

Agilent X-Series Signal Analyzer

**This manual provides documentation for the
for the following analyzers:**

**MXA Signal Analyzer N9020A
EXA Signal Analyzer N9010A**

N9080A LTE Measurement Application Measurement Guide



Agilent Technologies

Notices

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<http://www.agilent.com/find/mxa>

<http://www.agilent.com/find/exa>

To receive the latest updates by email, subscribe to Agilent Email Updates:

<http://www.agilent.com/find/emailupdates>

Information on preventing analyzer damage can be found at:

<http://www.agilent.com/find/tips>

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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) signal analyzers
- Monitor Spectrum measurement for viewing signal spectrum

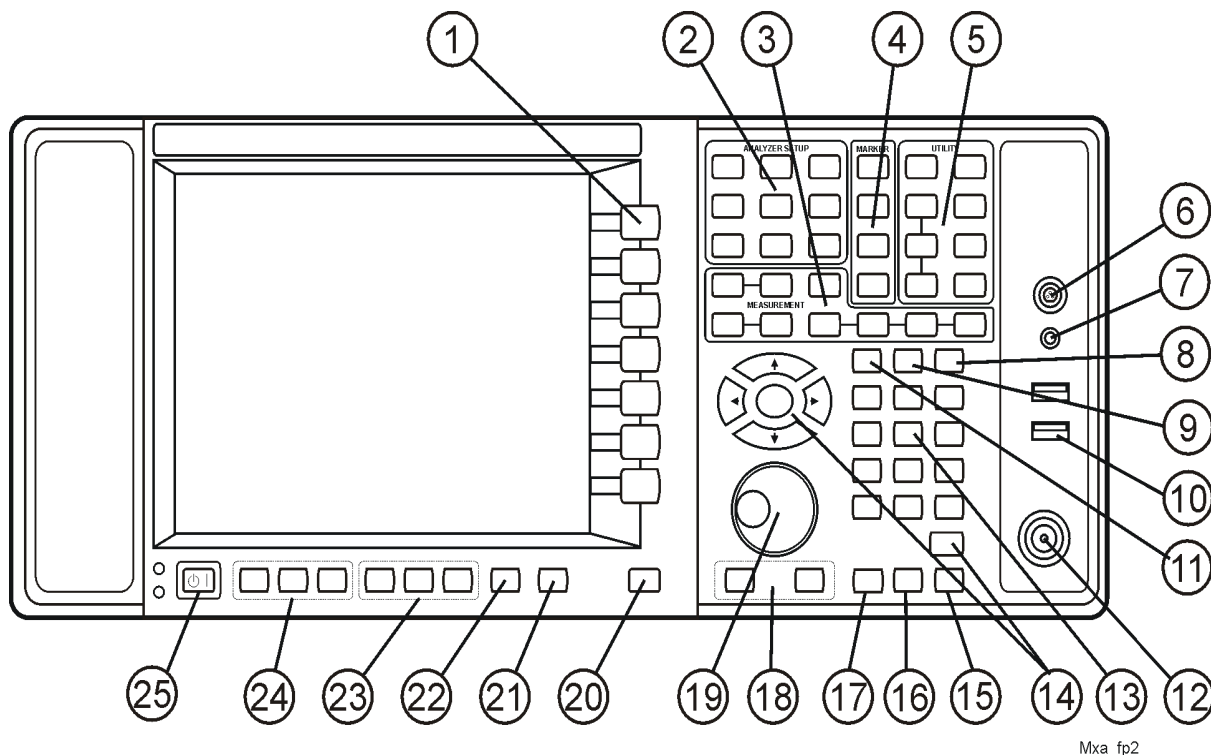
The N9080A 1FP LTE measurement application supports the following standards:

- 3GPP TS 36.101 V8.1.0 (2008-03)
- 3GPP TS 36.104 V8.1.0 (2008-03)
- 3GPP TS 36.211 V8.2.0 (2008-03)
- 3GPP TS 36.212 V8.2.0 (2008-03)
- 3GPP TS 36.213 V8.2.0 (2008-03)

- “Front Panel Features” on page 10
- “Display Annotations” on page 14
- “Rear-Panel Features” on page 16
- “Front and Rear Panel Symbols” on page 18

Front Panel Features

Front-Panel Connectors and Keys



Mxa_fp2

Item		Description
#	Name	
1	Menu Keys	Key labels appear to the left of the menu keys to identify the current function of each key. The displayed functions are dependent on the currently selected Mode and Measurement, and are directly related to the most recent key press.
2	Analyzer Setup Keys	These keys set the parameters used for making measurements in the current Mode and Measurement.
3	Measurement Keys	These keys select the Mode, and the Measurement within the mode. They also control the initiation and rate of recurrence of measurements.
4	Marker Keys	Markers are often available for a measurement, to measure a very specific point/segment of data within the range of the current measurement data.

Item		Description
#	Name	
5	Utility Keys	<p>These keys control system-wide functionality like:</p> <ul style="list-style-type: none"> • instrument configuration information and I/O setup, • printer setup and printing, • file management, save and recall, • instrument presets.
6	Probe Power	Supplies power for external high frequency probes and accessories.
7	Headphones Output	Headphones can be used to hear any available audio output.
8	Back Space Key	Press this key to delete the previous character when entering alphanumeric information. It also works as the Back key in Help and Explorer windows.
9	Delete Key	Press this key to delete files, or to perform other deletion tasks.
10	USB Connectors	Standard USB 2.0 ports, Type A. Connect to external peripherals such as a mouse, keyboard, DVD drive, or hard drive.
11	Local/Cancel/(Esc) Key	<p>If you are in remote operation, Local:</p> <ul style="list-style-type: none"> • returns instrument control from remote back to local (the front panel). • turns the display on (if it was turned off for remote operation). • can be used to clear errors. (Press the key once to return to local control, and a second time to clear error message line.) <p>If you have not already pressed the units or Enter key, Cancel exits the currently selected function without changing its value.</p> <p>Esc works the same as it does on a pc keyboard. It:</p> <ul style="list-style-type: none"> • exits Windows dialogs • clears errors • aborts printing • cancels operations.
12	RF Input	Connector for inputting an external signal. Make sure that the total power of all signals at the analyzer input does <i>not</i> exceed +30 dBm (1 watt).
13	Numeric Keypad	Enters a specific numeric value for the current function. Entries appear on the upper left of the display, in the measurement information area.
14	Enter and Arrow Keys	<p>The Enter key terminates data entry when either no unit of measure is needed, or you want to use the default unit.</p> <p>The arrow keys:</p> <ul style="list-style-type: none"> • Increment and decrement the value of the current measurement selection. • Navigate help topics. • Navigate, or make selections, within Windows dialogs. • Navigate within forms used for setting up measurements. • Navigate within tables. <hr/> <p>NOTE The arrow keys cannot be used to move a mouse pointer around on the display.</p> <hr/>

The function label of the active function is highlighted after that key has been selected. For example, press **AMPTD Y Scale**. This calls up the menu of related amplitude functions. Note the function labeled **Reference Level** (the default selected key in the Amplitude menu) is highlighted. **Reference Level** also appears in the upper left of the display in the measurement information area. The displayed value indicates that the function is selected and its value can now be changed using any of the data entry controls.

Some menu keys have multiple choices on their label like On/Off or Auto/Man. The different choices are selected by pressing the key multiple times. Take an Auto/Man type of key as an example. To select the function, press the menu key and notice that Auto is underlined and the key becomes highlighted. To change the function to manual, press the key again so that Man is underlined. If there are more than two settings on the key, keep pressing it until the desired selection is underlined.

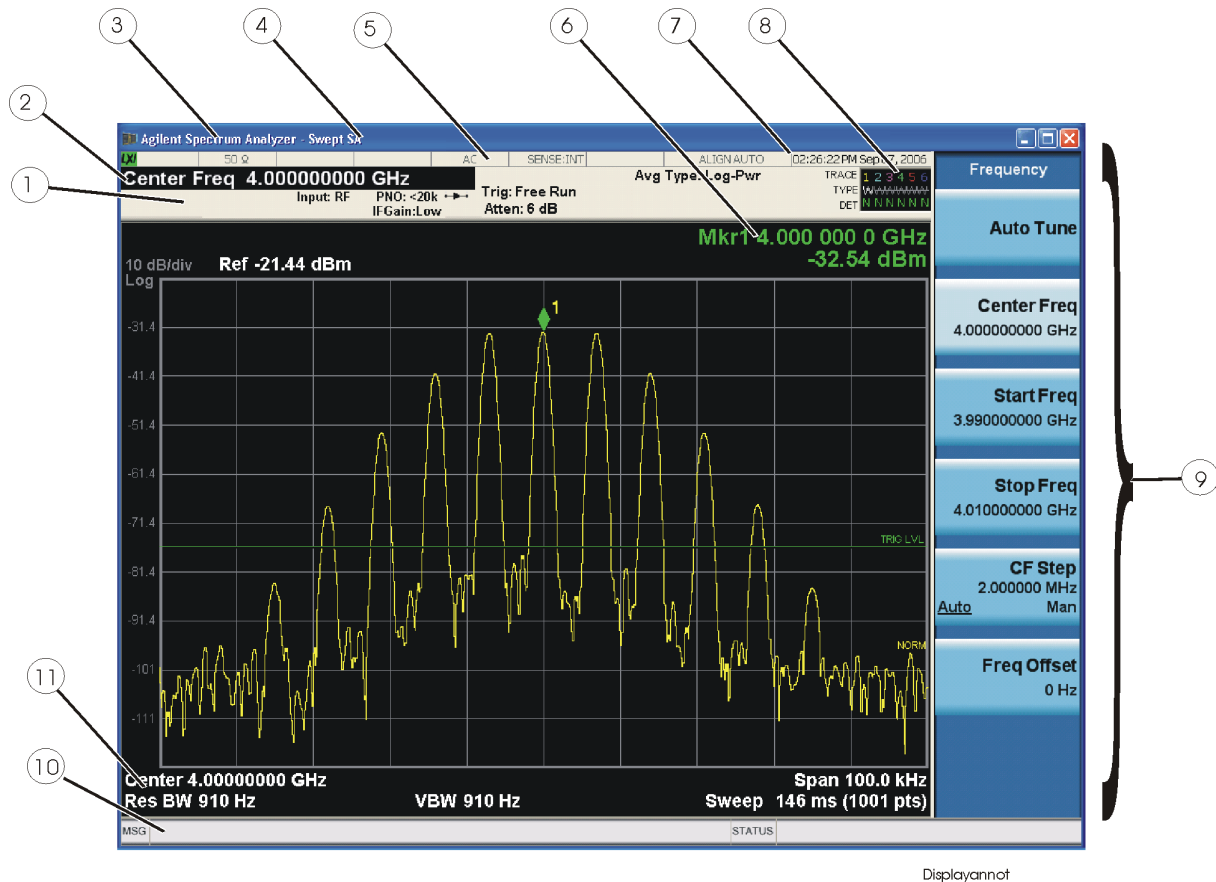
When a menu first appears, one key label will be highlighted to show which key is the default selection. If you press **Marker Function**, the **Marker Function Off** key is the menu default key, and it will be highlighted. Some of the menu keys are grouped together by a yellow bar running behind the keys near the left side or by a yellow border around the group of keys. When you press a key within the yellow region, such as **Marker Noise**, the highlight will move to that key to show it has been selected. The keys that are linked are related functions, and only one of them can be selected at any one time. For example, a marker can only have one marker function active on it. So if you select a different function it turns off the previous selection. If the current menu is two pages long, the yellow bar or border could include keys on the second page of keys.

In some key menus, a key label will be highlighted to show which key has been selected from multiple available choices. And the menu is immediately exited when you press one of the other keys. For example, when you press the **Select Trace** key (in the **Trace/Detector** menu), it will bring up its own menu of keys. The **Trace 1** key will be highlighted. When you press the **Trace 2** key, the highlight moves to that key and the screen returns to the **Trace/Detector** menu.


If a displayed key label shows a small solid-black arrow tip pointing to the right, it indicates that additional key menus are available. If the arrow tip is not filled in solid then pressing the key the first time selects that function. Now the arrow is solid and pressing it again will bring up an additional menu of settings.

Display Annotations

This section describes the display annotation as it is on the Spectrum Analyzer Measurement Application display. Other measurement application modes will have some annotation differences.

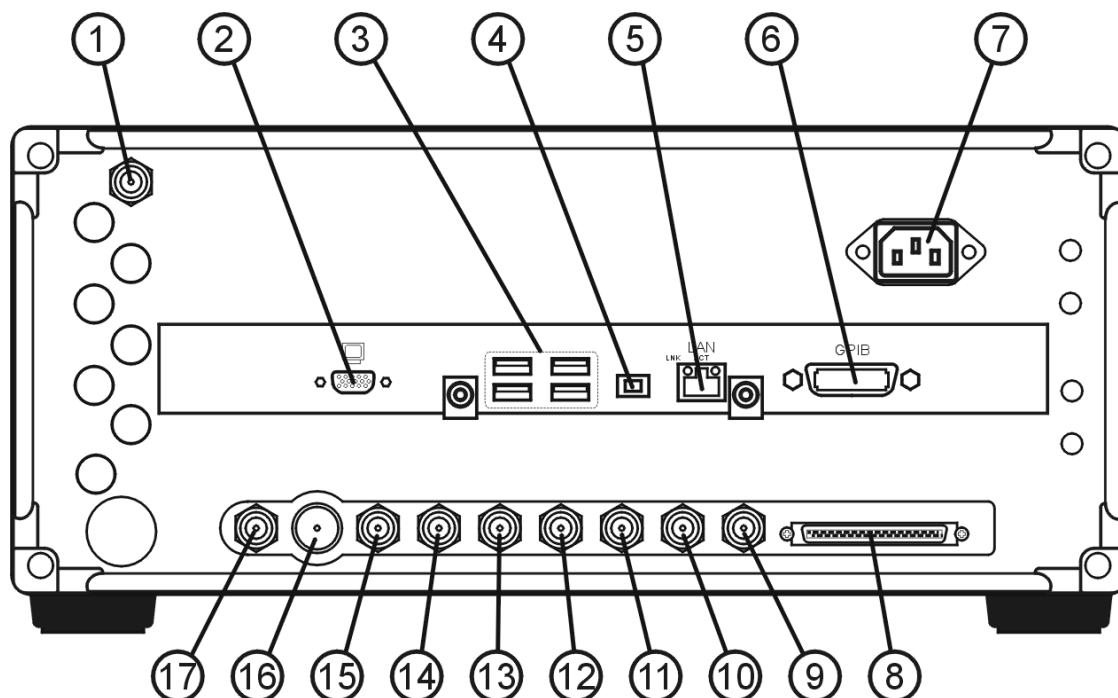


Displayannot

Item	Description	Function Keys
1	Measurement bar - Shows general measurement settings and information.  Indicates single/continuous measurement. Some measurements include limits that the data is tested against. A Pass/Fail indication may be shown in the lower left of the measurement bar.	All the keys in the Analyzer Setup part of the front panel.
2	Active Function (measurement bar) - when the current active function has a settable numeric value, it is shown here.	Currently selected front panel key.

