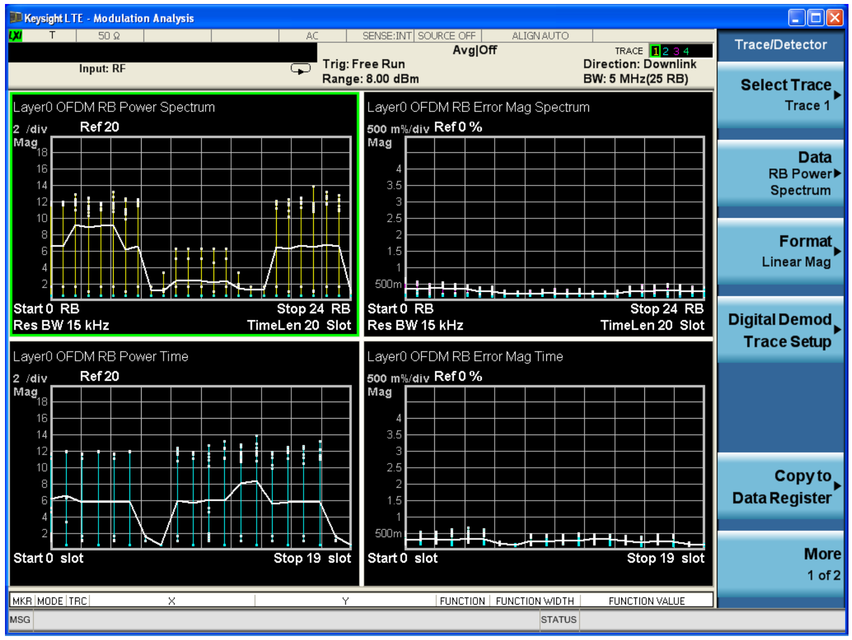


Figure 15. Resource block (RB) error and power traces are shown using the X-Series signal analyzer LTE measurement application.

RB power spectrum trace (upper left) shows the power in each RB with respect to frequency. Above each resource block index along the X-axis is the RMS power for that resource block in every slot. (Change the trace format to Linear Mag.)

RB error mag spectrum trace (upper right) shows the EVM of each RB with respect to frequency and displays EVM for every slot during that RB. The X-axis is RB, Y-axis is EVM, and Z-axis is slot. This example uses a 5-MHz LTE profile which has 25 RBs as shown on the X-axis. This is a useful display to see the range of EVM performance per user allocation.

RB power time trace (lower left) shows the power in each RB with respect to time. Above each slot on the X-axis is the power value for each resource block during that slot. This trace is also unique to Keysight.

RB error mag time (lower right) shows the EVM of each RB with respect to time. The X-axis is slot, Y-axis is EVM, and Z-axis is RB. This trace shows EVM across the measurement interval, which has 20 slots as shown on the X-axis.

