Agilent X-Series Signal Analyzer

This manual provides documentation for the following analyzers:

PXA Signal Analyzer N9030A

MXA Signal Analyzer N9020A

EXA Signal Analyzer N9010A

CXA Signal Analyzer N9000A

N9080A/W9080A LTE Measurement Application Measurement Guide

Agilent Technologies

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1   About the N9080A LTE Measurement Application

This chapter provides overall information on the Agilent N9080A LTE Measurement Application and describes the measurements made by the analyzer. Installation instructions for adding this option to your analyzer are provided in this section, in case you purchased this option separately.

What Does the Agilent N9080A LTE Measurement Application Do?

The N9080A LTE is a full-featured LTE signal analyzer that can help determine if an modulated source or transmitter is working correctly. There are standard and optional settings to enable complete analysis of LTE communications signals.

The N9080A 1FP LTE measurement application provides:

- Uplink (SC-FDMA), downlink (OFDMA), and Tx Diversity, MIMO analysis

- All LTE bandwidths: 1.4 MHz to 20 MHz

- All LTE modulation formats and sequences: BPSK, QPSK, 16QAM, 64QAM, CAZAC (Zadoff-Chu) Both downlink (OFDMA) and uplink (SC-FDMA) analysis

- Support for all LTE uplink channels and signals: PUSCH DM-RS, PUSCH, PUCCH DM-RS, and PUCCH

- Support for all LTE downlink channels and signals: RS, P-SS, S-SS, P-BCH, PDCCH, PCFICH, PHICH, and PDSCH

- View signal by: resource block, sub-carrier, slot, or symbol—select all or specific region for analysis. 2D graphical interface shows pictorial representation of user allocation

- Flexible display: Up to four simultaneous user-controllable trace displays

- Flexible markers: Up to 12 markers that can be coupled across different measurements

- X-Series front-panel operation with SCPI programmability

- Compatibility with all X-Series (MXA/EXA/CXA) signal analyzers

- Monitor Spectrum measurement for viewing signal spectrum

The N9080A 1FP LTE measurement application supports the following standards.

- 3GPP TS 36.101V9.4.0 (2010-06)

- 3GPP TS 36.104 V9.4.0 (2010-06)

- 3GPP TS 36.211 V9.1.0 (2010-03)

- 3GPP TS 36.212 V9.3.0 (2010-03)

- 3GPP TS 36.213 V9.2.0 (2010-06)

2 Making LTE Measurements

This chapter describes procedures used for making measurements of LTE signals and equipment. Instructions to help you set up and perform the measurements are provided, and examples of LTE measurement results are shown.

This chapter begins with instructions common to all measurements, and details all LTE measurements available by pressing the **MEASURE** key. For information specific to individual measurements refer to the sections at the page numbers below.

- "Making the Initial Signal Connection" on page 13
- "Modulation Analysis Measurements" on page 15
- "Monitor Spectrum Measurements" on page 57
- "Conformance EVM Measurement" on page 65

All the measurements above are referred to as one-button measurements. When you press the key to select a measurement it will become active, using settings and displays unique to that measurement. Data acquisition will automatically begin when trigger requirements, if any, are met.

Setting Up and Making a Measurement

Making the Initial Signal Connection

CAUTION   Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

See the Input Key menu for details on selecting input ports and the AMPTD Y Scale menu for details on setting internal attenuation to prevent overloading the analyzer.

Using Analyzer Mode and Measurement Presets

To set your current measurement mode to a known factory default state, press **Mode Preset**. This initializes the analyzer by returning the mode setup and all of the measurement setups in the mode to the factory default parameters.

To preset the parameters that are specific to an active, selected measurement, press **Meas Setup**, **Meas Preset**. This returns all the measurement setup parameters to the factory defaults, but only for the currently selected measurement.

The 3 Steps to Set Up and Make Measurements

All measurements can be set up using the following three steps. The sequence starts at the Mode level, is followed by the Measurement level, then finally, the result displays may be adjusted.

Table 2-1   *The 3 Steps to Set Up and Make a Measurement*

Step	Action	Notes
1. Select and Set Up the Mode	a. Press **Mode** b. Press a mode key, like **Spectrum Analyzer, LTE** or **GSM/EDGE**. c. Press **Mode Preset**. d. Press **Mode Setup**	All licensed, installed modes available are shown under the **Mode** key. Using **Mode Setup**, make any required adjustments to the mode settings. These settings will apply to all measurements in the mode.

Table 2-1   *The 3 Steps to Set Up and Make a Measurement*

Step	Action	Notes
2. Select and Set Up the Measurement	a. Press **Meas.** b. Select the specific measurement to be performed. c. Press **Meas Setup**	The measurement begins as soon as any required trigger conditions are met. The resulting data is shown on the display or is available for export. Use Meas Setup to make any required adjustment to the selected measurement settings. The settings only apply to this measurement.
3. Select and Set Up a View of the Results	Press **View/Display**. Select a display format for the current measurement data.	Depending on the mode and measurement selected, other graphical and tabular data presentations may be available. **X-Scale** and **Y-Scale** adjustments may also be made now.

NOTE   A setting may be reset at any time, and will be in effect on the next measurement cycle or view.

Table 2-2   *Main Keys and Functions for Making Measurements*

Step	Primary Key	Setup Keys	Related Keys
1. Select and set up a mode.	**Mode**	**Mode Setup, FREQ Channel**	**System**
2. Select and set up a measurement.	**Meas**	**Meas Setup**	**Sweep/Control**, **Restart**, **Single**, **Cont**
3. Select and set up a view of the results.	**View/Display**	**SPAN X Scale**, **AMPTD Y Scale**	**Peak Search**, **Quick Save**, **Save**, **Recall**, **File**, **Print**

Modulation Analysis Measurements

This section explains how to make Modulation Analysis measurements of LTE Uplink and Downlink signals. Modulation Analysis provides all the parameters necessary to determine the quality of modulation of an LTE signal.

The DUT under test must be set to transmit the RF power remotely through the system controller. The transmitted signal is connected to the RF input port of the instrument. Connect the equipment as shown.

Figure 2-1   *Modulation Analysis Measurement System*
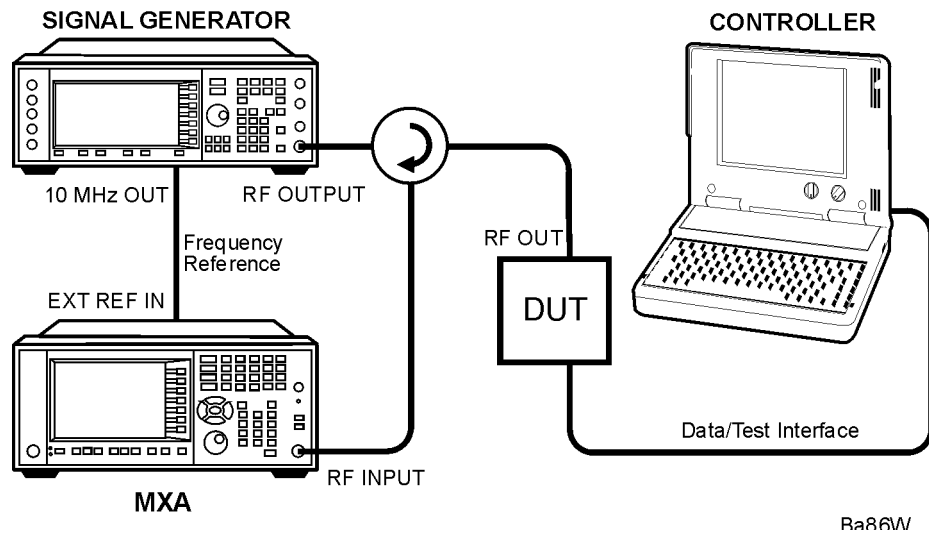
1. Using the appropriate cables, adapters, and circulator, connect the output signal of the DUT to the RF input of the analyzer.

2. Connect the transmitter simulator or signal generator to the MS through the circulator to initiate a link constructed with sync and reference channels, if required.

3. Connect a BNC cable between the 10 MHz OUT port of the signal generator and the EXT REF IN port of the analyzer.

4. Connect the system controller to the DUT to control the operation.

Making LTE Downlink Measurements

Setting the Downlink Signal (Example)

This example uses a signal generated using Agilent N7624B Signal Studio for 3GPP LTE FDD (using 2008-03 carriers).

Direction   Downlink

Frequency: 1.000 GHz

Output Power: -10 dBm

Bandwidth   5 MHz (25 PRB)

Carriers   1

Channel Configuration = Full-Filled QPSK 5 MHz (25 PRB)

Antennas   1

Physical Channels:

- PSS, SSS, RS Power = On, 0.65 dB
- RS Power = On, 2.50 dB

Transport Channel:

- DL-SCH = On, 0 dB
- BCH = On, 0 dB

Physical Channels:

- PBDCH, PHICH= On, 0 dB
- PDCCH, PCFICH = On, 0 dB
- PDSCH - RB = 1-20, 0 dB

Resource Block:

- Slots = 20
- RB = 0-24
- Power = 0 dB

Figure 2-2   *Signal Studio Downlink Setup Graphic Display*
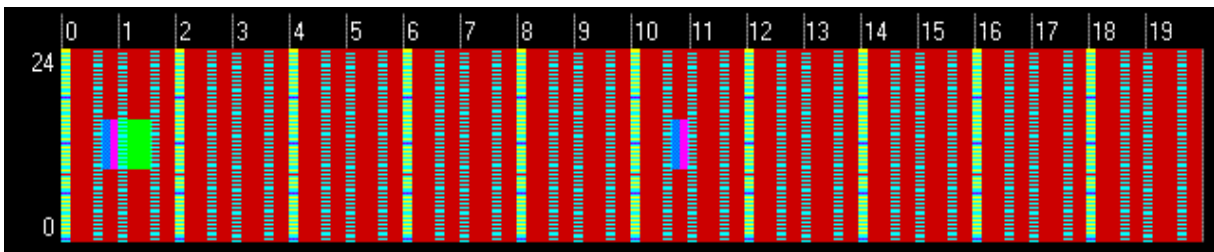
Downlink Measurement Procedure - RB Auto Detect On

The LTE auto-detection algorithm uses modulation type to synchronize the demodulation and to separate users. As long as all defined Users employ a different modulation type (QPSK, 16QAM, etc.), auto-detection will allow fully automatic measurements of an LTE DL signal.

NOTE   If an LTE Downlink signal contains defined Users that employ the same modulation type you must use manually-defined detection. For more information see: "Downlink Measurement Procedure - RB Auto Detect Off" on page 20

Step 1. Press **Mode**, **LTE** to enable LTE measurements.

Step 2. Press **Preset** to preset the mode.

NOTE   Downlink direction, Modulation Analysis measurement, 1 GHz center frequency and Auto-detect functionality are LTE mode defaults.

Step 3. Press **FREQ Channel, 1, GHz** to set the measurement center frequency to 1 GHz.

Step 4. Press **Mode Setup, Preset to Standard, 5 MHz (25 PRB)** to preset the measurement parameters for the standard signal bandwidth.

NOTE   Setting **Preset to Standard, 5 MHz (25 PRB)** is not the same as setting **Mode Setup, Bandwidth, 5 MHz (25 PRB)**. Presetting the measurement to a standard presets many measurement parameters besides BW. For a list of all presets effected see "Preset to Standard Default Settings" on page 50.

Step 5. Press **AMPTD Y Scale**, **Range**, **0, dBm** to set the RF input power range.

TIP   Be sure to set Range to a value at least equal to the expected RF input power for valid measurement results.

NOTE   In LTE Modulation Analysis measurement, for easy and quick parameter settings, several Recall functions are provided to automatically set up the parameters. You can use them by pressing **Recall, Data, xxxx Setup,** then **Open...**:

- Signal Studio Setup

  Recall the Agilent Signal Studio (N7624B for LTE FDD and N7625B for LTE TDD) setup file. This is not used for LTE TDD E-TM test model signal, instead you need use EVM Setup for it.

- Vector Signal Analyzer Setup

  Recall the Agilent 89600 Vector Signal Analyzer (option BHD for LTE FDD and option BHE for LTE TDD) setup file.

- EVM Setup

  Recall EVM parameter setting for E-URTA Test Models E-TM1.1, E-TM2, E-TM3.1, E-TM3.2 or E-TM3.3 in 3GPP standard.

Your measurement result should like .

Figure 2-3   *LTE Downlink Example (Basic Preset View)*
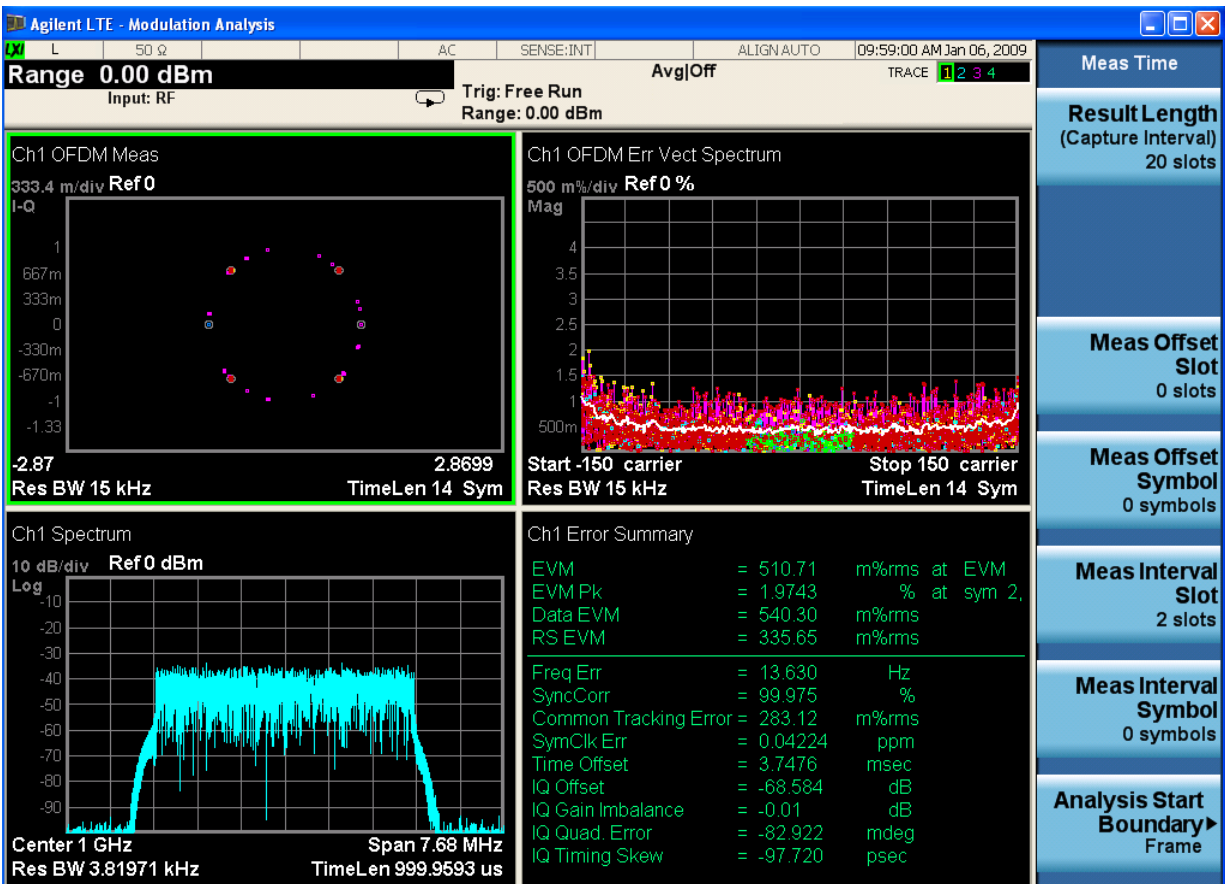
The default measurement view is the Basic Preset View, which provides a Grid 2x2 display of the measurement constellation, a Spectrum graph, a graph of the EVM Spectrum by subcarrier, and a Summary table of measurement results.

Step 6. (Optional) You can now view different Preset Views to display measurement results. See .

Step 7. (Optional) LTE Modulation Analysis measurements analyze Uplink PUSCH and PUCCH individually. You can now view individual signal and Channel results. See "To View Individual Signals or Channels (RS example):" on page 31.

Step 8. (Optional) If you want to change any allocations of Users or Slots you must turn Auto Detect off. See: "Downlink Measurement Procedure - RB Auto Detect Off" on page 20

Downlink Measurement Procedure - RB Auto Detect Off

The LTE auto-detection algorithm uses modulation type to synchronize the demodulation and to separate users.

As long as all defined Users employ a different modulation type (QPSK, 16QAM, etc.), Auto-detection will allow automatic measurements of an LTE DL signal. For more information see "Downlink Measurement Procedure - RB Auto Detect On" on page 17.

NOTE   If an LTE Downlink signal contains any defined Users that employ the same modulation type you must use manually-defined detection.

If you want to change any allocations of Users or Slots you must turn Auto Detect off.

NOTE   You may want to connect a PC mouse via a USB port to accomplish the manual detection settings.

Step 1. (Optional) Connect a PC mouse to a USB port to enable you accomplish the manual detection settings.

Step 2. Press **Mode**, **LTE** to enable LTE measurements.

Step 3. Press **Preset** to preset the mode.

NOTE   Downlink direction, Modulation Analysis measurement, and Auto-detect functionality are LTE mode defaults.

Step 4. Press **Mode Setup, Preset to Standard, 5 MHz (25 PRB)** to preset the measurement parameters for the standard signal bandwidth.

NOTE   Setting **Preset to Standard, 5 MHz (25 PRB)** is not the same as setting **Mode Setup, Bandwidth, 5 MHz (25 PRB)**. Presetting the measurement to a standard presets many measurement parameters besides BW. For a list of all presets effected see "Preset to Standard Default Settings" on page 50.

Step 5. Press **FREQ Channel**, **1**, **GHz** to set the center frequency to 1.000 GHz.

Step 6. Press **AMPTD Y Scale**, **Range**, **0, dBm** to set the RF input power range.

TIP   Be sure to set Range to a value at least equal to the expected RF input power for valid measurement results.

Step 7. Press **Meas Setup**, **Chan Profile Setup, Detection** to toggle RB Auto Detect to **Man**.

Step 8. Press **More, More, Edit User Mapping** to access the User Mapping table. For Downlink signals, only PDSCH mapping is required

Step 9. Press **Add** to allocate a new User to the signal. Users are assigned a number in order of their appearance. you can add up to 25 Users to a signal.

User01 is indicated as the table at the top row.

NOTE   Using a PC mouse connected to a USB port will make it easier for you to continue this procedure. You can also select table cells and checkboxes by pressing the Tab key repeatedly until you have the correct object selected. As an object is selected, a key menu appears that can be used to enter a value from the front panel.

Press **Help** to see the Help topic for any selected item in the table.

Step 10. Use the mouse to select the Include checkbox next to User1.

Step 11. Check the Mod Type checkbox, then select the modulation using the pull-down menu. This example uses QPSK, the default selection.

Step 12. Check the Power Boost checkbox, then select the power level using the pull-down menu. This example uses 0 dB.

Step 13. Select the field "No Allocations Defined". When it is selected it will have a blue background.

Step 14. Press **Add** to add to begin entering Downlink allocations

Your User Mapping table should look like .

Figure 2-4   *Editing User Mapping - Adding PDSCH Downlink Allocations*
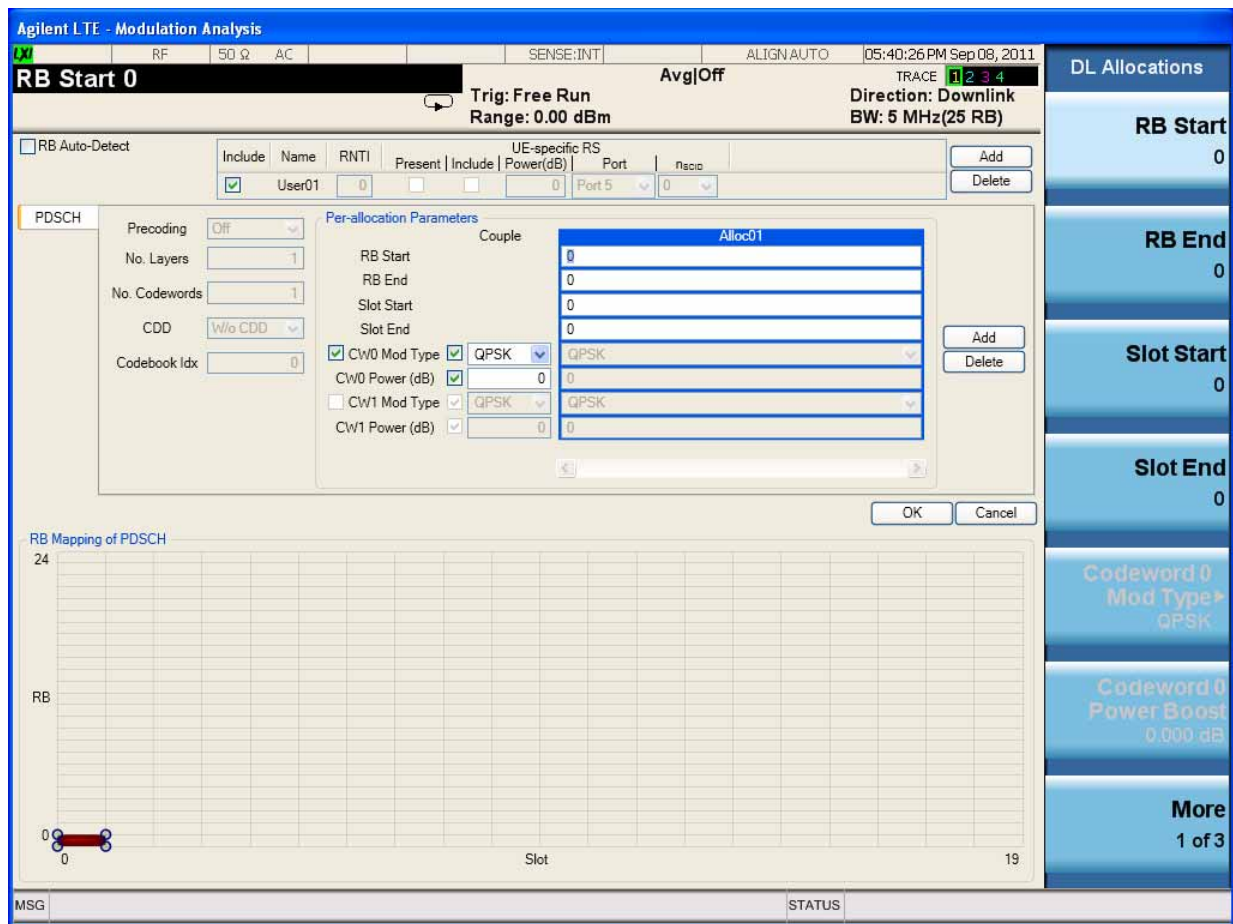
Step 15. Enter values for **RB Start, RB End, Slot Start**, and **Slot End**.

You can use the mouse to move the cursor between cells in the table, or press the **DL Allocations** soft keys and enter values from the front panel keypad, then **Enter**.

This example uses values of RB Start = 0, RB End = 24, Slot Start = 0, Slot End= 19.

After the slots are defined, the graph called RB Mapping to PDSCH should look like

Figure 2-5   *Editing User Mapping - Slots 0-19 Allocated for DL PDSCH*
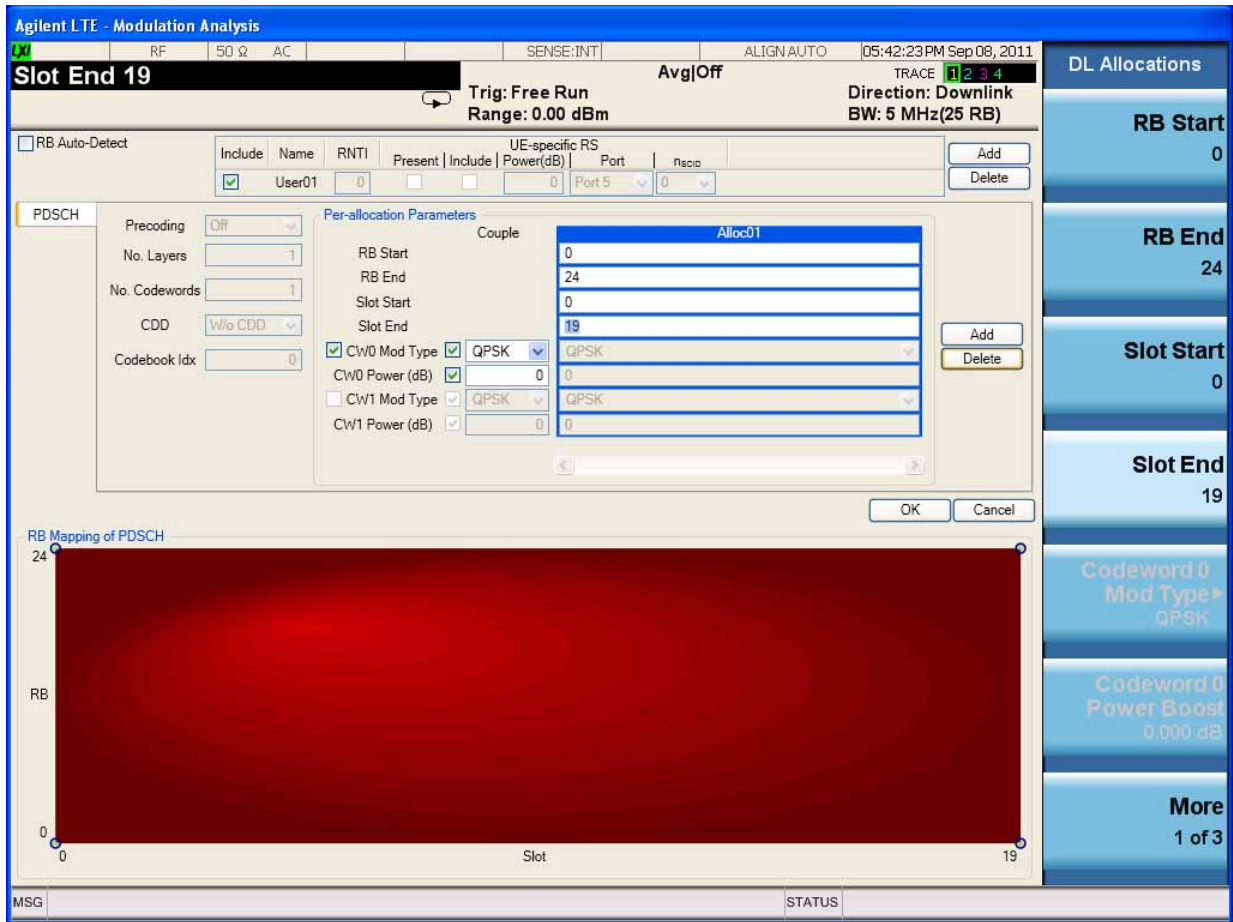
Step 16. Repeat Steps 11 through 15 as needed for all Users.

Step 17. Click OK to save the settings and exit the User Mapping table.

NOTE   It is not necessary to edit Control Chanels to accomplish synchronization of a Downlink signal.

Step 18. Your measurement result should like Figure 2-6 on page 24.

Figure 2-6   *LTE Modulation Analysis Measurement Result - Downlink Example (Basic Preset View)*
Measurement Interval = 2 Slots
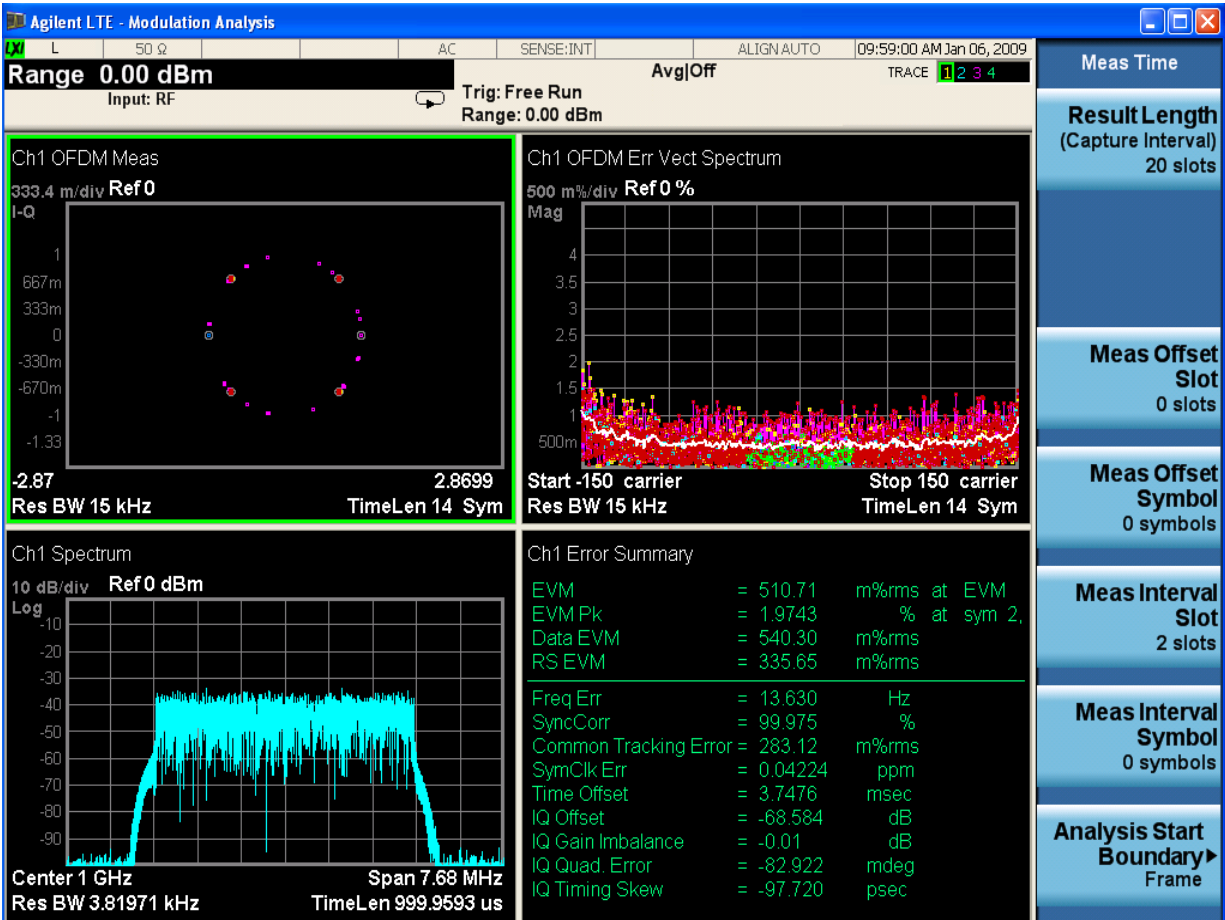
The default measurement view is the Basic Preset View, which provides a Grid 2x2 display of the measurement constellation, a Spectrum graph, a graph of the EVM Spectrum by subcarrier, and a Summary table of measurement results.

Step 19. You can now view data traces and use different Preset Views to display measurement results. See "Selecting Different Measurement Results Views" on page 25.

Selecting Different Measurement Results Views

You can change the traces displayed in any preset view:

Step 1. Press **View/Display, Preset View: Basic** to display the Basic View measurement results.

Step 2. Press **Trace/Detector**, **Trace, Select Trace, Trace 2**, **Data, Tables, Frame Summary** to display the Frame data summary in the Trace 2 position.

Figure 2-7   *LTE DL Example - Modified Preset View w/ Frame Summary*
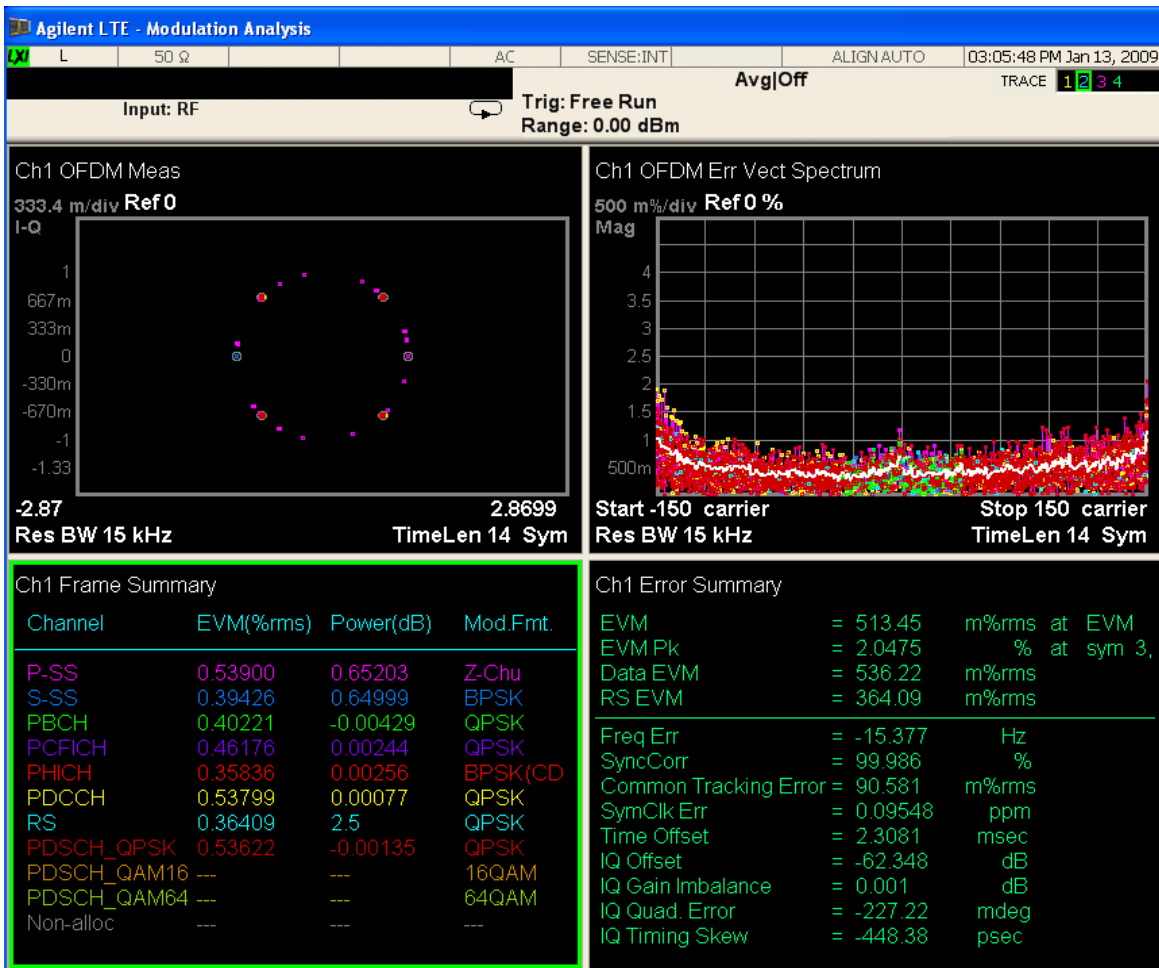
Your measurement result should like Figure 2-7.

The Frame Summary shows all the signals and Channels in the signal. The colors used in the summary are keyed to the colors used in the display of constellation and EVM graph data.

There is a wide variety of data traces available for display. For more information on the available data traces see the Data topic in the Trace/Detector section in the **LTE Measurement Application User's and Programmer's Guide**.

Step 3. Press **View/Display**, **Preset View: Meas Summary** to display a Stack 2 view of the Error and Frame summary result windows.

The Meas Summary result should look like Figure 2-8.

Figure 2-8   *Modulation Analysis Measurement Result - Meas Summary Preset View*
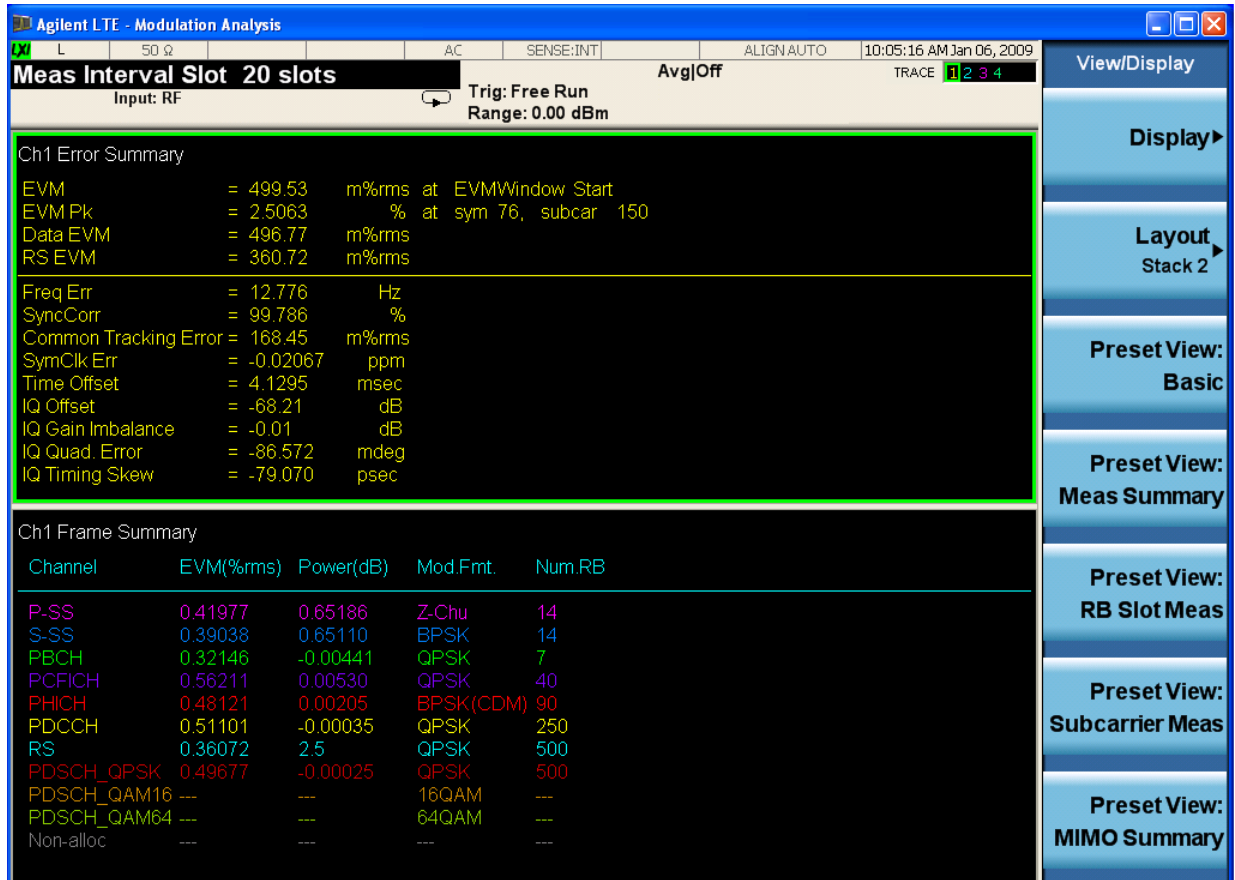
Step 4. Press **View/Display**, **Preset View: RB Slot Meas** to display the traces in units of RBs and SlotsS.