Item	Description	Function Keys
3	Banner - shows the name of the selected measurement application and the measurement that is currently running.	Mode, Meas
4	Measurement title (banner) - shows title information for the current Measurement, or a title that you created for the measurement.	Meas View/Display, Display, Title
5	Settings panel - displays system information that is not specific to any one application. <ul style="list-style-type: none"> • Input/Output status - green LXI indicates the LAN is connected. RLTS indicate Remote, Listen, Talk, SRQ • Input impedance and coupling • Selection of external frequency reference • Setting of automatic internal alignment routine 	Local and System, I/O Config Input/Output, Amplitude, System and others
6	Active marker frequency, amplitude or function value	Marker
7	Settings panel - time and date display.	System, Control Panel
8	Trace and detector information	Trace/Detector, Clear Write (W) Trace Average (A) Max Hold (M) Min Hold (m) Trace/Detector, More, Detector, Average (A) Normal (N) Peak (P) Sample (S) Negative Peak (p)
9	Key labels that change based on the most recent key press.	Softkeys
10	Displays information, warning and error messages. Message area - single events, Status area - conditions	
11	Measurement settings for the data currently being displayed in the graticule area. In the example above: center frequency, resolution bandwidth, video bandwidth, frequency span, sweep time and number of sweep points.	Keys in the Analyzer Setup part of the front panel.

Rear-Panel Features



Mxa_rp2

Item		Description
#	Name	
1	EXT REF IN	Input for an external frequency reference signal: For MXA – 1 to 50 MHz For EXA – 10 MHz.
2	MONITOR	Allows connection of an external VGA monitor.
3	USB Connectors	Standard USB 2.0 ports, Type A. Connect to external peripherals such as a mouse, keyboard, printer, DVD drive, or hard drive.
4	USB Connector	USB 2.0 port, Type B. USB TMC (test and measurement class) connects to an external pc controller to control the instrument and for data transfers over a 480 Mbps link.
5	LAN	A TCP/IP Interface that is used for remote analyzer operation.
6	GPIB	A General Purpose Interface Bus (GPIB, IEEE 488.1) connection that can be used for remote analyzer operation.
7	Line power input	The AC power connection. See the product specifications for more details.
8	Digital Bus	Reserved for future use.

Item		Description
#	Name	
9	Analog Out	For use with the Analog Demod measurement application.
10	TRIGGER 2 OUT	A trigger output used to synchronize other test equipment with the analyzer. Configurable from the Input/Output keys.
11	TRIGGER 1 OUT	A trigger output used to synchronize other test equipment with the analyzer. Configurable from the Input/Output keys.
12	Sync	Reserved for future use.
13	TRIGGER 2 IN	Allows external triggering of measurements.
14	TRIGGER 1 IN	Allows external triggering of measurements.
15	Noise Source Drive +28 V (Pulsed)	For use with Agilent 346A, 346B, and 346C Noise Sources
16	SNS Series Noise Source	For use with Agilent N4000A, N4001A, N4002A Smart Noise Sources (SNS).
17	10 MHz OUT	An output of the analyzer internal 10 MHz frequency reference signal. It is used to lock the frequency reference of other test equipment to the analyzer.

Front and Rear Panel Symbols



This symbol is used to indicate power ON (green LED).



This symbol is used to indicate power STANDBY mode (yellow LED).



This symbol indicates the input power required is AC.

The instruction documentation symbol. The product is marked with this symbol when it is necessary for the user to refer to instructions in the documentation.



The CE mark is a registered trademark of the European Community.



The C-Tick mark is a registered trademark of the Australian Spectrum Management Agency.



This is a marking of a product in compliance with the Canadian Interference-Causing Equipment Standard (ICES-001).

This is also a symbol of an Industrial Scientific and Medical Group 1 Class A product (CISPR 11, Clause 4).



The CSA mark is a registered trademark of the Canadian Standards Association International.



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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 21](#)
- [“Modulation Analysis Measurements” on page 23](#)
- [“Monitor Spectrum Measurements” on page 61](#)

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.

Step	Action	Notes
1. Select and Set Up the Mode	a. Press Mode	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.
	b. Press a mode key, like Spectrum Analyzer, W-CDMA with HSDPA/HSUPA , or GSM/EDGE .	
	c. Press Mode Preset .	
	d. Press Mode Setup	
2. Select and Set Up the Measurement	a. Press Meas .	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.
	b. Select the specific measurement to be performed.	
	c. Press Meas Setup	

Setting Up and Making a Measurement

Step	Action	Notes
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.

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

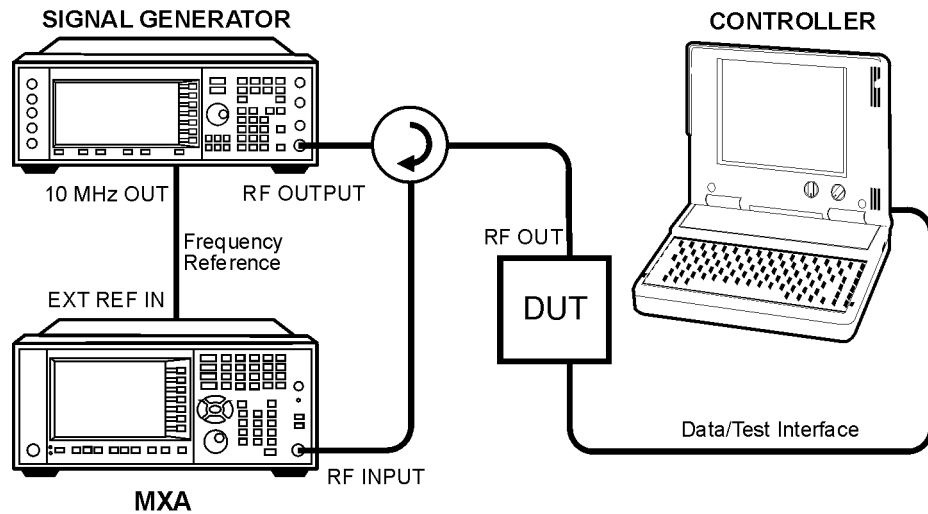
Modulation Analysis Measurements

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 3-1

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 Signal Studio N9624B 3GPP LTE (2008-03).

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

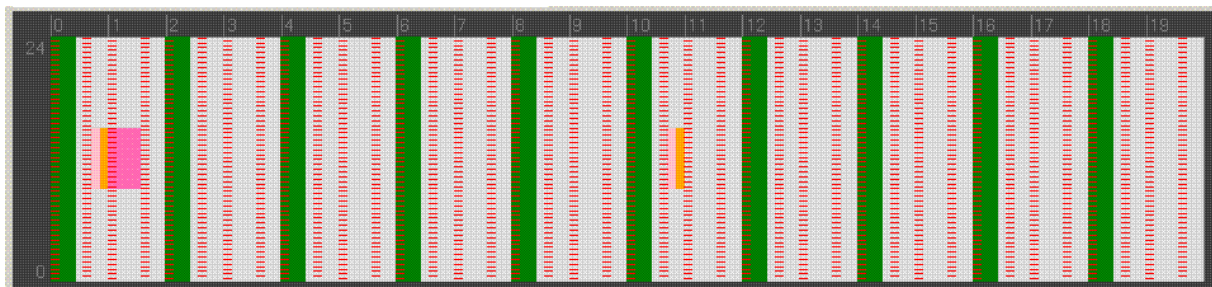
Physical Channels:

- 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 3-2 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 27](#)

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 54.](#)

Step 5. (Optional) Set Power Boost level if needed. The default value is 0 dB.

Press **Meas Setup, Chan Profile Setup, More, More, Edit User Mapping** to access the User Mapping table. For Downlink signals, adjustment of only the Power Boost setting may be required.

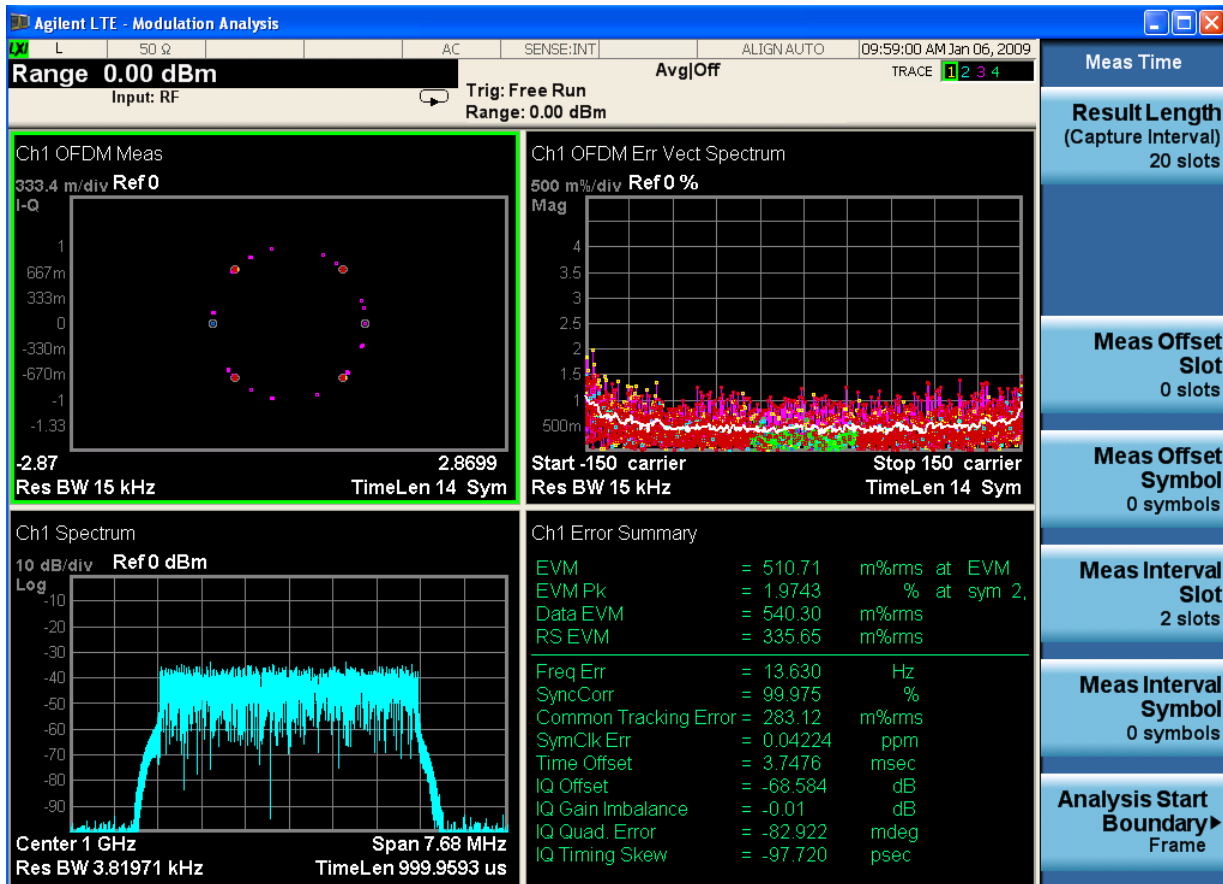
For more information on using the User Mapping table see: [“Downlink Measurement Procedure - RB Auto Detect Off” on page 27.](#)

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.

Your measurement result should like [Figure 3-6 on page 31.](#)

Figure 3-3 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 7.** (Optional) You can now view different Preset Views to display measurement results. See [“Selecting Different Measurement Results Views”](#) on page 32.
- Step 8.** (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 38.
- Step 9.** (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 27

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 25.

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 54.

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, RB Auto Detect** to toggle RB Auto Detect to **Off**.

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

Modulation Analysis Measurements

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.

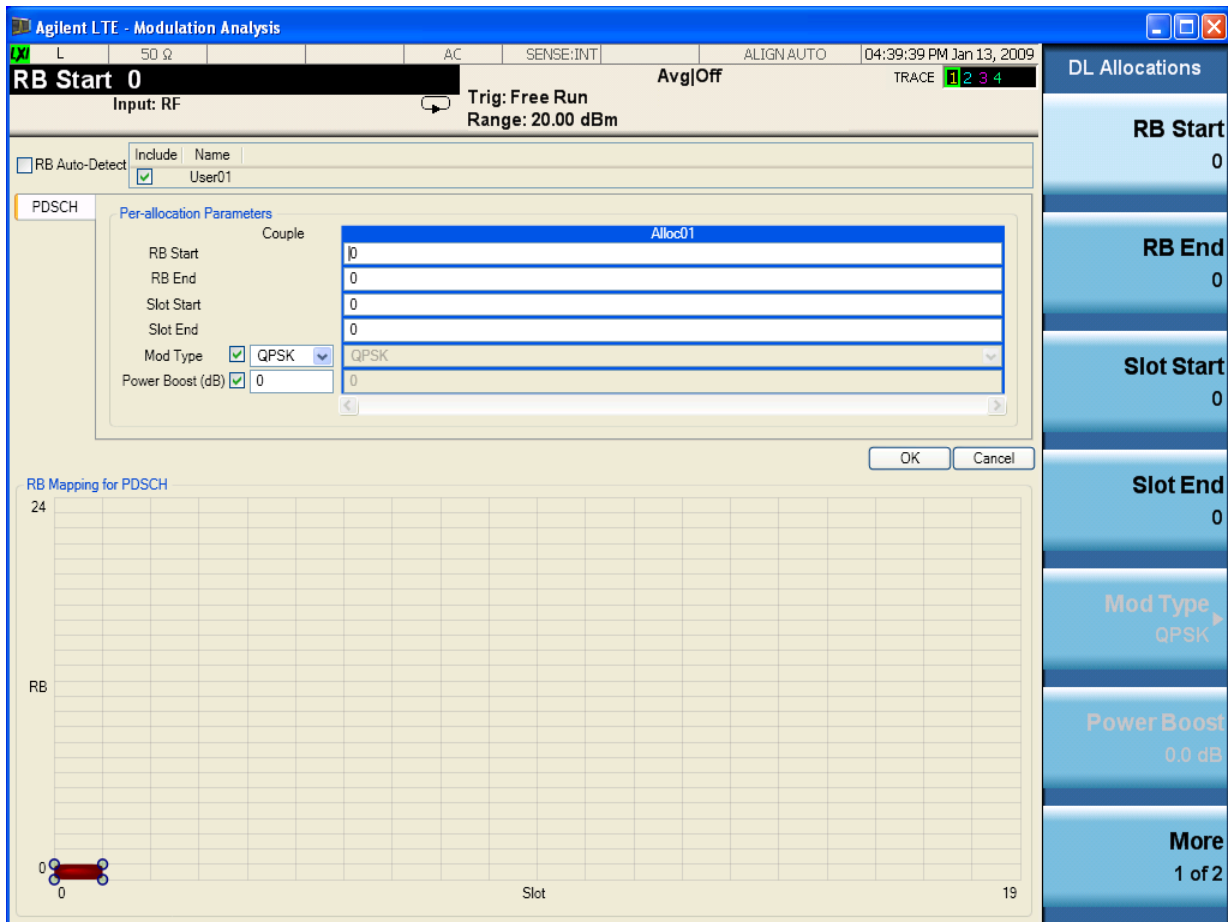
Step 12. Check the `Power Boost` checkbox, then select the power level using the pull-down menu. This example uses `0 dB`.