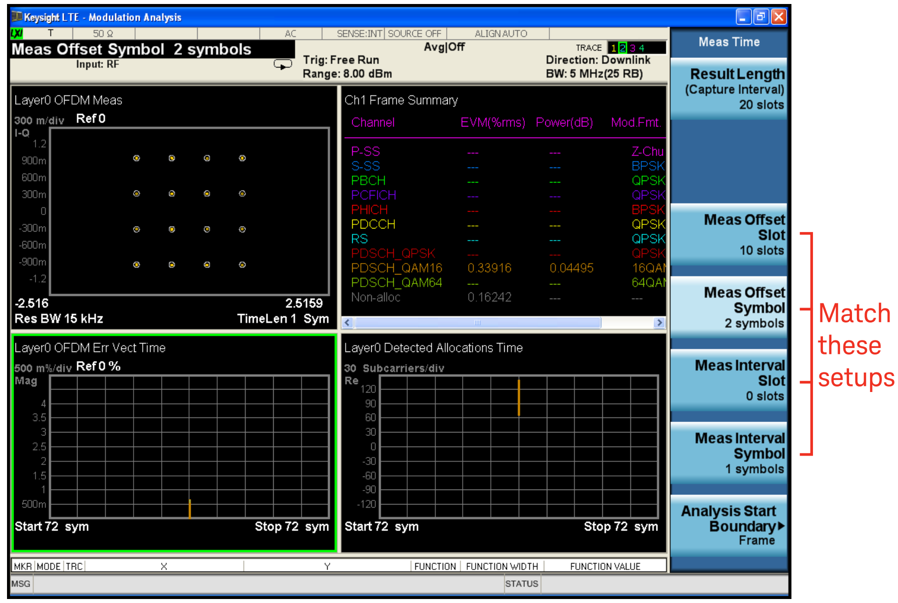


Figure 16. Modulation analysis traces for symbol #2 of slot #10. Note that EVM is reported in the frame summary trace (upper right) only for the 16QAM PDSCH since this is the only channel active during this symbol time. The X-Series signal analyzer LTE measurement applications support demodulation of any user specified slot number and OFDM symbol number within a rado frame. The ability to examine specific slots or symbols individually allows engineers to to make all the necessary measurements in order to determine the true root cause of a problem.

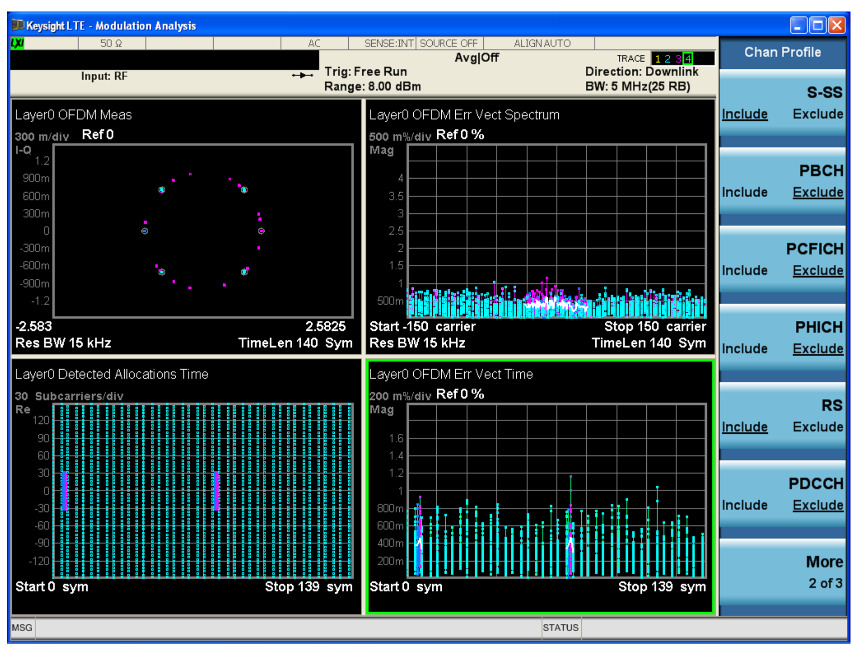


Figure 17. Modulation analysis traces for P-SS, S-SS, and RS only. All other channels were excluded from these measurement results and traces. Any physical channel or signal can be included or excluded in a modulation analysis measurement under {Meas Setup} > {Chan Profile Setup}.

Downlink channel decoding

When combined with the X-Series signal analyzers, the N9080A LTE FDD and N9082A LTE TDD measurement applications provide:

- Decoded channel information for PBCH, PCFICH, PDCCH and PDSCH
- PDCCH based auto detection of DL allocations
- Information bits provided for different points in the coding chain (demapped, deinterleaved, descrambled, deratematched, and decoded)

Advanced downlink transport channel decoding

Introduction

Modulation quality measurements (e.g. EVM) do not always provide RF designers with enough information for determining the exact cause of a transmitter error. Validation of correct channel coding may be required if the origin of the error resides in the baseband section of the transmitter where the coding is applied. For example, problems can be caused when the channel coding is generated according to one version of the standard while the demodulation is performed according to another. This type of troubleshooting challenge can only be overcome using a signal analyzer with a measurement application capable of demodulating and decoding LTE physical channels.