The **RB Slot Meas** result should look like Figure 2-9.

Figure 2-9   *Modulation Analysis Measurement Result - RB Slot Meas Preset View*
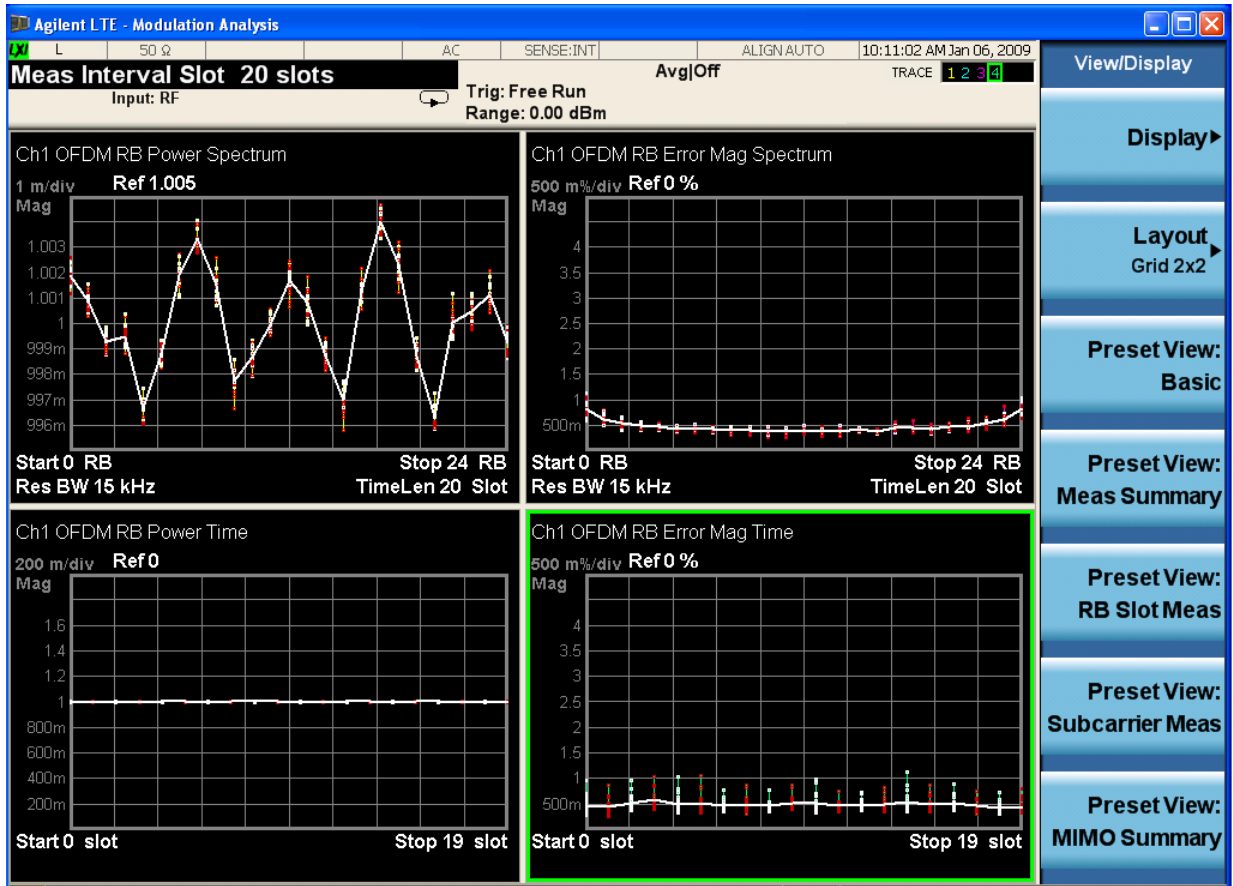
The RB Slot Preset view provides graphs of the Resource Block Power by slot and by time, and the RB EVM by slot and by time.

Step 5. You can Zoom to expand a window to full screen:

Press the **Next Window** key (below the display) to move the display focus (green outline) to the RB Error Mag Spectrum graph, then press the **Zoom** key.

You can also press **Trace/Detector**, **Trace, Select Trace, Trace 3**, then **Zoom** to display the RB Error Mag Spectrum graph.

The RB Error Mag Spectrum graph result should look like Figure 2-10.

Figure 2-10   *Modulation Analysis Measurement Result - RB Error Mag Spectrum*
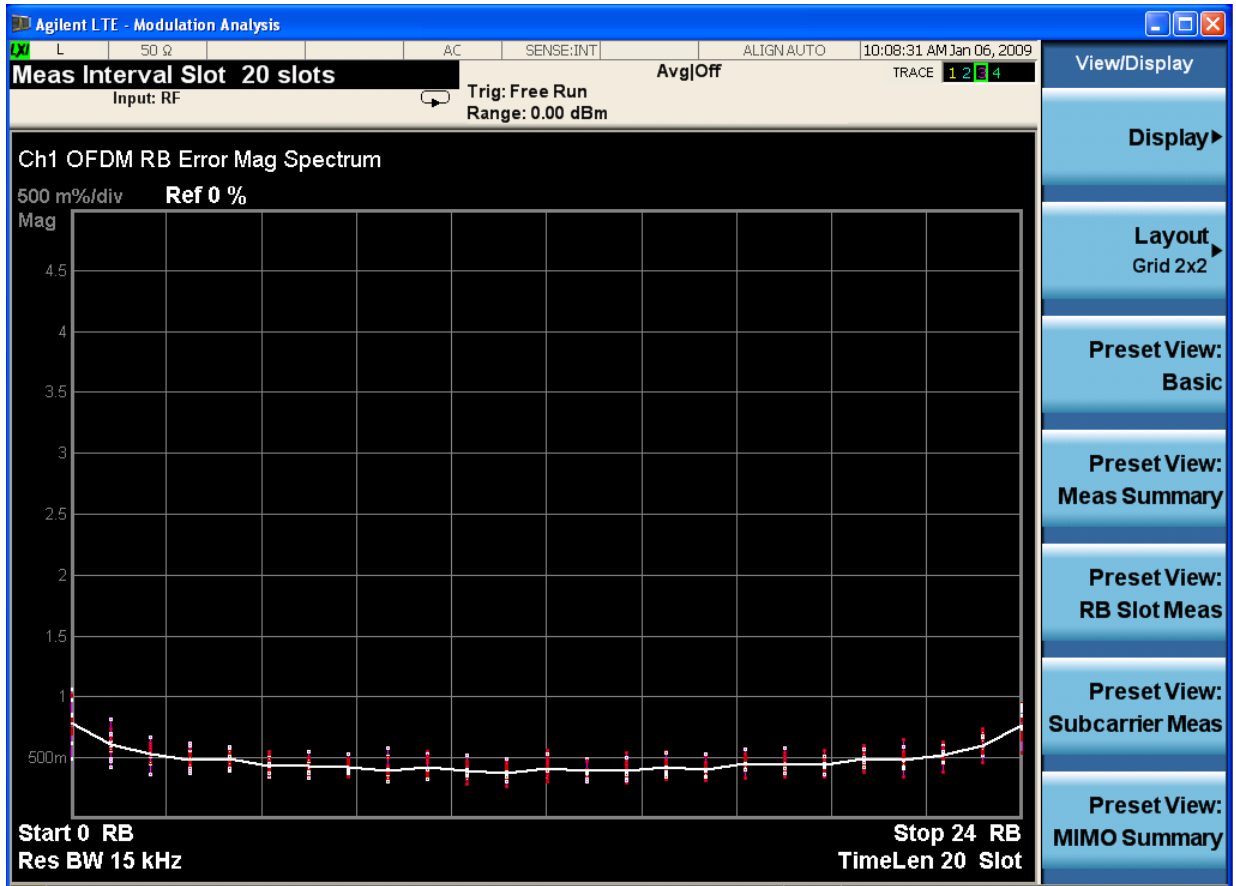
TIP   The RB Error Mag Spectrum graph is especially useful to determine whether there are any individual slots or RBs with excessive EVM.

Step 6. Press **View/Display**, **Preset View: Subcarrier Meas** to display a view of the Subcarrier measurement result windows.

The Subcarrier Meas result should look like Figure 2-11.

Figure 2-11   *Modulation Analysis Measurement Result - Subcarrier Meas Preset View*
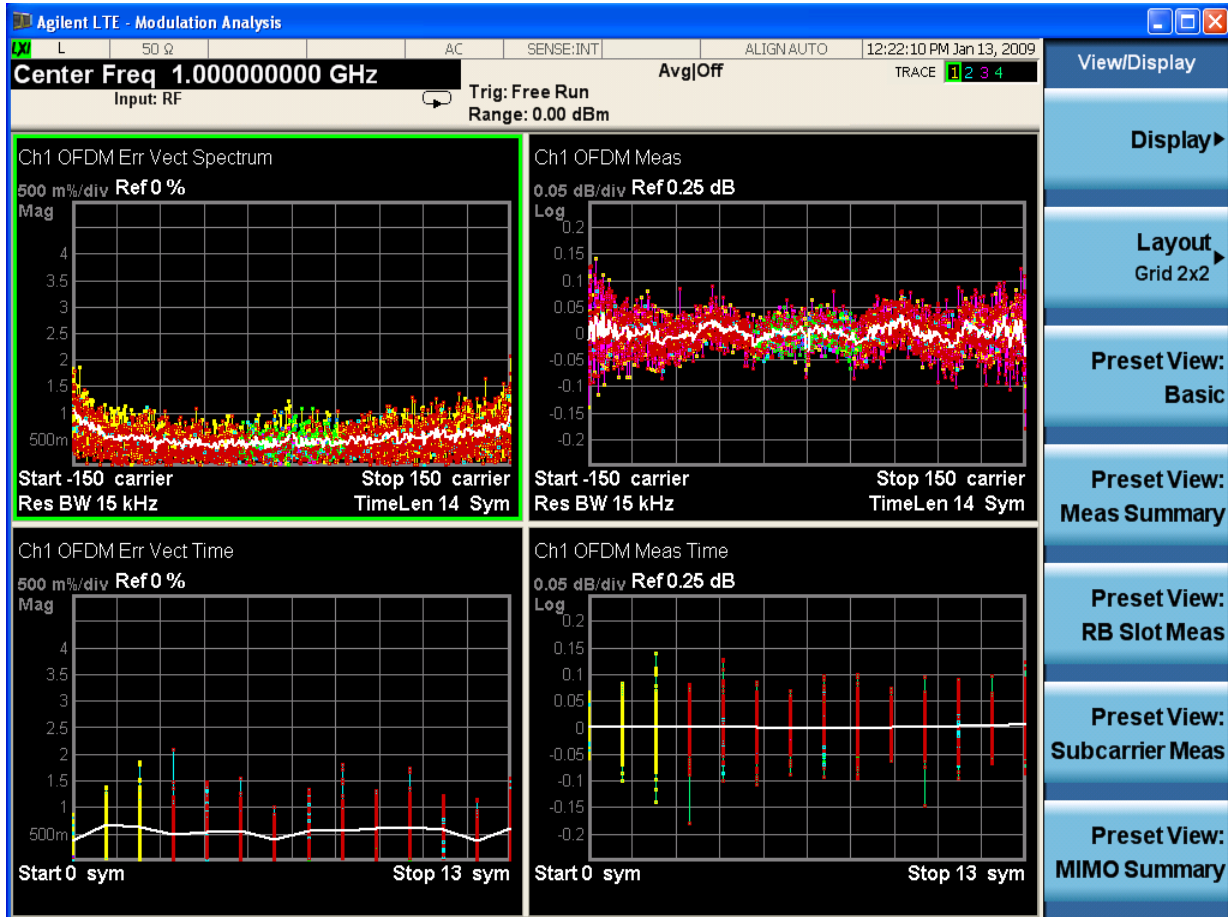
A Grid 2x2 layout with the modulation Error Vector Spectrum by subcarrier graph is shown, along with a graph of Error Vector by Time in symbols, a spectrum view of all OFDM subcarriers, and a graph of OFDM power vs. time in symbols.

Step 7. Press **View/Display**, **Preset View: MIMO Summary** to display a view of the MIMO Equalizer Frequency Response spectrum by carrier and MIMO Information summary result windows.

The MIMO Summary result should look like Figure 2-12.

Figure 2-12   *Modulation Analysis Measurement Result - MIMO Summary Preset View*

Step 8. (Optional) You can now view individual signal and Channel results. See "To View Individual Signals or Channels (RS example):" on page 31.

To View Individual Signals or Channels (RS example):

The default measurement setting for Channel Profile is to Include all signals and Channels. Displaying individual signals and Channels will make defects more obvious and will allow specific investigation of your modulation parameters.

NOTE   PUSCH and PUCCH are analyzed separately. If your signal contains both, only one can be displayed at a time.

Step 1. Press **View/Display, Preset View: Basic** to display the Basic View measurement results.

Step 2. Press **Meas Setup**, **Channel Profile Setup,** to see the menu allowing you Include or Exclude all signals and Channels in the carrier. The default is all signals and Channels are Included in the measurement. This can make distinguishing individual results difficult. Reducing the number of displayed results makes the display easier to observe.

Step 3. Press **Composite Include**, **Exclude All** to Exclude all signals and Channels in the carrier. The constellation and EVM Spectrum will be blank when Exclude All is in effect.

Step 4. Press **Include Users, RS** to toggle RS to Include to show only the Reference signal in the measurement results displayed.

Your measurement result should like Figure 2-13.

Because all channels except the Reference are excluded, you can now see only the QPSK constellation, and a corresponding slight decrease in the EVM error results. All data are shown in the same color (light blue), which corresponds to RS.

Figure 2-13   *LTE Modulation Analysis Measurement Result - Downlink Example (Basic Preset View) - Include RS Channel Only*
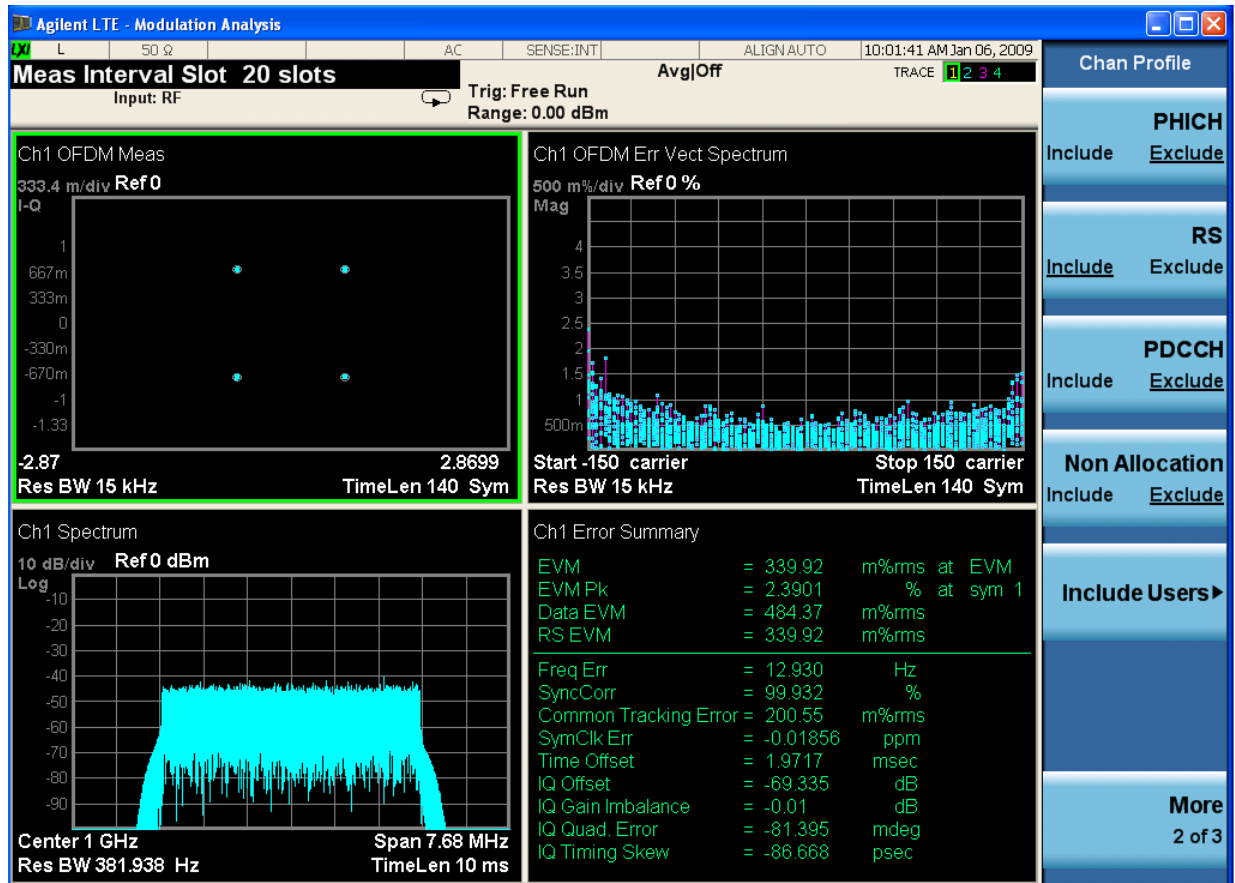
Step 5. (Optional) Press **Non Allocation**, and toggle the setting to Include or Exclude all Non Allocated signals and Channels in the carrier.

If you have a problem, and get an error message, see the "**Error Messages Guide**".

Making LTE Uplink Measurements

Setting the Uplink Signal (Example)

This example uses a signal generated using Agilent N7624B Signal Studio for 3GPP LTE FDD (using 2008-03 carriers).

Direction   Uplink

Frequency: 1.000 GHz

Output Power: -10 dBm

Bandwidth   5 MHz (25 PRB)

Carriers   1

Channel Configuration = Full-Filled QPSK 5 MHz (25 PRB)

Antennas   1

Transport Channel:

- UL-SCH = On, 0 dB, Channels 11-20

Physical Channels:

- PUSCH = On, 0 dB, 10 Chans, RBs 1&2 ... 19&20
- PUCCH = On, 0 dB, 10 Chans, RBs 21&22 ... 39&40

Resource Block:

- Slots = 20 (1-19)
- RB Allocations = 40
- PUSCH RB = 2-21
- PUCCH RB = 0, 24
- Power = 0 dB

Figure 2-14   *Signal Studio Uplink Setup Graphic Display*
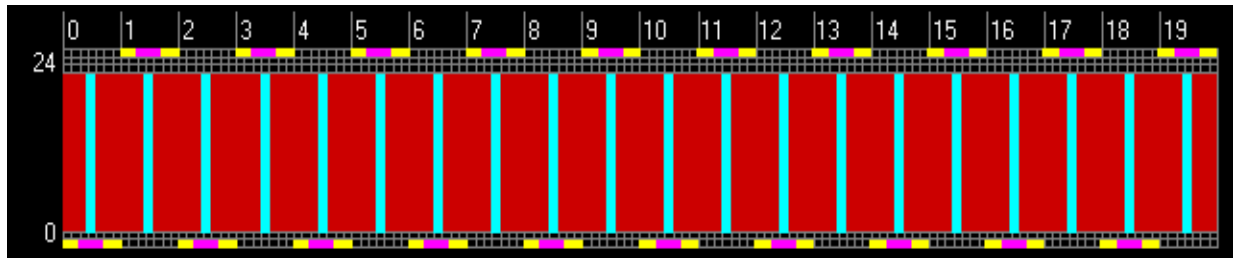

In Figure 2-14 you can see the PUCCH RB pairs at 0 and 24, alternately, and the PUSCH RB at 2-21 across all 20 slots.

Common UL Setup Steps (RB Auto Detect On or Off)

Uplink measurements of PUSCH can be simplified by using the RB Auto Detect function, allowing you to input a minimum of User Mapping parameters. Uplink measurements of PUCCH require that you input all User Mapping parameters.

The following procedures detail setting up analysis of both channels, with and without using RB Auto Detect.For front-panel testing a User Mapping table is provided to enable convenient entry of all required parameters.

NOTE   You will find it more convenient to follow this procedure if you connect a PC mouse via a USB port to accomplish the User Mapping settings detailed in later steps.

Step 1. (Optional) Connect a PC mouse to a USB port to enable you accomplish the manual detection settings.

Step 2. Press **Mode**, **LTE** to enable LTE measurements.

Step 3. Press **Preset** to preset the mode.

NOTE   Downlink direction, Modulation Analysis measurement, and 1 GHz center frequency are LTE mode defaults.

Step 4. Press **Mode Setup, Direction** to toggle the setting to **Uplink**.

Step 5. Press **Mode Setup, Preset to Standard, 5 MHz (25 PRB)** to preset the measurement parameters for the standard signal bandwidth.

NOTE   Setting **Preset to Standard, 5 MHz (25 PRB)** is not the same as setting **Mode Setup, Bandwidth, 5 MHz (25 PRB)**. Presetting the measurement to a standard presets many measurement parameters besides BW. For a list of all presets see "Preset to Standard Default Settings" on page 50.

Step 6. Press **FREQ Channel**, **1**, **GHz** to set the center frequency to 1.000 GHz.

Step 7. Press **AMPTD Y Scale**, **Range**, **0, dBm** to set the RF input power range.

TIP   Be sure to set **Range** to a value at least equal to the expected RF input power for valid measurement results.

Step 8. Continue to one of the following detailed UL or DL Procedures:

Input UL PUSCH Parameters - RB Auto Detect On

NOTE   To accomplish Uplink signal synchronization, it is only necessary to define a single User in terms of the Sync Slot and RB allocation. You must slect a Sync Slot that is a unique combination of RB Start, RB End, DMRS Group (u), DMRS Sequence (v), and DMRS Cyclic Shift.

For analysis of PUSCH with no unique slots, you must set **RB Auto Detect** to **Off** and manually set all User Mapping allocations. See: "Input UL PUSCH Parameters - RB Auto Detect Off" on page 42.

Step 9. Complete the initial procedure "Common UL Setup Steps (RB Auto Detect On or Off)" on page 34.

Step 10. Press **Meas Setup**, **Chan Profile Setup, Edit User Mapping** to access the User Mapping table. The PUSCH tab is selected by default.

Press **Add** to create a new User for the PUSCH.

`User01` will be shown as active in the setup table at the top row.

NOTE   Using a PC mouse connected to a USB port will make it easier for you to continue this procedure. You can also access the table cells and checkboxes by pressing the **Tab** key repeatedly until you have the correct object selected. As an object is selected, a menu appears with a key that can be used to enter a value from the front-panel.

Step 11. Set the **Sync Slot** value if not equal to zero. The default setting for **Sync Slot** of zero is correct for the signal used in this example.

Step 12. Set `Couple` values in the `Couple` column. This allows you to couple the values across all slots for checked values:

Select and enter values for **RB Start, RB End,** and all other necessary Per-Slot Parameters from the front panel keypad, then press **Enter**.

This example uses values of RB Start = 2, RB End = 21.

Step 13. Select the `No slots defined` field. When selected, the field is highlighted.

Press **Add** to create a new Slot for User01. Continue to press Add until you have added 19 more Slots, for a total of 20, to correspond with the example signal.

The User Mapping table with all required PUSCH parameters set should like Figure 2-15 on page 37.

Figure 2-15   *Editing Uplink User Mapping - PUSCH User01 RB Parameters*
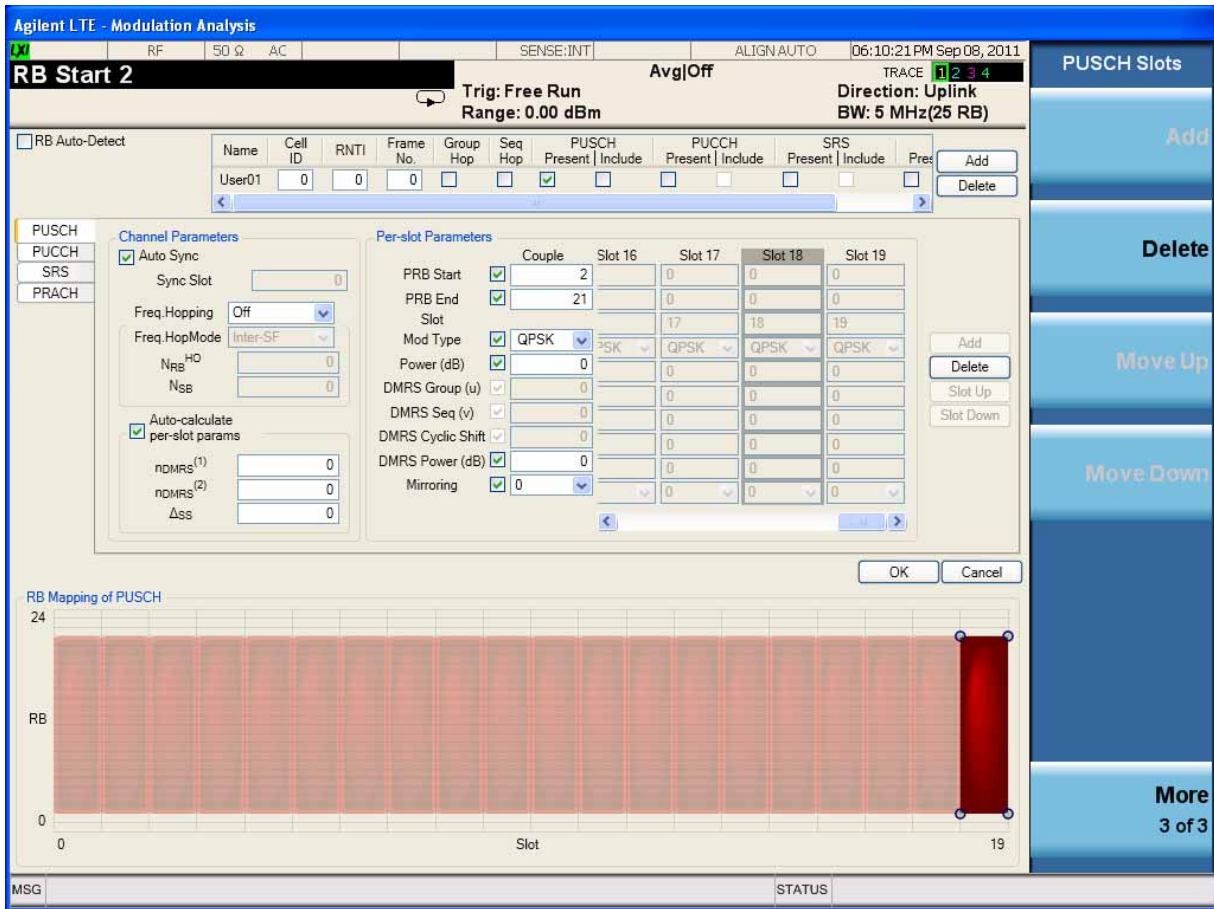
> **Step 14.** Click OK to save the settings and exit the User Mapping table.

NOTE   It is not necessary to edit the Control Chanel (PUCCH) mapping parameters to accomplish synchronization of a Downlink signal with **RB Auto Detect On**.

> **Step 15.** (Optional) You can now view different Preset Views to display measurement results. See *"Selecting Different Measurement Results Views" on page 25*.
>
> **Step 16.** (Optional) LTE Modulation Analysis measurements analyze Uplink PUSCH and PUCCH individually. You can now view individual signal and Channel results. See *"To View Individual Signals or Channels (RS example):" on page 31*.
>
> **Step 17.** (Optional) If you want to change any allocations of Users or Slots you must turn Auto Detect off. See: *"Input UL PUSCH Parameters - RB Auto Detect Off" on page 42*

TIP   You can save your settings as a recallable State:
Press **Save, State**, and select a **Register** to store the measurement settings. These settings are subject to reset by a power cycle.

To save the State settings in a file permanently:

Press **Save, State, to File...** and select a file name for recall later.

Press **Recall, State** and select a register or file to be recalled.

Input UL PUCCH Parameters - RB Auto Detect On

To accomplish Uplink PUCCH signal synchronization with **RB Auto Detect**, it is only necessary to define a single User in terms of the Sync Slot and RB allocation. You must slect a Sync Slot that is a unique combination of First RB, Format, Cyclic Shift, Power (dB), DMRS Group (u), and DMRS Power (dB).

For analysis of PUCCH with no unique subframes (like this UL example signal), the measurement result will sync on a random subframe. If you have more that one User in the signal, the measurement will provide a composite result of all Users. To analyize individual Users you must set **RB Auto Detect** to **Off** and manually set User Mapping allocations for all Users and Subframes. See: .

Step 18. Complete the initial procedure .

Step 19. Press **Meas Setup**, **Chan Profile Setup, Edit User Mapping** to access the User Mapping table. The PUSCH tab is selected by default.

Select the PUCCH tab.

NOTE   Using a PC mouse connected to a USB port will make it easier for you to continue this procedure. You can also access the table cells and checkboxes by pressing the Tab key repeatedly until you have the correct object selected. As an object is selected, a menu appears with a key that can be used to enter a value from the front-panel.

Step 20. Select the N_{RB} parameter in the top row of the table and enter a value of 2, which represents the number of resource blocks assigned to the PUCCH.

Select the Include PUCCH checkbox to Include the PUCCH for analysis.

Step 21. Set the **Sync Slot** value if not equal to zero. The default setting for **Sync Slot** of zero is correct for the signal used in this example.

Step 22. Set Couple values for the Per Subframe Parameters. This allows you to couple the values across all subframes for selected values.

Select and enter values for **First RB, Cyclic Shift,** and all other necessary parameters, then press **Enter**.

This example uses the default value of First RB = 0, and all other Per Subframe Parameters defaults.

Step 23. The User Mapping table with all required PUCCH parameters set should like Figure 2-16.

Figure 2-16   *Editing Uplink User Mapping - UL PUCCH RB Auto Detect On*

Step 24. Click OK to save the settings and exit the User Mapping table.

NOTE   It is not necessary to edit the Data Chanel (PUSCH) mapping parameters to accomplish synchronization of a Uplink signal with **RB Auto Detect On**.

Step 25. (Optional) You can now view different Preset Views to display measurement results. See "Selecting Different Measurement Results Views" on page 25.

Step 26. (Optional) LTE Modulation Analysis measurements analyze Uplink PUSCH and PUCCH individually. You can now view individual signal and Channel results. See "To View Individual Signals or Channels (RS example):" on page 31.

Step 27. (Optional) If you want to change any allocations of Users or Slots you must set **RB Auto Detect** to **Off**. See: "Input UL PUCCH Parameters - RB Auto Detect Off" on page 45

TIP	Save your settings as a recallable State: Press **Save, State**, and select a **Register** to store the measurement settings. These settings are subject to reset by a power cycle. To save the State settings in a file permanently: Press **Save, State, to File...** and select a file name.

Input UL PUSCH Parameters - RB Auto Detect Off

NOTE	If your signal of interest contains PUSCH with any unique slots, you can use **RB Auto Detect**. See: *"To accomplish Uplink signal synchronization, it is only necessary to define a single User in terms of the Sync Slot and RB allocation. You must slect a Sync Slot that is a unique combination of RB Start, RB End, DMRS Group (u), DMRS Sequence (v), and DMRS Cyclic Shift." on page 36*

For analysis of PUSCH with no unique slots, you must set **RB Auto Detect** to **Off** and manually set all User Mapping allocations.

NOTE	To accomplish Uplink signal synchronization with **RB Auto Detect** set to **Off** , it is necessary to define all Users in terms of the Sync Slot and RB allocation. You must also define all Sync Slot parameters for RB Start, RB End, DMRS Group (u), DMRS Sequence (v), and DMRS Cyclic Shift.

Step 28. Complete the initial procedure *"Common UL Setup Steps (RB Auto Detect On or Off)" on page 34*.

Step 29. Press **Meas Setup**, **Chan Profile Setup,** and toggle **RB Auto Detect** to **Off**.

Step 30. Press **Meas Setup**, **Chan Profile Setup, Edit User Mapping** to access the User Mapping table. The PUSCH tab is selected by default.

Press **Add** to create a new User for the PUSCH

`User01` will be shown as active in the table at the top row.

NOTE	Using a PC mouse connected to a USB port will make it easier for you to continue this procedure. You can also access the table cells and checkboxes by pressing the Tab key repeatedly until you have the correct object selected. As an object is selected, a menu appears with a key that can be used to enter a value from the front-panel.

Step 31. Set the **Sync Slot** value if not equal to zero. The default setting for **Sync Slot** of zero is correct for the signal used in this example.

Step 32. Set Couple Values in the `Couple` column. This allow you to couple the values across all slots for checked values:

Select and enter values for **RB Start, RB End,** and all other necessary Per-Slot Parameters from the front panel keypad, then press **Enter**.

This example uses values of RB Start = 2, RB End = 21.

Step 33. Select the `No slots defined` field. When selected, the field is highlighted.

Press **Add** to create a new Slot for User01. Continue to press Add until you have added 19 more Slots, for a total of 20, to correspond with the example signal.

The User Mapping table with all required PUSCH parameters set should like Figure 2-15 on page 37.

Figure 2-17   *Editing Uplink User Mapping - PUSCH User01 RB Parameters*
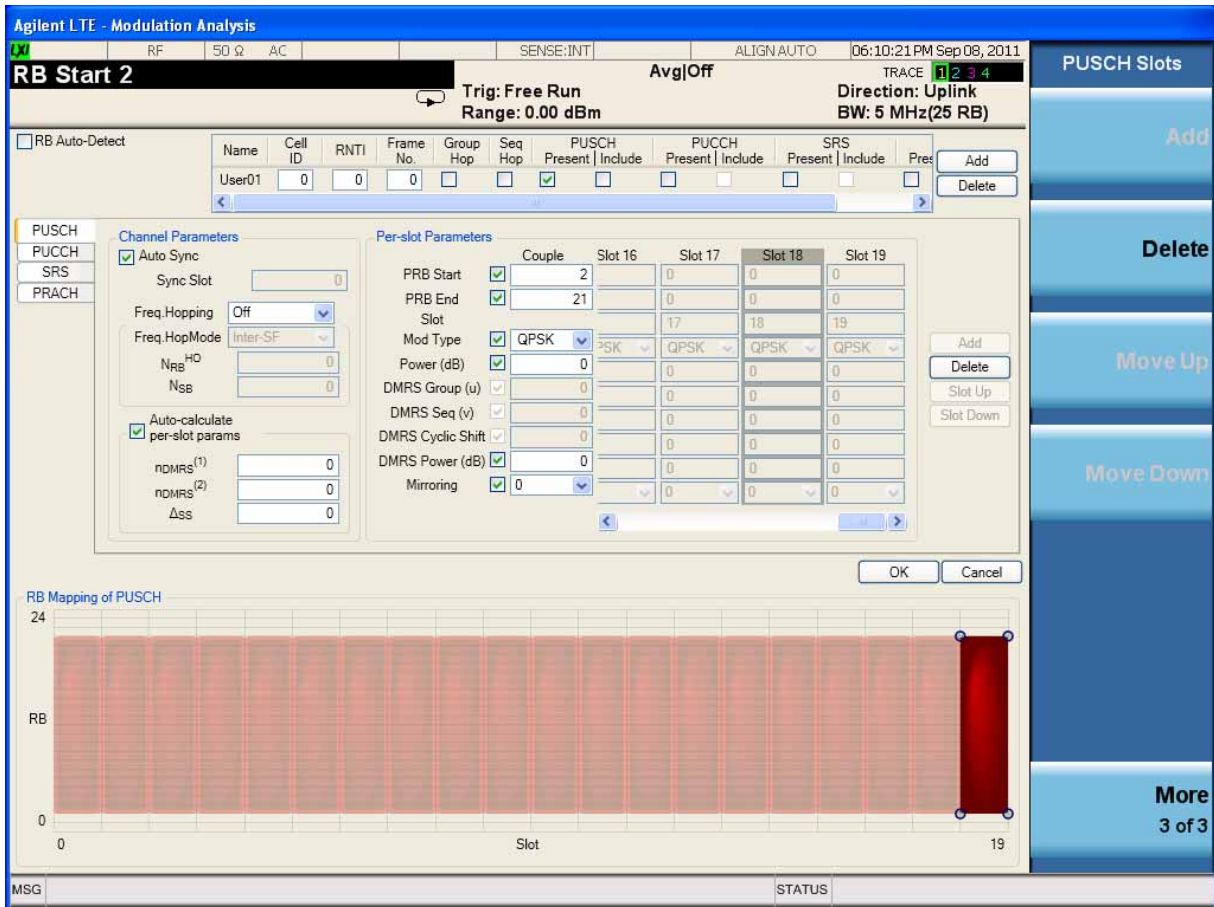
Step 34. Click OK to save the settings and exit the User Mapping table.

NOTE   If your signal of interest contains PUCCH, and **RB Auto Detect** is **Off**, you must input all PUCCH User Mapping parameters. See "Input UL PUCCH Parameters - RB Auto Detect Off" on page 45

Step 35. (Optional) You can now view different Preset Views to display measurement results. See "Selecting Different Measurement Results Views" on page 25.

Step 36. (Optional) LTE Modulation Analysis measurements analyze Uplink PUSCH and PUCCH individually. You can now view individual signal and Channel results. See "To View Individual Signals or Channels (RS example):" on page 31.

TIP

Save your settings as a recallable State: Press **Save, State**, and select a **Register** to store the measurement settings. These settings are subject to reset by a power cycle. To save the State settings in a file permanently: Press **Save, State, to File...** and select a file name.

Input UL PUCCH Parameters - RB Auto Detect Off

NOTE	If your signal of interest contains PUCCH with any unique slots, you can use **RB Auto Detect**. See: "Input UL PUCCH Parameters - RB Auto Detect On" on page 39

For analysis of PUCCH with no unique slots, you must set **RB Auto Detect** to **Off** and manually set all User Mapping allocations. See: "Input UL PUCCH Parameters - RB Auto Detect Off" on page 45

Step 37. Complete the initial procedure "Common UL Setup Steps (RB Auto Detect On or Off)" on page 34.