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 3-4 on page 29](#).

Figure 3-4 Editing User Mapping - Adding PDSCH Downlink Allocations



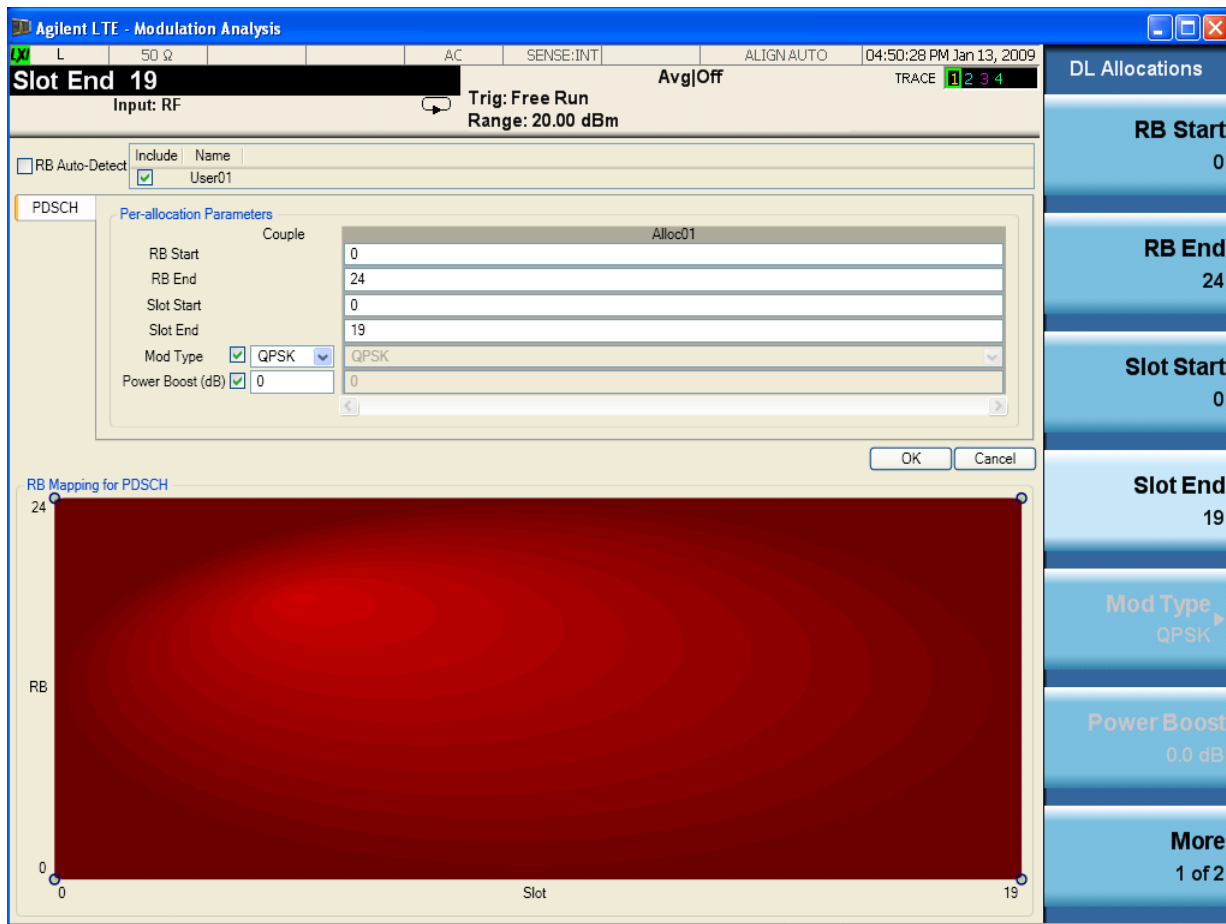
Step 15. Enter values for **RB Start**, **RB End**, **Slot Start**, and **Slot End**.

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 3-5 on page 30](#)

Figure 3-5 Editing User Mapping - Slots 0-19 Allocated for DL PDSCH



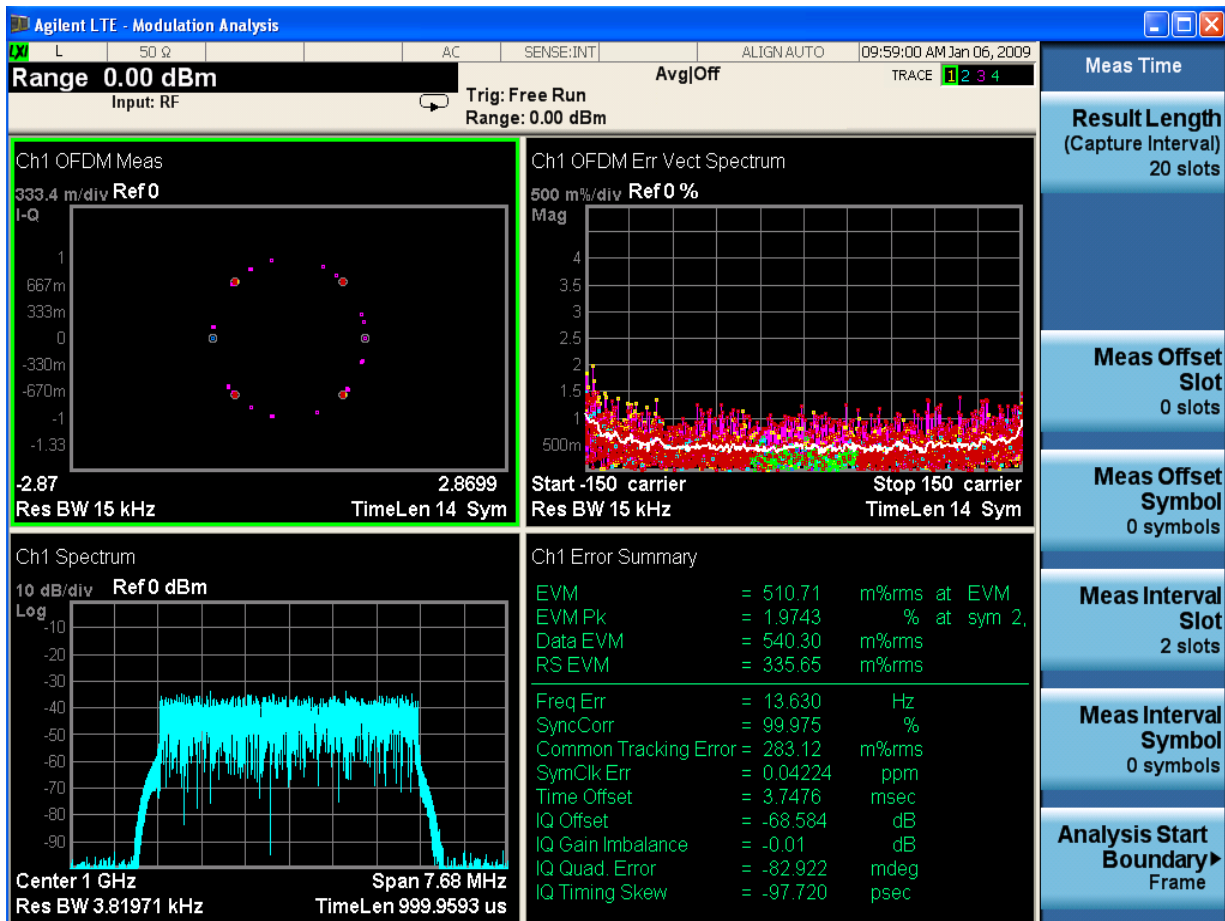
Step 16. Repeat Steps 11 through 15 as needed for all Users.

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

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

Step 18. Your measurement result should like [Figure 3-6 on page 31](#).

Figure 3-6 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 32](#).

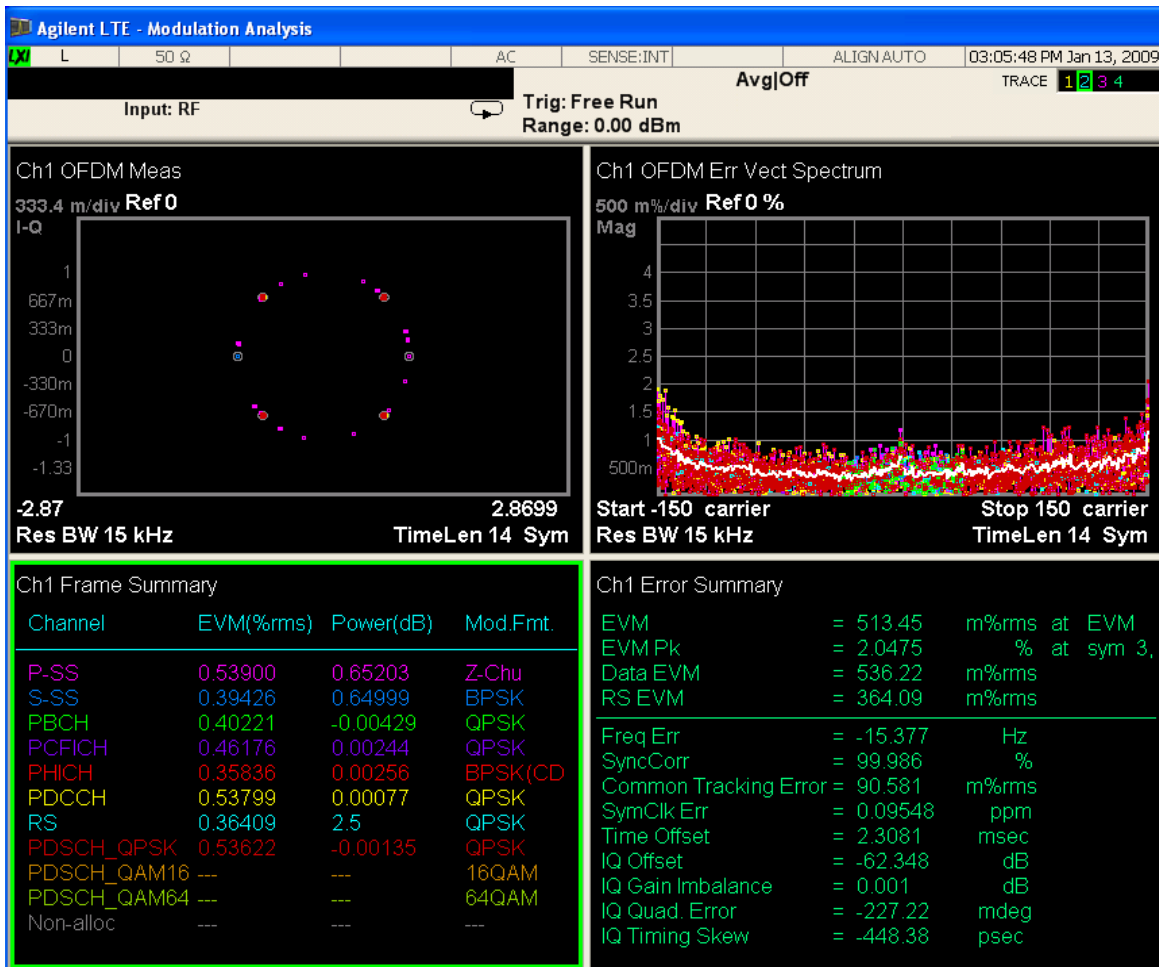
Modulation Analysis Measurements

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 3-7 LTE DL Example - Modified Preset View w/ Frame Summary



Your measurement result should look like [Figure 3-7](#).

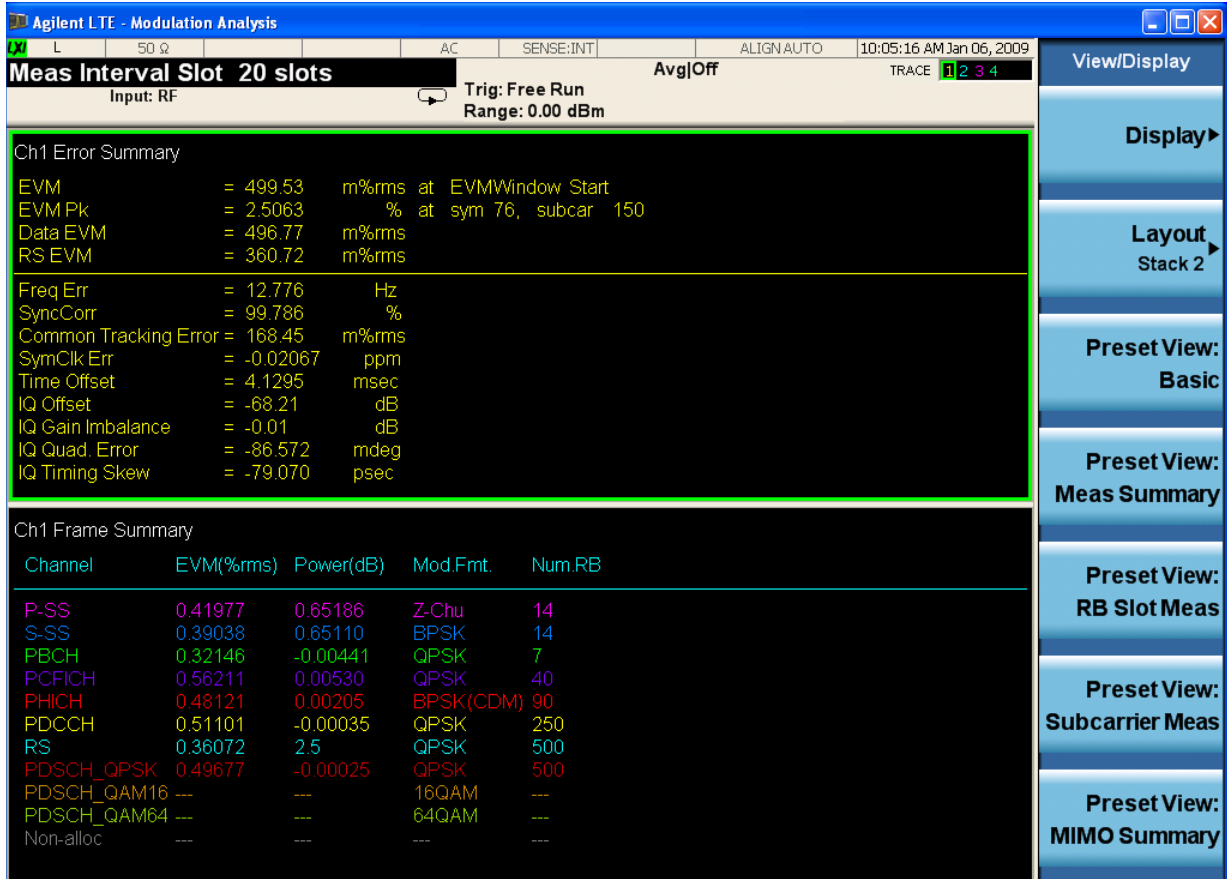
The Frame Summary shows all the signals and Channels in the signal. The colors used in the summary are keyed to the colors used in the display of constellation and EVM graph data.