Demonstration objectives

1. Create a user-defined advanced LTE FDD downlink signal using Signal Studio software and MXG vector signal generator
2. Observe downlink channel decoding of the X-Series signal analyzer LTE measurement application

Step 1.

Create a user-defined 10-MHz advanced LTE FDD downlink test signal using Signal Studio software and the MXG vector signal generator.

Signal Studio software	Software operation
Start the Signal Studio for 3GPP LTE FDD software	Start > All Programs > Keysight Signal Studio > 3GPP LTE FDD > 3GPP LTE FDD
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GHz** Amplitude = **–5 dBm** RF Output = **On**
Delete the default basic downlink carrier and add an advanced downlink LTE FDD carrier	In the tree view, left pane of the main window, select **Waveform Setup** and select the default **Carrier 1 (Basic LTE FDD Downlink)** in the right pane. Click the Delete Carrier button. Now, click the Add Carrier and select **Advanced LTE FDD Downlink (2010-06)** from the drop-down list.
Set the channel configuration to 10 MHz and waveform length to 10 ms (one complete frame)	In the tree view, left pane of the main window, select **Carrier 1.** In the right pane, set: Channel Configuration = **Full filled QPSK 10MHz (50RB)** Waveform Generation Length = **10 ms**

Configure the downlink shared channel (DL-SCH) #1	In the tree view, left pane of the main window, select Channel Setup. In the right pane, select **DL-SCH1** and set: Data #1 = **10101010** (AA in hexadecimal) Set **Transmission Configuration** to the following by selecting the Useful Tools button in the dialog box and using the 'Set all' feature. Set all "MCS" #1 = **16** Set all "RA Type" = **Type 0** Set all "RBG Bitmap" = **10000011110000001** Click **{OK}** See Figure 18
Configure the downlink control Information (DCI)	In the tree view, left pane of the main window, select **Channel Setup.** In the right pane, select the **DCI** channel in the table and set: PDCCH Allocation = **2,2,1,1,1,3,3,2,2,1**
Set the HARQ to NACK for sub-frame #1	In the tree view, left pane of the main window, select **Channel Setup.** In the right pane, select the **HI** channel in the table. Now, set the **Transmission Configuration** to the following by clicking Useful Tools button in the dialog box and using the 'Set all' feature. Set all **"HI1"** to **NACK** Click **{OK}**
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

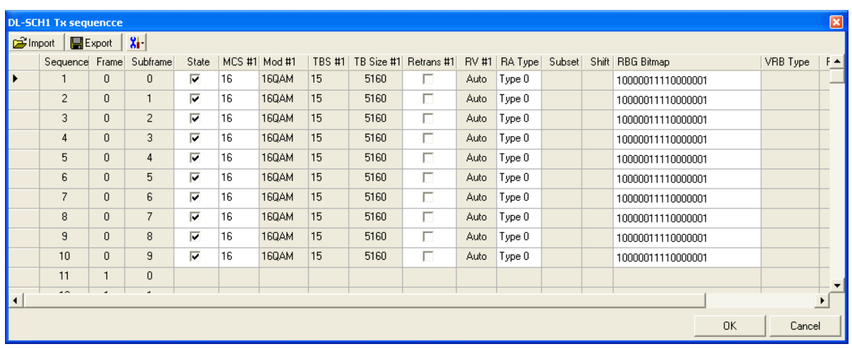


Figure 18. DL-SCH transmission configuration dialog box in Signal Studio 3GPP LTE software.

Step 2.