Step 38. Press **Meas Setup**, **Chan Profile Setup,** and toggle **RB Auto Detect** to **Off**.

Step 39. Select the PUSCH tab and press the down arrow or click the PUCCH tab.

User1 will be shown as active in the setup table at the top row.

Step 40. Select the No subframes defined field. When selected, the field is highlighted.

Press **Add** to create a new Subframe for User01. Each Subframe is a Slot pair, with the RB alternating in each Slot.

Step 41. Set Couple Values in the Couple column. This allow you to couple the values across all slots for checked values:

Set the **Sync Slot** value if not equal to zero. The default setting for **Sync Slot** of zero is correct for the signal used in this example.

Step 42. Select and enter values for **First RB, Cyclic Shift,** and all other necessary Per-Slot Parameters from the front panel keypad, then press **Enter**.

This example uses the default value of First RB = 0, and all other Pre-Slot Parameter defaults.

Step 43. Press **Add** to add 9 more new Subframes for User01 to a total of 10 Subframes, or 20 Slots.

Step 44. The User Mapping table with all required PUCCH parameters set should like Figure 2-18.

Figure 2-18   *Uplink User Mapping - PUCCH Parameters Auto Detect Off*

The Yellow PUCCH Slot and RB allocations are shown overlaid on the PUSCH allocations.

Step 45. Click OK to save the settings and exit the User Mapping table.

NOTE   If your signal of interest contains PUSCH, and **RB Auto Detect** is **Off**, you must input all PUCCH User Mapping parameters. See "Input UL PUSCH Parameters - RB Auto Detect Off" on page 42

Step 46. (Optional) You can now view different Preset Views to display measurement results. See "Selecting Different Measurement Results Views" on page 25.

Step 47. (Optional) LTE Modulation Analysis measurements analyze Uplink PUSCH and PUCCH individually. You can now view individual signal and Channel results. See "To View Individual Signals or Channels (RS example):" on page 31.

TIP	Save your settings as a recallable State: Press **Save, State**, and select a **Register** to store the measurement settings. Settings saved in a Register are subject to reset by a power cycle.
	To save State settings in a file permanently: Press **Save, State, To File...** and select a file name and location for the file. Be sure to use the `User Data D:` logical drive for saved files as it is not overwritten during software upgrades.
	To recall your saved settings: Press **Recall, State**, and select either a **Register** or From File... for state files.

Viewing Measurement Results

Step 1. Your measurement result should like Figure 2-19.

Figure 2-19   *LTE Modulation Analysis Measurement Result - UL*
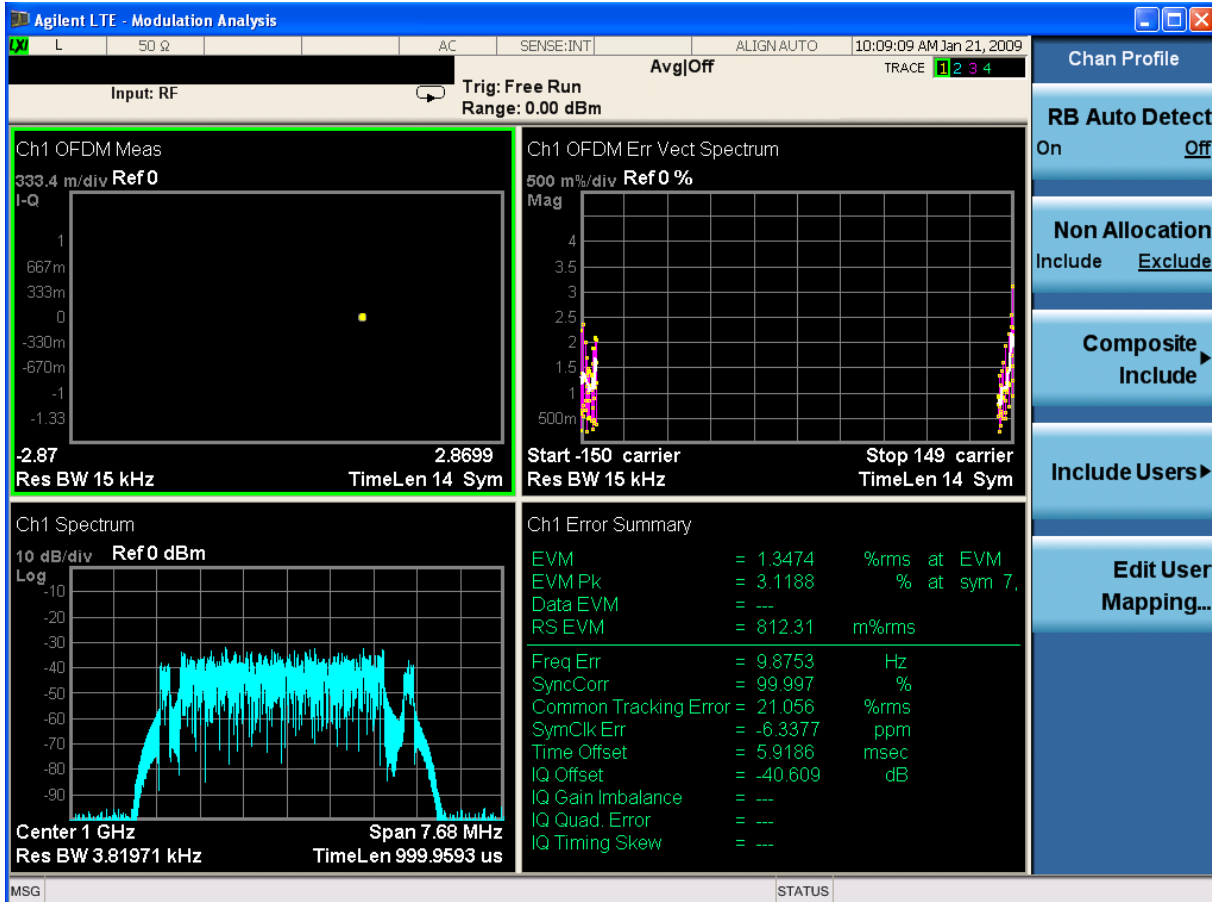
For this example, the constellation shown is a single On-Off modulation state which represents the PUCCH. The PUCCH is only shown at the extremes of the subcarrier Spectrum display, as well.

Step 2. Press **Include Users** to see the menu allowing you include or exclude signals and Channels in the carrier.

NOTE   LTE Modulation Analysis examines PUSCH and PUCCH individually. You can not Include PUCCH and PUSCH users simultaneously.

Step 3. Press **Composite Include** to include or exclude all PUSCH or PUSCH signals and Channels in the carrier. The constellation and EVM Spectrum will be blank when Exclude All is in effect.

Step 4. You can now view data traces and use different Preset Views to display measurement results. See *"Selecting Different Measurement Results Views" on page 25*.

Preset to Standard Default Settings

The following Preset to Standard bandwidths are available:

Available Bandwidths

1.4 MHz (6 RB)

3 MHz (15 RB)

5 MHz (25 RB)

10 MHz (50 RB)

15 MHz (75 RB)

20 MHz (100 RB)

In addition to bandwidth, presetting the demodulator also sets the measurement parameters to the default values listed below.

Modulation Analysis Demodulation Preset Defaults

Parameter	Default Value
Analysis Start Boundary	Frame
Antenna Detection Threshold	−10 dB
Cell ID	Auto
Composite Include	All channels selected:
	Downlink channels: QPSK, QAM16, QAM64, P-SS. S-SS, PBCH, PCFICH, PHICH, PDCCH, RS
	Uplink channels: User_01 PUSCH, User_01 PUSCH DMRS
Control Chan Precoding	Off
CP Length	Auto
Equalizer Training	RS, Moving Avg Filter selected: 19 RS
EVM Window Length	3GPP
Extend Freq Lock Range	Cleared
Frequency Span	The frequency span is determined by the sample rate and FFT size, which are set according to the LTE standard for the specified bandwidth.
Half Subcarrier Shift	Selected
IQ Offset Compensate	Cleared

Modulation Analysis Demodulation Preset Defaults

Parameter	Default Value
Measurement Interval	as many slots as possible up to 2 slots
Measurement Offset	0 slots, 0 symbol-times
Mirror Frequency Spectrum	Cleared
Non-Alloc	Cleared
Number of Tx Antenna	1
Power Boost Normalize	Selected
PUSCH DFT Swap	Selected
Report EVM in dB	Cleared
Result Length	as many slots as possible up to 20 slots
RS-PRS	Custom
Shared Chan Precoding	Off
Symbol Timing Adjust	Max of EVM Window Start / Stop
Sync Type	Downlink: P-SS
	Uplink: PUSCH DM-RS
Time Scale Factor	1
Track Amplitude	Selected
Track Phase	Selected
Track Timing	Selected
Tx Antenna results to display	Port 0
Tx Diversity / MIMO	Control Chan Precoding: Off
	Shared Chan Precoding: Off

LTE Allocation Editor (Edit User Mapping...) Defaults

Parameter	Default Value
Downlink	
RB Auto Detect	Selected
Include QPSK	Selected

LTE Allocation Editor (Edit User Mapping...) Defaults

Parameter	Default Value
Include QAM16	Selected
Include QAM64	Selected
PDSCH	
Power Boost (dB)	0
Uplink	
RB Auto Detect	Selected
Cell ID	0
nRBPUSCH	0
Group Hopping	Cleared
Sequence Hopping	Cleared
Include PUSCH	Selected
Include PUCCH	Checkbox disabled (PUCCH not configured by default)
PUSCH	
Sync Slot	0
DMRS Parameters	Cleared
RB Start	0
RB End	0
Mod Type	QPSK
Power (dB)	0
DMRS Group (u)	0
DMRS Seq (v)	0
DMRS Cyclic Shift	0
DMRS Power (dB)	0
PUCCH	
Sync Slot	0

LTE Allocation Editor (Edit User Mapping...) Defaults

Parameter	Default Value
First RB	0
Cyclic Shift	0
Format	Type 2
OS	Index0
Power (dB)	0
DMRS Group (u)	0
DMRS Power (dB)	0

LTE Downlink Control Channel Properties (Edit Control Params...) Defaults

Parameter	Default Value
P-SS Power Boost	0.65 dB
S-SS Power Boost	0.65 dB
PBCH Power Boost	0 dB
PCFICH Power Boost	0 dB
RS Power Boost	2.5 dB
PDCCH Power Boost	0 dB
PDCCH Allocations	3 per subframe for all subframes
PDCCH Allocation Const	Selected
PHICH Power Boost	0 dB
PHICH Despread IQ Orthog Seq Index	Cleared
PHICH Allocation (Ng)	1
PHICH Duration	Normal

Troubleshooting LTE Measurements

A poor EVM or phase error often indicates a problem with the I/Q baseband generator, filters, or modulator, or all three, in the transmitter circuitry of the unit under test (UUT). The output amplifier in the transmitter can also create distortion that causes unacceptably high phase error. In a real system, a poor phase error will reduce the ability of a receiver to correctly demodulate the received signal, especially in marginal signal conditions.

PROBLEM describes some common problems and possible solutions.

PROBLEM	POSSIBLE CAUSE	SOLUTION
Demodulation fails to lock-on signal	Signal not present.	Check test setup connections.
	Carrier too far from center frequency.	Enable extended frequency lock range and adjust center frequency to within ± 37.5 KHz of the carrier frequency.
	Input is over-loaded or under ranged.	Adjust input range.
	Frequency span is too narrow.	Increase frequency span.
	Downlink: Incorrect Cell ID, RS-PRS, or CP Length Uplink: Incorrect Half-subcarrier Shift, CP Length, or sync slot settings/user allocations.	Make sure that the LTE demodulator settings match the input signal parameters.
	I and Q channels are swapped.	Enable the Mirror Frequency Spectrum setting.
	Signal has an incorrect P-SS.	Change sync type to RS and set Cell ID manually.
	Signal has incorrect symbol clock.	Adjust Time Scale Factor to match the signal.
	I/Q misaligned using I+jQ receiver.	Ensure that ch1 and ch2 trigger delays are correct.
	Signal contains an antenna port transmission with a phase rotation of more than 45 degrees and RS-PRS is set to Custom.	Set RS-PRS to 3GPP to allow RS-PRS to be determined by Cell ID according to the standard.

PROBLEM	POSSIBLE CAUSE	SOLUTION
High EVM	Time capture includes data where no LTE frame is being transmitted.	Make sure that the entire time capture is filled with an LTE signal. The demodulator uses all of the time capture data (see Result Length) to calculate equalization coefficients.
	Time capture includes data where no LTE frame is being transmitted.	Make sure that the entire time capture is filled with an LTE signal. The demodulator uses all of the time capture data (see Result Length) to calculate equalization coefficients.

Monitor Spectrum Measurements

This chapter explains how to make Monitor Spectrum measurements on a 3GPP LTE FDD (using 2008-03 carriers) signal. Monitor Spectrum measurements show a spectrum domain display of the LTE signal. Marker functions may be used to provide Band Power, Noise and Band Interval Density measurements over the signal bandwidth.

Monitor Spectrum has a Gate function that enables you measure the Spectrum power over a precise interval, like an Slot or Subframe.

NOTE   Because LTE is bursted, you must use the Gate function to obtain valid results when measuring LTE OFDMA signals. See the measurement procedure for details.

This example shows a DUT under test set up to transmit RF power, and controlled remotely by a system controller. The transmitting signal is connected to the RF input port of the instrument. Connect the equipment as shown.

Figure 2-20   *Spectrum Measurement System*
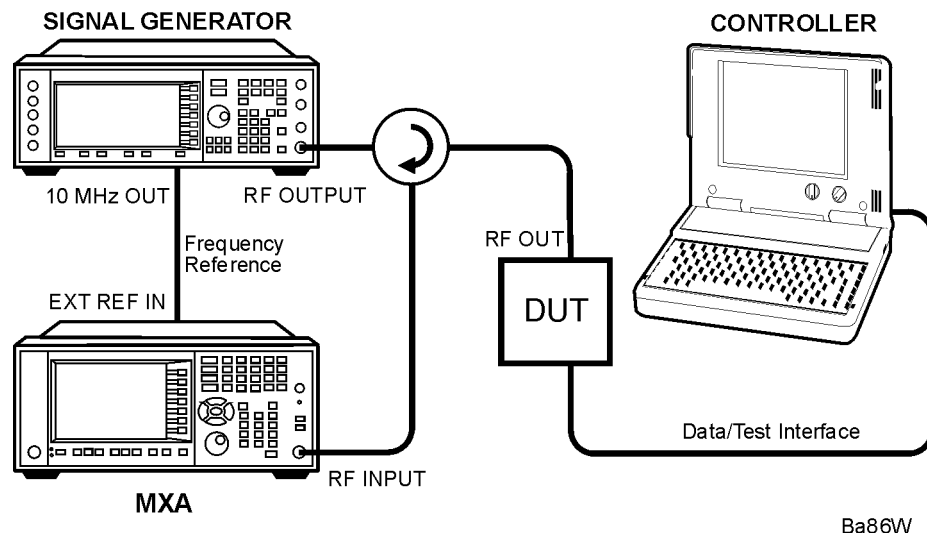
1. Using the appropriate cables, adapters, and circulator, connect the output signal of the DUT to the RF input of the analyzer.

2. Connect the transmitter simulator or signal generator to the MS through the circulator to initiate a link constructed with sync and reference channels, if required.

3. Connect a BNC cable between the 10 MHz OUT port of the signal generator and the EXT REF IN port of the analyzer.

4. Connect the system controller to the DUT to control the operation.

Making an LTE Downlink Measurements

Setting the Downlink Signal (Example)

This example uses a signal generated using Agilent N7624B Signal Studio for 3GPP LTE FDD (using 2008-03 carriers).

Direction   Downlink

Frequency: 1.000 GHz

Output Power: -10 dBm

Bandwidth   5 MHz (25 PRB)

Carriers   1

Channel Configuration = Full-Filled QPSK 5 MHz (25 PRB)

Antennas   1

Transport Channel:

- DL-SCH = On, 0 dB
- BCH = On, 0 dB

Physical Channels:

- PBDCH = On, 0 dB
- PDCCH = On, 0 dB
- PDSCH - RB = 1-20, 0 dB
- PCFICH = On, 0 dB
- PHICH = On, 0 dB
- PHICH = On, 0 dB

Resource Block:

- Slots = 20
- RB = 0-24
- Power = 0 dB

Figure 2-21   *Signal Studio Downlink Setup Graphic Display*
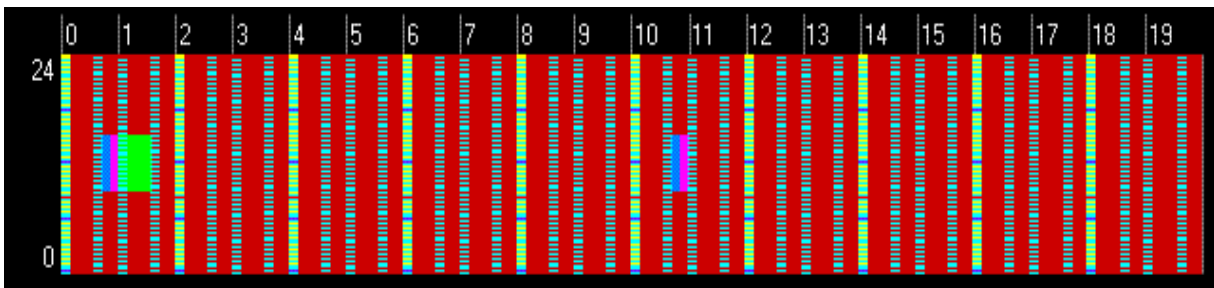
Monitor Spectrum Measurement Procedure

Step 1. Press **Mode**, **LTE** to enable LTE measurements.

Step 2. Press **Mode Preset** to preset the mode. Only do this to return the measurement settings to a known state for all measurements in the LTE mode

Step 3. Press **Meas**, **Monitor Spectrum** to initiate the Monitor Spectrum measurement.

Step 4. Press **FREQ Channel, 1, GHz** to set the measurement measurement center frequency to 1 GHz.

Step 5. If your DUT is a UE, or your signal of interest is an uplink (UL), press the **Mode Setup**, **Direction,** keys to toggle the setting to enable **Uplink** measurements. The default is **Downlink**.

Step 6. Press **FREQ Channel**, **1**, **GHz** to set the center frequency to 1.000 GHz.

Step 7. Press **Meas Setup, Meas Preset** to preset the measurement. This will return the measurement settings to a known state for only this measurement.

The Monitor Spectrum measurement LTE default result should look like Figure 2-22.

Figure 2-22   Monitor Spectrum Measurement - Default View (Autoscale On)
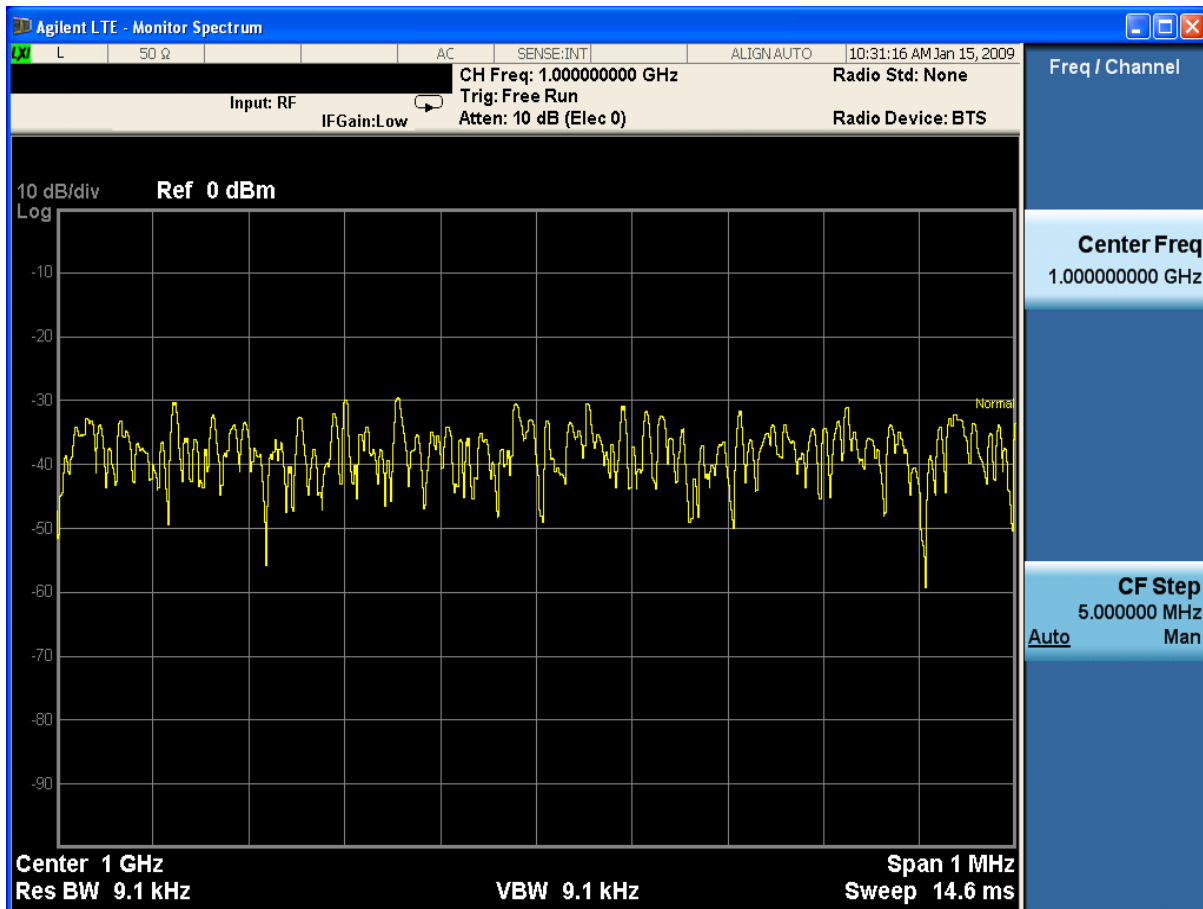
Step 8. To adjust the measurement span frequency press **SPAN X Scale**, enter a numerical span using the front-panel keypad, and select a units key, such as **5, MHz**. 5 MHz will display the entire bandwidth of the LTE signal.

The Monitor Spectrum triggered result should look like Figure 2-23.

Figure 2-23 *Monitor Spectrum Measurement - 5 MHz Span with Frame Trigger*
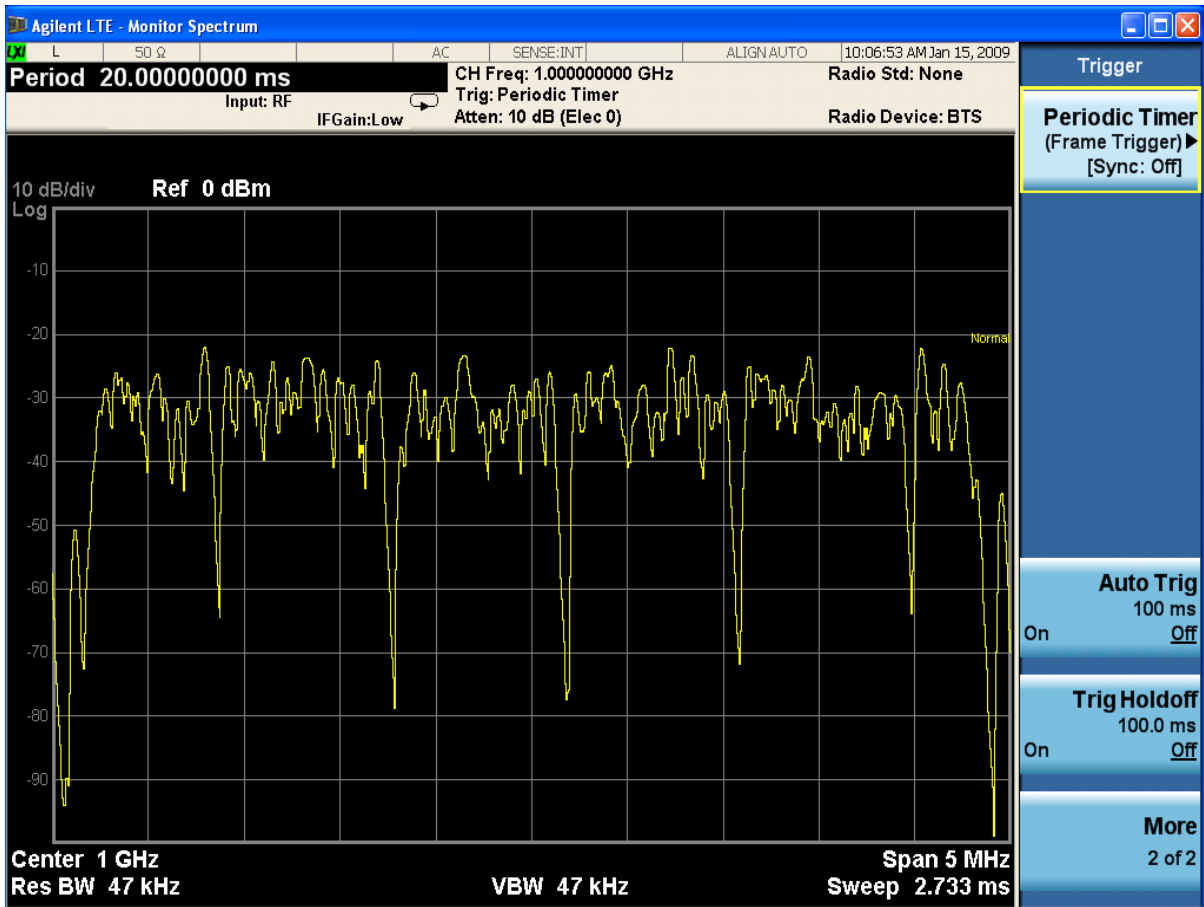
Step 9. To stabilize the signal display use a measurement trigger:
Press **Trigger, More, Periodic Timer (Frame Trigger)** to trigger the measurement with the Frame Timer.
Press **Periodic Timer (Frame Trigger)** again to access the Timer Setup menu.
Press Period, 10, ms (or any multiple of 10 ms, the LTE frame period) to trigger the measurement on the frame.

Step 10. Press **Sync Source** in the Timer Setup menu and select **RF Burst (Wideband)** to sync the periodic trigger to the RF Burst.

Step 11. (Optional) Press the **Meas Setup** key to adjust **Avg Number.**

Step 12. (Optional) You can use Markers to determine Band Power and other functions. Press **Marker Function, Band Interval/Power** and select **Band Adjust.** You can use the knob to dial the marker limits to the desired setting, or enter values directly from the front panel. Ths example display in Figure 2-24 on page 61 shows the limits at the band edges and indicates the Band Power measurement agrees closely wih the signal power applied at -10 dBm.

Figure 2-24   *Monitor Spectrum Measurement - Band Power Marker*
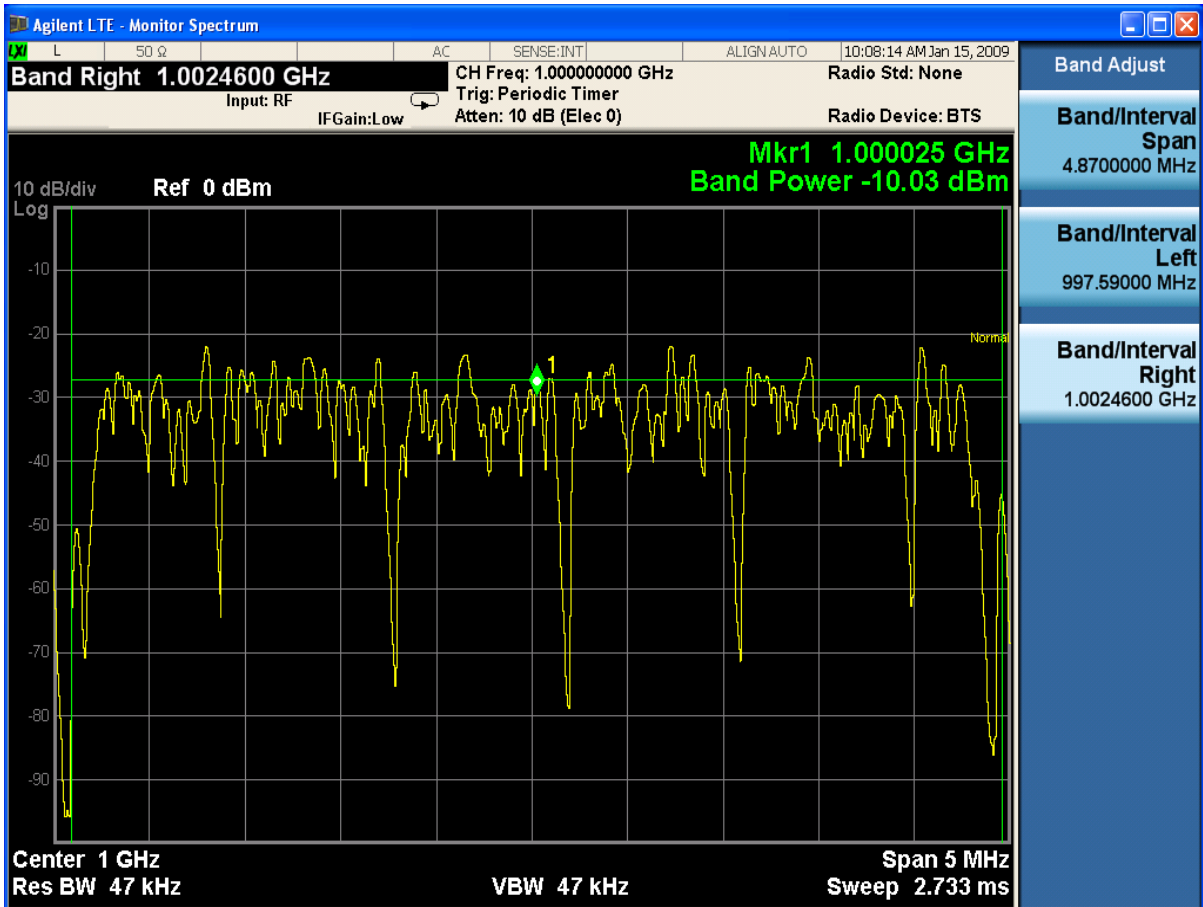
Other Marker Functions include Noise power measurement markers and Band Interval/Density power measurement markers.

If you have a problem, and get an error message, see the "**Error Messages Guide**".

Using Gate Functions

This procedure describes setting the Gate function to make a Monitor Spectrum measurement of a single slot in an LTE frame. This procedure assumes you have performed a basic Monitor Spectrum measurement procedure up to stabilizing the signal.

NOTE   The Gate function is coupled to the Spectrum view Center Frequency and Span.

The Monitor Spectrum triggered result should look like Figure 2-25.

Figure 2-25   *Monitor Spectrum Measurement - 5 MHz Span with Frame Trigger*
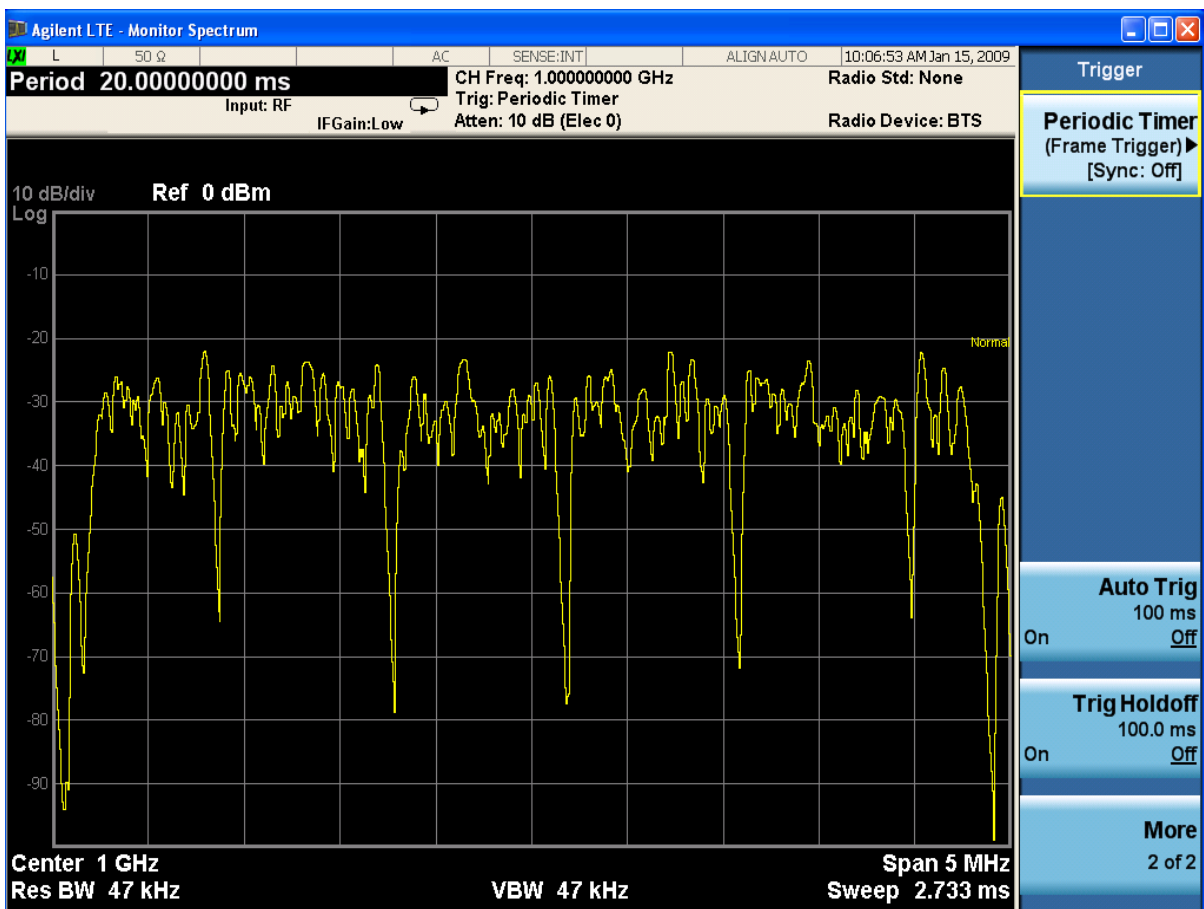
Step 1. To stabilize the signal display use a measurement trigger:
Press **Trigger, More, Periodic Timer (Frame Trigger)** to trigger the measurement with the Frame Timer.
Press **Periodic Timer (Frame Trigger)** again to acess the Timer Setup menu.
Press Period, 10, ms (or any multiple of 10 ms) to trigger the measurement on the frame.

Step 2. Press **Sync Source** in the Timer Setup menu and select **RF Burst (Wideband)** to sync the periodic trigger to the RF Burst.

Step 3. Press **Sweep/Control, Gate, Gate View** and toggle it to **On**.

Step 4. Press **Gate View Sweep Time** and set it to 2 ms (4 LTE slots).

Step 5. Press **Gate Delay** and set it to 0.5 ms. This sets Gate Start to begin at the beginning of the second slot in the Frame

---

TIP   For best results, always set **Gate Delay** to position `Gate Start` after `Max Fast` to allow the LO to "settle".

Step 6. Press **Gate Length** and set it to 0.5 ms, the length of an LTE slot.

Step 7. Press **Gate** and toggle it to **On**.

The Monitor Spectrum measurement result should look like Figure 2-22. The Gate Start and Gate Stop markers are shown in the time domain Gate View. The Spectrum display represents the average amplitude across the 5 MHz bandwidth during the single slot.

Figure 2-26   *Monitor Spectrum Measurement - Gate View - 1 LTE Slot*
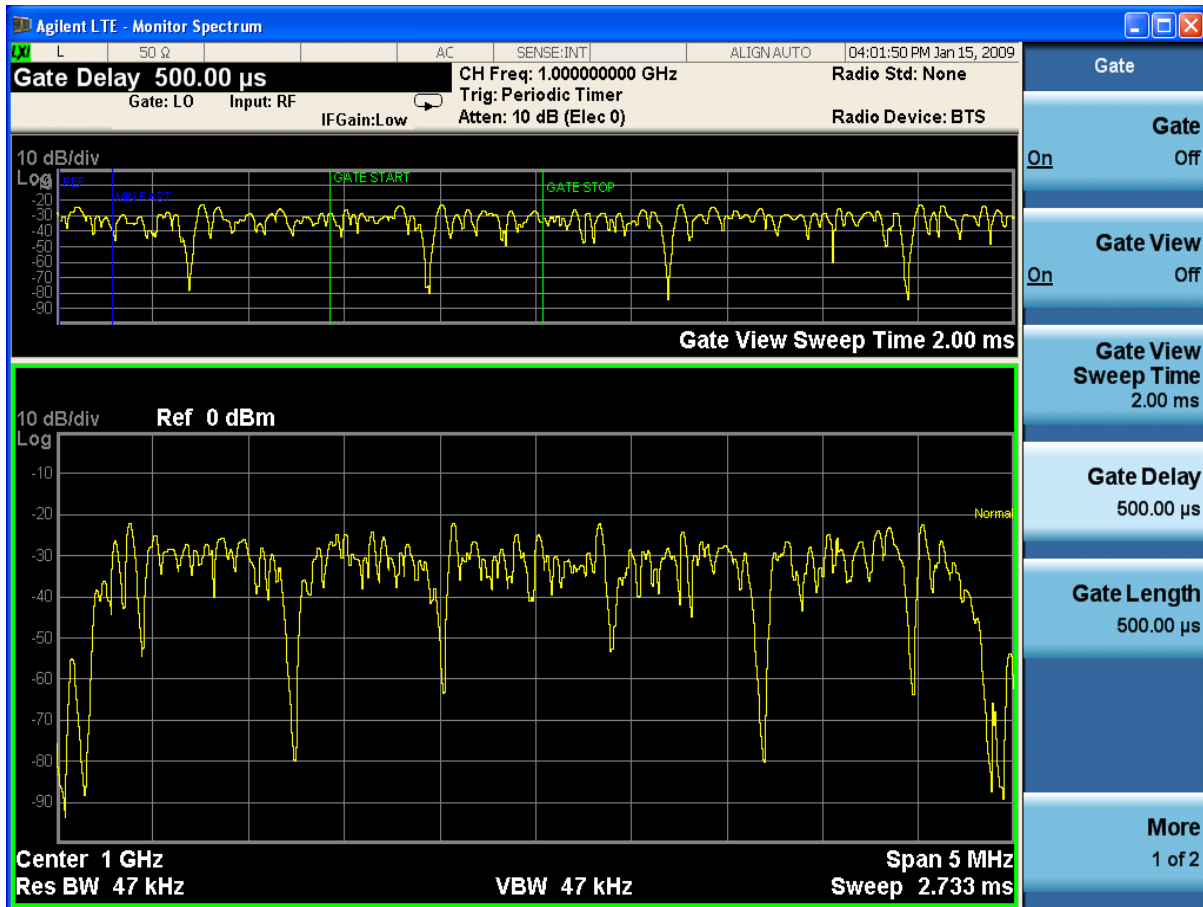
Conformance EVM Measurement

This section explains how to make the Conformance EVM measurement on a LTE FDD signal. For the detailed instruction about this measurement, see "LTE Coformance EVM Measurement Concepts" on page 140.