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 3-8](#).

Figure 3-8 Modulation Analysis Measurement Result - Meas Summary Preset View

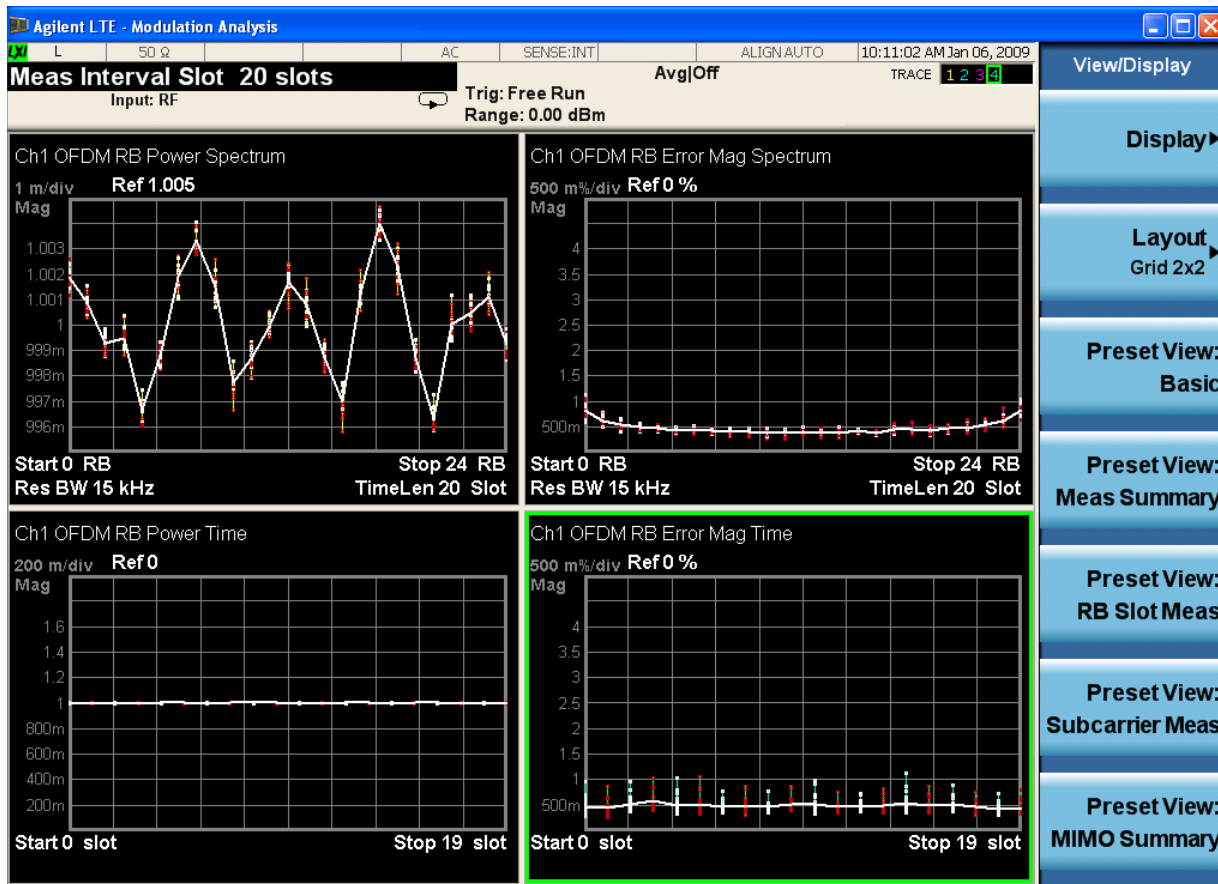


Modulation Analysis Measurements

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 3-9](#).

Figure 3-9 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.

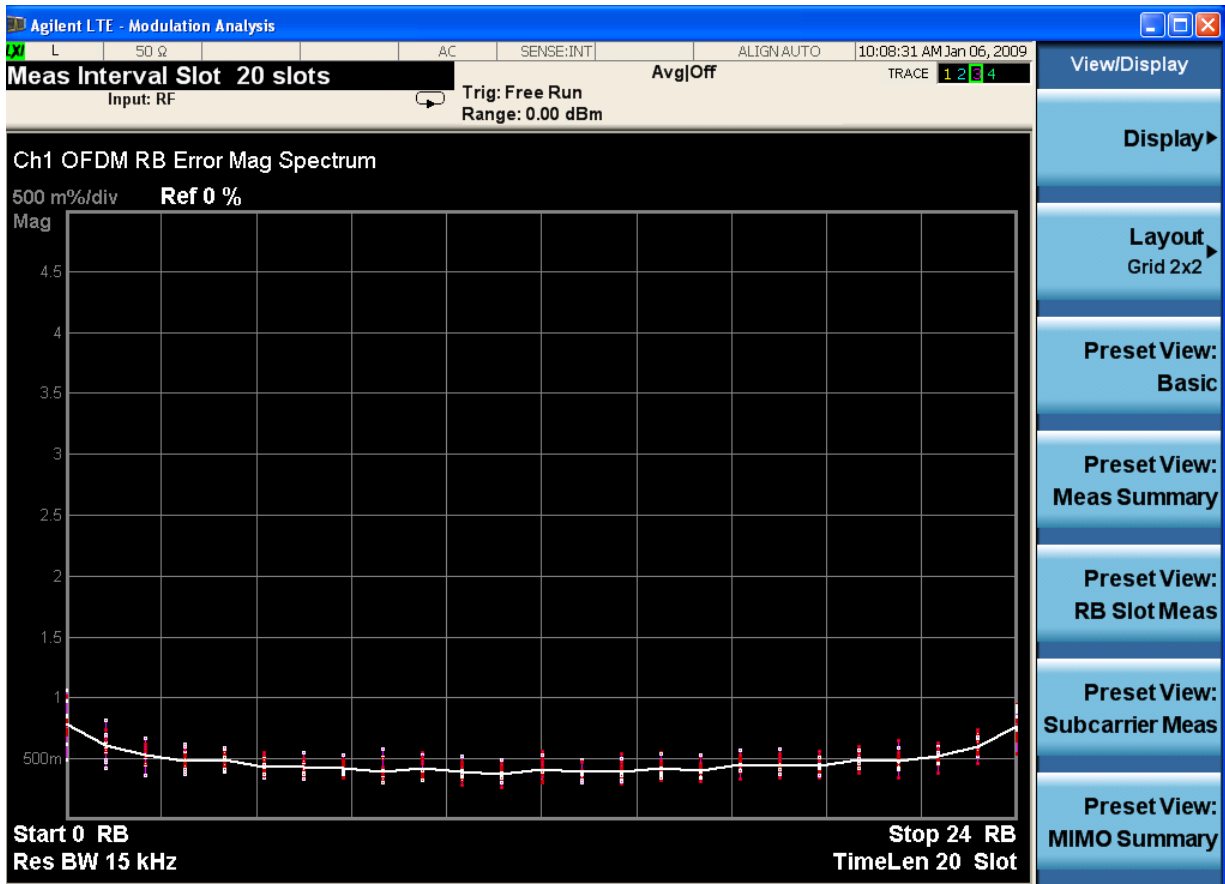
Step 5. You can Zoom to expand a window to full screen:

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 3-10](#).

Figure 3-10 Modulation Analysis Measurement Result - RB Error Mag Spectrum



TIP

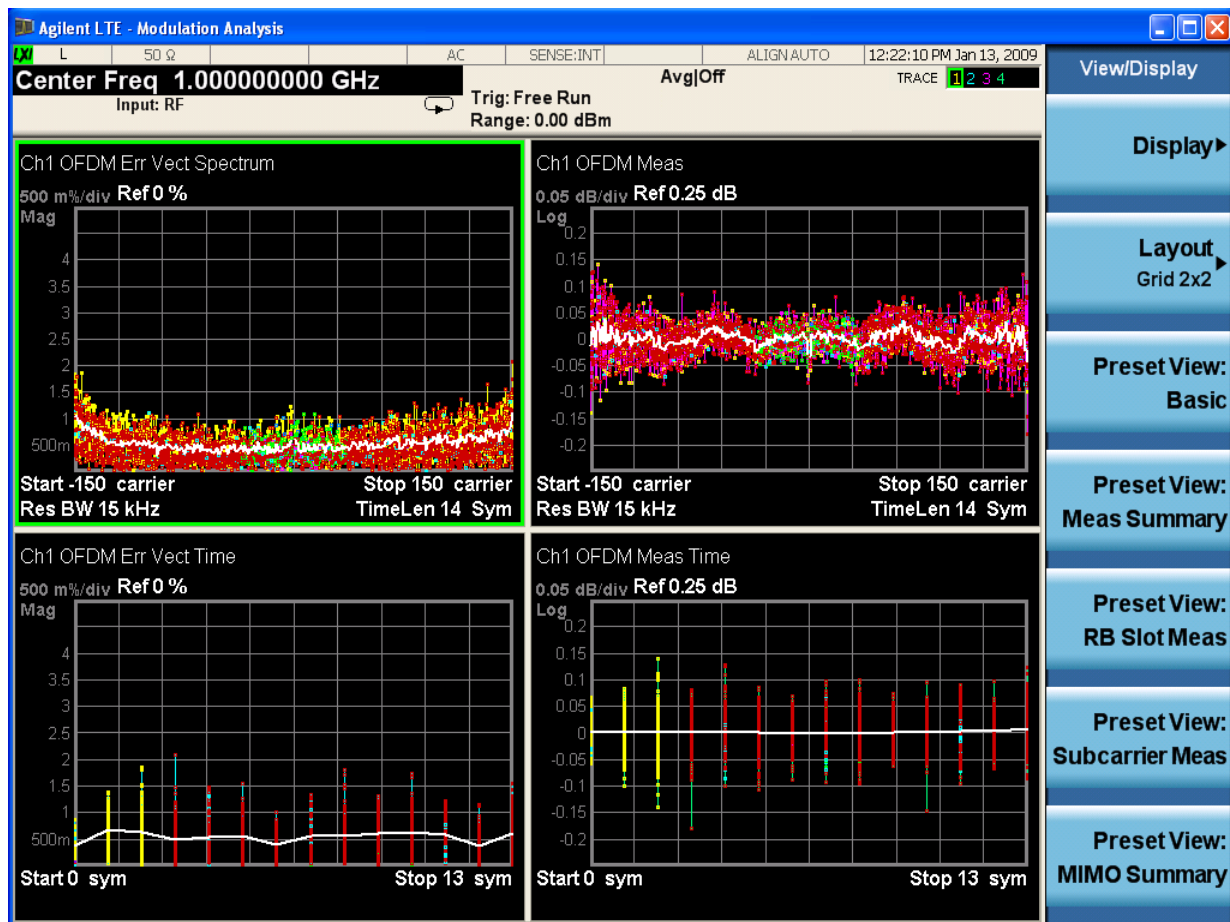
The RB Error Mag Spectrum graph is especially useful to determine whether there are any individual slots or RBs with excessive EVM.

Modulation Analysis Measurements

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 3-11](#).

Figure 3-11 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 3-12](#).

Figure 3-12 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 38.

Modulation Analysis Measurements

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.

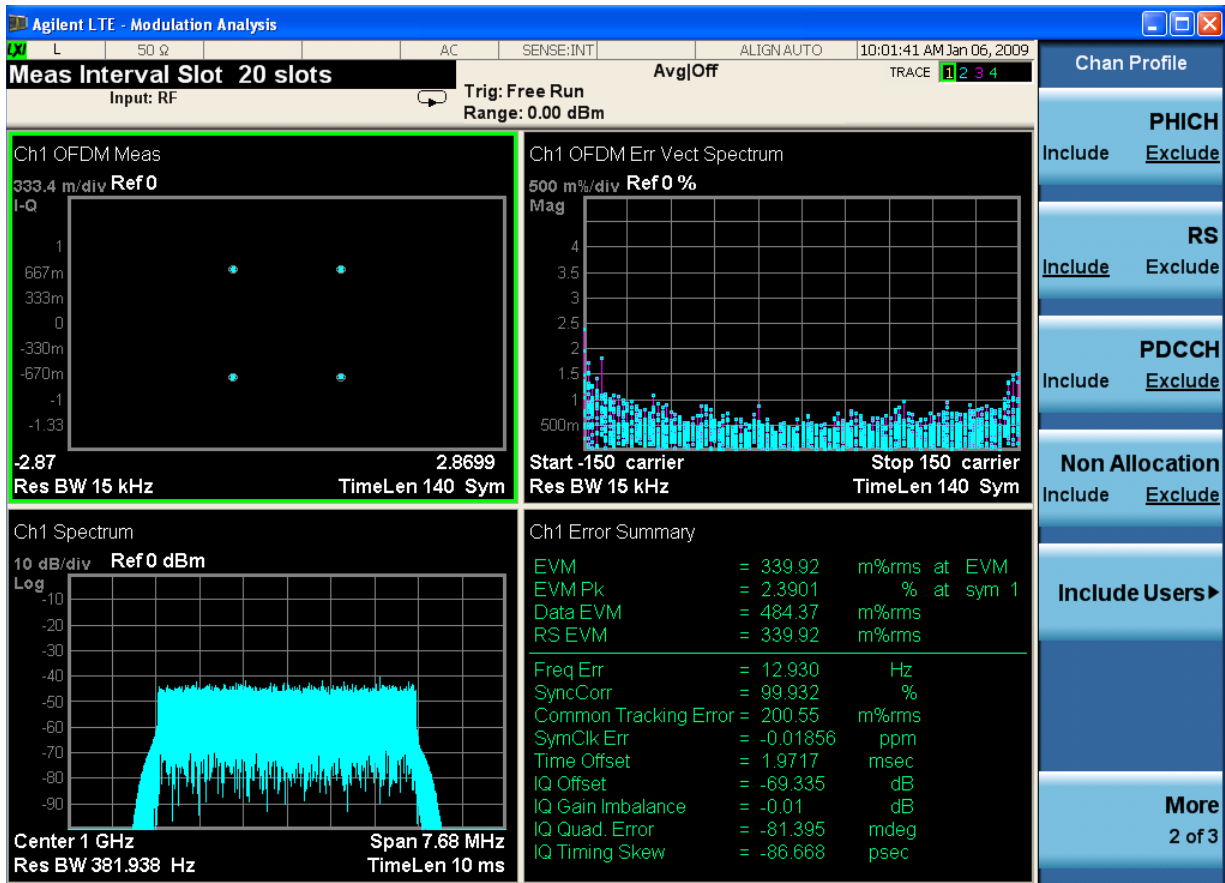
NOTE	PUSCH and PUCCH are analyzed separately. If your signal contains both, only one can be displayed at a time.
-------------	---

- 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 3-13](#).