Observe the downlink decoded information with X-Series signal analyzer LTE measurement application.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} = **2.14** {GHz}
Start LTE measurement application	[Mode] > **{LTE}** Note: The exact page may vary.
Set to 10 MHz (50 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{10 MHz (50RB)}**
Select modulation analysis measurement	[Meas] > {More 1 of 2} > **{Modulation Analysis}**
Adjust analyzer input level range for the given signal generator output power	[AMPTD Y Scale] > {Range} > **8** {dBm}
Change the measurement interval to display the entire frame (20 slots)	[Meas Setup] > {Meas Time Setup} > {Meas Interval Slot} > **20** {Enter}
Include all active channels and signals and set RB auto detect mode to decode the PDCCH	[Meas Setup] > {Chan Profile Setup} > {RB Auto Detect Mode} > **{Decoded PDCCH}** {Composite Include} > **{Include All}**
Set decode type for PBCH, PCFICH, PDCCH, and PDSCH	[Meas Setup] > {More} > {Decode} > {Decode Type} PBCH = **Decoded** PCFICH = **Decoded** PDCCH = **Decoded** PBSCH = **Decoded Code Block**
Change the display layout to a stack 2 configuration	[View/Display] > {Layout} > **{Stack 2}**
Change trace 1 to display downlink decoded information	[Trace/Detector] > {Select Trace} > {Trace 1} > {Data} > {Tables} > **{DL Decode Info}**
Change trace 2 to display decoded data	[Trace/Detector] > {Select Trace} > {Trace 2} > {Data} > {Tables} > **{Decoded Symbol Table}** See Figure 19

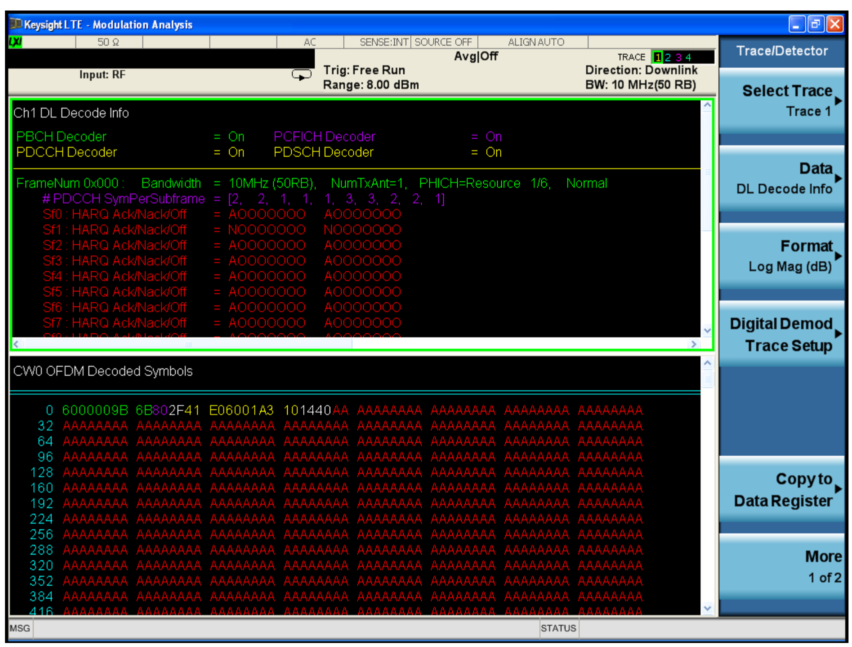


Figure 19. Downlink channel decoding traces of the X-Series signal analyzer LTE measurement applications.

DL decode info trace (top) displays decoded information for the PBCH, PCFICH, PHICH, PDCCH, and PDSCH. A color-coded legend is given at the very top. Scoll down and note that the information reported for each physical channel matches the values used in the signal creation of step 1, including the negative acknolowdgement (NACK) reported in subframe #1 of the PHICH (red).

OFDM decoded symbols trace (bottom) displays decoded symbols in hex format. Depending the the channel type, information bits can be displayed for different points in the transport coding chain (demapped, deinterleaved, descrambled, deratematched, and decoded). Note that PDSCH data chosen in step one matches the data reported (10101010 = AA in hexadecimal). This data is repeated to fill one complete frame.