"Making LTE Downlink Conformance EVM Measurement" on page 65

"Making LTE Uplink Conformance EVM Measurement" on page 69

Making LTE Downlink Conformance EVM Measurement

Setting the Downlink Signal

Test model E-TM1.1 with 5 MHz bandwidth is used as the example in the Conformance EVM measurement.

Configure the signal generator using the settings below. The Agilent Signal Studio N7624B for 3GPP LTE FDD (Basic LTE FDD Downlink 2009-12), is used in the example to generate the required waveform for testing.

Frequency: 1 GHz

Output Power: 0 dBm (at analyzer input)

Carrier: 1

Figure 2-27   *E-TM1.1 Signal Studio Mapping (Downlink Signal)*
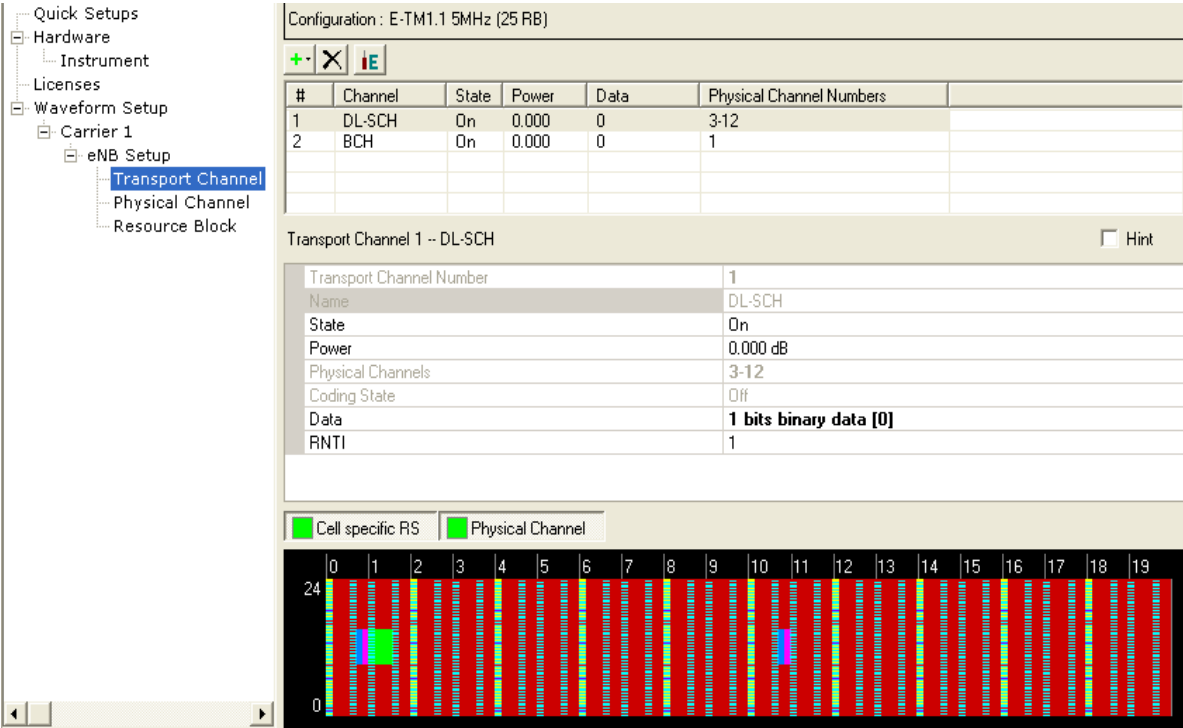
Measurement Procedure

Step 1. Enable the LTE measurements.

Press **Mode**, **LTE**.

Step 2. Preset the mode.

Press **Mode Preset**.

Step 3. Set the center frequency.

Press **FREQ Channel**, **1**, **GHz**.

Step 4. Initial Conformance EVM measurement.

Press **Meas, Conformance EVM**.

Step 5. Recall EVM setup.

NOTE   If you use a test model to do the measurement, the Recall function is provided for E-URTA Test Models (E-TM) to setup the parameters automatically.

Press **Recall, Data, EVM Setup** then **Open**.

Choose the file from the open window, the file TM1.1-BW5MHz.evms is used here.

NOTE   If you want to make the parameters setting in Modulation Analysis measurement apply to Conformance EVM measurement, press **Meas Setup, Copy from Mod Analysis**.

Now you will see the Result Metrics view.

Step 6. Select views.

Press **View/Display** to select different views: **Measurement List, Parameter List, Result Metrics** and **RF Envelope**.

Figure 2-28   *LTE Downlink Conformance EVM Measurement Measurement List*

Figure 2-29   *LTE Downlink Conformance EVM Parameter List*

NOTE   The parameter name, related SCPI and value are listed in Parameter List view with tabular form. You can send the SCPI to change them or you can manually change them by selectting the parameter using knob or up and down arows then enter the value using front panel keys.

Figure 2-30   *LTE Downlink Conformance EVM Result Metrics*

Figure 2-31   *LTE Downlink Conformance EVM RF Envelop*

If you have a problem, and get an error message, see the guide "**Instrument Messages**", which is provided on the Documentation CD ROM, and in the instrument here:

C:\Program Files\Agilent\SignalAnalysis\Infrastructure\Help\bookfiles.

Making LTE Uplink Conformance EVM Measurement

This section explains how to make the Conformance EVM measurement on a LTE FDD uplink signal. For detailed instruction about this measurement, see "LTE Coformance EVM Measurement Concepts" on page 140.

If you are using Fast Mode (only available on PXA with option B1X) for CEVM measurement, see "Fast Mode Measurement Example" on page 73.

Setting the Uplink Signal (Example)

Direction   Uplink

Frequency: 1.000 GHz

Output Power: -10 dBm

Bandwidth   5 MHz (25 RB)

Carriers   1

Channel Configuration = Full-Filled QPSK 5 MHz (25 RB)

Antennas   1

Transport Channel:

  • UL-SCH = On, 0 dB

Physical Channels:

  • PUSCH = On, 0 dB

Resource Block:

  • Slots = 20

  • RB = 0-24

  • Power = 0 dB

Figure 2-32   *LTE Signal Studio Mapping (Uplink Signal)*
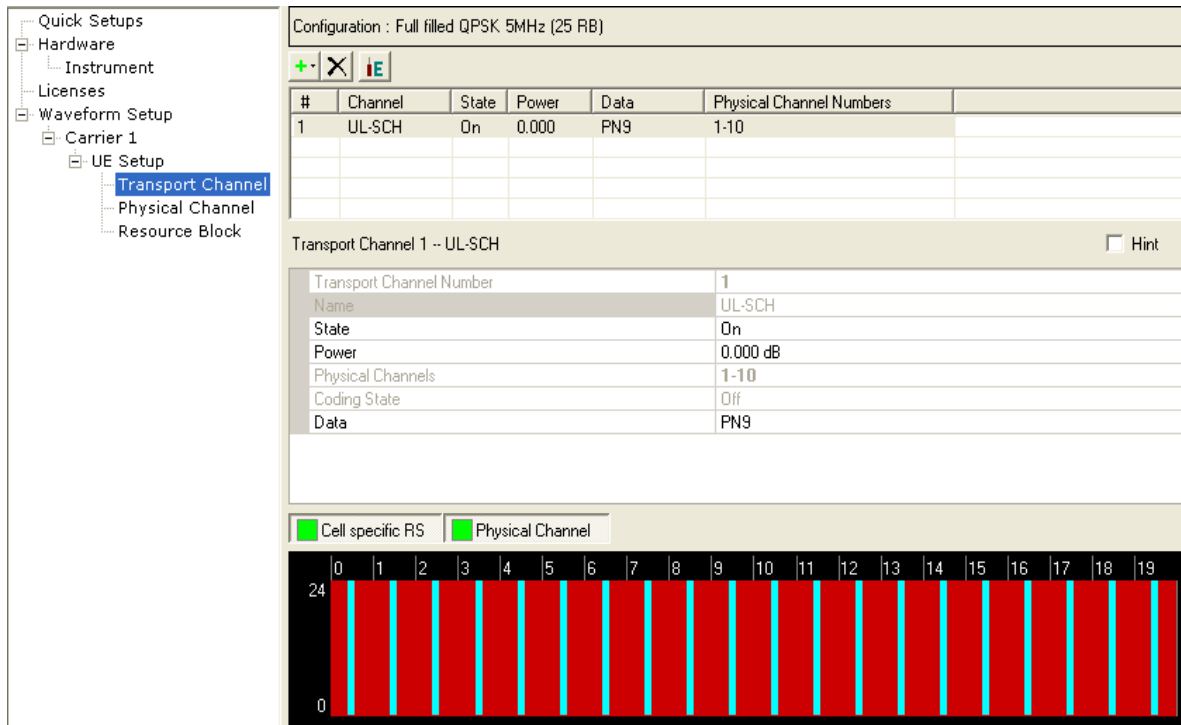
Measurement Procedure

Step 1. Enable the LTE measurements.

Press **Mode**, **LTE**.

Step 2. Preset the mode.

Press **Mode Preset**.

Step 3. Set the center frequency.

Press **FREQ Channel**, **1**, **GHz**.

Step 4. Select the direction to uplink.

Press **Mode Setup**, **Radio**, **Direction** to be **Uplink**.

Step 5. Select the system bandwidth.

Press **Mode Setup, Demod, Bandwidth**, **B5M**.

Step 6. Initiate the Conformance EVM measurement.

Press **Meas**, **Conformance EVM**.

Step 7. Setup other measurement parameters.

You need send SCPI commands or change parameter settings in Parameter List view (under View/Display).

NOTE	If you have already configure the setting in Modulation Analysis measurement, you can simply use Copy from Modulation function to automatically apply the parameter values to Conformance EVM. Press **Meas, Conformance EVM then Meas Setup, Copy from Mod Analysis**.

Step 8. Select views.

Press **View/Display** to select different views: **Measurement List, Parameter List, Result Metrics and RF Envelope**.

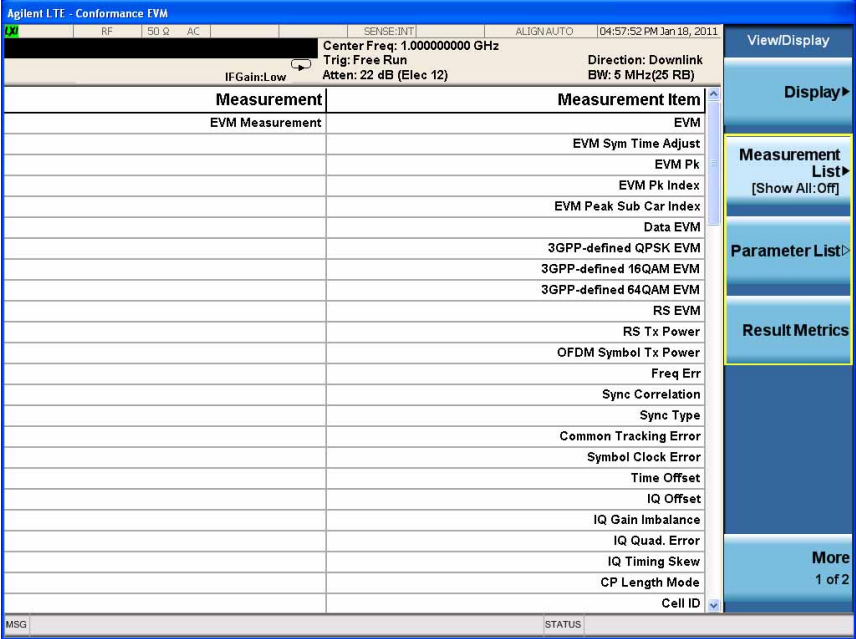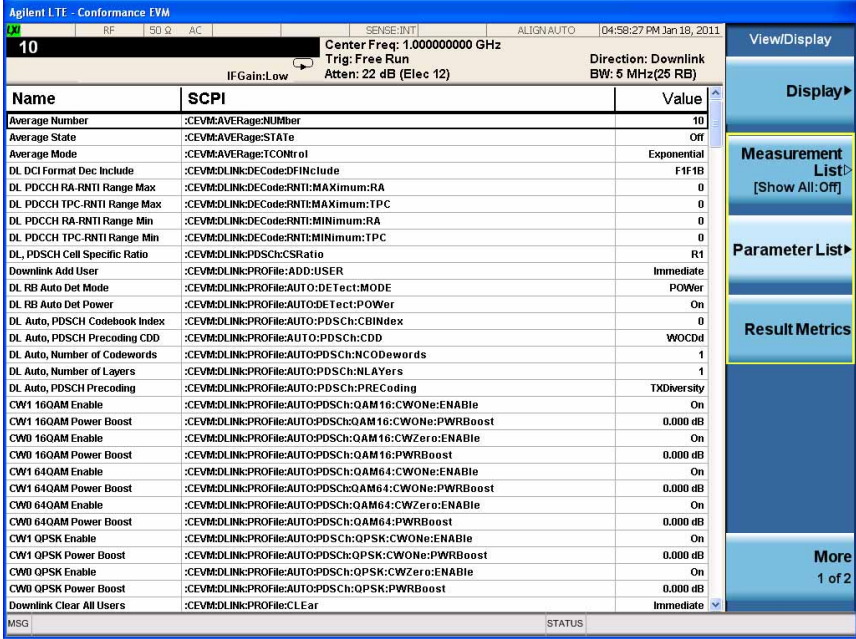*Figure 2-33* *LTE Uplink Conformance EVM Measurement Measurement List*

Figure 2-34   LTE Uplink Conformance EVM Parameter List

NOTE	The parameter name, related SCPI and value are listed in Parameter List view with tabular form. You can send the SCPI to change them or you can manually change them by selectting the parameter using knob or up and down arows then enter the value using front panel keys.

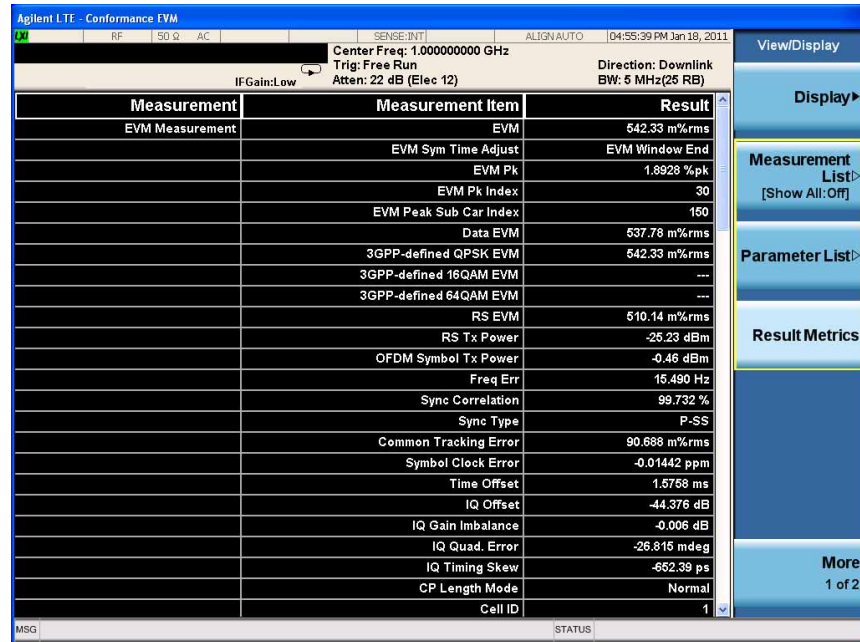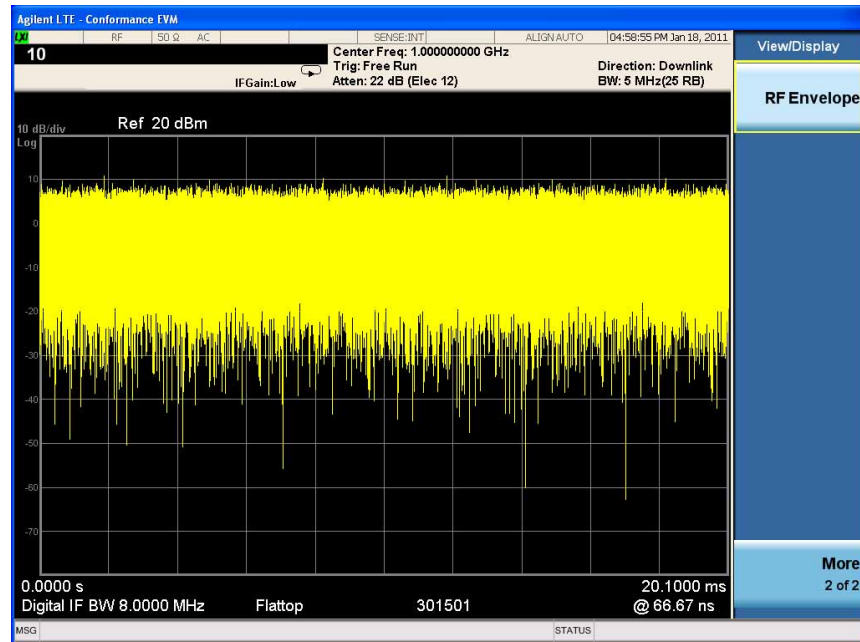**Figure 2-35**   LTE Uplink Conformance EVM Result Metrics

Figure 2-36   *LTE Uplink Conformance EVM RF Envelop*
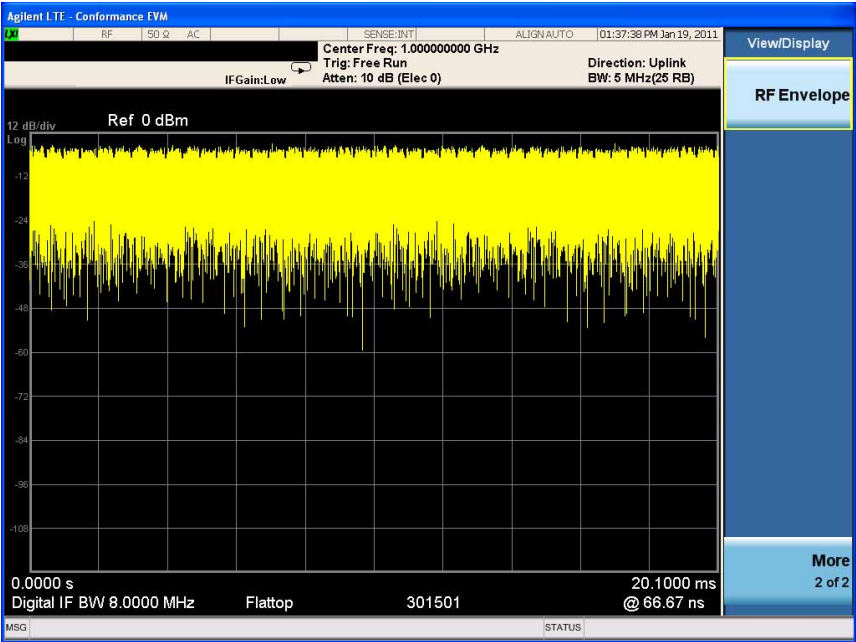
If you have a problem, and get an error message, see the guide "**Instrument Messages**", which is provided on the Documentation CD ROM, and in the instrument here:

C:\Program Files\Agilent\SignalAnalysis\Infrastructure\Help\bookfiles.

Fast Mode Measurement Example

Example of Uplink Signal

20MHz BW and Full RB Allocation with QPSK

CellID = 0

nDMRS(1) = 0

nDMRS(2) = 0

DeltaSS=0

Meas Interval = 20 Slots

Example of Manually Test

Step 1. Set necessary parameters and configure the user mapping in Modulation Analysis Measurement.

Press **Meas Setup**, **Chan Profile Setup, More, Edit User Mapping**.

Figure 2-37   *LTE Uplink Signal User Mapping for Fast Mode Example*
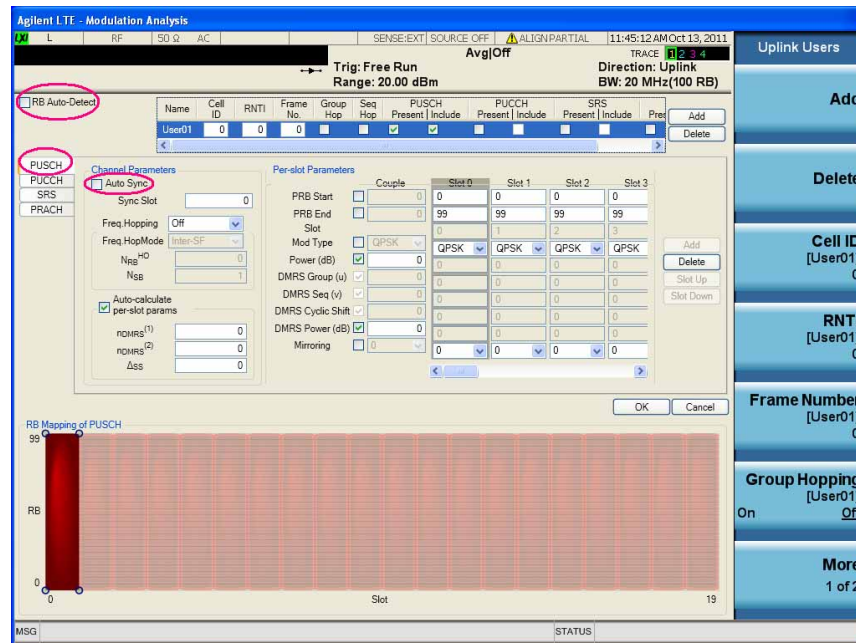
Step 2. Initiate the Conformance EVM measurement.

Press **Meas**, **Conformance EVM**.

Step 3. Copy the parameter settings from Modulation Analysis measurement to Conformance EVM measurement.

Press **Meas Setup, Copy from Mod Analysis**.

Step 4. Select the Fast mode.

Press **Meas Setup**, **Meas Method** and select **Fast**.

Save the state if necessary for later use of recalling.

Example of Remote SCPI Commands Test

After doing "Mode Preset" and switching to CEVM Measurement, the setup is completed by executing following list of SCPI commands.

:RAD:STAN:DIR ULIN

:RAD:STAN:PRES B20M

:POW:EATT:STAT 0

:CEVM:TIME:INT:SLOT 20

:CEVM:ULIN:SYNC:CPL NORM

:CEVM:PROF:AUTO:DET 0

:CEVM:TIME:ASB FRAM

:CEVM:ULIN:PROF:ADD:USER

*OPC?

:CEVM:ULIN:PROF:USER:CID 0

:CEVM:ULIN:PROF:USER:PUSC:DMRS:ONE 0

:CEVM:ULIN:PROF:USER:PUSC:DMRS:TWO 0

:CEVM:ULIN:PROF:USER:PUSC:DSS 0

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 0

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 1

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 2

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 3

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 4

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 5

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 6

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 7

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 8

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 9

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 10

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 11

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 12

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 13

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 14

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 15

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 16

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 17

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 18

:CEVM:ULIN:PROF:USER:PUSC:ADD:SLOT 19

*OPC?

:CEVM:ULIN:PROF:USER:PUSC:DMRS:PAR 1

:CEVM:ULIN:PROF:USER:PUSC:RB:STAR:COUP 1

:CEVM:ULIN:PROF:USER:PUSC:RB:END:COUP 1

:CEVM:ULIN:PROF:USER:PUSC:MOD:TYPE:COUP 1

:CEVM:ULIN:PROF:USER:PUSC:RB:STAR 0

:CEVM:ULIN:PROF:USER:PUSC:RB:END 99

:CEVM:ULIN:PROF:USER:PUSC:MOD:TYPE QAM16

:CEVM:ULIN:PROF:USER:PUSC:SSL 0

:CEVM:ULIN:PROF:USER:PUSC:SSL:AUTO 0

:CEVM:ULIN:PROF:USER:PUSC:ACT ON

:CEVM:ULIN:PROF:USER:PUSC INCL

:CEVM:ULIN:PROF:USER:PUSC:DMRS INCL

:CEVM:EQU:TRA RSD

:CEVM:METH FAST

3 Using Option BBA Baseband I/Q Inputs

Baseband I/Q Measurements Available for X-Series Signal Analyzers

The following table shows the measurements that can be made using Baseband I/Q inputs:

Table 3-1   *BBIQ Supported Measurements vs. Mode*

Mode	Measurements
GSM	IQ Waveform GMSK Phase & Freq EDGE EVM
802.16 OFDMA	IQ Waveform Power Stat CCDF Modulation Analysis
TD-SCDMA	IQ Waveform Power Stat CCDF Code Domain Mod Accuracy
cdma2000	IQ Waveform Power Stat CCDF Code Domain Mod Accuracy QPSK EVM
W-CDMA	IQ Waveform Power Stat CCDF Code Domain Mod Accuracy QPSK EVM
1xEV-DO	IQ Waveform Power Stat CCDF Forward Link Code Domain Reverse Link Code Domain Forward Link Mod Accuracy Reverse Link Mod Accuracy QPSK EVM
LTE	IQ Waveform Power Stat CCDF
LTE TDD	IQ Waveform Power Stat CCDF
DTMB (CTTB)	IQ Waveform Power Stat CCDF Mod Accuracy

Table 3-1   *BBIQ Supported Measurements vs. Mode*

Mode	Measurements
DVB-T/H with T2	IQ Waveform Power Stat CCDF DVB-T/H Mod Accuracy DVB-T2 Mod Accuracy
ISDB-T	IQ Waveform Power Stat CCDF Mod Accuracy
CMMB	IQ Waveform Power Stat CCDF Mod Accuracy
Digital Cable TV	IQ Waveform Power Stat CCDF Mod Accuracy
IQ Analyzer (Basic)	IQ Waveform Complex Spectrum

Baseband I/Q Measurement Overview

The Baseband I/Q functionality is a hardware option, Option BBA. If the option is not installed in the instrument, the I/Q functionality cannot be enabled.

The Baseband I/Q option provides four input ports and one Calibration Output port. The input ports are I, I-bar, Q, and Q-bar. The I and I-bar together compose the I channel and the Q and Q-bar together compose the Q channel. Each channel has two modes of operation:

Single Ended
(unbalanced)   In this mode, only the main port (I or Q) is used and the complementary ports (I-bar or Q-bar) are ignored. The I and Q ports are in single-ended mode when Differential "Off" is selected.

Differential
(balanced)   In this mode, both main and complementary ports are used. To activate this mode, select Differential "On" from the I and Q Setup softkey menus.

The system supports a variety of input passive probes as well as the Agilent 1153A active differential probe using the Infinimax probe interface.

NOTE   To avoid duplication, this section describes only the details unique to using the baseband I/Q inputs. For generic measurement details, refer to the previous "Making LTE Measurements" on page 11.

To make measurements using baseband I/Q Inputs, make the following selections:

Step 1. Select a measurement that supports baseband I/Q inputs.

Step 2. Select the I/Q Path.
Press **Input/Output, I/Q, I/Q Path**. Select from the choices present on the screen. The path selected is shown at the top of the measurement screen.

Step 3. Select the appropriate circuit location and probe(s) for measurements. For details see "Selecting Input Probes for Baseband Measurements" on page 149 in the Concepts chapter.

Step 4. Select baseband I/Q input connectors.

Step 5. If you have set the I/Q Path to **I+jQ** or to **I Only**, press **I Setup.**

   A. Select whether **Differential (Balanced)** input is **On** or **Off.**

   B. Select the input impedance, **Input Z**.

   C. Input a **Skew** value in seconds.

   D. Set up the I Probe by pressing **I Probe**.

       a. Select probe **Attenuation**.

   b. Calibrate the probe. Press **Calibrate…** to start the calibration procedure. Follow the calibration procedure, clicking **Next** at the end of each step.

Step 6. If you have set the I/Q Path to **I+jQ** or to **Q Only**, press **Q Setup**.

   A. Select whether **Differential (Balanced)** input is **On** or **Off.**

   B. Select the input impedance, **Input Z**.

   C. Input a **Skew** value in seconds.

   D. Set up the I Probe by pressing **I Probe**.

      a. Select probe **Attenuation**.

      b. Calibrate the probe. Press **Calibrate…** to start the calibration procedure. Follow the calibration procedure, clicking **Next** at the end of each step.

Step 7. Select the reference impedance by pressing **Reference Z**, and inputting a value from one ohm to one megohm. The impedance selected is shown at the top of the measurement screen.

Step 8. If you are using cables that were not calibrated in the probe calibration step, press **I/Q Cable Calibrate…** Follow the calibration procedure, clicking **Next** at the end of each step.

Step 9. After completing the baseband IQ setup procedures, make your desired measurement.

4   Interpreting Error Codes

During the execution of your measurement you may encounter problems which generate error codes. Referring to the following common errors may be helpful.

If `Err` is shown in the annunciator bar, press the **System**, **Show, Errors** hard and soft keys to read the detailed error information.

- **Error Code 145 "Under Range"**

  If the input signal level is too low to make a valid measurement, this error may appear. If you cannot increase the power into the tester, you need to increase the input sensitivity by adjusting the ADC range.

  Press **Meas Setup**, **More (1 of 3)**, **More (2 of 3)**, **Advanced**, **ADC Rang**e, and then **Manual** keys. Increase the setting from None (default) to 6 dB, for example. Another option is to use the **Auto** setting (the **Auto** setting is not used as the default to improve measurement speed).

  Press **Restart** to make another measurement and observe the results. Re-adjust the ADC as necessary to obtain a valid measurement.

- **Error Code 217 "Burst Not Found"**

  This error indicates the burst signal cannot be detected because of inappropriate parameter settings or an incorrect signal.

  For CDMA signals this error means that the tester has failed to find any active channels in the input signal as specified. To improve the correlation some critical parameters need to be adjusted, for example, the input signal level or scramble code.

- **Error Code 219 "Signal too noisy"**

  This error means that your input signal is too noisy to capture the correct I/Q components. To make a more stable measurement the trigger source may need to be set to **Frame**, for example.

- **Error Code 413 "ADC Input overload"**

  This warning means that your measurement has erroneous results due to the excessive input power level. To correct this condition, the input signal level must be reduced by using the internal and/or external attenuators.

  Press the **Mode Setup**, **Input**, **Input Atten** keys to enter an attenuation value to reduce the transmitted power from the MS. This allowable range is up to 40 dB.

If you want to attenuate more than 40 dB, connect your external attenuator between the **RF INPUT** port and the DUT. Be sure to add its attenuation value to the readings of the measurement result.

To automate this calculation, press the **Mode Setup**, **Input**, **Ext Atten** keys to enter the additional attenuation value. The allowable range is up to 100 dB. The power readings of the measurement take into account the external attenuation value.

For more details consult the chapter in this book dedicated to the measurement in question, or see the "Instrument Messages" manual.

5   Concepts

This chapter presents an overview of the 3GPP LTE communications system and details how various measurements are performed by the instrument. A list acronyms and a list of reference documents for further investigation is provided.

LTE Technical Overview

This section describes the Long Term Evolution (LTE) of the universal mobile telecommunication system (UMTS), which is being developed by the 3rd Generation Partnership Project (3GPP). Details include LTE's use of multiple antenna techniques and to a new modulation scheme called single carrier frequency division multiple access (SC-FDMA) used in the LTE uplink.

LTE is designed to provide the following features:

- Increased downlink and uplink peak data rates, as shown in Table 5-1 and Table 5-2. Note that the downlink is specified for single input single output (SISO) and multiple input multiple output (MIMO) antenna configurations at a fixed 64QAM modulation depth, whereas the uplink is specified only for SISO but at different modulation depths. These figures represent the physical limitation of the frequency division duplex (FDD) air interface in ideal radio conditions with allowance for signaling overheads.

- Scalable bandwidth from 1.4 to 20 MHz in both the uplink and the downlink

- Spectral efficiency, with improvements for high speed packet access (HSPA)

- Sub-5 ms latency for small internet protocol (IP) packets

- Optimized performance for low mobile speeds from 0 to 15 km/h; supported with high performance from 15 to 120 km/h; functional from 120 to 350 km/h. Support for 350 to 500 km/h is under consideration

- Co-existence with legacy standards while evolving toward an all-IP network.

Table 5-1   *LTE FDD Downlink Peak Data Rates (64QAM)*

Antenna configuration	SISO	2x2 MIMO	4x4 MIMO
Peak Data Rate Mbps	100	172.8	326.4

Table 5-2   *LTE FDD Uplink Peak Data Rates (Single Antenna)*

Modulation Depth	QPSK	16QAM	64QAM
Peak Data Rate Mbps	50	57.6	86.4

LTE Network Architecture

LTE employs a new network architecture made up of multiple Evolved Packet Cores (EPCs) that communicate with each other and with evolved universal terrestrial radio access network base stations (eNBs), see Figure 5-1. Each EPC contains a Mobile Management Entity (MME) and a System Architecture Evolution Gateway (SAE) comprised of Gateway elements (S-GW). The eNB stations communicate with the EPCs, with each other, and with user equipment (UE).

A new interface called X2 connects the eNBs, enabling direct communication between the elements and eliminating the need to funnel data back and forth through the radio network controller (RNC).

The E-UTRAN is connected to the EPC through the S1 interface, which connects the eNBs to the mobility management entity (MME) and serving gateway (S-GW) elements through a "many-to-many" relationship.

Figure 5-1   *LTE architecture with E-UTRAN (TS 36.300 V8.4.0 Figure 4)*
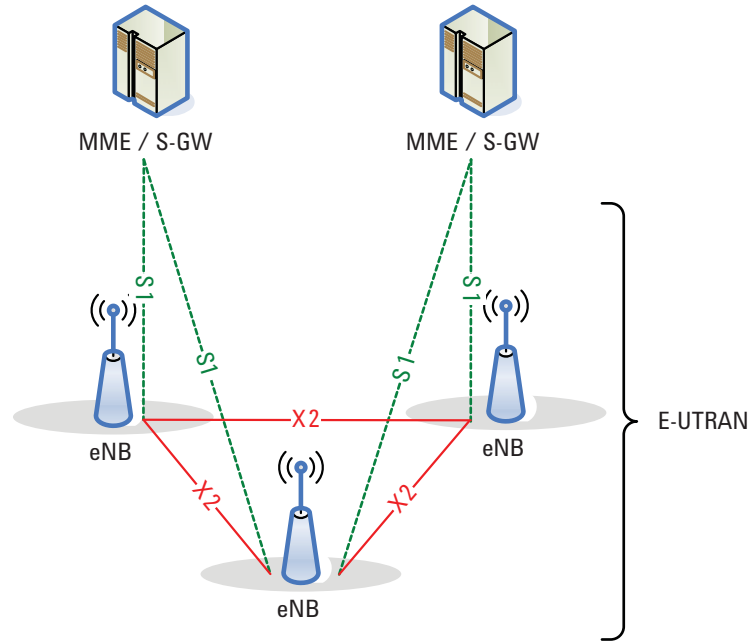
One of the simplifications of this architecture is to push more signaling down to the eNBs by splitting the user plane and mobility management entities. This functional split is depicted in Figure 5-2.

Figure 5-2   *Functional split between E-UTRAN and EPC (TS 36.300 V8.4.0 Figure 4.1)*
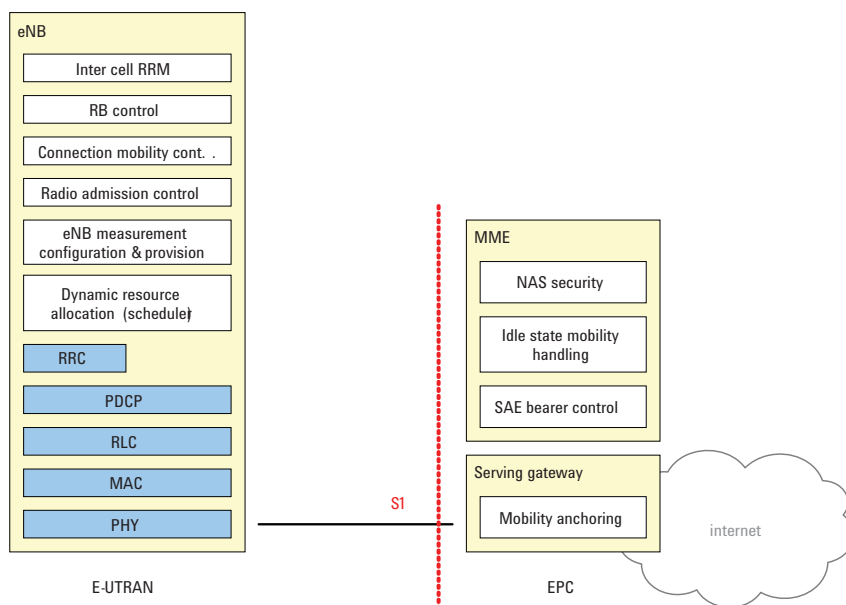
The eNB now hosts these functions:

- Radio resource management
- IP header compression and encryption
- Selection of MME at UE attachment
- Routing of user plane data towards S-GW
- Scheduling and transmission of paging messages and broadcast information
- Mobility measurement and reporting configuration

The MME functions include:

- Distribution of paging messages to eNBs
- Security control
- Idle state mobility control
- SAE bearer control
- Ciphering and integrity protection of non-access stratum (NAS) signaling

The S-GW hosts these functions:

- Termination of user-plane packets for paging reasons
- Switching of user plane for UE mobility

The radio protocol architecture of E-UTRAN is specified for the user plane and the control plane. The user plane comprises the packet data convergence protocol (PDCP), radio link control (RLC), medium access control (MAC), and physical layer (PHY); the control plane performs the radio resource control (RRC). Both the user plane and control plane are terminated in the eNB. A detailed description of the radio protocol architecture is beyond the scope of this document, however, more information is available in TS 36.3005 and other documents in the 36.300 series.

Multiple Access Technology in the Downlink: OFDM and OFDMA

Downlink and uplink transmission in LTE are based on the use of multiple access technologies: specifically, orthogonal frequency division multiple access (OFDMA) for the downlink, and single-carrier frequency division multiple access (SC-FDMA) for the uplink.