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 3-13 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 Signal Studio N9624B 3GPP LTE (2008-03).

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

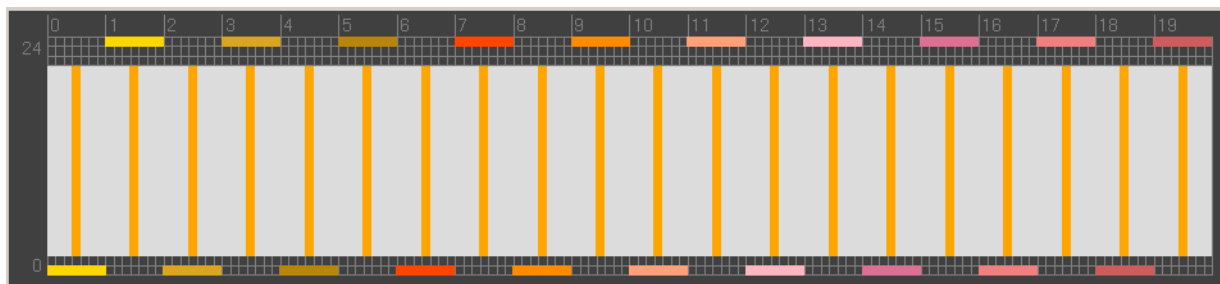
Physical Channels:

- 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 3-14 Signal Studio Uplink Setup Graphic Display



In [Figure 3-14](#) 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 54](#).

- 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 PUSCH or PUCCH Procedures:
 - [“Input UL PUSCH Parameters - RB Auto Detect On” on page 42.](#)
 - [“Input UL PUCCH Parameters - RB Auto Detect On” on page 45.](#)
 - [“Input UL PUSCH Parameters - RB Auto Detect Off” on page 48.](#)
 - [“Input UL PUCCH Parameters - RB Auto Detect Off” on page 50.](#)

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 select 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 48.

Step 1. Complete the initial procedure “[Common UL Setup Steps \(RB Auto Detect On or Off\)](#)” on page 41.

Step 2. 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 3. 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 4. 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**.

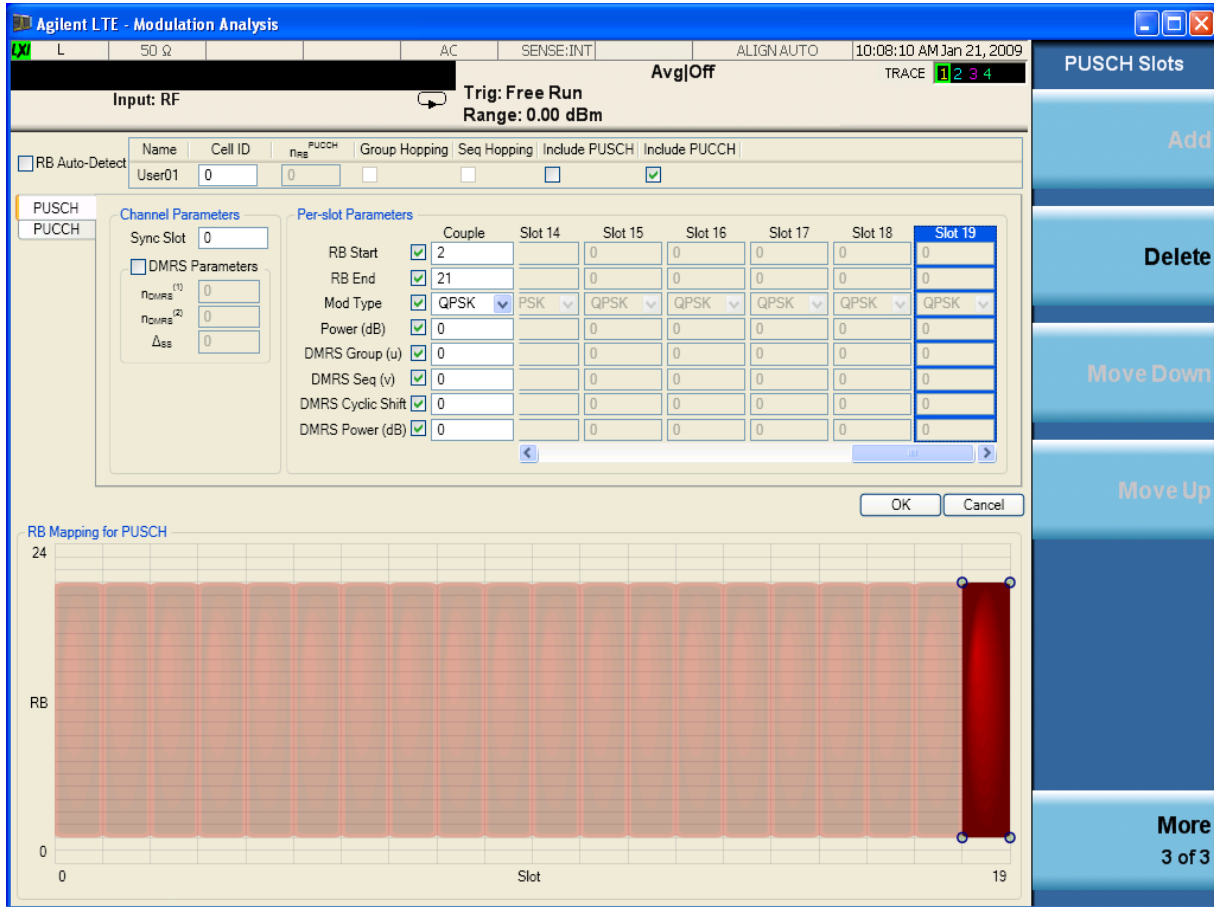
This example uses values of RB Start = 2, RB End = 21.

Step 5. 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 3-15](#) on page 43.

Figure 3-15 Editing Uplink User Mapping - PUSCH User01 RB Parameters



Step 6. Click OK to save the settings and exit the User Mapping table.

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

Step 7. (Optional) You can now view different Preset Views to display measurement results. See [“Selecting Different Measurement Results Views” on page 32](#).

Step 8. (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 38](#).

Step 9. (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 48](#)

TIP You can save your settings as a recallable State:

Modulation Analysis Measurements

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

NOTE

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 select 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 than one User in the signal, the measurement will provide a composite result of all Users. To analyze individual Users you must set **RB Auto Detect** to **Off** and manually set User Mapping allocations for all Users and Subframes. See: [“Input UL PUCCH Parameters - RB Auto Detect Off”](#) on page 50.

Step 1. Complete the initial procedure [“Common UL Setup Steps \(RB Auto Detect On or Off\)”](#) on page 41.

Step 2. 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 3. 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 4. 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 5. Set `Couple` values for the `Per Subframe Parameters`. This allows you to couple the values across all subframes for selected values.

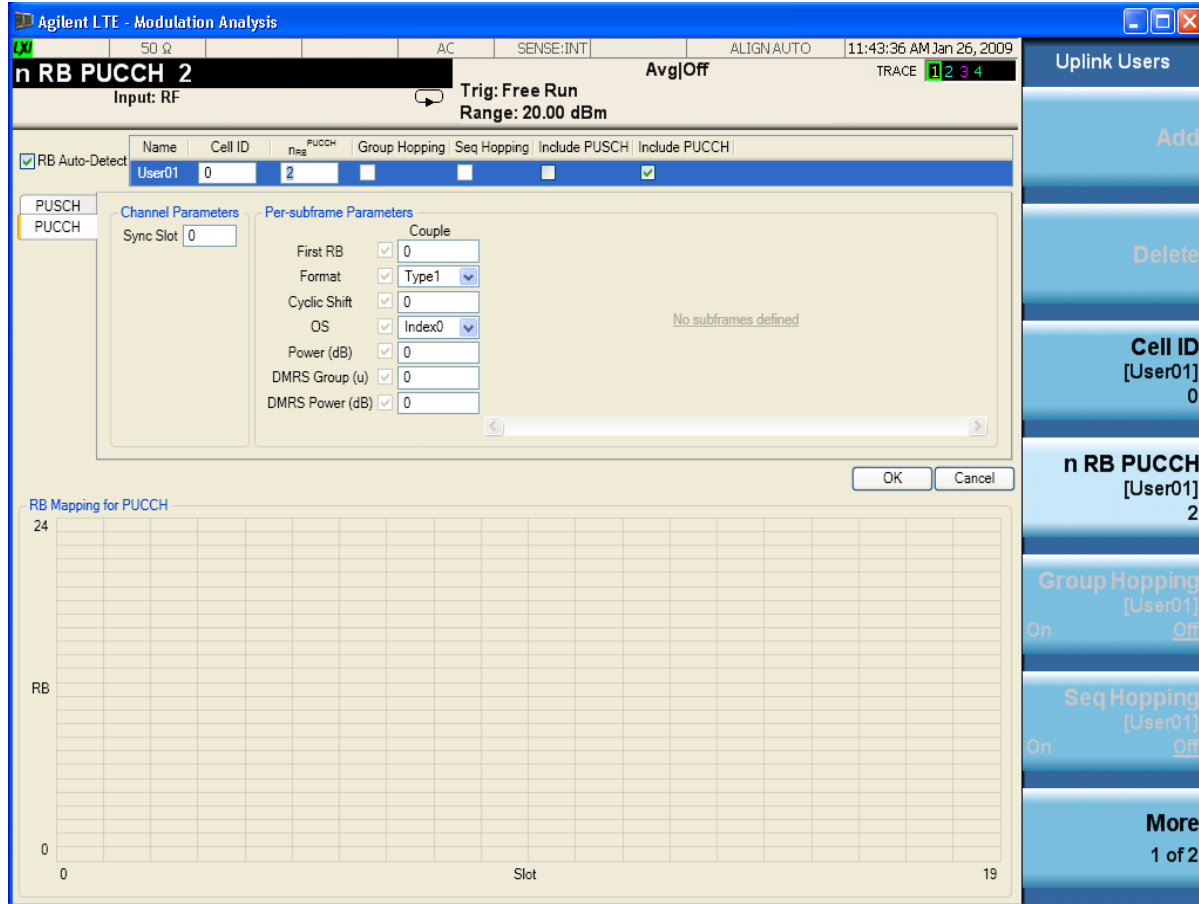
Select and enter values for **First RB, Cyclic Shift**, and all other necessary parameters, then press **Enter**.

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

Modulation Analysis Measurements

Step 6. The User Mapping table with all required PUCCH parameters set should like [Figure 3-16](#).

Figure 3-16 Editing Uplink User Mapping - UL PUCCH RB Auto Detect On



Step 7. Click OK to save the settings and exit the User Mapping table.

NOTE

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

Step 8. (Optional) You can now view different Preset Views to display measurement results. See [“Selecting Different Measurement Results Views”](#) on page 32.

Step 9. (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 38.

Step 10. (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 50](#)

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.

Modulation Analysis Measurements

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: [“Input UL PUSCH Parameters - RB Auto Detect On” on page 42](#)

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 1. Complete the initial procedure [“Common UL Setup Steps \(RB Auto Detect On or Off\)” on page 41](#).

Step 2. Press **Meas Setup**, **Chan Profile Setup**, and toggle **RB Auto Detect** to **Off**.

Step 3. 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 4. 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 5. 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**.

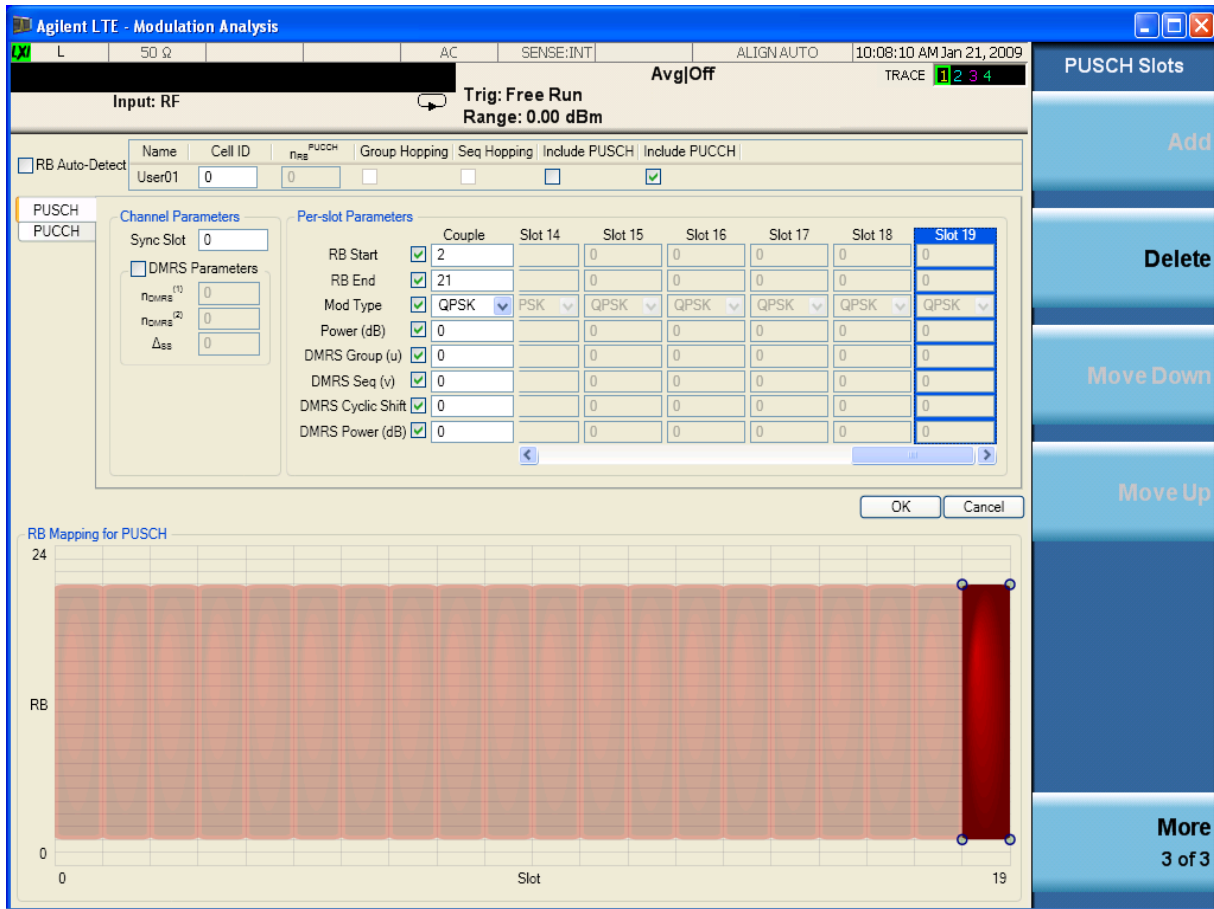
This example uses values of RB Start = 2, RB End = 21.