LTE TDD transmit ON/OFF power measurement

Introduction

The time domain division (TDD) mode of LTE technology, known as LTE TDD or TD-LTE, has now been accepted by major operators and most cellular equipment manufacturers. The transmit ON/OFF power conformance test – also known as the power-versus-time measurement – found in the 3GPP Technical Specification 36.141, test case 6.4, helps RF design engineers identify LTE base station transmitter and power amplifier (PA) issues. This test, however, requires a spectrum analyzer with enough dynamic range to measure the very high ON power and extremely low OFF power simultaneously to capture the entire power-time mask. Meeting such a strict requirement is nearly impossible for most spectrum and signal analyzers available today. To overcome this challenge, the Keysight N9082A LTE TDD measurement application has adopted two techniques: a two-sweep method and a noise correction (NC)/Noise Floor Extension (NFE) plus power limiter method. NC has been used widely in ACPR measurements for several years, while NFE is a newer technique introduced for the Keysight high-performance PXA signal analyzer. While NC or NFE can both lower the spectrum analyzer noise floor by 4 to 6 dB, NFE reduces measurement time by quickly recalling factory-stored calibration information for the current parameters and environment. For further information regarding this unique capability, please see application note *E-UTRA Base Station Transmit ON/OFF Power Measurement,* literature number 5990-5989EN.

High dynamic range with the PXA signal analyzer and Noise Floor Extension (NFE)

Comparing the requirements specified in TS 36.141 with even the best dynamic range and noise floor performance available in signal and spectrum analyzers today will show that the PXA signal analyzer is unique, as it can provide enough test margin when using a very innovative technique called Noise Floor Extension (NFE). With NFE applied, the analyzer noise floor can be lowered to –169 dBm/Hz, which provides adequate margin to measure the –165 dBm/Hz OFF power signal requirement. Additionally, measurement time is significantly reduced with NFE since each PXA's native noise floor is measured during factory calibration and stored prior to shipping. Before making a measurement, the analyzer just needs to recall this information for a given measurement setup. This is different than the traditional noise correction method previously used which required a measurement of the spectrum analyzer's noise floor before each signal measurement.

Demonstration objectives

1. Create a basic LTE TDD downlink test signal using Signal Studio software and MXG vector signal generator
2. Measure transmit ON/OFF power with X-Series signal analyzer LTE TDD measurement application

Step 1.

Create a 10 MHz LTE TDD downlink test signal configured for E-TM 1.1 using Signal Studio software
and an MXG vector signal generator.

Signal Studio software	Software operation
Start the Signal Studio for 3GPP LTE TDD software	Start > All Programs > Keysight Signal Studio > 3GPP LTE TDD > 3GPP LTE TDD
Connect to the MXG signal generator via GPIB or LAN (TCP/IP)	Follow the Signal Studio on-screen instructions to connect to the MXG signal generator
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GHz** Amplitude = **–5 dBm** RF Output = **On**
Set default basic LTE downlink carrier for E-TM 1.1 and 10 MHz bandwidth configuration using test model wizard	In the tree view, left pane of the main window, select **Downlink** under **Carrier 1.** In the right pane, click Test Model Wizard to access a dialog box and set: System Bandwidth = **10 MHz (50RB)** Test Model Type = **E-TM1.1** Click **{OK}**
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

Step 2.

Measure transmit ON/OFF power with LTE TDD measurement application and X-Series signal analyzer.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} = **2.14** {GHz}
Start LTE TDD measurement application	[Mode] > {More} > **{LTE TDD}** Note: The exact page may vary.
Select transmit On/Off power measurement	[Meas] > {More} > **{Transmit On/Off Power}**
Set to 10 MHz (50 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{10 MHz (50RB)}**
Set uplink/downlink allocation to configuration 3	[Mode Setup] > {Radio} > ULDL Alloc = **Configuration 3** Dw/GP/Up Len = **Configuration 8**
Select slot 10 as the first time slot for view of the entire busted signal of 20 slots	[Mode Setup] > {Predefined Parameters} > Analysis Slot = **TS10** Meas Interval = **20 slots**
Set averaging to 10	[Meas Setup] > {Avg/Hold Num 10} **ON**
Turn ON Noise Floor Extension (NFE) and observe the transmit ON/OFF power	[Mode Setup] > {Noise Reduction} > {Noise Floor Extension ON} > Press **[Restart]** See Figure 20