OFDM vs. CDMA

The LTE downlink is transmitted using OFDMA, a variant of orthogonal frequency division multiplexing (OFDM), a digital multi-carrier modulation scheme that is widely used in wireless systems but relatively new to cellular. Rather than transmit a high-rate stream of data with a single carrier, OFDM makes use of a large number of closely spaced orthogonal subcarriers that are transmitted in parallel.

Each subcarrier is modulated with a conventional modulation scheme (such as QPSK, 16QAM, or 64QAM) at a low symbol rate. The combination of hundreds or thousands of subcarriers enables data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

The diagram in Figure 5-3 taken from TS 36.8929 illustrates the key features of an OFDM signal in frequency and time. In the frequency domain, multiple adjacent tones or subcarriers are each independently modulated with data. Then in the time domain, guard intervals are inserted between each of the symbols to prevent inter-symbol interference at the receiver caused by multi-path delay spread in the radio channel.

Figure 5-3   *OFDM Signal Represented in Frequency and Time*
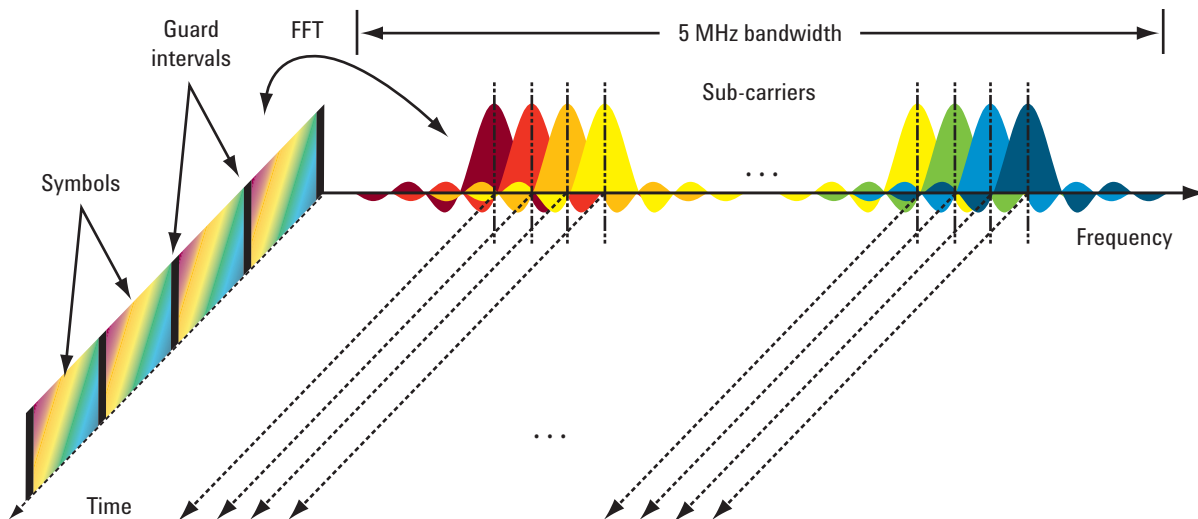
Although OFDM has been used for many years in communication systems, its use in mobile devices is more recent. The European Telecommunications Standards Institute (ETSI) fi rst looked at OFDM for GSM back in the late 1980s; however, the processing power required to perform the many FFT operations at the heart of OFDM was at that time too expensive and demanding for a mobile application. In 1998, 3GPP seriously considered OFDM for UMTS, but again chose an alternative technology based on code

division multiple access (CDMA). Today the cost of digital signal processing has been greatly reduced and OFDM is now considered a commercially viable method of wireless transmission for the handset.

When compared to the CDMA technology upon which UMTS is based, OFDM offers a number of distinct advantages:

- OFDM can easily be scaled up to wide channels that are more resistant to fading.

- OFDM channel equalizers are much simpler to implement than are CDMA equalizers, as the OFDM signal is represented in the frequency domain rather than the time domain.

- OFDM can be made completely resistant to multi-path delay spread. This is possible because the long symbols used for OFDM can be separated by a guard interval known as the cyclic prefi x (CP). The CP is a copy of the end of a symbol inserted at the beginning. By sampling the received signal at the optimum time, the receiver can remove the time domain interference between adjacent symbols caused by multi-path delay spread in the radio channel.

- OFDM is better suited to MIMO. The frequency domain representation of the signal enables easy pre-coding to match the signal to the frequency and phase characteristics of the multi-path radio channel.

However, OFDM does have some disadvantages. The subcarriers are closely spaced making OFDM sensitive to frequency errors and phase noise. For the same reason, OFDM is also sensitive to Doppler shift, which causes interference between the subcarriers. Pure OFDM also creates high peak-to-average signals, and that is why a modifi cation of the technology called SC-FDMA is used in the uplink. SC-FDMA is discussed later.

OFDM is more difficult to operate than CDMA at the edge of cells. CDMA uses scrambling codes to provide protection from inter-cell interference at the cell edge whereas OFDM has no such feature. Therefore, some form of frequency planning at the cell edges is required. Figure 5-4 gives one example of how this might be done. The color yellow represents the entire channel bandwidth and the other colors show a plan for frequency re-use to avoid inter-cell interference at the cell edges.

Figure 5-4   *Example of Frequency Planning to Avoid Inter-Cell Interference at the Cell Edges*
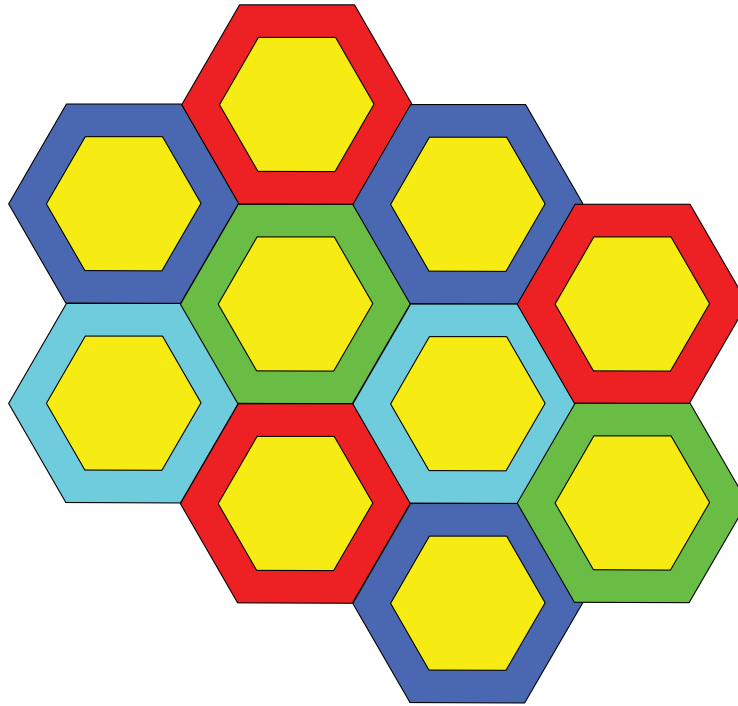
The main differences between CDMA and OFDM are shown in Table 5-3.

Table 5-3   *Comparison of CDMA and OFDM*

Attribute	CDMA	OFDM
Transmission Bandwidth	Full ystem bandwidth	Variable up to full system bandwidth
Symbol period	Very short – inverse of system bandwidth	Very long - defined by subcarrier spacing and independent of system spacing
Separation of users	Orthogonal spreading codes	Frequency and time

Adding TDMA to OFDM to Create ODFMA

With standard OFDM, very narrow UE-specific transmissions can suffer from narrowband fading and interference. That is why for the downlink 3GPP chose OFDMA, which incorporates elements of time division multiple access (TDMA). OFDMA allows subsets of the subcarriers to be allocated dynamically among the different users on the channel, as shown in Figure 5-5. The result is a more robust system with increased capacity. This is due to the trunking effi ciency of multiplexing low rate users and the ability to schedule users by frequency, which provides resistance to multi-path fading.

Figure 5-5　　　　　*Comparison of Static and Dynamic OFDMA Subcarrier Allocation*
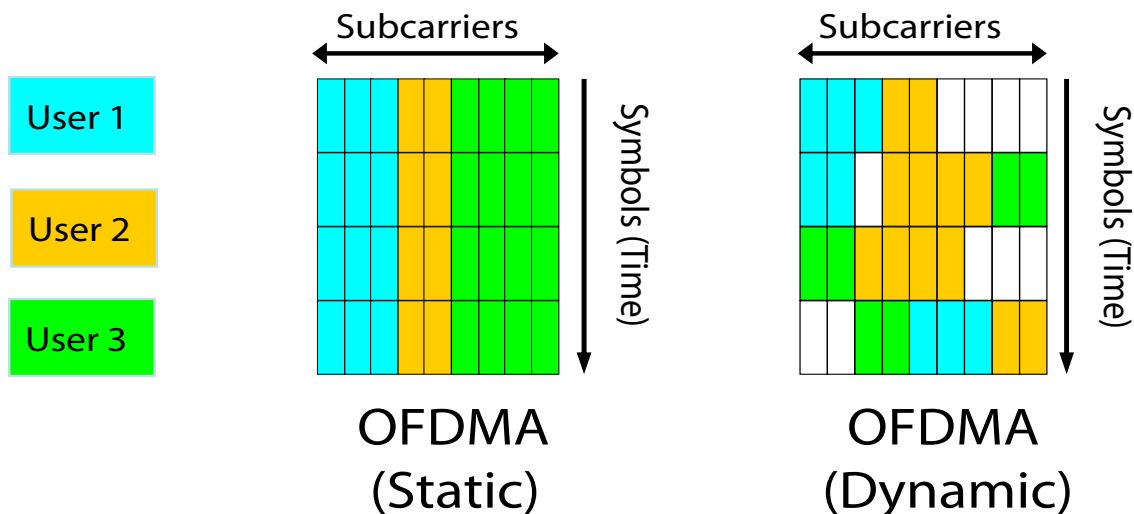
LTE Modulation and Frame Types

There are two types of frame structure in the LTE standard, Type 1 and Type 2. Type 1 uses Frequency Division Duplexing (uplink and downlink separated by frequency), and TDD uses Time Division Duplexing (uplink and downlink separated in time).

In FDD mode, uplink and downlink frames are separated in frequency. Both uplink and downlink frames are 10 ms long and are transmitted continuously. The base station (eNB) can specify a time offset (in PDCCH) to be applied to the uplink frame relative to the downlink frame.

Transmission Bandwidths

LTE must support the international wireless market and regional spectrum regulations and spectrum availability. To this end the specifi cations include variable channel bandwidths selectable from 1.4 to 20 MHz, with subcarrier spacing of 15 kHz. Subcarrier spacing is constant regardless of the channel bandwidth. 3GPP has defined the LTE air interface to be "bandwidth agnostic," which allows the air interface to adapt to different channel bandwidths with minimal impact on system operation.

The smallest amount of resource that can be allocated in the uplink or downlink is called a resource block (RB). An RB is 180 kHz wide and lasts for one 0.5 ms timeslot. For LTE, an RB is comprised of 12 subcarriers at a 15 kHz spacing. The maximum number of RBs and subcarriers supported by each transmission bandwidth is given in Table 5-4.

Table 5-4   *Transmission Bandwidth Configurations*

Channel BW (MHz)	1.4	3.0	5	10	15	20
Nominal bandwidth configuration (resource blocks)	6	15	25	50	75	100
Downlink Subcarriers	73	181	301	601	901	1201
Uplink Subcarriers	72	180	300	600	900	1200

For downlink signals, the DC subcarrier is not transmitted, but is counted in the number of subcarriers. For uplink, the DC subcarrier does not exist because the entire spectrum is shifted down in frequency by half the subcarrier spacing and is symmetric about DC.

LTE Time units

There are four time units used in describing an LTE frame: frame, subframe, slot, and symbol as shown in Table 5-5.

Table 5-5   *LTE Time Units*

Time Unit	Value
Frame	10 ms
Subframe	1 ms
Slot	0.5 ms
Symbol	0.5 ms / 7

The time units are illustrated in Figure 5-6. A resource block (RB) is the smallest unit of resources that can be allocated to a user. The resource block is 12 subcarriers wide in frequency and 7 symbols (1 slot) long in time.

Frequency units can be expressed in number of subcarriers or resource blocks. For instance, a 5 MHz downlink signal could be described as being 25 resource blocks wide or 301 subcarriers wide in frequency.

Figure 5-6   *LTE Time Units*
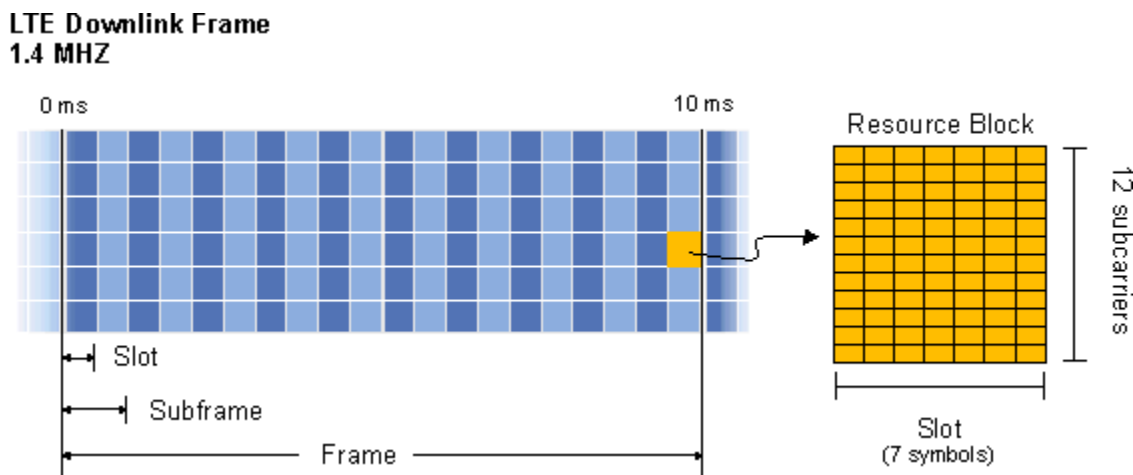
Duplexing Techniques

To support transmission in paired and unpaired spectrum, the LTE air interface supports both frequency division duplex (FDD) and time division duplex (TDD) modes.

Modulation and Coding

Just like High Speed Data Packet Access (HSDPA), the LTE system also uses adaptive modulation and coding (AMC) to improve data throughput. This technique varies the downlink modulation coding scheme based on the channel conditions for each user. When the link quality is good, the LTE system can use a higher order modulation scheme (more bits per symbol), which will result in more system capacity. On the other hand, when link conditions are poor due to problems such as signal fading, the LTE system can change to a lower modulation scheme to maintain an acceptable radio link margin. The modulation schemes supported for payload in the downlink and uplink are QPSK, 16QAM and 64QAM. The reference signals and synchronization signals use a Constant Amplitude Zero-Auto-Correlation (CAZAC) modulation sequence.

Two channel coding schemes are used in LTE for the TrCH: turbo coding for the UL-SCH, DL-SCH, PCH, and MCH; and tail-biting convolutional coding for the BCH. For both schemes, the coding rate is R=1/3. Control information is coded using various schemes, including tail-biting convolutional coding, block code and repetition code.

Uplink and Downlink Physical Resource Elements and Blocks

The smallest time-frequency unit for uplink and downlink transmission is called a resource element. A resource element corresponds to one OFDM subcarrier during one OFDM symbol interval. A group of contiguous subcarriers and symbols form a resource block (RB) as shown in Figure 5-7. Data is allocated to each user in terms of RB.

For a Type 1 frame structure using normal Cyclic Prefix (CP), an RB spans 12 consecutive subcarriers at a subcarrier spacing of 15 kHz, and 7 consecutive symbols over a slot duration of 0.5 ms. Thus, an RB has 84 resource elements (12 subcarriers x 7 symbols) corresponding to one slot in time domain and 180 kHz (12 subcarriers x 15

kHz spacing) in the frequency domain. Even though an RB is defined as 12 subcarriers during one 0.5 ms slot, scheduling is carried out on a subframe (1 ms) basis. Using normal CP, the minimum allocation the base station uses for UE scheduling is 1 sub-frame (14 symbols) by 12 subcarriers. The size of an RB is the same for all bandwidths; therefore, the number of available physical RBs depends on the transmission bandwidth as shown in Table 5-4.

Figure 5-7   *Downlink Resource Grid*

One slot, $T_{slot} = 15360 \, T_s = 0.5$ ms

One sub-frame

One downlink slot, T_{slot}

N_{symb}^{DL} OFDM symbols

$k = N_{RB}^{DL} \times N_{sc}^{RB} - 1$

$N_{RB}^{DL} \times N_{sc}^{RB}$ subcarriers

N_{sc}^{RB} subcarriers

Resource block $N_{symb}^{DL} \times N_{sc}^{RB}$ resource elements

Resource element (k, l)

$k = 0$

$l = 0$ $l = N_{symb}^{DL} - 1$
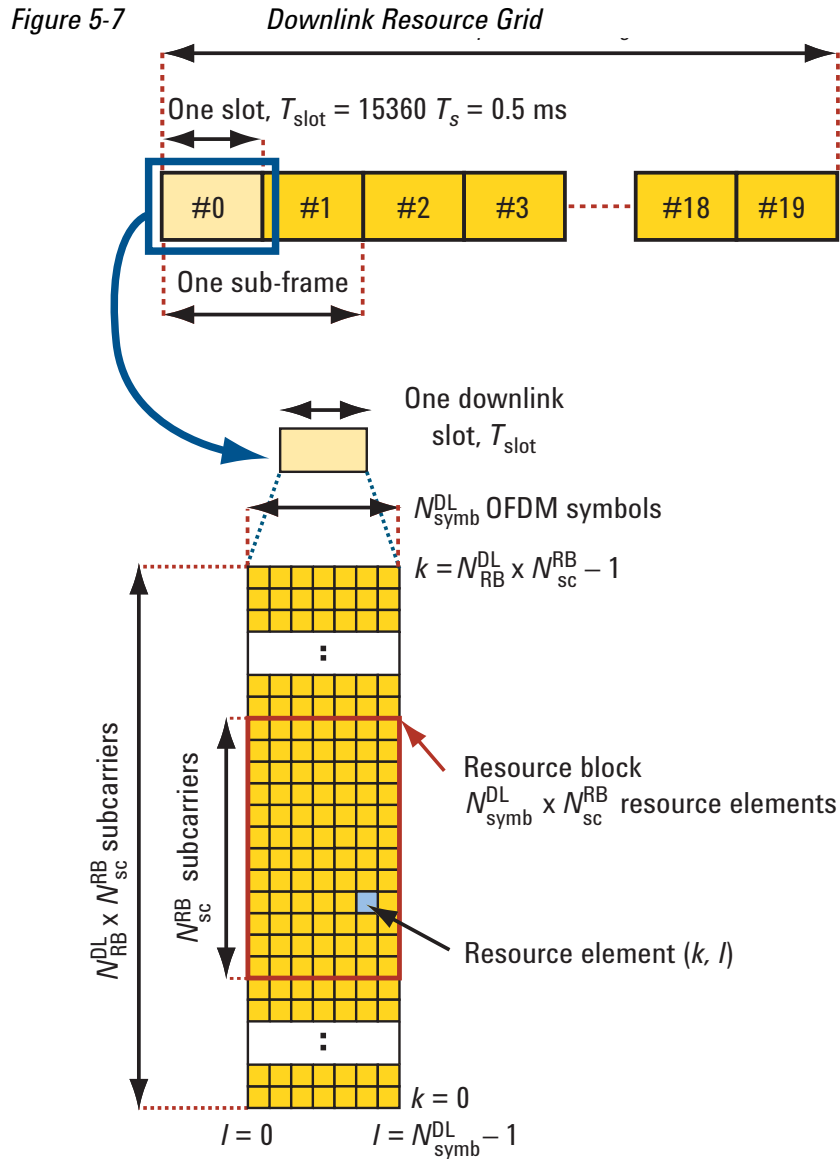
Figure 5-7 shows the downlink resource grid for a 0.5-ms timeslot which incorporates the concepts of a resource element and a resource block. A resource element is the smallest identifiable unit of transmission and consists of one subcarrier for one symbol period. However, transmissions are scheduled in larger units called resource blocks which comprise 12 adjacent subcarriers for a period of one 0.5-ms timeslot.

Physical Layer Channels

The LTE DL and UL are composed of two sets of physical layer channels: physical channels and physical signals. Physical channels carry information from higher layers and are used to carry user data, as well as user control information. Physical signals are used for system synchronization, cell identification and radio channel estimation, but do not carry information originating from higher layers.

Modulation Types

LTE uplink and downlink signals are created and modulated differently. For downlink signals, the base station uses multi-carrier OFDMA to transmit the signal (see Figure 5-12). First, a user's data is split up into subcarrier values (constellation points). Then the subcarrier values are placed onto the current symbol's subcarriers in the resource blocks allocated to the user. After values have been assigned for all subcarriers in an OFDM symbol (including the reference signal and control channels), the symbol is sent through an IFFT, which converts the symbol into time data that can be transmitted. Figure 5-8 illustrates this process.

Figure 5-8   *Downlink Modulation - Bits to OFDMA Subcarrier Allocation*
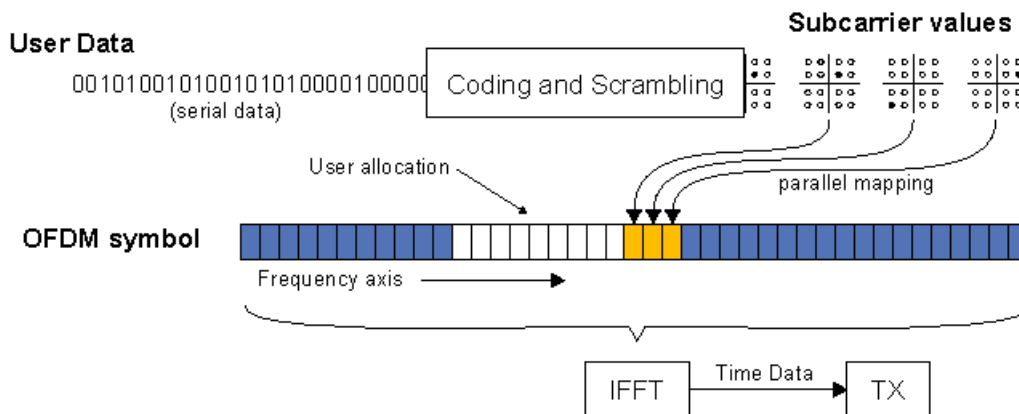
The subcarrier symbol points can be QPSK, 16QAM, or 64QAM.

OFDM has a large peak-to-average power ratio which means that the amplifiers have to be higher quality and more expensive (and consume more power). These are not major concerns when designing a base station that can be powered externally, but is an issue for mobile devices where low cost is desired and battery life is limited.

For uplink signals, the LTE standard uses Single Carrier Frequency Division Multiple Access (SC-FDMA) modulation, which has a lower peak-to-average ratio, meaning lower cost amplifiers and less power usage.

Downlink Physical Layer Channels and Signals

The DL physical channels are Physical Downlink Shared Channel (PDSCH), Physical Downlink Control Channel (PDCCH), and Physical Broadcast Channel (PBCH). The DL physical signals are reference signal (RS) and synchronization signal. Figure 5-9 has information on the modulation format and purpose for each of the downlink channels and signals.

Figure 5-9   *LTE Downlink Channels and Signals*

DL channels	Full name	Modulation format	Purpose
PBCH	Physical Broadcast Channel	QPSK	Carries cell-specific information
PDCCH	Physical Downlink Control Channel	QPSK	Scheduling, ACK/NACK
PDSCH	Physical Downlink Shared Channel	QPSK 16QAM 64QAM	Payload
PMCH	Physical Multicast Channel	QPSK 16QAM 64QAM	Payload for Multimedia Broadcast Multicast Service (MBMS)
PCFICH	Physical Control Format Indicator Channel	QPSK	Carries information about the number of OFDM symbols (1, 2 or 3) used for transmission of PDCCHs in a sub-frame.
PHICH	Physical Hybrid ARQ Indicator Channel	Not defined yet in 3GPP TS 36.211 V8.1.0	Carries the hybrid-ARQ ACK/NAK

DL signals	Full name	Modulation sequence	Purpose
P-SCH	Primary Synchronization Channel	One of 3 Zadoff-Chu sequences	Used for cell search and identification by the UE. Carries part of the cell ID (one of 3 orthogonal sequences).
S-SCH	Secondary Synchronization Channel	Two 31-bit M-sequences (binary) - one of 170 Cell IDs plus other info	Used for cell search and identification by the UE. Carries the remainder of the cell ID (one of 170 binary sequences).
RS	Reference Signal (Pilot)	OS*PRS defined by Cell ID (P-SCH & S-SCH)	Used for DL channel estimation. Exact sequence derived from cell ID, (one of 3 * 170 = 510).

Downlink Time-Domain Frame Structure

Two radio frame structures are defined in LTE: Type 1 frame structure, which uses Frequency Division Duplexing (FDD) and Type 2 frame structure, which uses Time Division Duplexing (TDD). Although LTE supports both FDD and TDD, the majority of deployed systems will be FDD. Therefore, the current Agilent analysis solution supports FDD, and section describes LTE FDD systems only.

Figure 5-10 shows a DL Type 1 FDD frame structure. A radio frame has a duration of 10 ms and consists of 20 slots with a slot duration of 0.5 ms. Two slots comprise a sub-frame. A sub-frame, also known as the Transmission Time Interval (TTI), has a duration of 1 ms.

Figure 5-10   *DL FDD Type 1 Frame Structure*
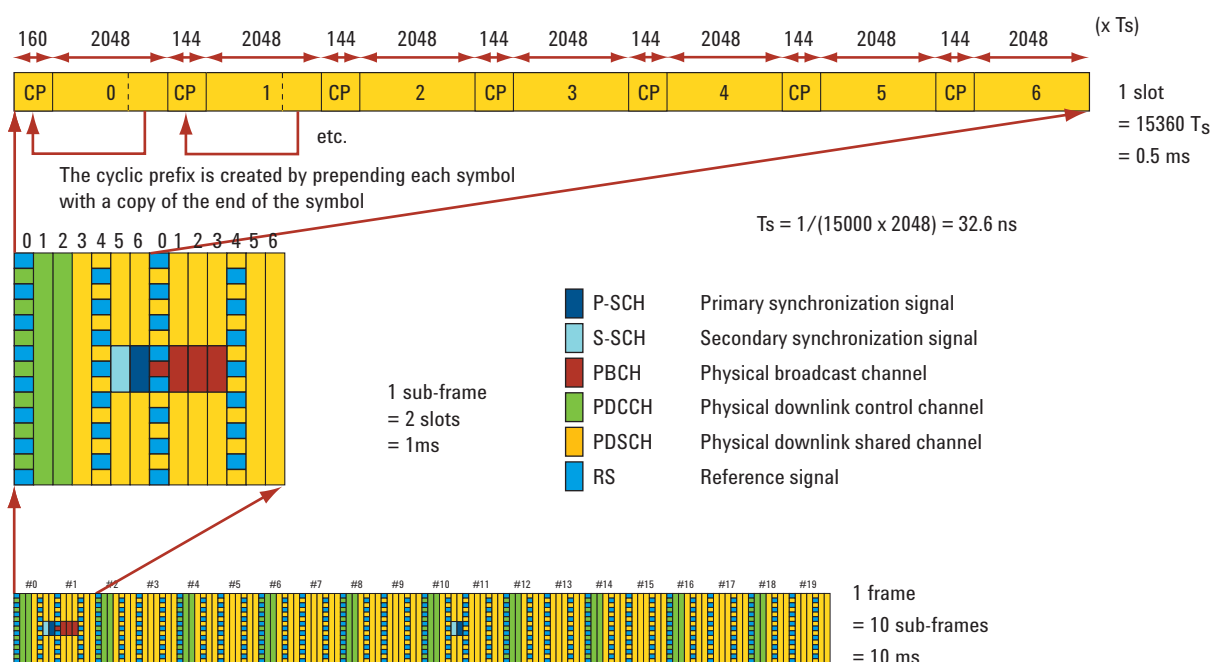
As shown in Figure 5-10, the physical mapping of the DL physical signals and channels are:

- Reference signal (pilot) is transmitted at every 6th subcarrier of OFDMA symbols #0 & #4 of every slot

- PDCCH is transmitted at OFDM symbol #0, #1 and #2 of the first slot of the sub-frame. Multiple PDCCHs can be transmitted in each subframe.

- P-SCH is transmitted on 62 out of the 72 reserved subcarriers centered around the DC subcarrier at OFDM symbol 6 of slots 0 and 10 in each radio frame

- S-SCH is transmitted on 62 out of the 72 reserved subcarriers centered around the DC subcarrier at OFDM symbol #5 of slots 0 and 10 in each radio frame

- PBCH is transmitted on 72 subcarriers centered around DC at OFDMA symbol #3 and #4 of slot 0 and symbol #0 and #1 of slot 1. Excludes reference signal subcarriers.

- PDSCH is transmitted on any assigned OFDM subcarriers not occupied by any of the above channels and signals

Figure 5-11 shows the downlink mapping across frequency and time. The central DC subcarrier of the downlink channel is not used for transmission, but is reserved for energy generated due to local-oscillator feedthrough in the signal-generation process.

Figure 5-11   *Downlink Frame Structure 1 Showing Subframe vs. Frequency*

16QAM   64QAM   QPSK

Frequency
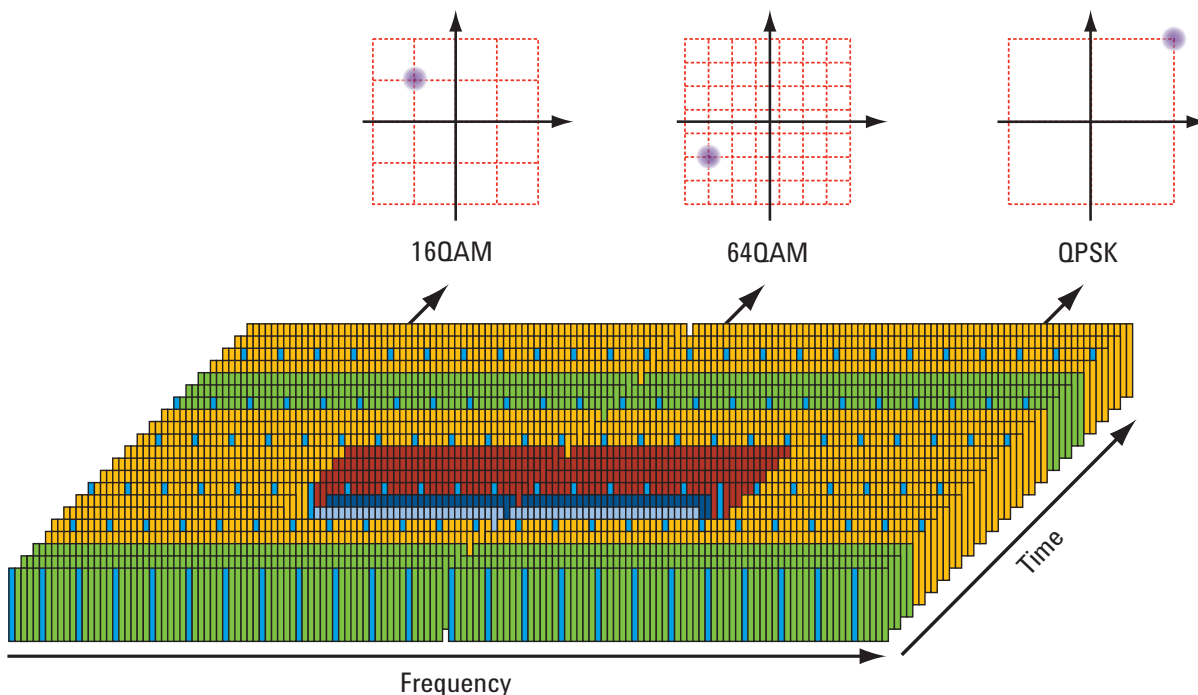
Cyclic Prefix (CP)

Table 5-6 summarizes the options for CP length and number of symbols per timeslot. The extended CP of 512 x Ts (16.67 µs) is available for use in larger cells and provides protection for up to a 5-km delay spread. The price for this increased protection is a reduction in system capacity since the extended CP allows for only six symbols per timeslot. The longest protection from delay spread is achieved when using the extended CP of 1024 x Ts (33.33 µs) with the optional 7.5-kHz subcarrier spacing for eMBMS. This enables transmissions from multiple cells to be combined in a Multicast/Broadcast over Single Frequency Network (MBSFN) with protection from delay spread of up to 10 km. This very long CP means there are only three symbols per timeslot, but this capacity loss is counteracted by the doubling up of the subcarriers.

Table 5-6   *Cyclic Prefix Configurations for DL FS1*

CP in Ts by Symbol Number	0	1	2	3	4	5	6
Normal $\Delta f = 15$ kHz	160	144	144	144	144	144	144
Extended $\Delta f = 15$ kHz	512	512	512	512	512	512	-

Multiple Access Technology in the Uplink: SC-FDMA

The high peak-to-average ratio (PAR) associated with OFDM led 3GPP to look for a different transmission scheme for the LTE uplink. SC-FDMA was chosen because it combines the low PAR techniques of single-carrier transmission systems, such as GSM and CDMA, with the multi-path resistance and flexible frequency allocation of OFDMA.

A graphical comparison of OFDMA and SC-FDMA as shown in Figure 5-12 is helpful in understanding the differences between these two modulation schemes. For clarity this example uses only four (M) subcarriers over two symbol periods with the payload data represented by quadrature phase shift keying (QPSK) modulation. As described earlier, real LTE signals are allocated in units of 12 adjacent subcarriers.

Figure 5-12   *Comparison of OFDMA (DL) and SC-FDMA (UL)*

OFDMA
Data symbols occupy 15 kHz for
one OFDMA symbol period

SC-FDMA
Data symbols occupy M*15 kHz for
1/M SC-FDMA symbol periods
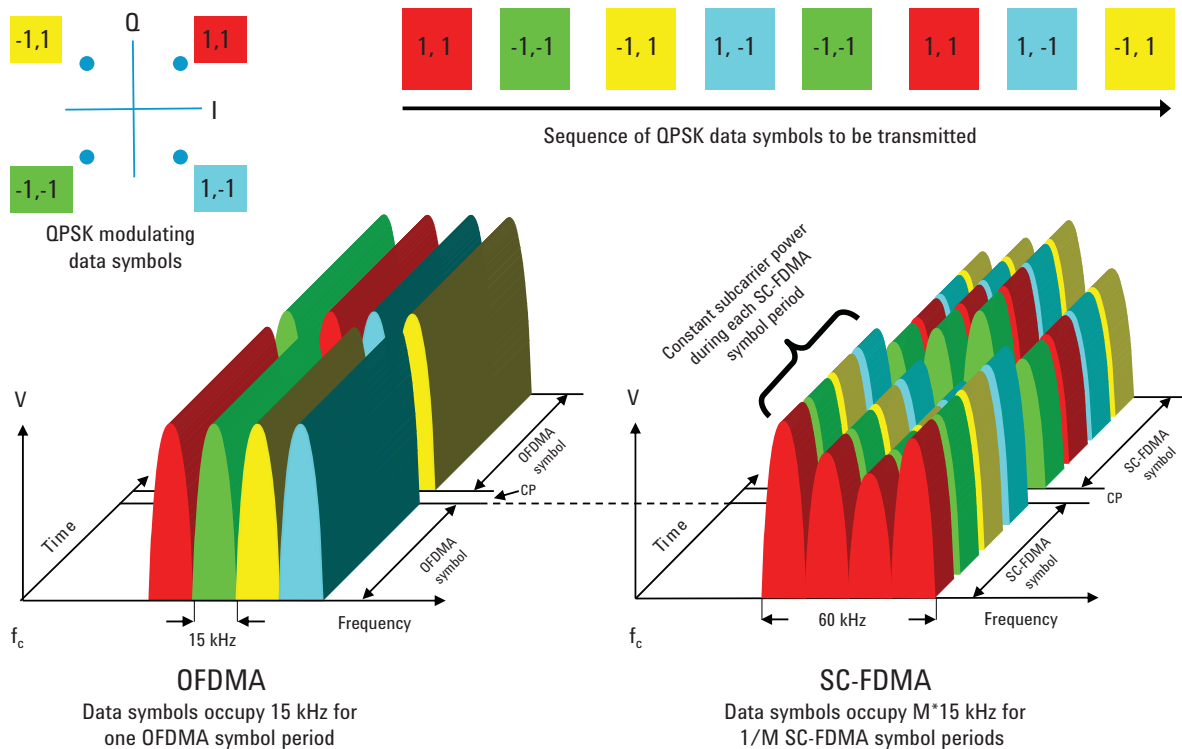
On the left side of Figure 5-12, M adjacent 15 kHz subcarriers—already positioned at the desired place in the channel bandwidth—are each modulated for the OFDMA symbol period of 66.7 μs by one QPSK data symbol. In this four subcarrier example, four symbols are taken in parallel. These are QPSK data symbols so only the phase of each subcarrier is modulated and the subcarrier power remains constant between symbols. After one OFDMA symbol period has elapsed, the CP is inserted and the next four symbols are transmitted in parallel. For visual clarity, the CP is shown as a gap; however, it is actually fi lled with a copy of the end of the next symbol, which means that the transmission power is continuous but has a phase discontinuity at the symbol

boundary. To create the transmitted signal, an IFFT is performed on each subcarrier to create M timedomain signals. These in turn are vector-summed to create the fi nal time-domain waveform used for transmission.

SC-FDMA signal generation begins with a special pre-coding process but then continues in a manner similar to OFDMA. However, before getting into the details of the generation process it is helpful to describe the end result as shown on the right side of Figure 5-12. The most obvious difference between the two schemes is that OFDMA transmits the four QPSK data symbols in parallel, one per subcarrier, while SC-FDMA transmits the four QPSK data symbols in series at four times the rate, with each data symbol occupying M x 15 kHz bandwidth.

Visually, the OFDMA signal is clearly multi-carrier with one data symbol per subcarrier, but the SC-FDMA signal appears to be more like a single-carrier (hence the "SC" in the SC-FDMA name) with each data symbol being represented by one wide signal. Note that OFDMA and SC-FDMA symbol lengths are the same at 66.7 μs; however, the SC-FDMA symbol contains M "sub-symbols" that represent the modulating data. It is the parallel transmission of multiple symbols that creates the undesirable high PAR of OFDMA. By transmitting the M data symbols in series at M times the rate, the SC-FDMA occupied bandwidth is the same as multi-carrier OFDMA but, crucially, the PAR is the same as that used for the original data symbols. Adding together many narrow-band QPSK waveforms in OFDMA will always create higher peaks than would be seen in the wider-bandwidth, single-carrier QPSK waveform of SC-FDMA. As the number of subcarriers M increases, the PAR of OFDMA with random modulating data approaches Gaussian noise statistics but, regardless of the value of M, the SC-FDMA PAR remains the same as that used for the original data symbols.