Step 6. 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 3-15 on page 43](#).

Figure 3-17 Editing Uplink User Mapping - PUSCH User01 RB Parameters



Step 7. 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 50

Step 8. (Optional) You can now view different Preset Views to display measurement results. See [“Selecting Different Measurement Results Views”](#) on page 32.

Step 9. (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 38.

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.

Modulation Analysis Measurements

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 45

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 50

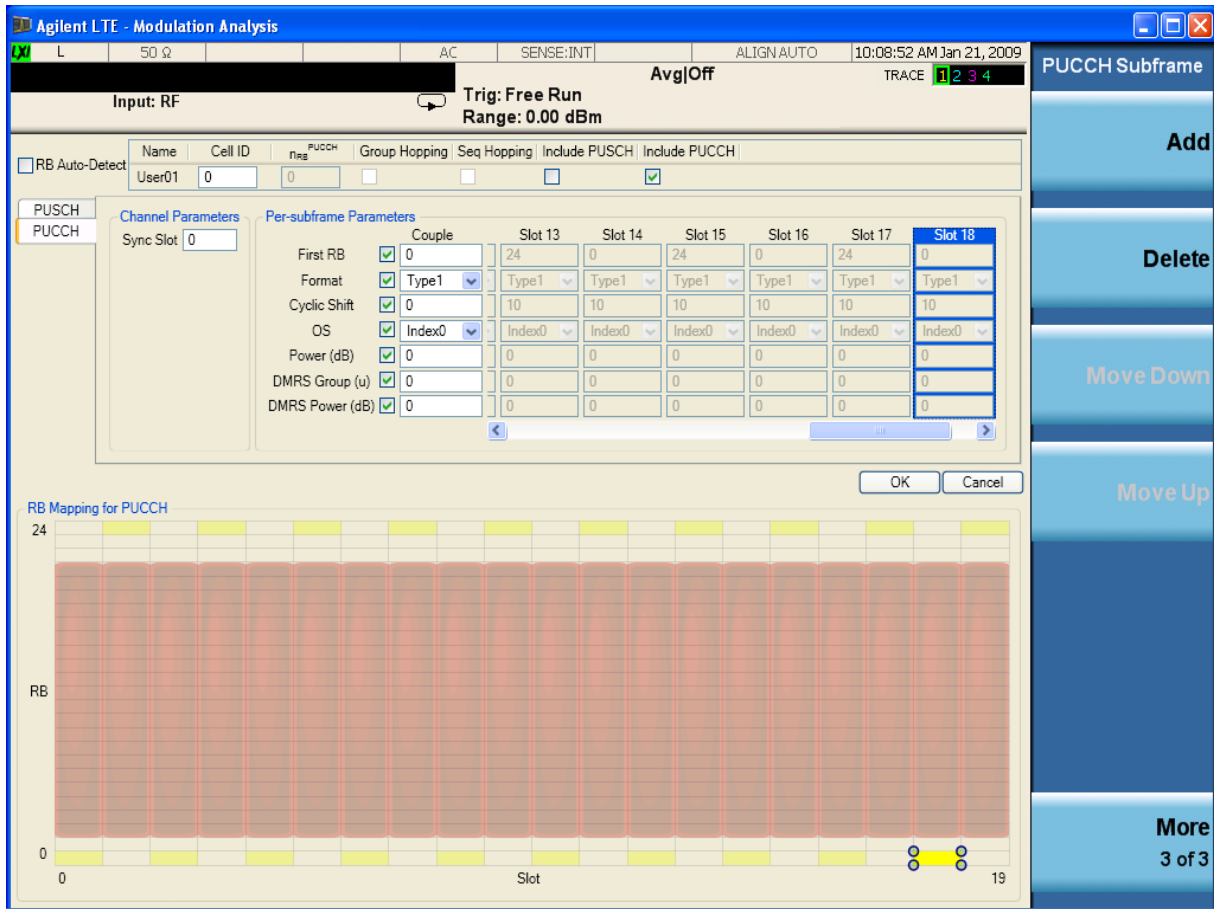
- Step 1.** Complete the initial procedure “[Common UL Setup Steps \(RB Auto Detect On or Off\)](#)” on page 41.
- Step 2.** Press **Meas Setup**, **Chan Profile Setup**, and toggle **RB Auto Detect** to **Off**.
- Step 3.** Select the PUSCH tab and press the down arrow or click the PUCCH tab.
User1 will be shown as active in the setup table at the top row.
- Step 4.** 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 5.** 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 6.** 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 7.** Press **Add** to add 9 more new Subframes for User01 to a total of 10 Subframes, or 20 Slots.
- Step 8.** The User Mapping table with all required PUCCH parameters set should like [Figure 3-18](#).

Figure 3-18 Uplink User Mapping - PUCCH Parameters Auto Detect Off



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

Step 9. 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 48

Step 10. (Optional) You can now view different Preset Views to display measurement results. See [“Selecting Different Measurement Results Views”](#) on page 32.

Step 11. (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 38.

TIP

Save your settings as a recallable State: Press **Save, State**, and select a

Modulation Analysis Measurements

Register to store the measurement settings. Settings saved in a Register are subject to reset by a power cycle.

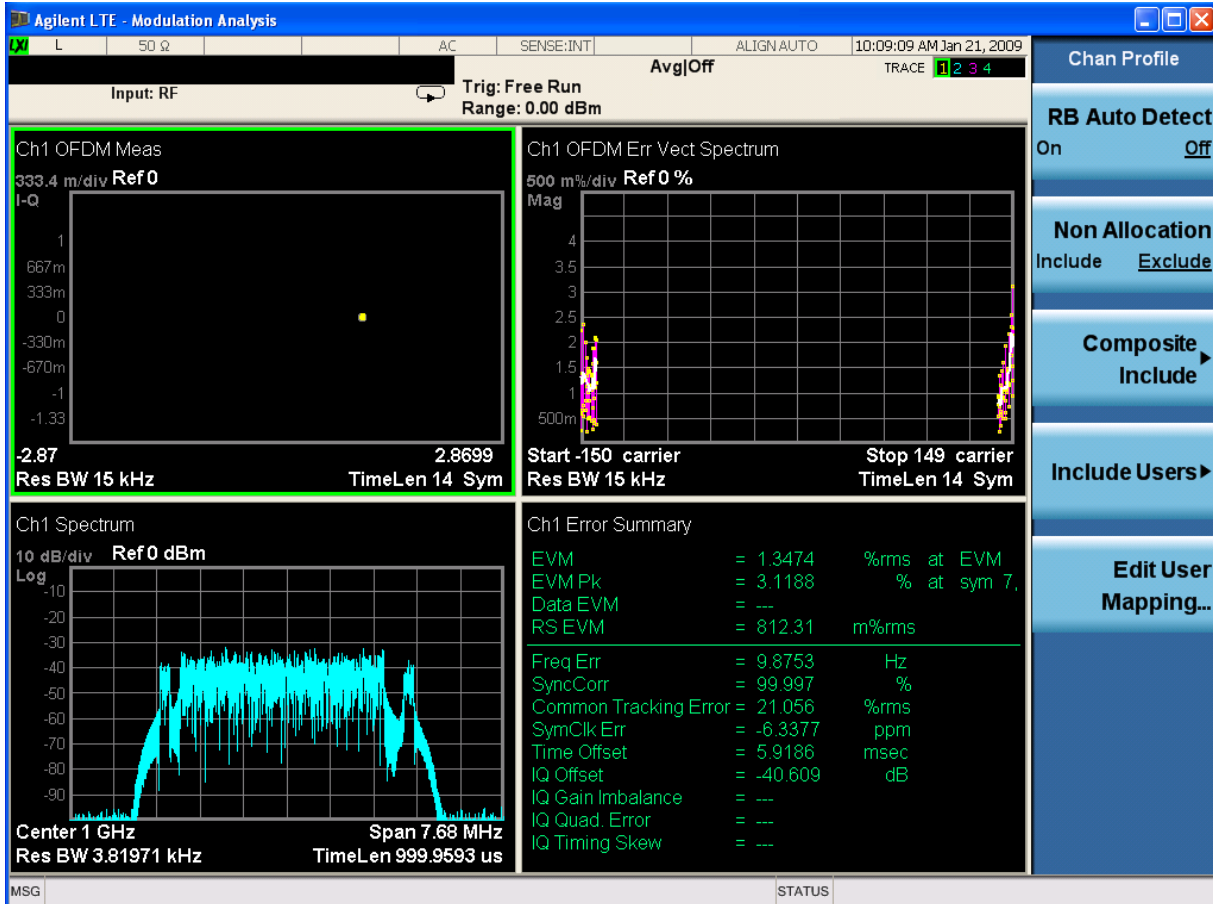
To save State settings in a file permanently: Press **Save, State, To File...** and select a file name and location for the file. Be sure to use the User Data D: logical drive for saved files as it is not overwritten during software upgrades.

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 3-19](#).

Figure 3-19 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 32.

Modulation Analysis Measurements

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
Measurement Interval	as many slots as possible up to 2 slots

Modulation Analysis Demodulation Preset Defaults

Parameter	Default Value
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
Include QAM16	Selected
Include QAM64	Selected

Modulation Analysis Measurements

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

Parameter	Default Value
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
First RB	0
Cyclic Shift	0
Format	Type 2
OS	Index0

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

Parameter	Default Value
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.

[Troubleshooting LTE Measurements](#) describes some common problems and possible solutions.

Table 3-1 Troubleshooting LTE Measurements

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.

Table 3-1 Troubleshooting LTE Measurements

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.

Modulation Analysis Measurements

Monitor Spectrum Measurements

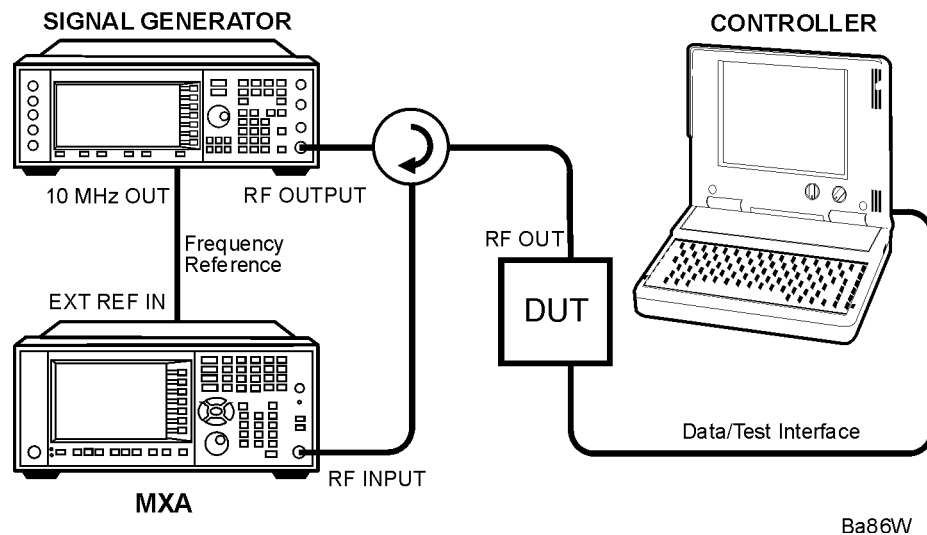
This chapter explains how to make Monitor Spectrum measurements on a 3GPP LTE (2008-3) signal. Monitor Spectrum measurements show a spectrum domain display of the LTE signal. Marker functions may be used to provide Band Power, Noise and Band.Interval Density measurements over the signal bandwidth.

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 bursty, 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 3-20 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 Measurement

Setting the Downlink Signal (Example)

This example uses a signal generated using Agilent Signal Studio N9624B 3GPP LTE (2008-03).

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

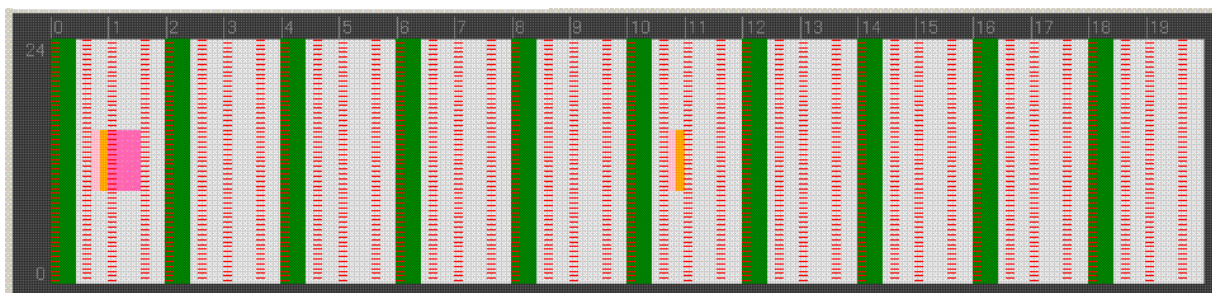
Physical Channels:

- 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 3-21 Signal Studio Downlink Setup Graphic Display