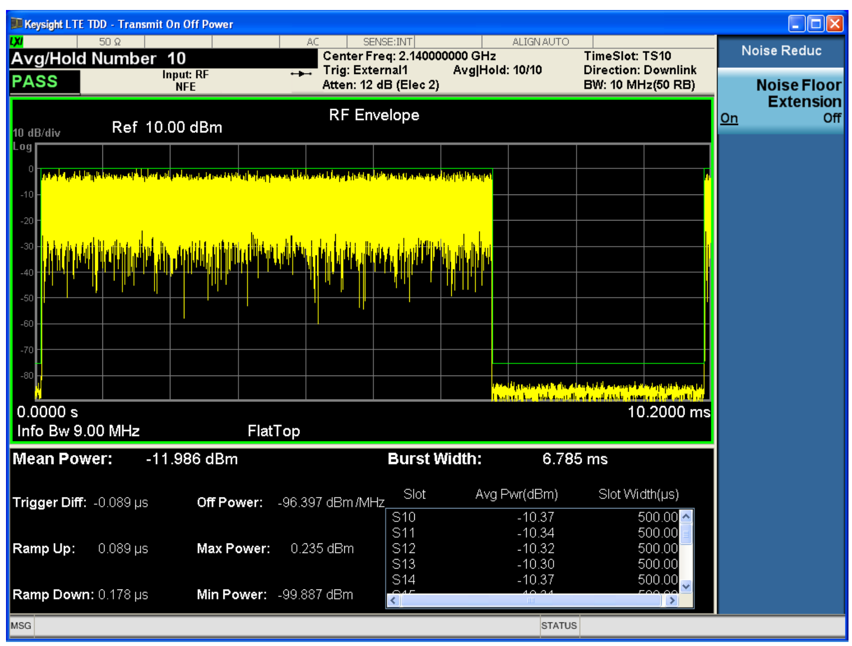


Figure 20. Transmit ON/OFF power measurement shows –96.4 dBm/MHz using Noise Floor Extension (NFE) capability of the PXA signal analyzer and LTE TDD measurement application.

Time alignment measurement for multiple Tx antennas

Introduction

The 3GPP time alignment test (test case 6.5.3) is particularly important for LTE because of the widespread use of transmit diversity, spatial multiplexing, and beamsteering. The signals from these multiple antennas must be aligned when being transmitted. The purpose of this test is to measure time delay between the signals from the multiple transmit antennas. The current 3GPP test is defined for the case of two transmit antennas, and, if four Tx antennas are available, the unused antenna ports must be terminated. The requirement for time alignment is 90 ns (65 ns + 25 ns TT). The timing offset measurement is a reference signal (pilot) based measurement. In LTE, the reference signals are not pre-coded and do not overlap in frequency between the multiple transmit antennas; therefore they uniquely identify each transmitter. Because of this, the output of the two transmitters can be combined using a power combiner and cross channel measurements such as timing and phase measurements can be made using a single input X-Series signal analyzer (see Figure 21).

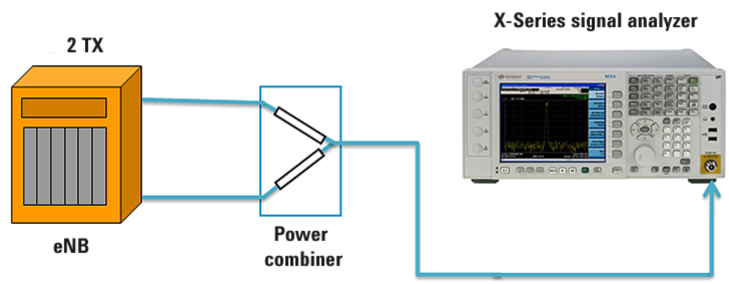


Figure 21. Time alignment test setup for multiple transmit antennas.