SC-FDMA maps the data onto a single carrier modulation format (QPSK, QAM16, or QAM64). Then it takes the time domain set of symbols, performs an FFT, and maps the frequency domain values to the subcarriers that are assigned to the user. Then it takes an IFFT of the entire OFDM symbol and transmits the resulting time data. Figure 5-13 illustrates this process.

Figure 5-13   *Uplink Modulation - Bits to SC-TDMA Carrier Allocation*
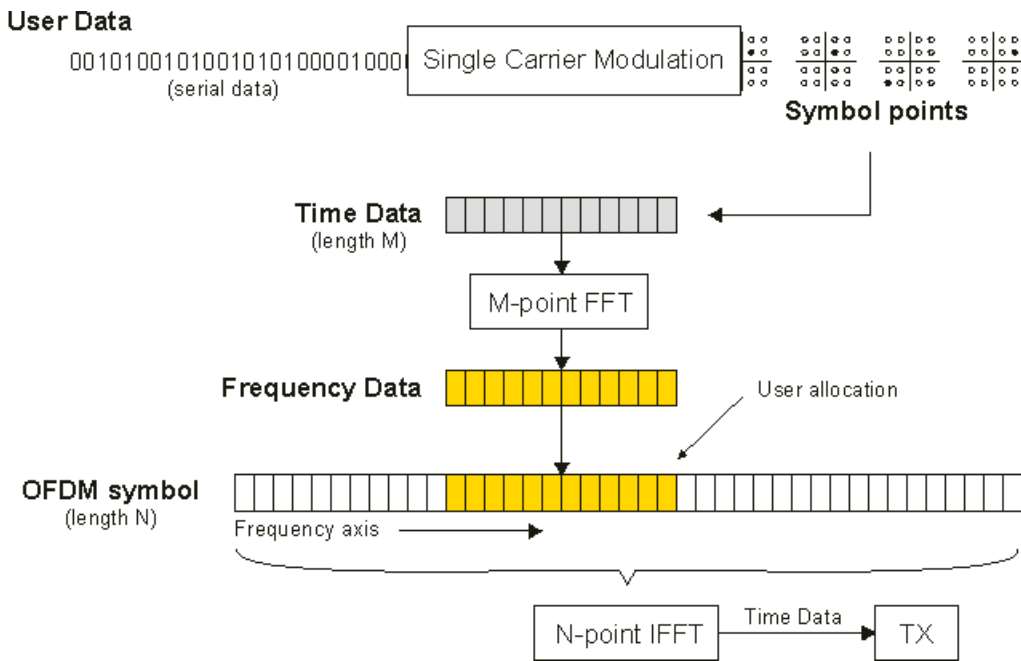
Table 5-7 summarizes the differences between the OFDMA and SC-FDMA modulation schemes. When OFDMA is analyzed one subcarrier at a time, it resembles the original data symbols. At full bandwidth, however, the signal looks like Gaussian noise in terms of its PAR statistics and the constellation. The opposite is true for SC-FDMA. In this case, the relationship to the original data symbols is evident when the entire signal bandwidth is analyzed. The constellation (and hence low PAR) of the original data symbols can be observed rotating at M times the SC-FDMA symbol rate, ignoring the seven percent rate reduction that is due to adding the CP. When analyzed at the 15 kHz subcarrier spacing, the SC-FDMA PAR and constellation are meaningless because they are M times narrower than the information bandwidth of the data symbols.

Table 5-7   *Analysis of OFDMA and SC-FDMA at Different Bandwidths*

Modulation Format	OFDMA		SC-FDMA	
Analysis Bandwidth	15 kHz	Signal Bandwidth (M x 15 kHZ)	15 kHz	Signal Bandwidth (M x 15 kHZ)
Peak-to-average power ratio (PAR)	Same as data symbol	High PAR (Gaussian)	< Data symbol (not meaningful)	Same as Data symbol
Observable IQ constellation	Same as data symbol at 66.7 μs	Not meaningful (Gaussian)	Not meaningful (Gaussian)	Same as data symbol at 66.7 μs

Examining the SC-FDMA Signal

Unlike the eNB (base station transmitter), the UE does not normally transmit across the entire channel bandwidth. A typical uplink confi guration with the definition of terms is shown in Figure 5-14.

Figure 5-14   *SC-FDMA Channel BW and Transmission BW Configuration*
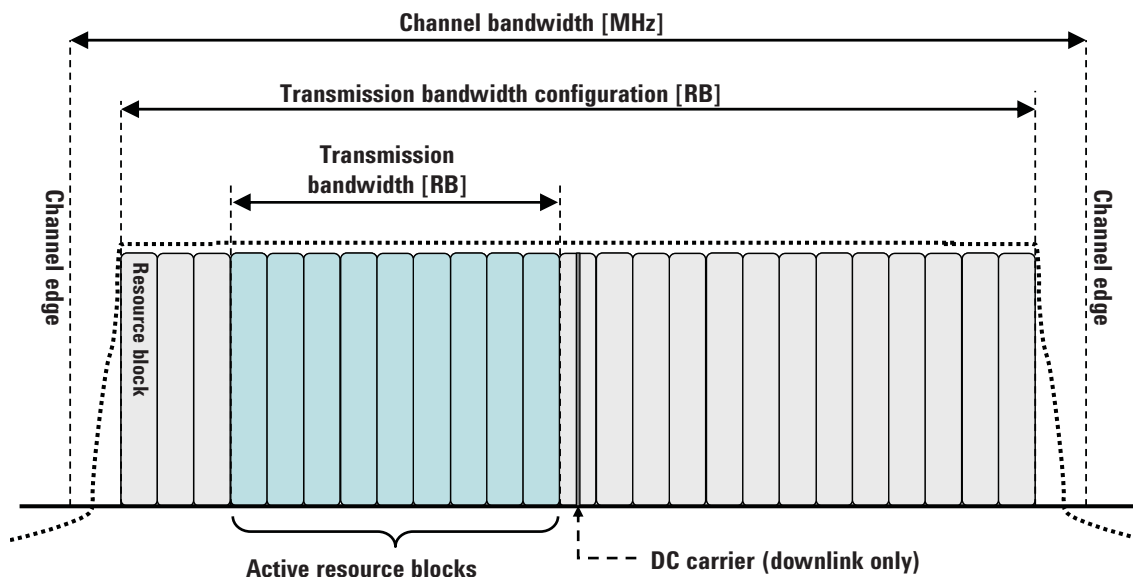
Uplink Physical Layer Channels and Signals

Uplink (UL) physical channels are Physical Uplink Shared Channel (PUSCH), Physical Uplink Control Channel (PUCCH) and Physical Random Access Channel (PRACH). Two types of uplink reference signals are supported: demodulation reference signal (DM-RS) which is associated with transmission of PUSCH or PUCCH, and sounding reference signal (S-RS) which is not associated with transmission of PUSCH or PUCCH. Figure 5-15 below has information on the modulation format and purpose for each of the uplink channels and signals.

Figure 5-15   *LTE Uplink Channels and Signals*

UL channels	Full name	Modulation format	Purpose
PRACH	Physical Random Access Channel	**QPSK**	Call setup
PUCCH	Physical Uplink Control Channel	**BPSK, QPSK**	Scheduling, ACK/NACK
PUSCH	Physical Uplink Shared Channel	**QPSK 16QAM 64QAM**	Payload

UL signals	Full name	Modulation sequence	Purpose
DM-RS	Demodulation Reference Signal	**uth root Zadoff-Chu**	Used for synchronization to the UE and UL channel estimation
S-RS	Sounding Reference Signal	**Zadoff-Chu**	Used to monitor propagation conditions with UE.

Uplink Time-Domain Frame Structure

The uplink (UL) FDD frame structure is similar to downlink (DL) frame structure in terms of frame, sub-frame and slot length. A UL frame structure is shown in Figure 5-16 below.

The UL demodulation reference signals, which are used for channel estimation for coherent demodulation, are transmitted in the fourth symbol (i.e symbol # 3) of every slot.

Figure 5-16   *Uplink Type 1 FDD Frame Structure*
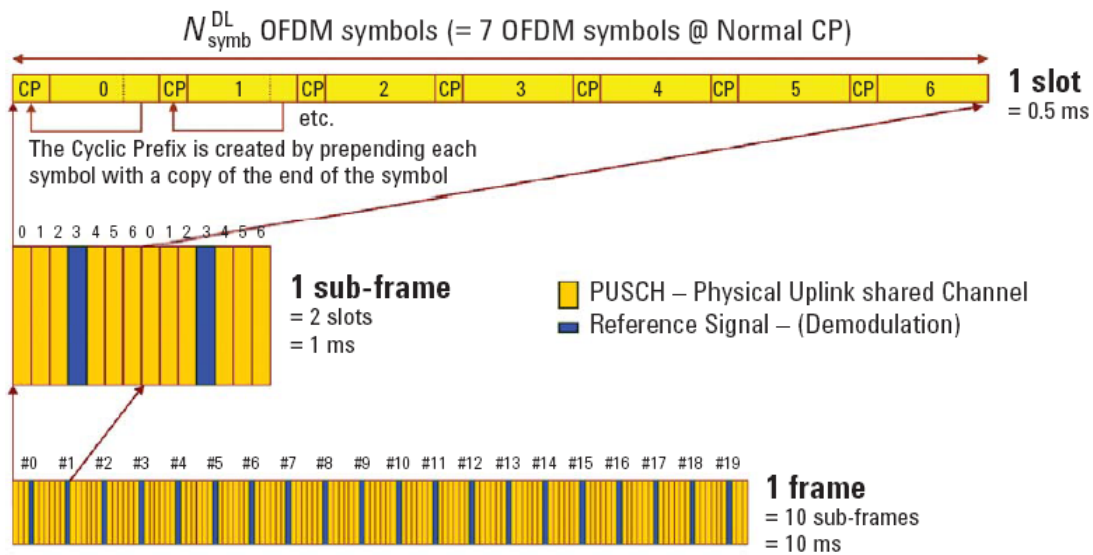
Overview of Multiple Antenna Techniques (MIMO)

Central to LTE is the concept of multiple antenna techniques, which are often loosely referred to as MIMO (multiple inputs, multiple outputs). MIMO takes advantage of spatial diversity in the radio channel. Multiple antenna techniques are of three main types: diversity, MIMO, and beamforming. These techniques are used to improve signal robustness and to increase system capacity and single-user data rates. Each technique has its own performance benefits and costs.

Figure 5-17 illustrates the range of possible antenna techniques from the simplest to the most complex, indicating how the radio channel is accessed by the system's transmitters and receivers.

Figure 5-17   *MIMO Radio-Channel Access Modes*
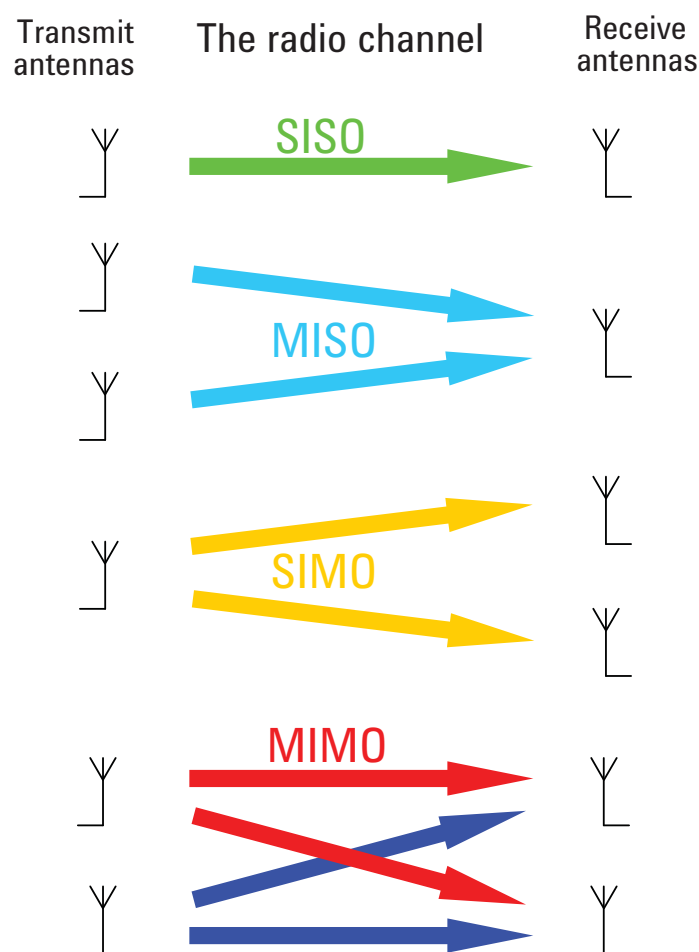
SISO - The most basic radio channel access mode is single input single output (SISO), in which only one transmit antenna and one receive antenna are used. This is the form of communications that has been the default since radio began and is the baseline against which all the multiple antenna techniques are compared.

MISO - Slightly more complex than SISO is multiple input single output (MISO) mode, which uses two or more transmitters and one receiver. (Figure 5-17 shows only two transmitters and one receiver for simplicity.) MISO is more commonly referred to as

transmit diversity. The same data is sent on both transmitting antennas but coded such that the receiver can identify each transmitter. Transmit diversity increases the robustness of the signal to fading and can increase performance in low signal-to-noise ratio (SNR) conditions; however, it does not increase data rates as such, but rather supports the same data rates using less power. Transmit diversity can be enhanced with closed loop feedback from the receiver to indicate the balance of phase and power used for each antenna.

SIMO - The third mode shown in Figure 5-17 is single input multiple output (SIMO), which—in contrast to MISO—uses one transmitter and two or more receivers. SIMO is often referred to as receive diversity. Similar to transmit diversity, it is particularly well suited for low SNR conditions in which a theoretical gain of 3 dB is possible when two receivers are used. As with transmit diversity, there is no change in the data rate since only one data stream is transmitted, but coverage at the cell edge is improved due to the lowering of the usable SNR.

MIMO - The final mode is full MIMO, which requires two or more transmitters and two or more receivers. This mode is not just a superposition of SIMO and MISO since multiple data streams are now transmitted simultaneously in the same frequency and time, taking full advantage of the different paths in the radio channel. For a system to be described as MIMO, it must have at least as many receivers as there are transmit streams. The number of transmit streams should not be confused with the number of transmit antennas. Consider the Tx diversity (MISO) case in which two transmitters are present but only one data stream. Adding receive diversity (SIMO) does not turn this into MIMO, even though there are now two Tx and two Rx antennas involved. SIMO + MISO ≠ MIMO. It is always possible to have more transmitters than data streams but not the other way around. If N data streams are transmitted from fewer than N antennas, the data cannot be fully descrambled by any number of receivers since overlapping streams without the addition of spatial diversity just creates interference. However, by spatially separating N streams across at least N antennas, N receivers will be able to fully reconstruct the original data streams provided the crosstalk and noise in the radio channel are low enough.

One other crucial factor for MIMO operation is that the transmissions from each antenna must be uniquely identifi able so that each receiver can determine what combination of transmissions has been received. This identifi cation is usually done with pilot signals, which use orthogonal patterns for each antenna.

The spatial diversity of the radio channel means that MIMO has the potential to increase the data rate. The most basic form of MIMO assigns one data stream to each antenna and is shown in Figure 5-18.

Figure 5-18   *Non-Precoded 2x2 MIMO*
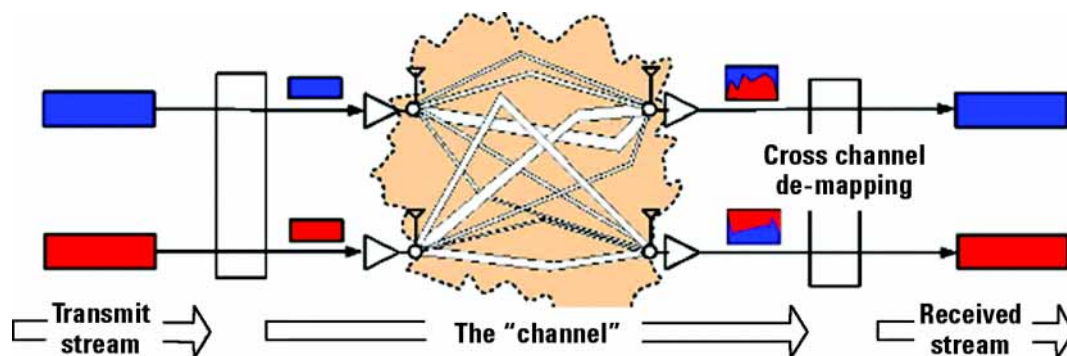
In this form, one data stream is uniquely assigned to one antenna. The channel then mixes up the two transmissions such that at the receivers, each antenna sees a combination of each stream. Decoding the received signals is a clever process in which the receivers, by analyzing the patterns that uniquely identify each transmitter, determine what combination of each transmit stream is present. The application of an inverse filter and summing of the received streams recreates the original data.

A more advanced form of MIMO includes special pre-coding to match the transmissions to the Eigen modes of the channel. This optimization results in each stream being spread across more than one transmit antenna. For this technique to work effectively the transmitter must have knowledge of the channel conditions and, in the case of FDD, these conditions must be provided in real time by feedback from the UE. Such optimization signifi cantly complicates the system but can also provide higher performance. Pre-coding for TDD systems does not require receiver feedback because the transmitter independently determines the channel conditions by analyzing the received signals that are on the same frequency.

The theoretical gains from MIMO are a function of the number of transmit and receive antennas, the radio propagation conditions, the ability of the transmitter to adapt to the changing conditions, and the SNR. The ideal case is one in which the paths in the radio channel are completely uncorrelated, almost as if separate, physically cabled connections with no crosstalk existed between the transmitters and receivers. Such conditions are almost impossible to achieve in free space, and with the potential for so many variables, it is neither helpful nor possible to quote MIMO gains without stating the conditions. The upper limit of MIMO gain in ideal conditions is more easily defined, and for a 2x2 system with two simultaneous data streams a doubling of capacity and data rate is possible. MIMO works best in high SNR conditions with minimal line of sight. Line of sight equates to channel crosstalk and seriously diminishes the potential for gains. As a result, MIMO is particularly suited to indoor environments, which can exhibit a high degree of multi-path and limited line of sight.

Single User, Multiple User, and Cooperative MIMO

It is important to note that Figure 5-18 does not make explicit whether the multiple transmitters or receivers belong to the same base station or UE. This leads to a further elaboration of MIMO that is presented in Figure 5-18.

The first case is single user MIMO (SU-MIMO), which is the most common form of MIMO and can be applied in the uplink or downlink. The primary purpose of SU-MIMO is to increase the data rate to one user. There is also a corresponding increase in the capacity of the cell. Figure 5-19 shows the downlink form of 2x2 SU-MIMO in which two data streams are allocated to one UE. The data streams in the example are coded red and blue, and in this case are further pre-coded in such a way that each stream is represented at a different power and phase on each antenna. The colors of the data streams change at the transmit antennas, which is meant to signify the mixing of the data streams. The transmitted signals are further mixed by the channel. The purpose of the pre-coding is to optimize the transmissions to the characteristics of the radio channel so that when the signals are received, they can be more easily separated back into the original data streams.

Figure 5-19   *Single User, Multiple User, and Cooperative MIMO*
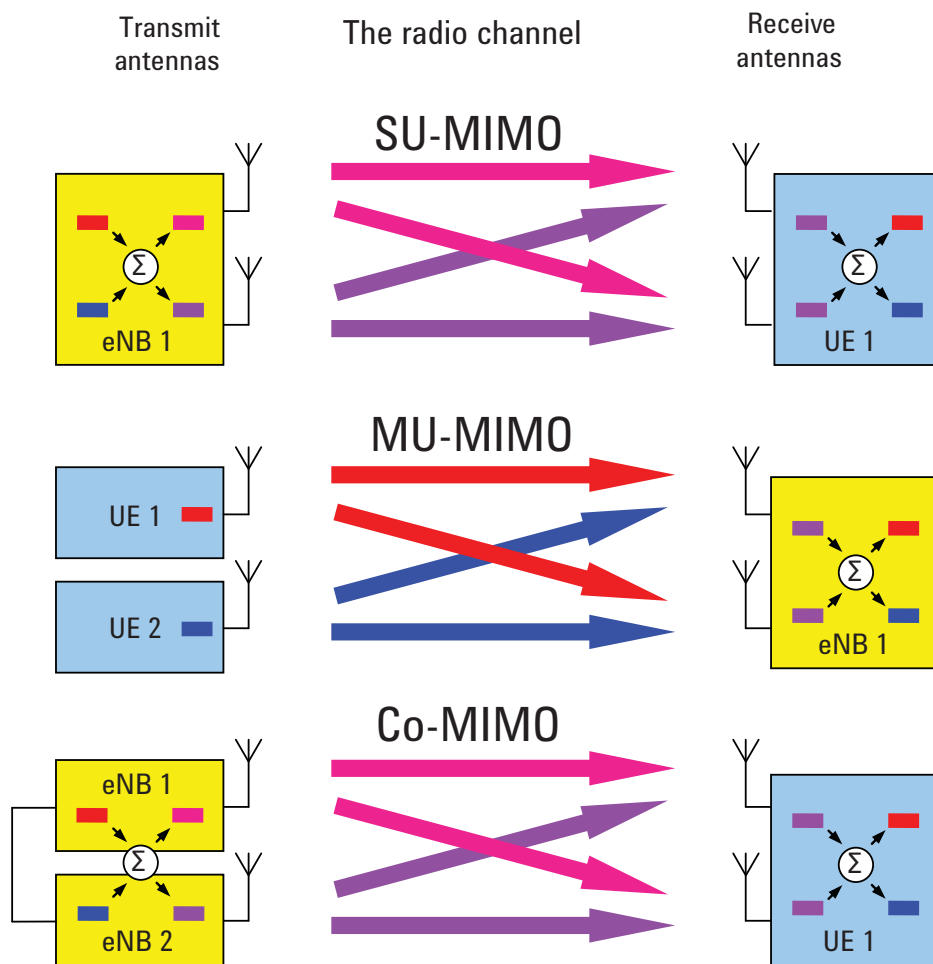
The second case shows 2x2 multiple user MIMO (MU-MIMO), which is used only in the uplink. (MU-MIMO is described in the WiMAX™ specifi cations as collaborative spatial multiplexing or collaborative MIMO). MU-MIMO does not increase an individual user's data rate but it does offer cell capacity gains that are similar to, or better than, those provided by SU-MIMO. In Figure 5-19, the two data streams originate from different UE. The two transmitters are much farther apart than in the single user case,

and the lack of physical connection means that there is no opportunity to optimize the coding to the channel Eigen modes by mixing the two data streams. However, the extra spatial separation does increase the chance of the eNB picking up pairs of UE which have uncorrelated paths. This maximizes the potential capacity gain, in contrast to the pre-coded SU-MIMO case in which the closeness of the antennas could be problematic, especially at frequencies less than 1 GHz. MU-MIMO has an additional important advantage: the UE does not require the expense and power drain of two transmitters, yet the cell still benefits from increased capacity. To get the most gain out of MU-MIMO, the UE must be well aligned in time and power as received at the eNB.

The third case shown in Figure 5-19 is cooperative MIMO (Co-MIMO). This term should not be confused with the WiMAX term "collaborative MIMO" described earlier. The essential element of Co-MIMO is that two separate entities are involved at the transmission end. The example here is a downlink case in which two eNB "collaborate" by sharing data streams to pre-code the spatially separate antennas for optimal communication with at least one UE. When this technique is applied in the downlink it is sometimes called network MIMO. The most advantageous use of downlink Co-MIMO occurs when the UE is at the cell edge. Here the SNR will be at its worst but the radio paths will be uncorrelated, which offers signifi cant potential for increased performance. Co-MIMO is also possible in the uplink but is fundamentally more diffi cult to implement as no physical connection exists between the UE to share the data streams. Uplink Co-MIMO without a connection between the UE collapses into MU-MIMO, which as we have seen does not use pre-coding. Uplink Co-MIMO is also known as virtual MIMO. Co-MIMO is not currently part of the Release 8 LTE specifications but is being studied as a possible enhancement to LTE in Release 9 or Release 10 to meet the goals of the ITU's IMT-Advanced 4G initiative.

Beamforming

Beamforming uses the same signal processing and antenna techniques as MIMO but rather than exploit de-correlation in the radio path, beamforming aims to exploit correlation so that the radiation pattern from the transmitter is directed towards the receiver. This is done by applying small time delays to a calibrated phase array of antennas. The effectiveness of beamforming varies with the number of antennas. With just two antennas little gain is seen, but with four antennas the gains are more useful. Obtaining the initial antenna timing calibration and maintaining it in the field are challenge.

Turning a MIMO system into a beamforming system is simply a matter of changing the pre-coding matrices. In practical systems, however, antenna design has to be taken into account and things are not so simple. It is possible to design antennas to be correlated or uncorrelated; for example, by changing the polarization. However, switching between correlated and uncorrelated patterns can be problematic if the physical design of the antennas has been optimized for one or the other.

Since beamforming is related to the physical position of the UE, the required update rate for the antenna phasing is much lower than the rates needed to support MIMO pre-coding. Thus beamforming has a lower signaling overhead than MIMO.

The most advanced form of multiple antenna techniques is probably the combination of beamforming with MIMO. In this mode MIMO techniques could be used on sets of antennas, each of which comprises a beamforming array. Given that beamforming with only two antennas has limited gains, the advantage of combining beamforming and MIMO will not be realized unless there are many antennas. This limits the practical use of the technique on cost grounds.

LTE Downlink MultipleAntenna Schemes

For the LTE downlink, three of the multiple antenna schemes previously described are supported: Tx diversity (MISO), Rx diversity (SIMO), and spatial multiplexing (MIMO). The first and simplest downlink LTE multiple antenna scheme is open-loop Tx diversity. It is identical in concept to the scheme introduced in UMTS Release 99. The more complex, closed-loop Tx diversity techniques from UMTS have not been adopted in LTE, which instead uses the more advanced MIMO, which was not part of Release 99. LTE supports either two or four antennas for Tx diversity. Figure 5-20 shows a two Tx example in which a single stream of data is assigned to the different layers and coded using space-frequency block coding (SFBC). Since this form of Tx diversity has no data rate gain, the code words CW0 and CW1 are the same. SFBC achieves robustness through frequency diversity by using different subcarriers for the repeated data on each antenna.

The second downlink scheme, Rx diversity, is mandatory for the UE. It is the baseline receiver capability for which performance requirements will be defined. A typical use of Rx diversity is maximum ratio combining of the received streams to improve the SNR in poor conditions. Rx diversity provides little gain in good conditions.

Figure 5-20   *Signal Processing for Tx Diversity and Spatial Multiplexing*
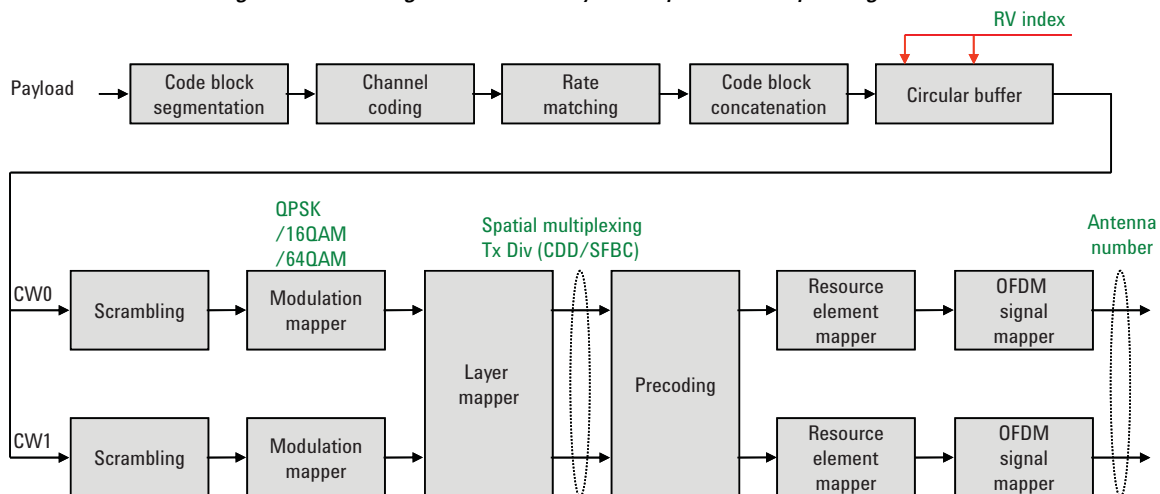
The third downlink scheme is spatial multiplexing, or MIMO, which is also supported for two and four antenna confi gurations. Assuming a two-channel UE receiver, this scheme allows for 2x2 or 4x2 MIMO. A four-channel UE receiver, which is required for a 4x4 configuration, has been defined but is not likely to be implemented in the near future. The most common configuration will be 2x2 SU-MIMO. In this case the payload data will be divided into the two code-word streams CW0 and CW1 and processed according to the steps in Figure 5-20.

Depending on the pre-coding used, each code word is represented at different powers and phases on both antennas. In addition, each antenna is uniquely identifi ed by the position of the reference signals within the frame structure. This process is described later. LTE uses the closed loop form of MIMO with pre-coding of the streams, so for the FDD case the transmitter must have knowledge of the channel. Channel information is provided by the UE on the uplink control channel. The channel feedback uses a codebook approach to provide an index into a predetermined set of pre-coding matrices. Since the channel is continually changing, this information will be provided for multiple points across the channel bandwidth, at regular intervals, up to several hundred times a second. At the time of writing, the exact details are still to be specified. However, the UE that can best estimate the channel conditions and then signal the best coding to use will get the best performance out of the channel. Although the use of a codebook for pre-coding limits the best fit to the channel, it significantly simplifies the channel estimation process by the UE and the amount of uplink signaling needed to convey the desired pre-coding.

The pre-coding matrices for LTE support both MIMO and beamforming. There are four codebook entries for 2x2 SU-MIMO and 16 for 4x4 SU-MIMO.

In addition to MIMO pre-coding there is an additional option called cyclic delay diversity (CDD). This technique adds antenna-specific cyclic time shifts to artificially create multi-path on the received signal and prevents signal cancellation caused by the close spacing of the transmit antennas. Normally multipath would be considered undesirable, but by creating artifi cial multi-path in an otherwise flat channel, the eNB UE scheduler can choose to transmit on those RBs that have favorable propagation conditions. The CDD system works by adding the delay only to the data subcarriers while leaving the RS subcarriers alone. The UE uses the flat RS subcarriers to report the received channel flatness and the eNB schedules the UE to use the RB that it knows will benefit from the artificially induced frequency un-flatness. By not applying the CDD to the RS, the eNB can choose to apply the CDD on a per-UE basis.

When the CDD is enabled there is a choice of small or large delay. The large delay is approximately half a symbol, which creates significant ripple in the channel, whereas the small delay is defined by channel bandwidth and varies from 65 ns for the 20 MHz channel to just over 1 μs for the 1.4 MHz channel. For the widest channels using the small delay will be a challenge because the required time shift is very close to the limits of antenna timing calibration. It is possible to apply a small delay CDD to the entire cell, including the RS. Doing so would make the CDD transparent to the UE but worsen the performance of channel quality indicator (CQI) reporting for those UE that would otherwise provide frequency-selective CQI reports.

LTE Uplink MultipleAntenna Schemes

The baseline configuration of the UE has one transmitter. This configuration was chosen to save cost and battery power, and with this configuration the system can support MU-MIMO—that is, two different UE transmitting in the same frequency and time to the eNB. This configuration has the potential to double uplink capacity (in ideal conditions) without incurring extra cost to the UE.

An optional configuration of the UE is a second transmit antenna, which allows the possibility of uplink Tx diversity and SU-MIMO. The latter offers the possibility of increased data rates depending on the channel conditions. For the eNB, receive diversity is a baseline capability and the system will support either two or four receive antennas.

Capturing Signals for Measurement

An analyzer performing vector signal analysis is not a real-time receiver but rather is a block-mode receiver. It captures a time record, and processes and displays the result before capturing the next block of data. Typically the processing and analysis time is longer than the capture time so there may be a gap between the end of one time record and the beginning of the next. Those gaps in time imply that the analyzer is not a real-time processor. This also applies to an analyzer that is configured to trigger on an event such as the change in the amplitude at the beginning of a burst. It may take the analyzer longer to process the current record than the time it takes for the next trigger event to occur.

Here again, the analyzer is not operating in real-time. Fortunately, vector signal analyzers provide a way to get real-time measurements for a limited length of time by using a time capture or recording of the input waveform. Time capturing allows the storage of complete time records with no time gaps produced in the record. The time capture is performed prior to data processing and once the waveform is captured, the signal is played back for analysis.

The signal analyzer captures the time record directly from the measurement hardware and stores the record in memory for immediate analysis or future use. Capturing the time record has the added benefit that the same signal can be analyzed over many different combinations of instrument settings including all the time and frequency measurements discussed in this section. One benefit of starting with a good set of vector measurements is the ability to choose a time capture length that is long enough for complete analysis, but not so long as to cause slow transfer due to excessively large capture files.

Figure 5-21   *Signal Capture and Measurement Interval Diagram*
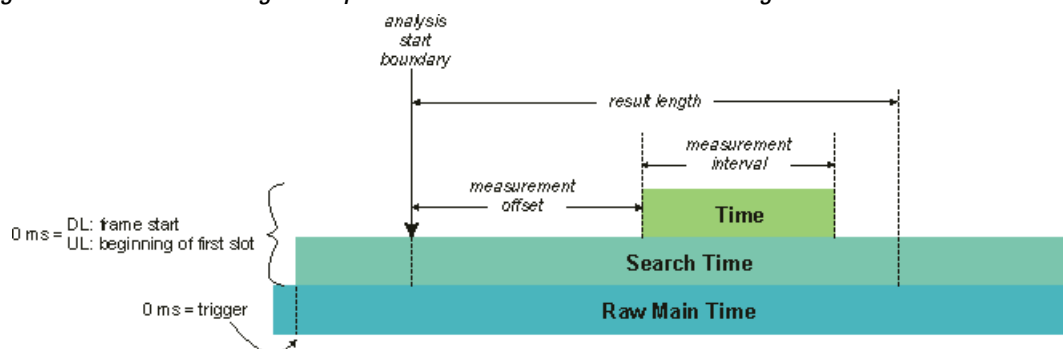
Measurement time-related parameters include:

- Result Length: Determines the signal capture length. This is the data used bythe analyzer for demodulation and signal analysis.

  Analysis Start Boundary: This specifies the boundary at which the Result Length must start. For DL signals, you can choose to begin at the frame, half-frame, subframe or slot boundary. For UL signals, only the slot boundary start position is available. This is because there are no sync channels for the UL signal, so it is difficult to automatically determine frame and sub-frame boundaries.

Measurement Interval: Determines the time length of Result Length data that is used for computing and displaying the trace data results.

Measurement Offset: Determines the start position of the Measurement Interval within the Result Length.

Finding Frames and Triggering Measurements

When first examining the pulsed characteristics of the LTE signal, it is often necessary to adjust the time record length in order to see the entire frame or several frames within the waveform display.

A time-domain display using a large number of points and showing one to two frames can be used to measure the subframe lengths and transition gaps.

Triggering the analyzer at specific time intervals within the LTE waveform will require setting the trigger type and magnitude level. Once the analyzer is properly triggered, analysis of different parts within the waveform can then be made using the trigger delay function of the instrument.

Finding the Trigger Level

The trigger level is typically set (in linear voltage units) to a percentage of the total signal range. One way to determine this level, prior to triggering, is to examine the time domain waveform in a linear power format. A level setting that is 10 to 50 percent of the approximate voltage maximum is a good start for bursted signals. This assumes that the voltage is close to zero during the "off" times in the waveform.

Introducing a Trigger Delay

Trigger delay allows detailed measurements of specific parts of the signal. If trigger delay is zero, the analyzer takes data immediately after the trigger conditions are satisfied and then processes the results. If a trigger delay is positive (this is called a "post-trigger delay") the analyzer waits through the duration of the delay before data is acquired. The post-trigger delay allows the analyzer to begin the measurement at any time into the waveform, for example, at the beginning of the first uplink frame. A trigger delay that is negative, which is called a "pre-trigger delay", allows measurement of the rising edge of the RF burst including any transient effect that may occur prior to the trigger.

Stabilizing the displayed measurement using the trigger functions allows you to verify and troubleshoot the OFDMA signal using time and frequency domain analysis. For example, by measuring signal level changes such as amplitude droop in the time domain or flatness and ripple effects in the frequency domain, you may uncover thermal problems in the amplifiers power stages or improper analog or digital filtering respectively. Unexpected frequency tilt and poor center frequency accuracy may be the result of poor component or synthesizer performance. Turn on and turn-off transients may create demodulation errors in the LTE receiver.

These may seem like very basic measurements, but a significant number of system problems can be traced to these behaviors. Such problems may come from analog or digital circuits, or interactions between them. Linking time and frequency measurements with proper triggering can provide a high level of confidence in the signal quality before digital demodulation takes place.

Time Gating Concepts

Introduction: Using Time Gating on a Simplified Digital Radio Signal

This section shows you the concepts of using time gating on a simplified digital radio signal. The section on Making Time-Gated Measurements demonstrates time gating examples.

Figure 5-22 shows a signal with two radios, radio 1 and radio 2, that are time-sharing a single frequency channel. Radio 1 transmits for 1 ms then radio 2 transmits for 1 ms.

Figure 5-22   *Simplified Digital Mobile-Radio Signal in Time Domain*
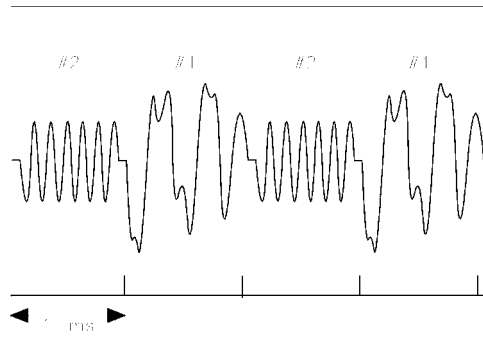
We want to measure the unique frequency spectrum of each transmitter.