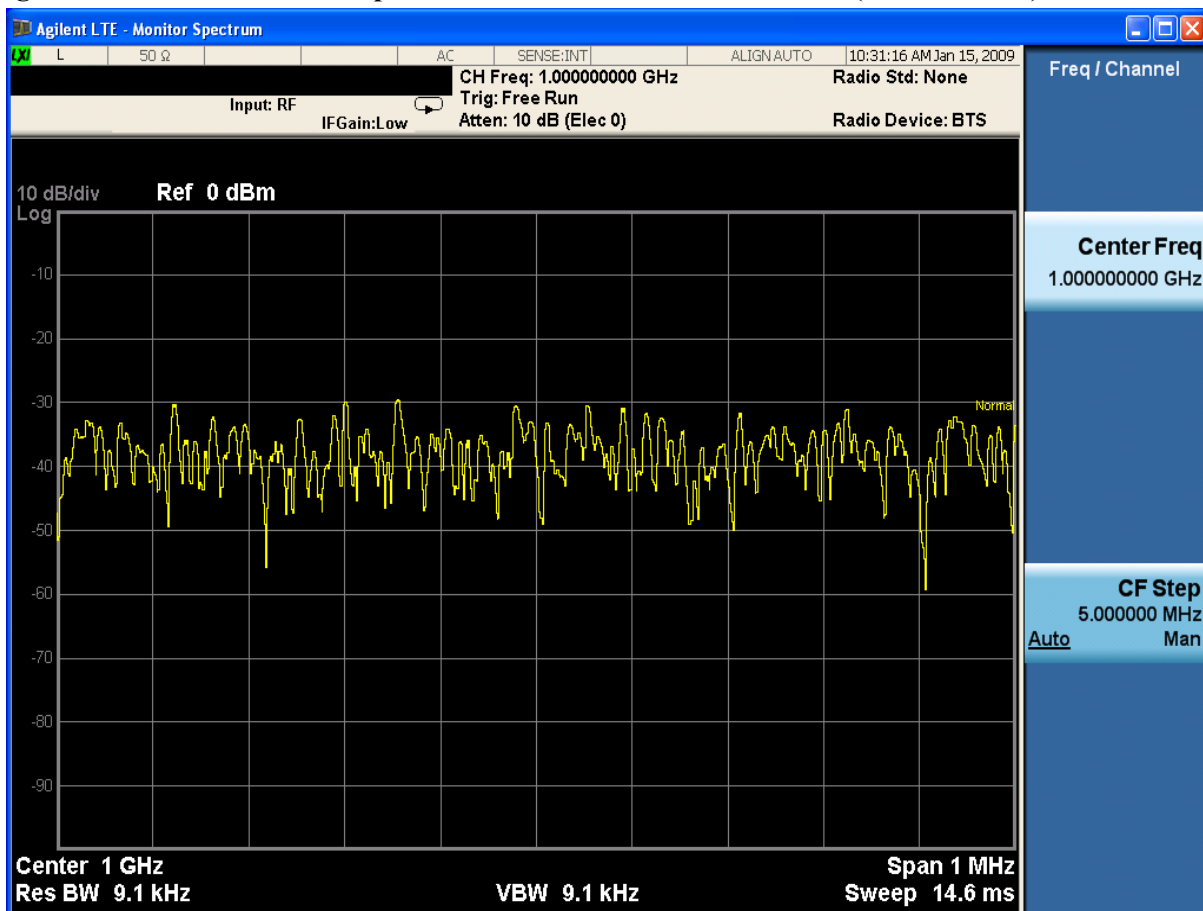


Monitor Spectrum Measurement Procedure

- 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 3-22](#).

Figure 3-22 Monitor Spectrum Measurement - Default View (Autoscale On)

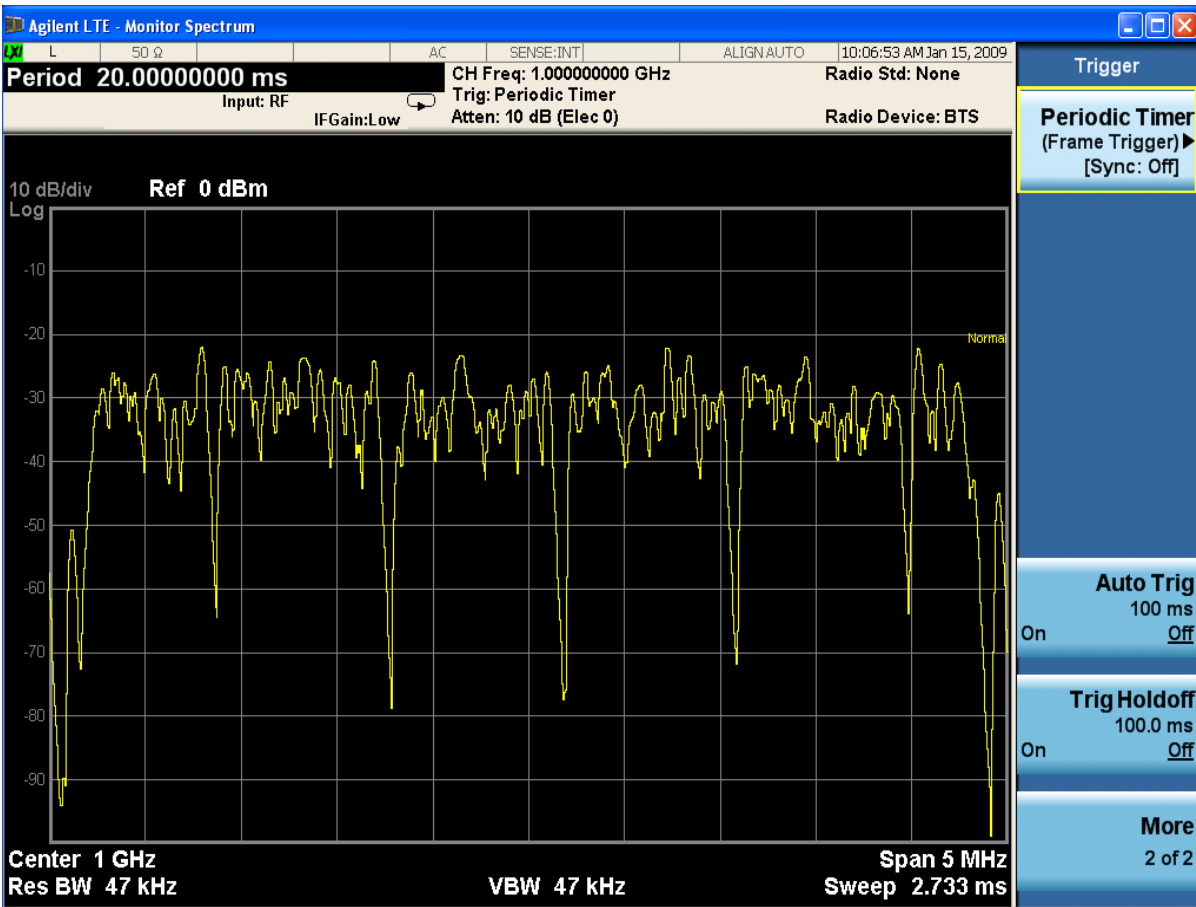


Monitor Spectrum Measurements

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 3-23](#).

Figure 3-23 Monitor Spectrum Measurement - 5 MHz Span with Frame Trigger



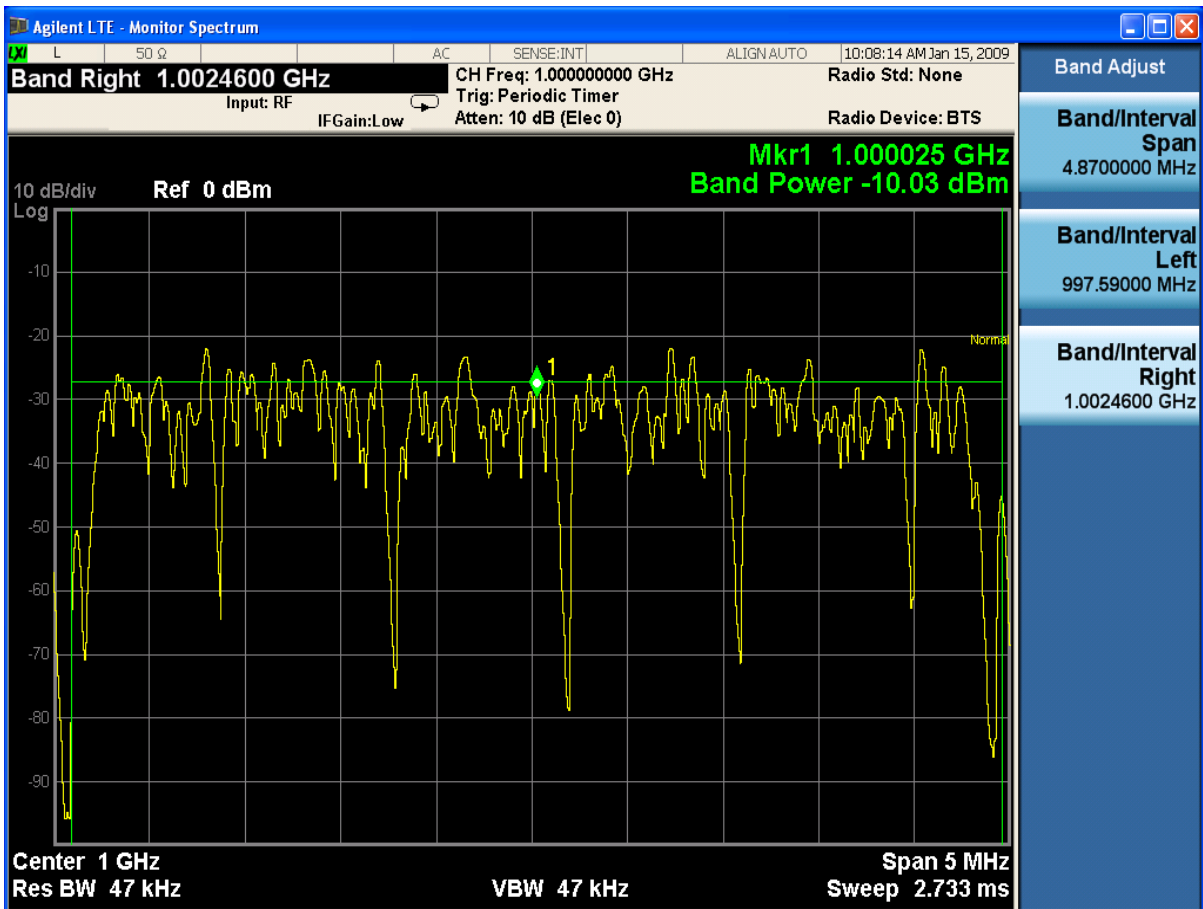
Step 9. To stabilize the signal display use a measurement trigger:
Press **Trigger, More, Periodic Timer (Frame Trigger)** to trigger the measurement with the Frame Timer.
Press **Periodic Timer (Frame Trigger)** again to access the Timer Setup menu.
Press **Period, 10, ms** (or any multiple of 10 ms, 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. This example display in [Figure 3-24 on page 65](#) shows the limits at the band edges and indicates the Band Power measurement agrees closely with the signal power applied at -10 dBm.

Figure 3-24 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*”.

Monitor Spectrum Measurements

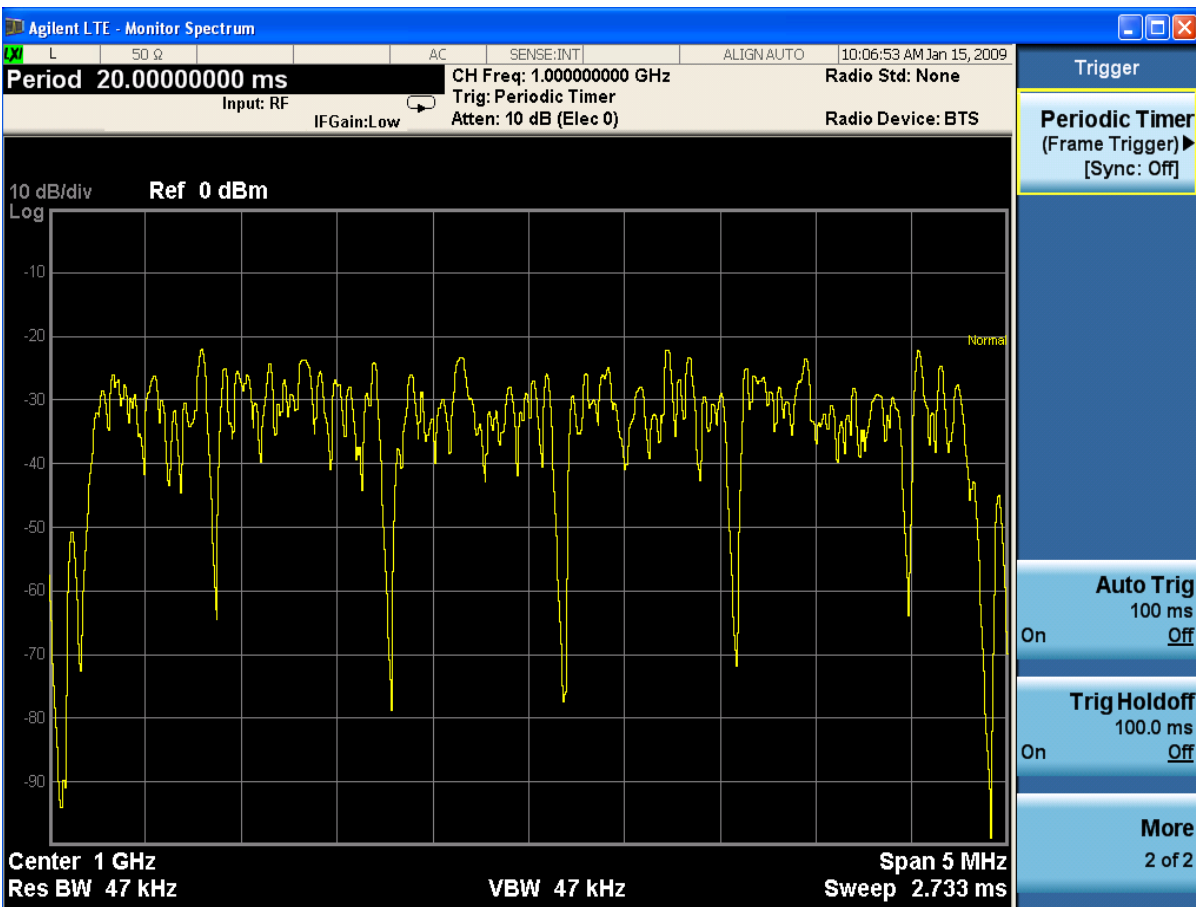
Using Gate Functions

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 3-25](#).