Demonstration setup

For demonstration purposes, a single MXG vector signal generator with Signal Studio software, licensed for advanced LTE FDD capability, can be used to simulate two Tx antennas.

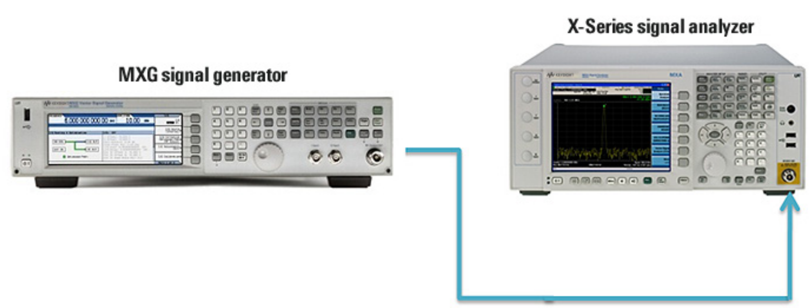


Figure 22. Single MXG signal generator simulating the eNB two Tx at the output of the combiner in Figure 21 and the time alignment measurement of the two of Tx antennas being performed using a single X-Series signal analyzer.

Step 1.

Create a 10-MHz LTE FDD downlink signal configured to simulate two Tx antennas using Signal Studio software and an MXG vector signal generator.

Use one X-Series signal analyzer for multiple antenna measurements

The N9080A/N9082A LTE measurement application performs these cross channel measurements (for 2x2, 4x2 and 4x4 antenna systems) using a single X-Series signal analyzer. The output signals from the multiple transmit antennas will need to be combined using a power combiner prior to applying the signal to the RF input of the X-Series signal analyzer as shown in Figure 22.

Signal Studio software	Software operation
Start the Signal Studio for 3GPP LTE FDD software	Start > All Programs > Keysight Signal Studio > 3GPP LTE FDD > 3GPP LTE FDD
Connect to the MXG signal generator via GPIB or LAN (TCP/IP)	Follow the Signal Studio on-screen instructions to connect to the MXG signal generator and choose **1 Antenna.**
Set the basic parameters of the MXG vector signal generator	In the tree view, left pane of the main window, select **Instrument** under **Hardware** Click the green **Preset** button and set: Frequency = **2.14 GH** Amplitude = **–5 dBm** RF Output = **On**
Delete the default basic downlink carrier and add an advanced downlink LTE FDD carrier	In the tree view, left pane of the main window, select **Waveform Setup** and select the default **Carrier 1 (Basic LTE FDD Downlink)** in the right pane. Click [Delete Carrier]. Now, click the [Add Carrier] and select **Advanced LTE FDD Downlink (2010-06)** from the drop-down list. See Figure 23
Set the total number of antennas to 2 and system bandwidth to 10 MHz	In the tree view, left pane of the main window, select **Downlink** under **Carrier 1** and set: Total number of Antennas = **2** System Bandwidth = **10 MHz (50RB)**
Turn on channel state and set second antenna to 65 ns delay and –10 dB power	In the tree view, left pane of the main window, select **Carrier 1** under **Waveform Setup** and set: Channel State = **ON** Within **Multi-Path Setting (static)** field dialog box, set: Channel H00 first row (path 0) = **enabled** Channel H01 first row (path 0) = **enabled, 65 ns Delay, -10 dB power.** Click **{OK}** Note: 65 ns is within the 90 ns maximum offset allowed per the 3GPP time alignment conformance test.
Generate and download waveform to MXG vector signal generator	Press Generate and Download button on the top tool bar. MXG signal generator should now be set to correct frequency, power, and display ARB on screen.