A signal analyzer without time gating cannot do this. By the time the signal analyzer has completed its measurement sweep, which lasts about 50 ms, the radio transmissions switch back and forth 25 times. Because the radios are both transmitting at the same frequency, their frequency spectra overlap, as shown in Figure 5-23 The signal analyzer shows the combined spectrum; you cannot tell which part of the spectrum results from which signal.

Figure 5-23   *Frequency Spectra of the Combined Radio Signals*
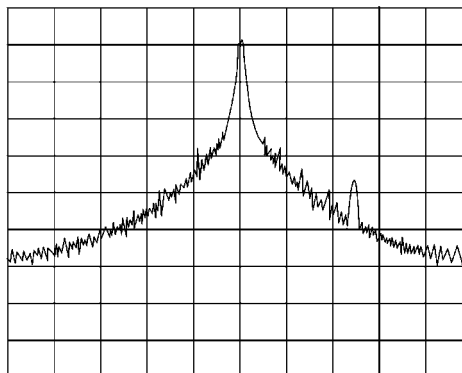
Time gating allows you to see the separate spectrum of radio 1 or radio 2 to determine the source of the spurious signal, as shown in Figure 5-24

Figure 5-24   Time-Gated Spectrum of Radio 1
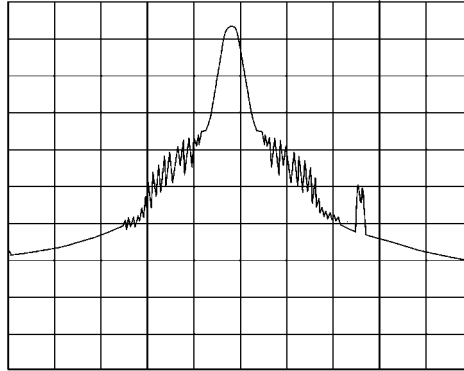
Figure 5-25   Time-Gated Spectrum of Radio 2
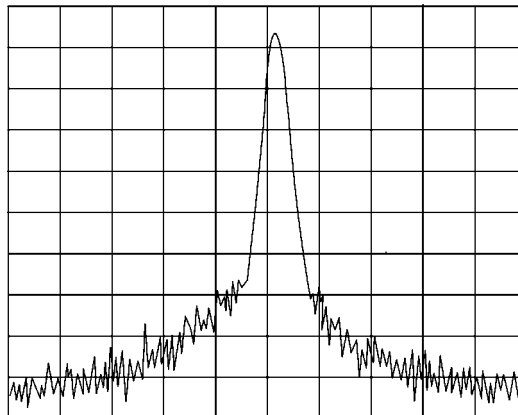
Time gating lets you define a time window (or time gate) of when a measurement is performed. This lets you specify the part of a signal that you want to measure, and exclude or mask other signals that might interfere.

How Time Gating Works

Time gating is achieved by the signal analyzer selectively interrupting the path of the detected signal, with a gate, as shown in Figure 5-27 and Figure 5-28. The gate determines the times at which it captures measurement data (when the gate is turned "on," under the Gate menu, the signal is being passed, otherwise when the gate is "off," the signal is being blocked). Under the right conditions, the only signals that the analyzer measures are those present at the input to the analyzer when the gate is on. With the correct signal analyzer settings, all other signals are masked out.

There are typically two main types of gating conditions, **edge** and **level**:

- With edge gating, the gate timing is controlled by user parameters (gate delay and gate length) following the selected (rising or falling) edge of the trigger signal. The gate passes a signal on the edge of the trigger signal (after the gate delay time has been met) and blocks the signal at the end of the gate length.

   With edge gating, the gate control signal is usually an external periodic TTL signal that rises and falls in synchronization with the rise and fall of the pulsed radio signal. The gate delay is the time the analyzer waits after the trigger event to enable the gate (see Figure 5-26).

- With level gating, the gate will pass a signal when the gate signal meets the specified level (high or low). The gate blocks the signal when the level conditions are no longer satisfied (level gating does not use gate length or gate delay parameters).

Figure 5-26   *Edge Trigger Timing Relationships*
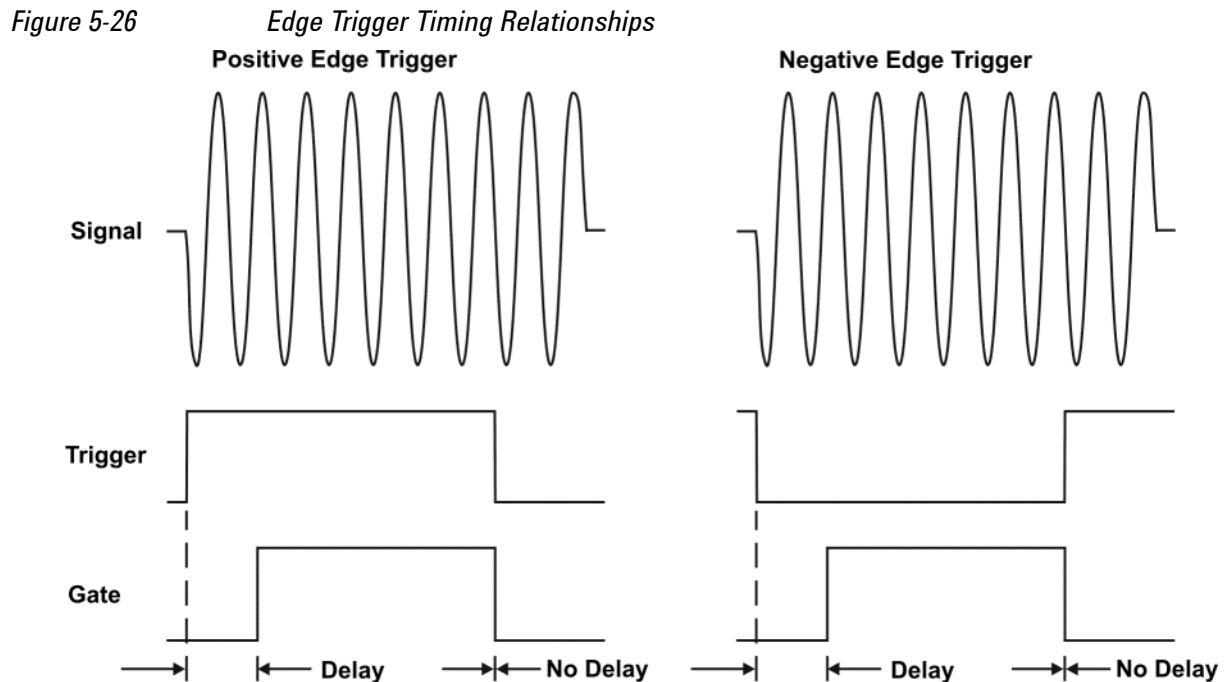
With Agilent signal analyzers, there are three different implementations for time gating: gated LO, gated video and gated FFT.

Gated Video Concepts

Gated video may be thought of as a simple gate switch, which connects the signal to the input of the signal analyzer. When the gate is "on" (under the Gate menu) the gate is passing a signal. When the gate is "off," the gate is blocking the signal. Whenever the gate is passing a signal, the analyzer sees the signal. In Figure 5-27 notice that the gate is placed after the envelope detector and before the video bandwidth filter in the IF path (hence "gated video").

The RF section of the signal analyzer responds to the signal. The selective gating occurs before the video processing. This means that there are some limitations on the gate settings because of signal response times in the RF signal path.

With video gating the analyzer is continually sweeping, independent of the position and length of the gate. The analyzer must be swept at a minimum sweep time (see the sweep time calculations later in this chapter) to capture the signal when the gate is passing a signal. Because of this, video gating is typically slower than gated LO and gated FFT.

Figure 5-27   *Gated Video Signal Analyzer Block Diagram*
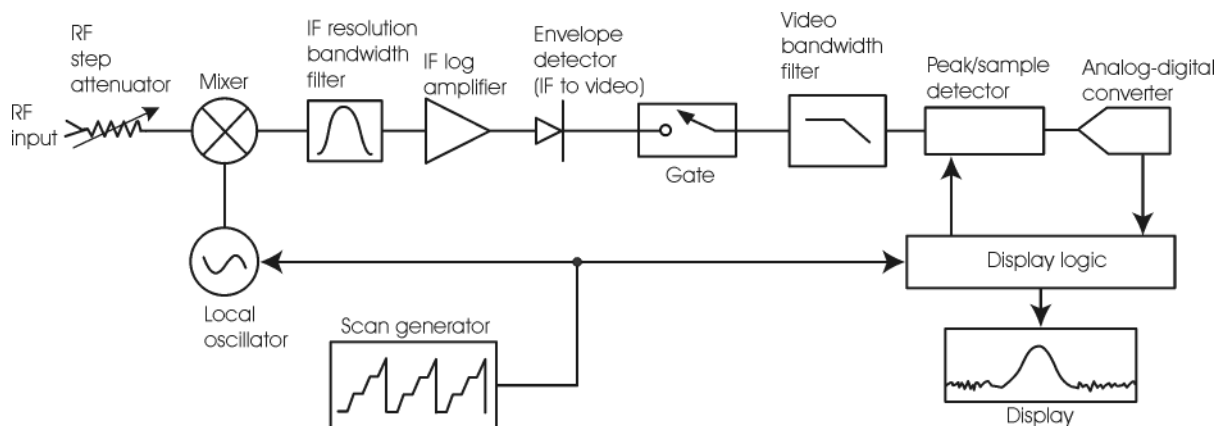
Gated LO Concepts

Gated LO is a very sophisticated type of time gating that sweeps the LO only while the gate is "on" and the gate is passing a signal. See Figure 5-28 for a simplified block diagram of gated LO operation. Notice that the gate control signal controls when the scan generator is sweeping and when the gate passes or blocks a signal. This allows the analyzer to sweep only during the periods when the gate passes a signal. Gated LO is faster than Gated Video because Gated Video must constrain sweep time so that each point is long enough to include a burst event. On the other hand, when in Gated LO, multiple points may be swept during each gate.

Figure 5-28   *Gated LO Signal Analyzer Block Diagram*
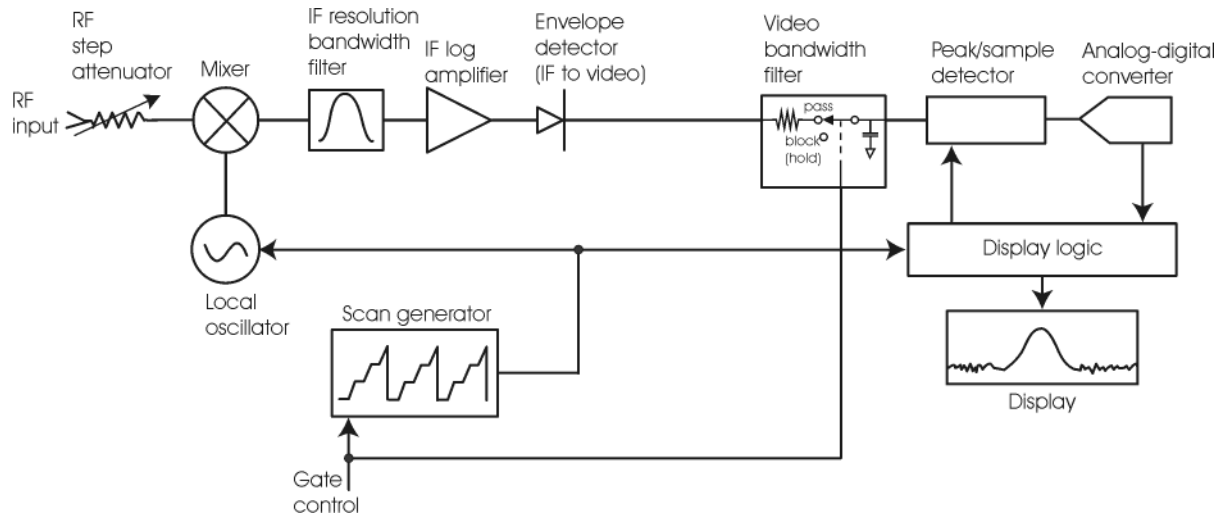
Gated FFT Concepts

Gated FFT (Fast-Fourier Transform) is an FFT measurement which begins when the trigger conditions are satisfied.

The process of making a spectrum measurement with FFTs is inherently a "gated" process, in that the spectrum is computed from a time record of short duration, much like a gate signal in swept-gated analysis.

Using the analyzer in FFT mode, the duration of the time record to be gated is:

$$FFT\ Time\ Record\ (to\ be\ gated)\ =\ \frac{1.83}{RBW}$$

The duration of the time record is within a tolerance of approximately 3% for resolution bandwidths up through 1 MHz. Unlike swept gated analysis, the duration of the analysis in gated FFT is fixed by the RBW, not by the gate signal. Because FFT analysis is faster than swept analysis (up to 7.99 MHz), the gated FFT measurements can have better frequency resolution (a narrower RBW) than swept analysis for a given duration of the signal to be analyzed.

Figure 5-29   *Gated FFT Timing Diagram*
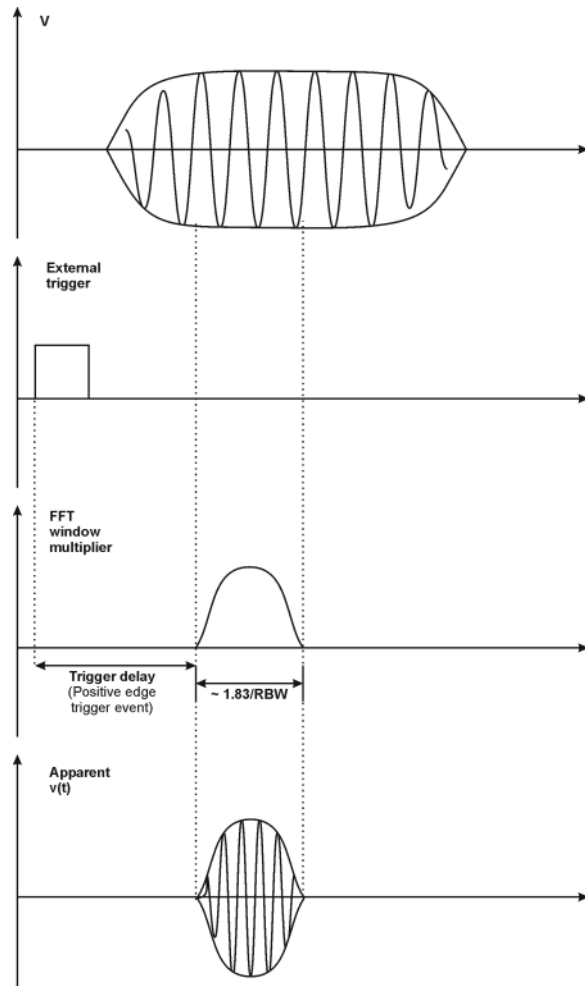
Time Gating Basics (Gated LO and Gated Video)

The gate passes or blocks a signal with the following conditions:

- Trigger condition - Usually an external transistor-transistor logic (TTL) periodic signal for edge triggering and a high/low TTL signal for level triggering.

- Gate delay - The time after the trigger condition is met when the gate begins to pass a signal.

- Gate length - The gate length setting determines the length of time a gate begins to pass a signal.

To understand time gating better, consider a spectrum measurement performed on two pulsed-RF signals sharing the same frequency spectrum. You will need to consider the timing interaction of three signals with this example:

- The composite of the two pulsed-RF signals.

- The gate trigger signal (a periodic TTL level signal).

- The gate signal. This TTL signal is low when the gate is "off" (blocking) and high when the gate is "on" (passing).

The timing interactions between the three signals are best understood if you observe them in the time domain (see Figure 5-30).

The main goal is to measure the spectrum of signal 1 and determine if it has any low-level modulation or spurious signals.

Because the pulse trains of signal 1 and signal 2 have almost the same carrier frequency, their spectra overlap. Signal 2 will dominate in the frequency domain due to its greater amplitude. Without gating, you won't see the spectrum of signal 1; it is masked by signal 2.

To measure signal 1, the gate must be on only during the pulses from signal 1. The gate will be off at all other times, thus excluding all other signals. To position the gate, set the gate delay and gate length, as shown in Figure 5-30, so that the gate is on only during some central part of the pulse. Carefully avoid positioning the gate over the rising or falling pulse edges. When gating is activated, the gate output signal will indicate actual gate position in time, as shown in the line labeled "Gate."

Figure 5-30   *Timing Relationship of Signals During Gating*
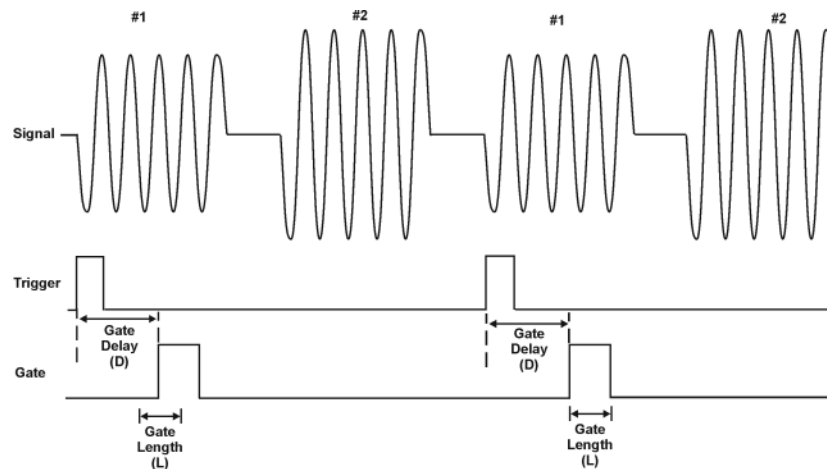
Once the signal analyzer is set up to perform the gate measurement, the spectrum of signal 1 is visible and the spectrum of signal 2 is excluded, as shown if Figure 5-32 In addition, when viewing signal 1, you also will have eliminated the pulse spectrum generated from the pulse edges. Gating has allowed you to view spectral components that otherwise would be hidden.

Figure 5-31   *Signal within pulse #1 (time-domain view)*
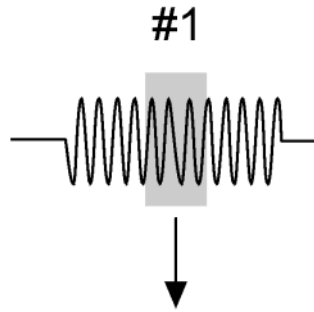
Figure 5-32   *Using Time Gating to View Signal 1 (spectrum view)*
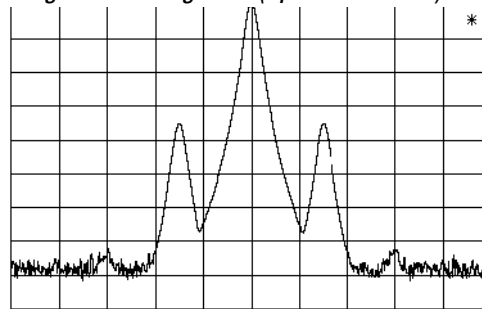
Moving the gate so that it is positioned over the middle of signal 2 produces a result as shown in Figure 5-34 Here, you see only the spectrum within the pulses of signal 2; signal 1 is excluded.

Figure 5-33   *Signal within pulse #2 (time-domain view)*
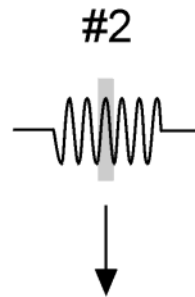
Figure 5-34   *Using Time Gating to View Signal 2 (spectrum view)*
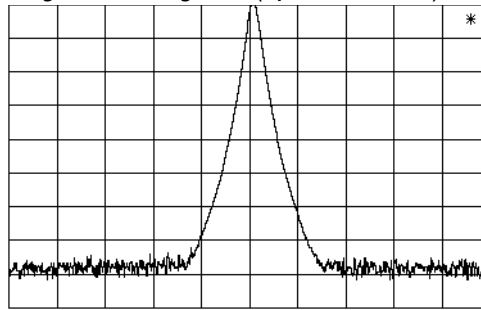
Measuring a Complex/Unknown Signal

NOTE   The steps below help to determine the signal analyzer settings when using time gating. The steps apply to the time gating approaches using gated LO and gated video.

This example shows you how to use time gating to measure a very specific signal. Most signals requiring time gating are fairly complex and in some cases extra steps may be required to perform a measurement.

Step 1. Determine how your signal under test appears in the time domain and how it is synchronized to the trigger signal.

You need to do this to position the time gate by setting the delay relative to the trigger signal. To set the delay, you need to know the timing relationship between the trigger and the signal under test. Unless you already have a good idea of how the two signals look in the time domain, you can examine the signals with an oscilloscope to determine the following parameters:

- Trigger type (edge or level triggering)

- Pulse repetition interval (PRI), which is the length of time between trigger events (the trigger period).

- Pulse width, or τ

- Signal delay (SD), which is the length of time occurring between the trigger event and when the signal is present and stable. If your trigger occurs at the same time as the signal, signal delay will be zero.

Figure 5-35   *Time-domain Parameters*
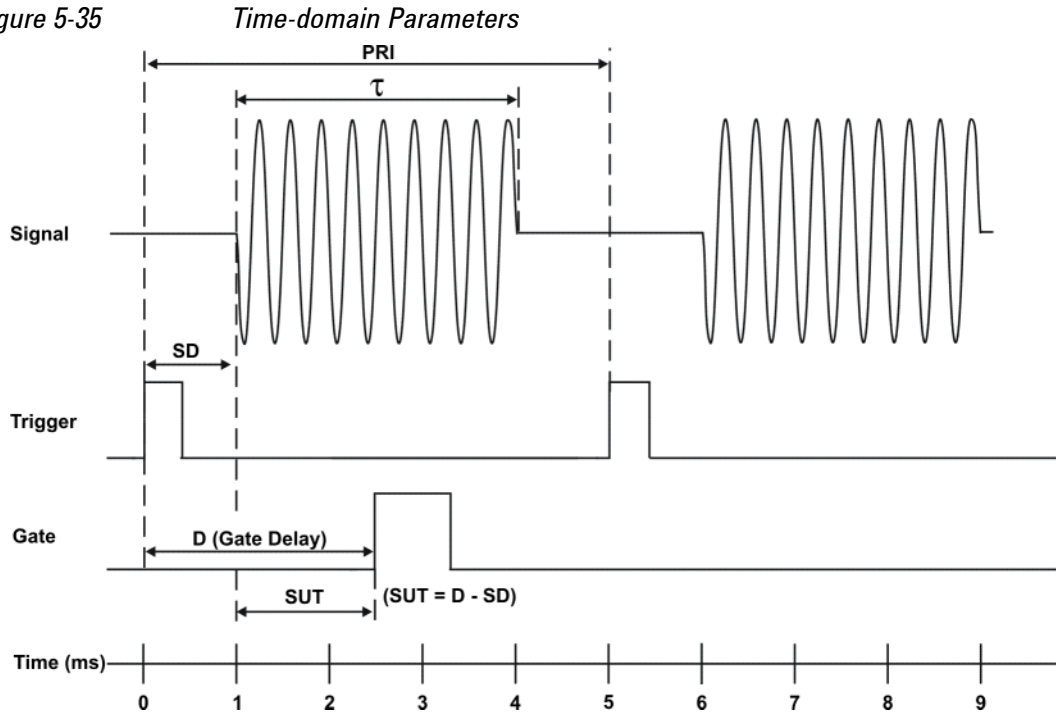
In Figure 5-35, the parameters are:

- Pulse repetition interval (PRI) is 5 ms.

- Pulse width (τ) is 3 ms.

- Signal delay (SD) is 1 ms for positive edge trigger (0.6 ms for negative edge trigger).

- Gate delay (D) is 2.5 ms.

- Setup time (SUT) is 1.5 ms.

Step 2. Set the signal analyzer sweep time:

Gated LO: Sweep time does not affect the results of gated LO unless the sweep time is set too fast. In the event the sweep time is set too fast, `Meas Uncal` appears on the screen and the sweep time will need to be increased.

Gated Video: Sweep time does affect the results from gated video. The sweep time must be set accordingly for correct time gating results. The recommended sweep time is at least the number of **sweep points – 1** multiplied by the **PRI (pulse repetition interval)**. Measurements can be made with sweep times as fast as (sweep points–1)*(PRI–τ).

Step 3. Locate the signal under test on the display of the signal analyzer. Set the center frequency and span to view the signal characteristics that you are interested in measuring. Although the analyzer is not yet configured for correct gated measurements, you will want to determine the approximate frequency and span in which to display the signal of interest. If the signal is erratic or intermittent, you may want to hold the maximum value of the signal with **Max Hold** (located under the **Trace/Detector** menu) to determine the frequency of peak energy.

To optimize measurement speed in the Gated LO case, set the span narrow enough so that the display will still show the signal characteristics you want to measure. For example, if you wanted to look for spurious signals within a 200 kHz frequency range, you might set the frequency span to just over 200 kHz.

Step 4. Determine the setup time and signal delay to set up the gate signal. Turn on the gate and adjust the gate parameters including gate delay and gate length as shown below.

Generally, the gate should be positioned over a part of the signal that is stable, not over a pulse edge or other transition that might disturb the spectrum. Starting the gate at the center of the pulse gives a setup time of about half the pulse width. Setup time describes the length of time during which that signal is present and stable before the gate comes on. The setup time (SUT) must be long enough for the RBW filters to settle following the burst-on transients. Signal delay (SD) is the length of time after the trigger, but before the signal of interest occurs and becomes stable. If the trigger occurs simultaneously with the signal of interest, SD is equal to zero, and SUT is equal to the gate delay. Otherwise, SUT is equal to the gate delay minus SD. See Figure 5-36

Figure 5-36   *Positioning the Gate*
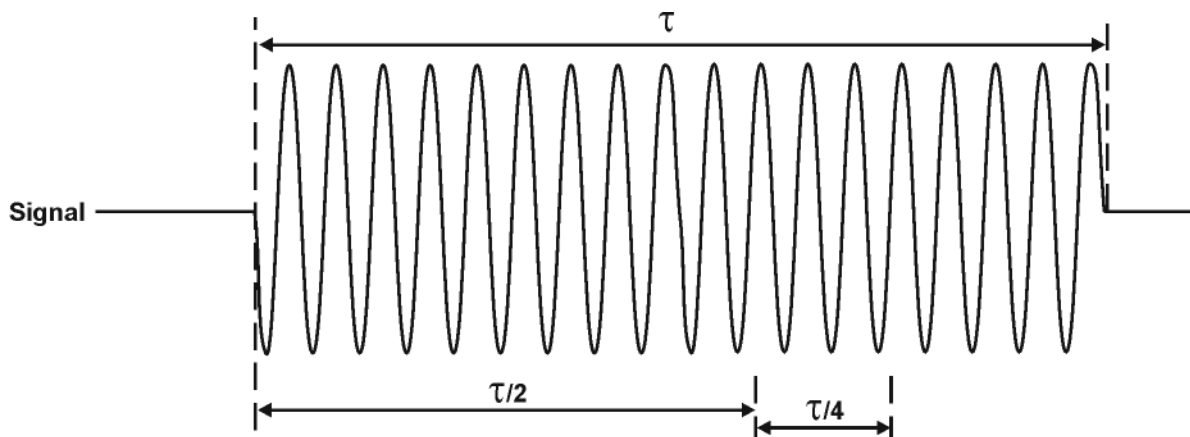
There is flexibility in positioning the gate, but some positions offer a wider choice of resolution bandwidths. A good rule of thumb is to position the gate from 20 % to 90 % of the burst width. Doing so provides a reasonable compromise between setup time and gate length.

Figure 5-37   *Best Position for Gate*
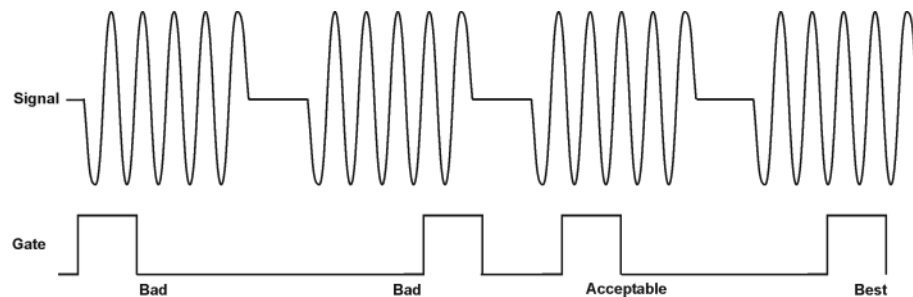
As a general rule, you will obtain the best measurement results if you position the gate relatively late within the signal of interest, but without extending the gate over the trailing pulse edge or signal transition. Doing so maximizes setup time and provides the resolution bandwidth filters of the signal analyzer the most time to settle before a gated measurement is made. "Relatively late," in this case, means allowing a setup time of at least 3.84/resolution bandwidth (see step 5 for RBW calculations).

As an example, if you want to use a 1 kHz resolution bandwidth for measurements, you will need to allow a setup time of at least 3.84 ms.

Note that the signal need not be an RF pulse. It could be simply a particular period of modulation in a signal that is continuously operating at full power, or it could even be during the off time between pulses. Depending on your specific application, adjust the gate position to allow for progressively longer setup times (ensuring that the gate is not left on over another signal change such as a pulse edge or transient), and select the gate delay and length that offer the best representation of the signal characteristics of interest on the display.

If you were measuring the spectrum occurring between pulses, you should use the same (or longer) setup time after the pulse goes away, but before the gate goes on. This lets the resolution bandwidth filters fully discharge the large pulse before the measurement is made on the low-level interpulse signal.

Figure 5-38   *Setup Time for Interpulse Measurement*
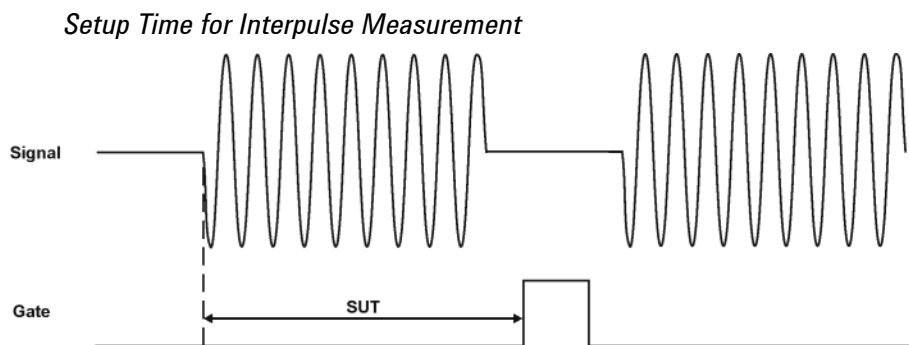
Step 5. The resolution bandwidth will need to be adjusted for gated LO and gated video. The video bandwidth will only need to be adjusted for gated video.

Resolution Bandwidth:

The resolution bandwidth you can choose is determined by the gate position, so you can trade off longer setup times for narrower resolution bandwidths. This trade-off is due to the time required for the resolution-bandwidth filters to fully charge before the gate comes on. Setup time, as mentioned, is the length of time that the signal is present and stable before the gate comes on.

Figure 5-39   *Resolution Bandwidth Filter Charge-Up Effects*
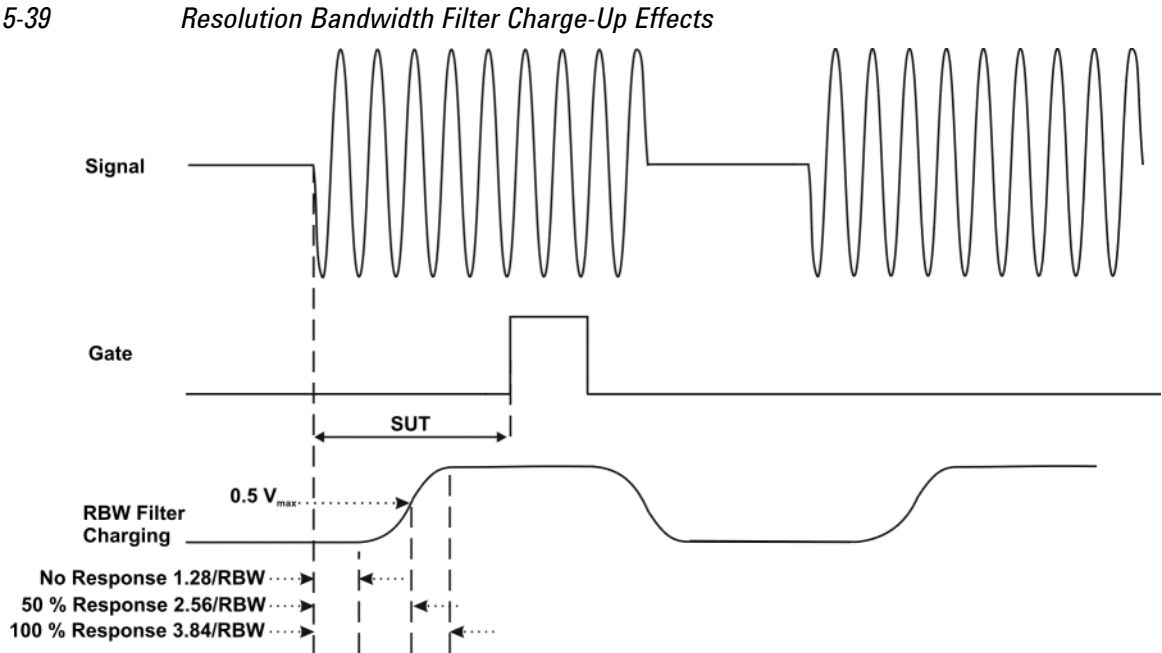
Because the resolution-bandwidth filters are band-limited devices, they require a finite amount of time to react to changing conditions. Specifically, the filters take time to charge fully after the analyzer is exposed to a pulsed signal.

Because setup time should be greater than filter charge times, be sure that:

$$SUT > \frac{3.84}{RBW}$$

where SUT is the same as the gate delay in this example. In this example with SUT equal to 1.5 ms, RBW is greater than 2.56 kHz; that is, RBW is greater than 1333 Hz. The resolution bandwidth should be set to the next larger value, 2.7 kHz.

Video Bandwidth:

For gated LO measurements the VBW filter acts as a track-and-hold between sweep times. With this behavior, the VBW does not need to resettle on each restart of the sweep.

Step 6. Adjust span as necessary, and perform your measurement.

The analyzer is set up to perform accurate measurements. Freeze the trace data by activating single sweep, or by placing your active trace in view mode. Use the markers to measure the signal parameters you chose in step 1. If necessary, adjust span, but do not decrease resolution bandwidth, video bandwidth, or sweep time.

"Quick Rules" for Making Time-Gated Measurements

This section summarizes the rules described in the previous sections.

Table 5-8   *Determining Signal Analyzer Settings for Viewing a Pulsed RF Signal*

Signal Analyzer Function	Signal Analyzer Setting	Comments
Sweep Time (gated video only)	Set the sweep time to be equal to or greater than (number of sweep points - 1) $\times$ pulse repetition interval (PRI):	Because the gate must be on at least once per trace point, the sweep time should be set such that the sweep time for each trace point is greater than or equal to the pulse repetition interval.
Gate Delay	The gate delay is equal to the signal delay plus one-fourth the pulse width: Gate Delay = Signal Delay + $\tau/5$	The gate delay must be set so that the gating captures the pulse. If the gate delay is too short or too long, the gating can miss the pulse or include resolution bandwidth transient responses.
Gate Length	The gate length minimum is equal to one-fourth the pulse width (maximum about one-half): Gate Length = 0.7 x $\tau/4$	If the gate length is too long, the signal display can include transients caused by the signal analyzer filters. The recommendation for gate placement can be between 20 % to 90 % of the pulse width.
Resolution Bandwidth	Set the resolution bandwidth: RBW > $19.5/\tau$	The resolution bandwidth must be wide enough so that the charging time for the resolution bandwidth filters is less than the pulse width of the signal.

Figure 5-40   *Gate Positioning Parameters*
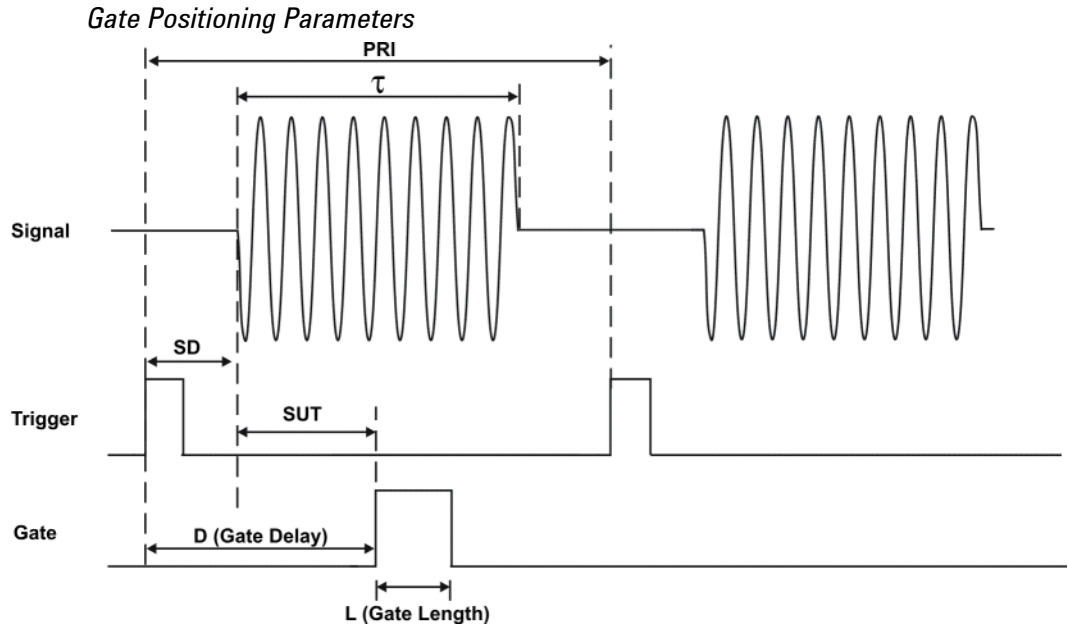
Most control settings are determined by two key parameters of the signal under test: the pulse repetition interval (PRI) and the pulse width (τ). If you know these parameters, you can begin by picking some standard settings. Table 5-9 summarizes the parameters for a signal whose trigger event occurs at the same time as the beginning of the pulse (in other words, SD is 0). If your signal has a non-zero delay, just add it to the recommended gate delay.

Table 5-9   *Suggested Initial Settings for Known Pulse Width (τ) and Zero Signal Delay*

Pulse width (τ)	Gate Delay (SD + $\tau/5$)	Resolution Bandwidth (>19.5/τ)	Gate Length (0.7 x $\tau/4$)
4 µs	0.8 µs	4.875 MHz	0.7 µs
10 µs	2 µs	1.95 MHz	1.753 µs
50 µs	10 µs	390 kHz	8.75 µs
63.5 µs	12.7 µs	307 kHz	11.11 µs
100 µs	20 µs	195 kHz	17.5 µs
500 µs	100 µs	39 kHz	87.5 µs
1 ms	200 µs	19.5 kHz	0.175 µs
5 ms	1 ms	3.9 kHz	0.875 ms
10 ms	2 ms	1.95 kHz	1.75 ms
16.6 ms	3.32 ms	1.175 kHz	2.905 ms
33 ms	6.6 ms	591 Hz	5.775 ms
50 ms	10 ms	390 Hz	8.75 ms

Table 5-9   Suggested Initial Settings for Known Pulse Width (τ) and Zero Signal Delay

Pulse width (τ)	Gate Delay (SD + $\tau/5$)	Resolution Bandwidth (>19.5/τ)	Gate Length (0.7 x $\tau/4$)
100 ms	20 ms	195 Hz	17.5 ms
≥130 ms	26 ms	151 Hz	22.75 ms

Table 5-10　　　　　　*If You Have a Problem with the Time-Gated Measurement*

Symptom	Possible Causes	Suggested Solution
Erratic analyzer trace with dropouts that are not removed by increasing analyzer sweep time; oscilloscope view of gate output signal jumps erratically in time domain.	Gate Delay may be greater than trigger repetition interval.	Reduce Gate Delay until it is less than trigger interval. Check **Gate View** to make sure the gate delay is timed properly.
Gate does not trigger.	1) Gate trigger voltage may be wrong. 2) Gate may not be activated. 3) **Gate Source** selection may be wrong.	With external gate trigger: ensure that the trigger threshold is set near the midpoint of the waveform (view the waveform on and oscilloscope using high input impedance, not 50 Ω). With RF Burst Gate Source: ensure that the start and stop frequencies are within 10 MHz of the center frequency of the carrier. Check to see if other connections to trigger signal may be reducing voltage. If using an oscilloscope, check that all inputs are high impedance, not 50 Ω.
Display spectrum does not change when the gate is turned on.	Insufficient setup time.	Increase setup time for the current resolution bandwidth, or increase resolution bandwidth.
Displayed spectrum too low in amplitude.	Resolution bandwidth or video bandwidth filters not charging fully.	Widen resolution bandwidth or video bandwidth, or both.

Using the Edge Mode or Level Mode for Triggering

Depending on the trigger signal that you are working with, you can trigger the gate in one of two separate modes: edge or level. This gate-trigger function is separate from the normal external trigger capability of the signal analyzer, which initiates a sweep of a measurement trace based on an external signal.

Edge Mode

Edge mode lets you position the gate relative to either the rising or falling edge of a trigger signal. The left diagram of Figure 5-41 shows triggering on the positive edge of the trigger signal while the right diagram shows negative edge triggering.

Example of key presses to initiate positive edge triggering:
Press **Sweep**, **Gate**, **More**, **Polarity** (Pos).

Figure 5-41   *Using Positive or Negative Edge Triggering*
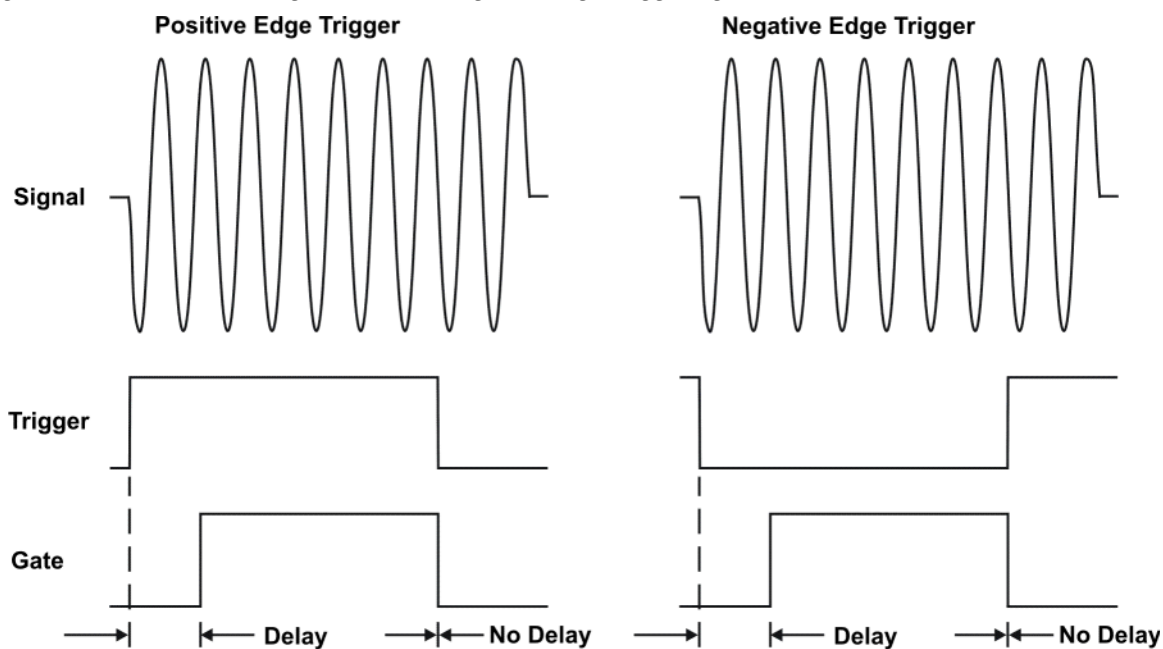
Level Mode

In level gate-control mode, an external trigger signal opens and closes the gate. Either the TTL high level or TTL low level opens the gate, depending on the setting of **Trig Slope**. Gate delay affects the start of the gate but not the end. Gate length is applicable when using level mode triggering. Level mode is useful when your trigger signal occurs at exactly the same time as does the portion of the signal you want to measure.

Noise Measurements Using Time Gating

Time gating can be used to measure many types of signals. Noise and noise-like signals are often a special case in spectrum analysis. With the history of gated measurements, these signals are especially noteworthy.

The average detector is the best detector to use for measuring noise-like signals because it uses all the available noise power all the time in its measurement. The sample detector is also a good choice because it, too, is free from the peak biases of the peak detector, normal and negative peak detectors.

When using the average or sample detector, noise density measurements using the noise marker or band/interval density marker can be made without any consideration of the use of gating--gated measurements work just as well as non-gated measurements. Thus, the average detector is recommended for noise density measurements.

Older analyzers only had the gated video version of gating available, and these only worked with the peak detector, so the rest of this section will discuss the trade-offs associated with trying to replicate these measurements with an MXA.

Unlike older analyzers, MXA can make competent measurements of noise density using the noise marker with all detectors, not just those that are ideal for noise measurements. Thus, MXA can make noise density measurements with peak detection, compensating for the extent to which peak detection increases the average response of the analyzer to noise. When comparing a gated video measurement using the noise marker between MXA and an older analyzer where both use the peak detector, the MXA answer will be approximately correct, while the older analyzer will need a correction factor. That correction factor is discussed in Agilent Technologies Application Note 1303, Spectrum Analyzer Measurements and Noise, in the section on Peak-detected Noise and TDMA ACP Measurements.

When making measurements of Band/Interval Power or Band/Interval Density, the analyzer does not make compensations for peak detection. For best measurements with these marker functions, average or sample detection should be used.

Measuring the Frequency Spectrum

The analyzer can perform spectrum analysis using either a scalar (also called "stepped FFT measurements") or a vector measurement. Scalar measurements provide amplitude-only information over the full frequency range of the instrument. Vector measurements provide both phase and amplitude information over the processing bandwidth of the instrument.

Measuring the Wideband Spectrum

Analysis of an LTE signal typically starts with a wideband spectrum measurement. A wideband spectrum measurement is used to verify the center frequency, nominal signal bandwidth, amplitude level, and sidelobe level of the LTE signal. It is also an opportunity to verify the level of any spurs and other interference signals present in the frequency band that may cause errors during digital demodulation.

Verifying the spectral content is typically performed using a maximum-hold detection scheme. For peak amplitude and spurious measurements of the OFDM signal, the analyzer is configured with a large frequency span (perhaps using the scalar measurement mode) and max-hold averaging. Continuous peak-hold averaging is a measurement function used by the analyzer to measure and display the largest magnitude (determined over many measurements) for each frequency point in the span.

Measurement of low level spurious and interference signals should be performed using a Gaussian window, which provides the highest dynamic range in the measurement. The Gaussian window offers the lowest sidelobe level of any analyzer window at slightly reduced amplitude accuracy. Combining peak hold averaging and Gaussian windowing is ideal to ensure that no significant signals are missed either in the band or out.

Lastly, the analyzer's input range must be correctly set in order to obtain accurate measurements. If the input range testing is too low (more sensitive than necessary), the analyzer's analog-to-digital converter (ADC) circuitry is overloaded and introduces distortion into the measurement. If the range is set too high (less sensitive than necessary), there may be a loss of dynamic range due to additional noise. If the wideband spectrum for the LTE test signal is acceptable, the instrument can be re-configured for the next analysis step, which is a measurement of the narrowband spectrum.

Measuring the Narrowband Spectrum

For narrowband spectrum analysis of the LTE signal, the instrument's frequency span should be set to approximately 1.1 times the nominal bandwidth of the signal. Alternately the span can be configured to match the bandwidth of a typical LTE front-end filter. Using a frequency span close to a typical receiver's RF bandwidth allows the analyzer measurements to be performed with similar input noise and interference levels as would be seen in practice.

Narrowband measurements also provide improved frequency resolution and greater accuracy in setting the center frequency of the instrument or verifying the center frequency of the signal under test. The improved frequency resolution results from the inverse relationship between span and RBW. Accurate amplitude measurements of the LTE signal are required for system verification, troubleshooting and compliance with local regulations.

Amplitude measurements as a function of frequency for these noise-like signals should be performed using RMS (video) averaging and RMS detection. The detection mechanisms in the analyzer are always RMS. The analyzer calculates the frequency spectrum using a Fast Fourier Transform (FFT) that directly results in the true RMS power of the signal whether it is a single tone, noise, or any complex signal. RMS averaging produces a statistical approximation of the true power level over the measured time record(s), which includes on/off times and the transient effects of the bursted OFDM signal.

Time-variant signals such as LTE signals often require spectral analysis over a smaller portion of the entire waveform, for example, during a subframe. In this case, the measurement needs to be stabilized using the trigger control in the analyzer. Triggering the analyzer can easily be accomplished and the details will be provided in the next section. The importance of triggering for a time-variant waveform can be seen in , which shows the difference between the spectrum of a OFDM signal when the instrument is not triggered (upper display) and when it is triggered (lower display). The sidelobe levels for the untriggered response rapidly change from individual measurement to measurement as the spectrum measurement is made on different parts of the time-variant waveform. In comparison, the triggered response maintains the spectral shape as the instrument is triggered at the beginning of each OFDM frame. Both measurements were made with the averaging disabled. Both measurements are accurate, but the change in trigger conditions changes the portion of the signal that is measured.

Figure 5-42   *Frequency domain response of a OFDM signal without using an instrument trigger (upper trace) and using a trigger to set the beginning of the downlink frame (lower trace). (Example from the Agilent 89600).*
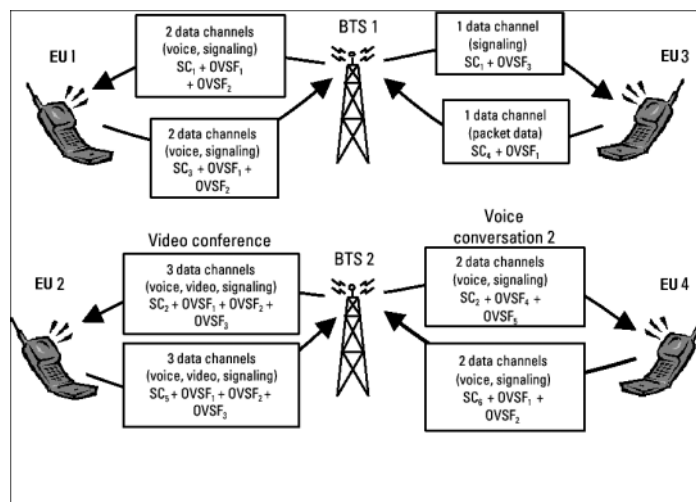
LTE Modulation Analysis Measurement Concepts

The Modulation Analysis measurement provides LTE modulation analysis capabilities for the N9080A LTE SOApp. The functionality is equivalent to the capabilities of option BHD of the 89601A VSA application. (Some of the functionality is optional and requires an additional license.)

As nearly as possible given the significant differences in the operational models between a PC application and an instrument embedded application, the measurement operates and is organized in the same way as the measurement capabilities of the 89601A VSA. The measurement is based on the analysis of IQ Pairs for all analysis functions.

A detailed description of the measurement algorithms is beyond the scope of this document. At a general level, the measurement loop consists of the following steps:

1. Acquire new data

2. Locate the first complete pulse/burst

3. Demodulate the burst

4. Compute measurement results, in some cases computing averaged results

5. Display the measurement results

The Modulation Analysis measurement provides an auto-detect feature for downlink signals that makes measurement of all parameters automatically. For uplink signals, because of the lack of a Reference or pilot signal, the instrument must be provided slot setup information to sucessfully demodulate the signal.

Monitor Spectrum (Frequency Domain) Measurement Concepts

Purpose

The Monitor Spectrum measurement provides spectrum analysis capability for the instrument. The control of the measurement was designed to be familiar to those who are accustomed to using swept spectrum analyzers. The primary use of Monitor Spectrum is to allow you to visually make sure you have the RF carrier available to the instrument, and the instrument is tuned to the frequency of interest.

This measurement is FFT (Fast Fourier Transform) based. The FFT-specific parameters are located in the **Advanced** menu. Also available under Basic Mode, the Complex Spectrum measurement provides an I/Q window, which shows the I and Q signal waveforms in parameters of voltage versus time. The advantage of having an I/Q view available while in the spectrum measurement is that it allows you to view complex components of the same signal without changing settings or measurements.

Measurement Method

The measurement uses digital signal processing to sample the input signal and convert it to the frequency domain. With the instrument tuned to a fixed center frequency, samples are digitized at a high rate, converted to I and Q components with DSP hardware, and then converted to the frequency domain with FFT software.

Troubleshooting Hints

Changes made by the user to advanced spectrum settings, particularly to ADC range settings, can inadvertently result in spectrum measurements that are invalid and cause error messages to appear. Care needs to be taken when using advanced features.

LTE Coformance EVM Measurement Concepts

Purpose

The Conformance EVM (CEVM) measurement provides quick and easy measurement for LTE modulatin analysis.The major functionality is the same as the LTE Modulation Analysis measurement (EVM); however, the measurement items of result are tailored for the speed and therefore some of the functionalities and results are excluded or limited. The user can get the same result as the Error Summary on EVM.

Measurement Method

All available measurement parameters are accessible through RUI (SCPI). CEVM doesn't have softkeys for setting parameters except for some common keys. Basically it has three views: Measurement List view, Parameter List view and Result Metrics view. These views are in tabular form. There is another view named RF Envelope which shows a time domain RF envelope for debug purpose.

Differences from LTE Modulation Analysis Measurement

Most functions are the same as the LTE Modulation Analysis (EVM) measurement. If you have a set of SCPI lists to set up the current existent EVM measurement, you can easily convert it for the CEVM measurement by simply replacing the node name "EVM" with "CEVM".

For example,

EVM[:SENSe]:EVM:PROFile:AUTO:DETect ON|OFF

CEVM[:SENSe]:CEVM:PROFile:AUTO:DETect ON|OFF

However, some features are different between EVM and CEVM as shown below.

- The results displayed on Error Summary in the EVM measurement are also available in CEVM. On the other hand, the other results such as Frame Summary, symbols, and various traces are not available in CEVM.

- CEVM uses "Mech Atten" and "Elec Atten" commands, but does not use "Range" commands in modulation analysis measurement. Modulation Analysis measurement Range seeting is independent from other measurement's Attenuation setting.

- For Trigger Setting, CEVM also applies xSA-based SCPI commands.

- The parameter "Update" concept in EVM doesn't exist in CEVM. Any users and allocation changes take effect immediately. Same applies to "Ignore" commands.

- For IF BW setting, EVM uses the command "[:SENSe]:FREQuency:SPAN," and CEVM uses "[:SENSe]:CEVM:IFBW". Since IF BW is automatically set whenever the Demod Bandwidth is changed, the user doesn't have to change it.

- Some SCPI commands in EVM are not available in CEVM, see "SCPI Commands available in EVM are not supported in CEVM" on page 141. Some SCPI commands are newly added in CEVM, see "SCPI Commands only available in CEVM" on page 144.

SCPI Commands available in EVM are not supported in CEVM

These averaging capabilities are not implemented in CEVM. CEVM only supports exponential averaging.

- [:SENSe]:EVM:AVERage:FAST
- [:SENSe]:EVM:AVERage:FAST:URATe
- [:SENSe]:EVM:AVERage:FAST:URATe:AUTO
- [:SENSe]:EVM:AVERage:TCONtrol
- [:SENSe]:EVM:AVERage:TYPE

Parameter changes take effect immediately in CEVM.

- [:SENSe]:EVM:DLINk:PROFile:UPDate
- [:SENSe]:EVM:ULINk:PROFile:UPDate
- [:SENSe]:EVM:DLINk:PROFile:IGNore
- [:SENSe]:EVM:ULINk:PROFile:IGNore

These functions are not implemented in CEVM.

- [:SENSe]:EVM:PROFile:COPY[:IMMediate]
- [:SENSe]:EVM:DLINk:DECode:PBCH
- [:SENSe]:EVM:DLINk:DECode:PCFich
- [:SENSe]:EVM:DLINk:DECode:PDCCh
- [:SENSe]:EVM:DLINk:DECode:PDSCh
- [:SENSe]:EVM:REPort:DB
- [:SENSe]:EVM:REPort:POWer:RELative
- [:SENSe]:EVM:TIME:SCALe:FACTor
- [:SENSe]:EVM:ULINk:PROFile:AUTO:PUSCh:MODulation:TYPE
- [:SENSe]:EVM:DLINk:SYNC:CPLength:AUTO
- [:SENSe]:EVM:ULINk:SYNC:CPLength:AUTO

These display related commands are not available in CEVM.

- :DISPlay:EVM:AFPoints
- :DISPlay:EVM:ANNotation:TITLe:DATA
- :DISPlay:EVM:FANNotation

- :DISPlay:EVM:TRACe(1:4):COPY/nquery/

- :DISPlay:EVM:TRACe(1:4):DDEMod:ALINe

- :DISPlay:EVM:TRACe(1:4):DDEMod:EYE:COUNt

- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol

- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol:FORMat

- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol:SHAPe

- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol:SIZE

- :DISPlay:EVM:TRACe(1:4):DDEMod:UNIT:FREQuency

- :DISPlay:EVM:TRACe(1:4):DDEMod:UNIT:TIME

- :DISPlay:EVM:TRACe(1:4):FEED

- :DISPlay:EVM:TRACe(1:4):FORMat

- :DISPlay:EVM:TRACe(1:4):FORMat:DELay:APERture

- :DISPlay:EVM:TRACe(1:4):FORMat:PHASe:OFFSet

- :DISPlay:EVM:TRACe(1:4):FORMat:PHASe:UNWRap:REFerence

- :DISPlay:EVM:TRACe(1:4):RLINe

- :DISPlay:EVM:TRACe(1:4):VHCenter

- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:COUPle

- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:RLEVel

- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:RPOSition

- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:SPAN

- :DISPlay:EVM:TRACe(1:4):Y:LRATio

- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:AUTO:ONCE/nquery/

- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:PDIVision

- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:RLEVel

- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:RLEVel:AUTO

- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:RPOSition

- :DISPlay:EVM:TRACe(1:4):Y:UNIT?/qonly/

- :DISPlay:EVM:TRACe(1:4):Y:UNIT:PREFerence

- :DISPlay:EVM:VIEW:PRESet/nquery/

- :DISPlay:EVM:WINDow:FORMat

These calc and trace related commandsare not available in CEVM.

- :CALCulate:EVM:DATA(1:4)?/qonly/

- :CALCulate:EVM:DATA(1:4):HEADer:NAMes?/qonly/

- :CALCulate:EVM:DATA(1:4):HEADer[:NUMBer]?/qonly/

- :CALCulate:EVM:DATA(1:4):HEADer:STRing?/qonly/

- :CALCulate:EVM:DATA(1:4):HEADer:TYPE?/qonly/

- :CALCulate:EVM:DATA(1:4):NAMes?/qonly/

- :CALCulate:EVM:DATA(1:4):POINts?/qonly/

- :CALCulate:EVM:DATA(1:4):RAW?/qonly/

- :CALCulate:EVM:DATA(1:4):RAW:COMPlex?/qonly/

- :CALCulate:EVM:DATA(1:4):RAW:POINts?/qonly/

- :CALCulate:EVM:DATA(1:4):TABLe:NAMes?/qonly/

- :CALCulate:EVM:DATA(1:4):TABLe[:NUMBer]?/qonly/

- :CALCulate:EVM:DATA(1:4):TABLe:STRing?/qonly/

- :CALCulate:EVM:DATA(1:4):TABLe:UNIT?/qonly/

- :CALCulate:EVM:MARKer(1:12):AOFF/nquery/

- :CALCulate:EVM:MARKer(1:12):CFORmat

- :CALCulate:EVM:MARKer(1:12):COUPle[:STATe]

- :CALCulate:EVM:MARKer(1:12):CPSearch[:STATe]

- :CALCulate:EVM:MARKer(1:12):FCOunt[:STATe]

- :CALCulate:EVM:MARKer(1:12):FCOunt:X?/qonly/

- :CALCulate:EVM:MARKer(1:12):FUNCtion

- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:CENTer

- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:LEFT

- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:RIGHt

- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:SPAN

- :CALCulate:EVM:MARKer(1:12):FUNCtion:BDENsity:CTYPe

- :CALCulate:EVM:MARKer(1:12):FUNCtion:BPOWer:CTYPe

- :CALCulate:EVM:MARKer(1:12):MAXimum/nquery/

- :CALCulate:EVM:MARKer(1:12):MAXimum:LEFT/nquery/

- :CALCulate:EVM:MARKer(1:12):MAXimum:NEXT/nquery/

- :CALCulate:EVM:MARKer(1:12):MAXimum:PREVious/nquery/

- :CALCulate:EVM:MARKer(1:12):MAXimum:RIGHt/nquery/

- :CALCulate:EVM:MARKer(1:12):MINimum/nquery/

- :CALCulate:EVM:MARKer(1:12):MODE

- :CALCulate:EVM:MARKer(1:12):POSition

- :CALCulate:EVM:MARKer(1:12):REFerence

- :CALCulate:EVM:MARKer(1:12):TABLe[:STATe]

- :CALCulate:EVM:MARKer(1:12):TRACe

- :CALCulate:EVM:MARKer(1:12):X

- :CALCulate:EVM:MARKer(1:12):X:POSition

- :CALCulate:EVM:MARKer(1:12):X:UNIT?/qonly/

- :CALCulate:EVM:MARKer(1:12):Y:IMAGinary

- :CALCulate:EVM:MARKer(1:12):Y[:REAL]

- :CALCulate:EVM:MARKer(1:12):Y:UNIT?/qonly/

- :CALCulate:EVM:MARKer(1:12):Z

- :CALCulate:EVM:MARKer(1:12):Z:UNIT?/qonly/

- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:BANDwidth|BWIDth:INTegration

- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:FILTer:RRC:ALPHa

- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:FILTer:RRC:STATe

- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:FREQuency

- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:FILTer:RRC:STATe

- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:BANDwidth|BWIDth:INTegration

- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:FILTer:RRC:ALPHa

- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:FREQuency

- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:RCARrier

- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:RCARrier:TEST

- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:STATe

- :CALCulate:EVM:TRACe(1:4):ACPower:STATe

- :CALCulate:EVM:TRACe(1:4):OBWidth:CENTroid?/qonly/

- :CALCulate:EVM:TRACe(1:4):OBWidth:LIMit:FBLimit

- :CALCulate:EVM:TRACe(1:4):OBWidth:LIMit[:TEST]

- :CALCulate:EVM:TRACe(1:4):OBWidth:PERCent

- :CALCulate:EVM:TRACe(1:4):OBWidth:STATe

SCPI Commands only available in CEVM

The following SCPI commands are available only in CEVM, not in EVM.

- [:SENSe]:CEVM:IFBW

  For IF BW setting, EVM uses the command "[:SENSe]:FREQuency:SPAN". On the other hand, CEVM uses "[:SENSe]:CEVM:IFBW". Since IF BW is automatically set whenever the Demod Bandwidth is changed, the user doesn't have to change it.

- [:SENSe]:CEVM:EVM:COPY[:IMMediate]

- [:SENSe]:CEVM:DLINk:RESult

- [:SENSe]:CEVM:ULINk:RESult

Baseband I/Q Inputs (Option BBA) Measurement Concepts

The N9020A Option BBA Baseband I/Q Inputs provides the ability to analyze baseband I/Q signal characteristics of mobile and base station transmitters. This option may be used only in conjunction with the following modes:

- IQ Analyzer (Basic)

- 802.16 OFDMA (WiMAX/WiBro)

- cdma2000

- GSM/EDGE

- TD-SCDMA

- W-CDMA

- 1xEV-DO

- LTE

- LTE TDD

- DTMB (CMMB)

- DVB-T/H with T2

- ISDB-T

- CMMB

- Digital Cable TV

What are Baseband I/Q Inputs?

Option BBA consists of a Baseband Input module, four input connectors, and a calibration output connector. The connectors are at the left side of the front panel. The two ports labeled "I" and "Q" are the "unbalanced" inputs.

An unbalanced or "single-ended" baseband measurement of an I or Q signal is made using a probe connected to the I or Q connector. A simultaneous I/Q unbalanced single-ended measurement may be made using two probes connected to the I and Q input connectors.

If "balanced" signals are available, they may be used to make a more accurate measurement. Balanced signals are signals present in two separate conductors, are symmetrical about ground, and are opposite in polarity, or out of phase by 180 degrees.

Measurements using balanced signals can have a higher signal to noise ratio resulting in improved accuracy. Noise coupled into each conductor equally in a "common mode" to both signals may be separated from the signal. The measure of this separation is "common-mode rejection".

To make a balanced measurement, the two connectors labeled "I" and "Q" are used in conjunction with the I and Q inputs. The terms "I-bar" and "Q-bar" may be applied to the signals, as well as the inputs themselves. Probes (customer provided) must be used to input balanced baseband I/Q signals. This may be referred to as a balanced measurement.

Balanced baseband measurements are made using the I and connectors for I only signal measurements, while the Q and connectors are used for a Q only signal measurement. Balanced measurements of I/Q require differential probe connections to all four input connectors. For details of probe selection and use, refer to "Selecting Input Probes for Baseband Measurements" on page 149.

What are Baseband I/Q Signals?

In transmitters, the term baseband I/Q refers to signals that are the fundamental products of individual I/Q modulators, before the I and Q component signals are combined, and before upconversion to IF or RF frequencies.

In receivers, baseband I/Q analysis may be used to test the I and Q products of I/Q demodulators, after a RF signal has been downconverted and demodulated.

Why Make Measurements at Baseband?

Baseband I/Q measurements are a valuable means of making qualitative analyses of the following operating characteristics:

- I/Q signal layer access for performing format-specific demodulation measurements (for example, ISDB-T, CMMB, W-CDMA).

- Modulation accuracy – that is,. I/Q plane metrics:

  — error vector magnitude; rms, peak

  — frequency error

  — magnitude and phase errors

- CCDF of $I^2 + Q^2$

- Basic analysis of I and Q signals in isolation including: DC content, rms and peak to peak levels, CCDF of each channel

Comparisons of measurements made at baseband and RF frequencies produced by the same device are especially revealing. Once signal integrity is verified at baseband, impairments can be traced to specific stages of upconversion, amplification, or filtering by RF analysis. In addition, impairments to signal quality that are apparent at RF frequencies may be traceable to baseband using baseband analysis.

Selecting Input Probes for Baseband Measurements

The selection of baseband measurement probe(s) and measurement method is primarily dependent on the location of the measurement point in the circuit. The probe must sample voltages without imposing an inappropriate load on the circuit.

The system supports a variety of 1 MΩ impedance input passive probes as well as the Agilent 1153A active differential probe using the InfiniMax probe interface.

The Agilent 1153A active probe can be used for both single-ended and differential measurements. In either case a single connection is made for each channel (on either the I or Q input). The input is automatically configured to 50 Ω single-ended type measurement and the probe power is supplied through the InfiniMax interface. The probe can be configured for a variety of input coupling and low frequency rejection modes. In addition, a wide range of offset voltages and probe attenuation accessories are supported at the probe interface. The active probe has the advantage that it does not significantly load the circuit under test, even with unity gain probing.

With passive 1 MΩ probes, the probe will introduce a capacitive load on the circuit, unless a higher attenuation is used at the probe interface. Higher attenuation helps isolate the probe, however, it reduces the signal level and degrades the signal-to-noise-ratio of the measurement. Passive probes are available with a variety of attenuation values for a moderate cost. Many Agilent passive probes can be automatically identified by the system, setting the input impedance required as well as the nominal attenuation. For single-ended measurements a single probe is used for each channel. Other passive probes can be used, after manually setting the attenuation and probe impedance configurations.

For full differential measurements, the system supports probes on each of the four inputs. The attenuation for each of the probes should be the same for good common mode rejection and channel match.

Supported Probes

The following table lists the probes currently supported by Option BBA:

Probe Type	Model Number	Description
Active	1130A	1.5 GHz differential probe amp (No probe head)
	1131A[a]	InfiniMax 3.5 GHz probe
	1132A[a]	InfiniMax 5 GHz probe
	1133A[a]	InfiniMax 7 GHz probe
Passive	1161A	Miniature passive probe, 10:1, 10 MΩ, 1.5 m

a. Probe heads are necessary to attach to your device properly. Probe con-
nectivity kits such as the E2668A, E2669A or E2675A are needed. For
more details, refer to the Agilent probe configuration guide, 5968-7141EN
and 5989-6162EN.

Probes without Stored Calibration

The following 115xA active probes may be used with the MXA's baseband IQ inputs
and may use the same probe calibration utility software. However, the probe
calibration data is not stored in the MXA and will be lost if power is cycled. Use of the
E2655B de-skew and calibration kit, including the calibration fixture, is required
because of the different physical configuration of the probes. (The physical
connections are different mechanically, not electrically.)

Probe Type	Model Number	Description
Active	1153A	200MHz differential probe
	1156A	Active probe, 1.5 GHz
	1157A	Active probe, 2.5 GHz
	1158A	Active probe, 4 GHz

Refer to the current Agilent probe data sheet for specific information regarding
frequency of operation and power supply requirements.

Baseband I/Q Measurement Views

Measurement result views made in the IQ Analyzer (Basic) mode are available for
baseband signals if they relate to the nature of the signal itself. Many measurements
which relate to the characteristics that baseband I and Q signals have when mixed and
upconverted to signals in the RF spectrum can be made as well. However,
measurements which relate to the characteristics of an upconverted signal that lie
beyond the bandwidth available to the Baseband I/Q Input circuits can not be
measured (the limits are dependent on the installed options: Standard — 10 Hz to 20
MHz, Option B25 — 10 Hz to 50 MHz, and Option S40 — 10 Hz to 80 MHz).

At RF frequencies, power measurements are conventionally displayed on a logarithmic
vertical scale in dBm units, whereas measurements of baseband signals using
Baseband I/Q inputs may be conveniently displayed as voltage using a linear vertical
scale as well as a log scale.

Spectrum Views and 0 Hz Center Frequency

To view the Spectrum display of I only or Q only signals, use the Complex Spectrum
measurement capability in IQ Analyzer (Basic) Mode.

I only and Q only Spectrum views are conventional, displayed with 0 Hz at the left side
of the horizontal axis. When upconverted or multiplied, an I only or Q only signal could
ultimately lie above or below the carrier center frequency, but in either case it will only
occupy half the bandwidth.

Waveform Signal Envelope Views of I only or Q only

To view the Signal Envelope display of I only or Q only signals, use the Waveform measurement capability in IQ Analyzer (Basic) Mode.

The I and Q Waveform of an I/Q signal is very different from the complex signal displayed in the RF Envelope view. That is because the RF Envelope is a product of both the I and Q modulation waveforms.

However, an I and Q Waveform measurement of an I only or Q only signal is exactly the same signal displayed in the RF Envelope view. That is because an I only or Q only waveform determines the I only or Q only signal envelope. Thus, the RF Envelope view can be used to measure an I only or Q only waveform directly.

Other Sources of Measurement Information

Additional measurement application information is available through your local Agilent Technologies sales and service office. The following application notes treat digital communications measurements in much greater detail than discussed in this section.

- Application Note

    3GPP Long Term Evolution: System Overview, Product Development, and Test Challenges
    Agilent part number 5989-8931EN

- N9080A LTE Measurement Application - Technical Overview with Self-Guided Demonstration
    Agilent part number 5989-6537EN

- Technical Overview

    Agilent Technologies Solutions for 3GPP LTE
    Agilent part number 5989-6133EN

- Application Note 1298

    Digital Modulation in Communications Systems - An Introduction
    Agilent part number 5965-7160E

- Application Note

    Characterizing Digitally Modulated Signals with CCDF Curves
    Agilent part number 5968-5858E

- Application Note

    HSDPA RF Measurements for User Equipment
    Agilent part number 5989-4099EN

- For more information about the 3GPP and LTE specifications visit 3GPP home page http://www.3gpp.org/

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

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

Instrument Updates at www.agilent.com

These web locations can be used to access the latest information about the instrument, including the latest firmware version.

http://www.agilent.com/find/pxa
http://www.agilent.com/find/mxa
http://www.agilent.com/find/exa

List of Acronyms

3G 3rd Generation

3GPP 3rd Generation Partnership Project

ACLR Adjacent channel leakage ratio

ACPR Adjacent channel power ratio

ACS Adjacent channel selectivity

ADS Advanced Design System

AMC Adaptive modulation and coding

A-MPR Additional maximum power reduction

ARQ Automatic repeat request

BCCH Broadcast control channel

BTS Base transceiver station

CDD Cyclic delay diversity

CCDF Complementary cumulative distribution function

CDMA Code division multiple access

CFI Control format indicator

Co-MIMO Cooperative MIMO

CP Cyclic prefi x

CPICH Common pilot channel

CPRI Common public radio interface

CQI Channel quality indicator

CRC Cyclic redundancy check

DCI Downlink control indicator

DFT Discrete Fourier transform

DFT-SOFDM Discrete Fourier transform spread OFDM

DL Downlink (base station to subscriber transmission)

DL-SCH Downlink shared channel

D-PHY 500 Mbps physical layer

DSP Digital signal processing

DT Development toolset

DVSA Digital vector signal analysis

EDA Electronic design automation

E-DCH Enhanced dedicated channel

E-UTRAN Evolved UMTS terrestrial radio access network

eMBMS Evolved multimedia broadcast multicast service

eNB Evolved Node B

EPC Evolved packet core

EPRE Energy per resource element

ETSI European Telecommunications Standards Institute

E-UTRA Evolved UTRA

E-UTRAN Evolved UTRAN

EVM Error vector magnitude

FDD Frequency division duplex

FFT Fast Fourier transform

FRC Fixed reference channel

FS1 Frame structure type 1

FS2 Frame structure type 2

GSM Global system for mobile communication

HARQ Hybrid automatic repeat request

HDL Hardware description language

HI HARQ indicator

HSDPA High speed downlink packet access

HSPA High speed packet access

HSUPA High speed uplink packet access

IFFT Inverse FFT

IOT Interoperability test

IP Internet protocol

LO Local oscillator

LTE Long term evolution

MAC Medium access control

MBMS Multimedia broadcast multicast service

MBSFN Multicast/broadcast over single-frequency network

MCH Multicast channel

MIMO Multiple input multiple output

MISO Multiple input single output

MME Mobility management entity

MOP Maximum output power

MPR Maximum power reduction

MU-MIMO Multiple user MIMO

NAS Non-access stratum

OBSAI Open base station architecture interface

OFDM Orthogonal frequency division multiplexing

OFDMA Orthogonal frequency division multiple access

PAPR Peak-to-average power ratio

PAR Peak-to-average ratio

PBCH Physical broadcast channel

P-CCPCH Primary common control physical channel

PCFICH Physical control format indicator channel

PCH Paging channel

PDCCH Physical downlink control channel

PDCP Packet data convergence protocol

PDSCH Physical downlink shared channel

PHICH Physical hybrid ARQ indicator channel

PHY Physical layer

PRACH Physical random access channel

PMCH Physical multicast channel

PMI Pre-coding matrix indicator

P-SCH Primary synchronization signal

PUCCH Physical uplink control channel

PUSCH Physical uplink shared channel

QAM Quadrature amplitude modulation

QPSK Quadrature phase shift keying

RACH Random access channel

RAT Radio access technology

RB Resource block

RF Radio frequency

RFDE RF design environment

RLC Radio link control

RMC Reference measurement channel

RNC Radio network controller

RRC Radio resource control

RRM Radio resource management

RS Reference signal

RSCP Received signal code power

RSRP Reference signal received power

RSRQ Reference signal received quality

RSSI Received signal strength indicator

SAE System architecture evolution

SAP Service access point

SC-FDMA Single carrier frequency division multiple access

SFBC Space-frequency block coding

S-GW Serving gateway

SIMO Single input multiple output

SISO Single input single output

SNR Signal-to-noise ratio

SRS Sounding reference signal

S-SCH Secondary synchronization signal

SU-MIMO Single user MIMO

TDD Time division duplex

TDMA Time division multiple access

TR Technical report

TrCH Transport channel

TS Technical specifi cation

TTA Telecommunications Technology Association

TTI Transmission time interval

UCI Uplink control indicator

UE User equipment

UL Uplink (subscriber to base station transmission)

UL-SCH Uplink shared channel

UMB Ultra-mobile broadband

UMTS Universal mobile telecommunications system

UTRA Universal terrestrial radio access

UTRAN Universal terrestrial radio access network

VSA Vector signal analyzer

W-CDMA Wideband code division multiple access

References

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http://www.3gpp.org/ftp/Specs/html-info/25913.htm

3. "Long Term Evolution of the 3GPP radio technology"
http://www.3gpp.org/Highlights/LTE/LTE.htm.

4. 3GPP TR 23.882 V1.15.0 (2008-02)
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