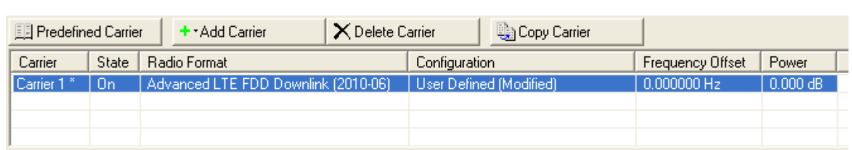


Figure 23. Signal Studio software carrier setup table shows carrier 1 as the Advanced LTE FDD downlink (2010-06) carrier.

Step 2.

Measure time offset of the two simulated Tx antennas using the LTE FDD measurement application and X-Series signal analyzer.

X-Series signal analyzer	Keystrokes
Preset analyzer to default values	**[Mode Preset]**
Change frequency to 2.14 GHz	[Freq] > {Center Freq} = **2.14** {GHz}
Start LTE measurement application	[Mode] > **{LTE}** Note: The exact page may vary.
Set to 10 MHz (50 RB) system bandwidth	[Mode Setup] > {Preset To Standard} > **{10 MHz (50RB)}**
Select modulation analysis measurement	[Meas] > {More 1 of 2} > **{Modulation Analysis}**
Set analyzer input level range for a given signal generator output power	[AMPTD Y Scale] > {Range} > **8** {dBm}
Select two Tx antennas	[Meas Setup] > {Sync/Format Setup} > {TX Antenna} > {Number TX Antenna} > **{2 antennas}**
Turn on Tx diversity	[Meas Setup] > {Chan Profile Setup} > {More} > {Edit User Mapping} > Set Precoding = **Tx Div**
Change the display to show MIMO specific traces	[View/Display] > **{Preset View: MIMO Summary}**
Select auto scale trace 1	[AMPTD Y Scale] > **{Auto Scale [Trace 1]}**
Put marker on path 0 (Tx Ant. 0)	[Marker] > {Select Marker} > {Marker 1} → by default marker 1 is placed on Path 0 (Tx antenna 0)
Put marker on path 1 (Tx Ant. 1)	[Marker] > {Select Marker} > {Marker 2} > {Normal} > {More 1 of 2} > {Position} > {Marker Z} > [1] {Enter} → Now marker 2 is placed on path 1
Turn on marker table	[Marker] > {More 1 of 2} > **{Marker Table On/Off}** See Figure 24

Figure 24. Time offset measurement of 65.1 ns for two simulated Tx antennas measured using an X-Series signal analyzer with the LTE FDD measurement application. The signal is simulated using Signal Studio for 3GPP LTE software and a single MXG vector signal generator. Trace 1 (top): Frequency response of both antenna paths. Trace 2 (bottom): Reference signal power, EVM, time offset, phase, etc., for both transmit paths.

Additional Resources

Web Resources

N7624B Signal Studio for 3GPP LTE FDD software
www.keysight.com/find/N7624B

N7625B Signal Studio for 3GPP LTE TDD software
www.keysight.com/find/N7625B

N5182A MXG vector signal generator
www.keysight.com/find/N5182A

N9080A LTE FDD X-Series measurement application
www.keysight.com/find/N9080A

N9082A LTE TDD X-Series measurement application
www.keysight.com/find/N9082A

Keysight X-Series signal analyzers
www.keysight.com/find/X-Series

Long Evolution - LTE Test
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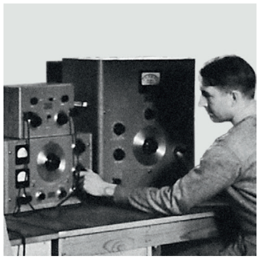

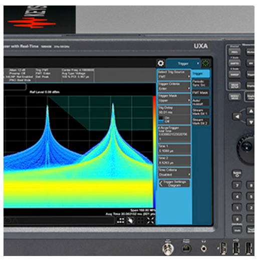

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