Figure 3-25 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 access 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

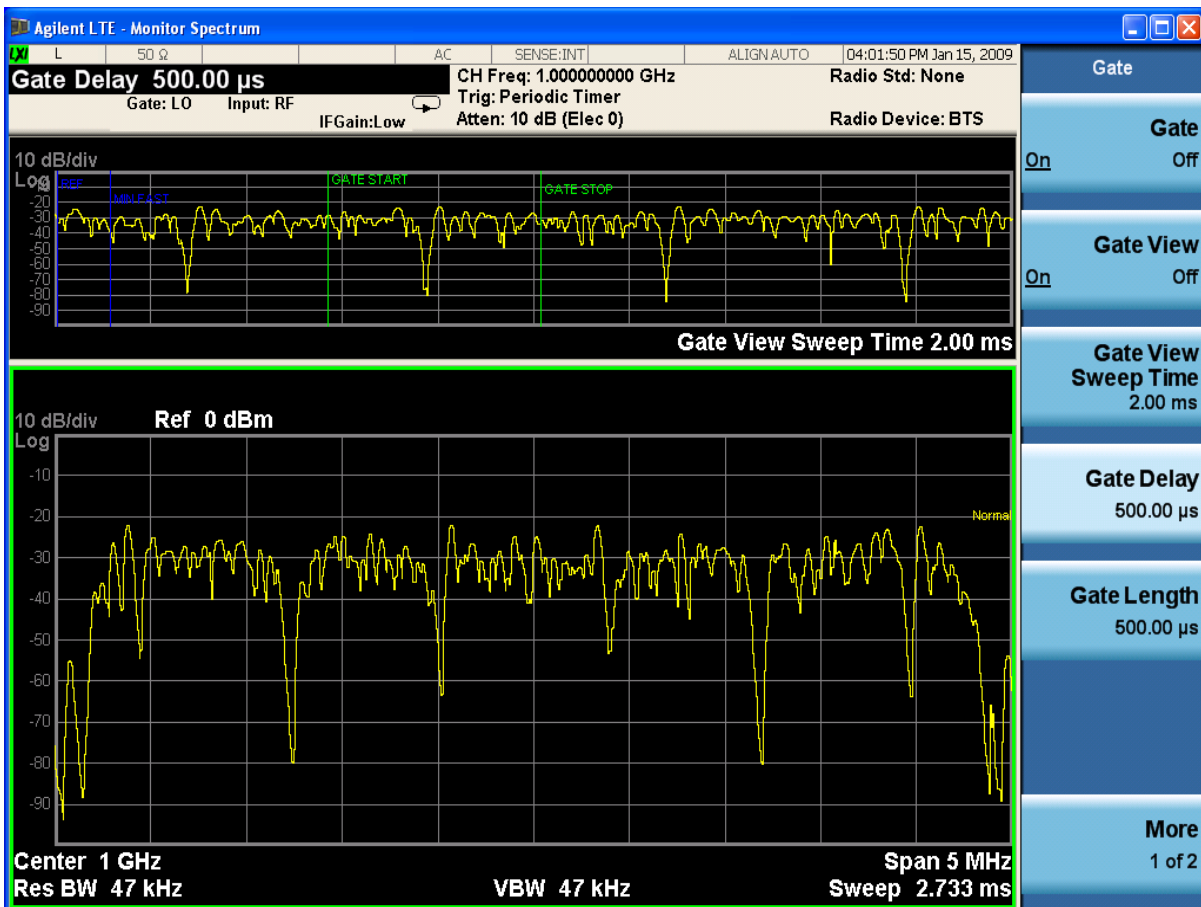
TIP For best results, always set **Gate Delay** to position Gate Start after Max Fast to allow the LO to “settle”.

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 3-22](#). 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 3-26 Monitor Spectrum Measurement - Gate View - 1 LTE Slot



Monitor Spectrum Measurements

4 Interpreting Common 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 Range**, 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.

This chapter presents an overview of the 3GPP LTE communications system and details how various measurements are performed by the instrument. A list of 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 Asntenna)

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

LTE Network Architecture

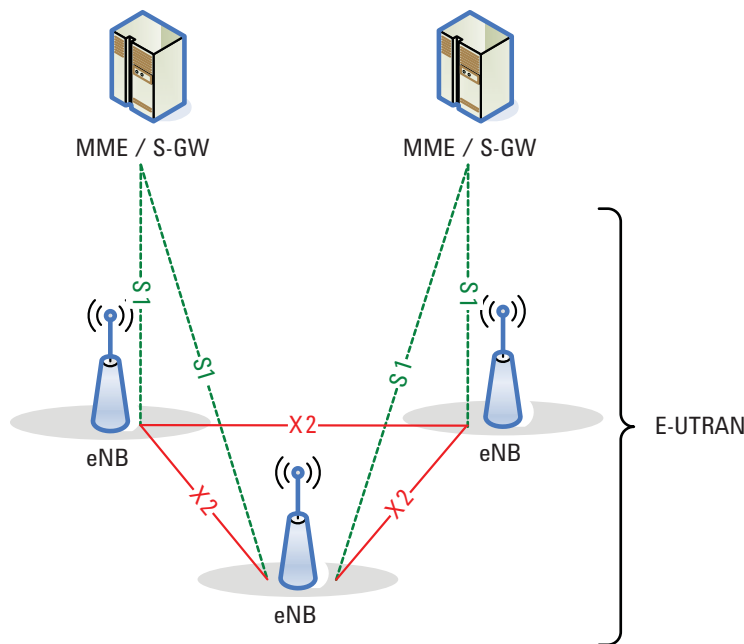
LTE employs a new network architecture made up of multiple Evolved Packet Cores (EPCs) that communicate with each other and with evolved universal terrestrial radio access network base stations (eNBs), see [Figure 5-1](#). Each EPC contains a Mobile Management Entity (MME) and a System Architecture Evolution 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

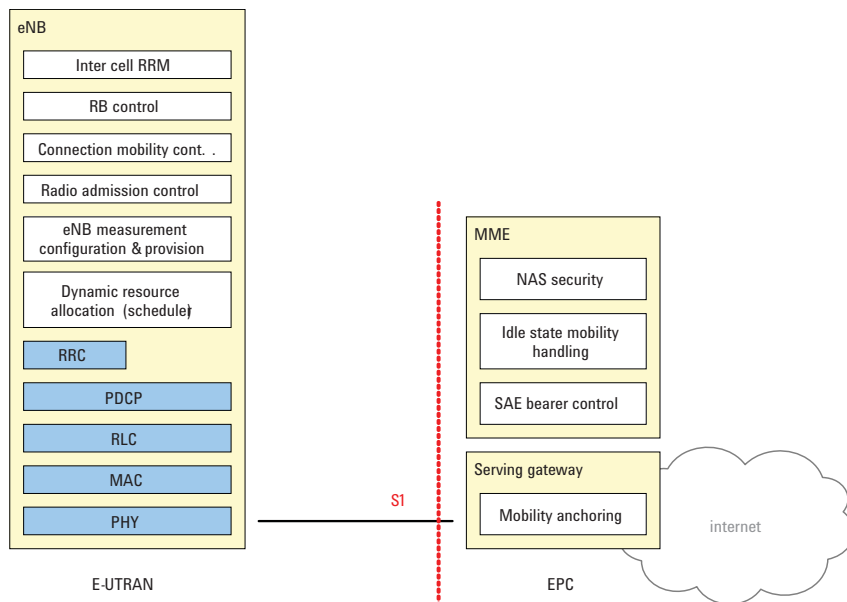
mobility management entity (MME) and serving gateway (S-GW) elements through a “many-to-many” relationship.

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.

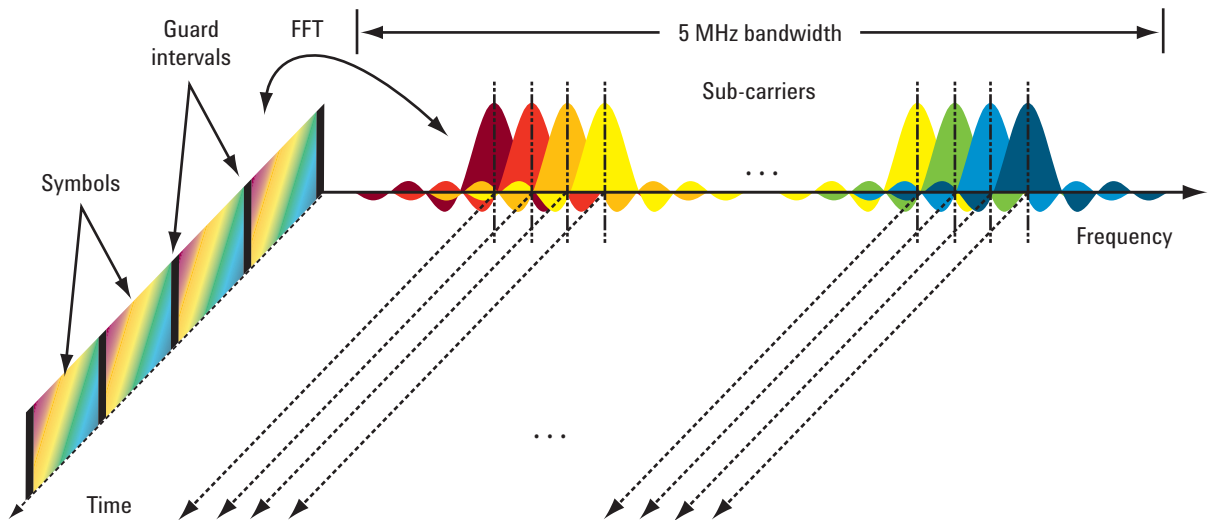
OFDM vs. CDMA

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) first 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:

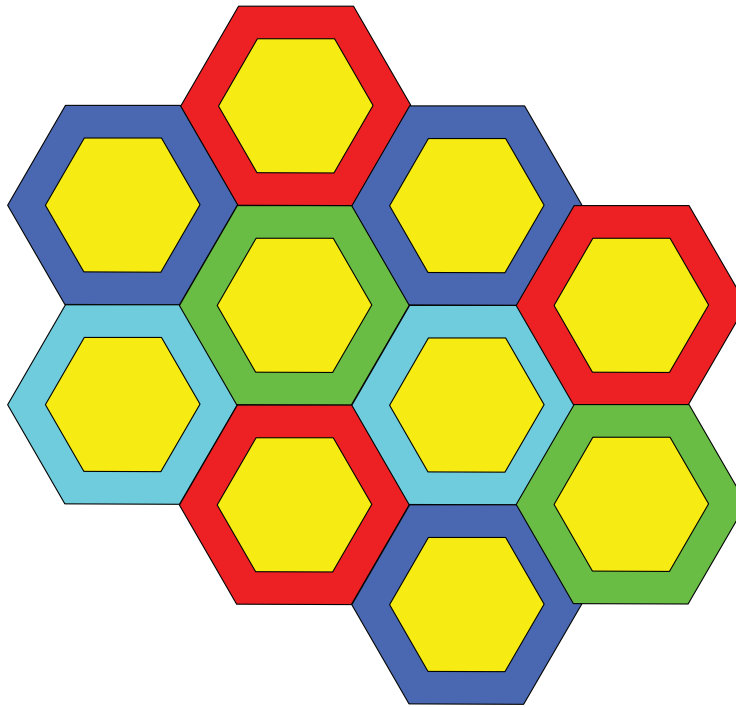
- OFDM can easily be scaled up to wide channels that are more resistant to fading.
- OFDM channel equalizers are much simpler to implement than are CDMA equalizers, as the OFDM signal is represented in the frequency domain rather than the time domain.
- OFDM can be made completely resistant to multi-path delay spread. This is possible because the long symbols used for OFDM can be separated by a guard interval known as the cyclic prefix (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 modification 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 Figure 5-3 on page 76.

Table 5-3 Comparison of CDMA and OFDM

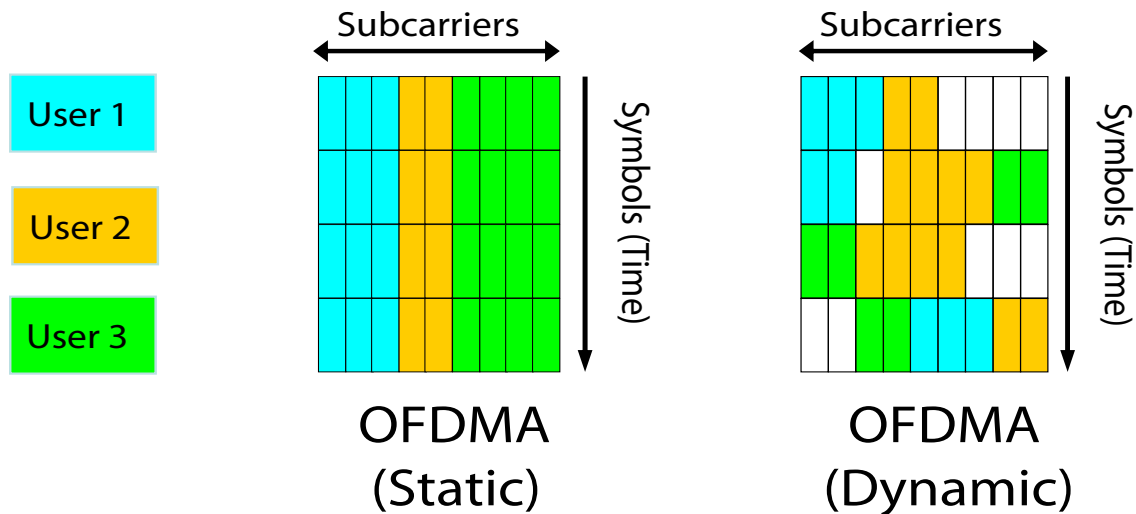
Attribute	CDMA	OFDM
Transmission Bandwidth	Full system bandwidth	Variable up to full system bandwidth
Symbol period	Very short – inverse of system bandwidth	Very long - defined by subcarrier spacing and independent of system spacing
Separation of users	Orthogonal spreading codes	Frequency and time

Adding TDMA to OFDM to Create OFDMA

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 efficiency 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 specifications 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](#).

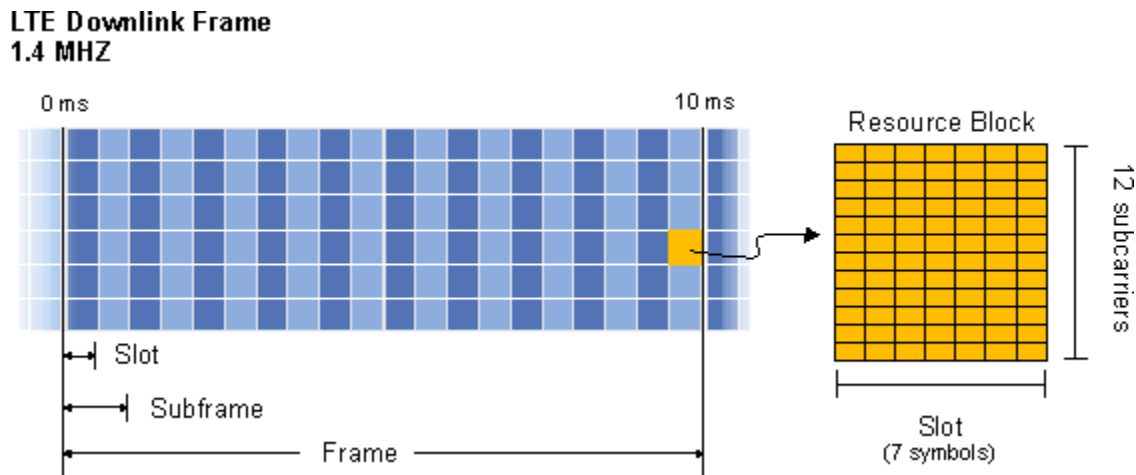
Table 5-5 LTE Time Units

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 on page 78.

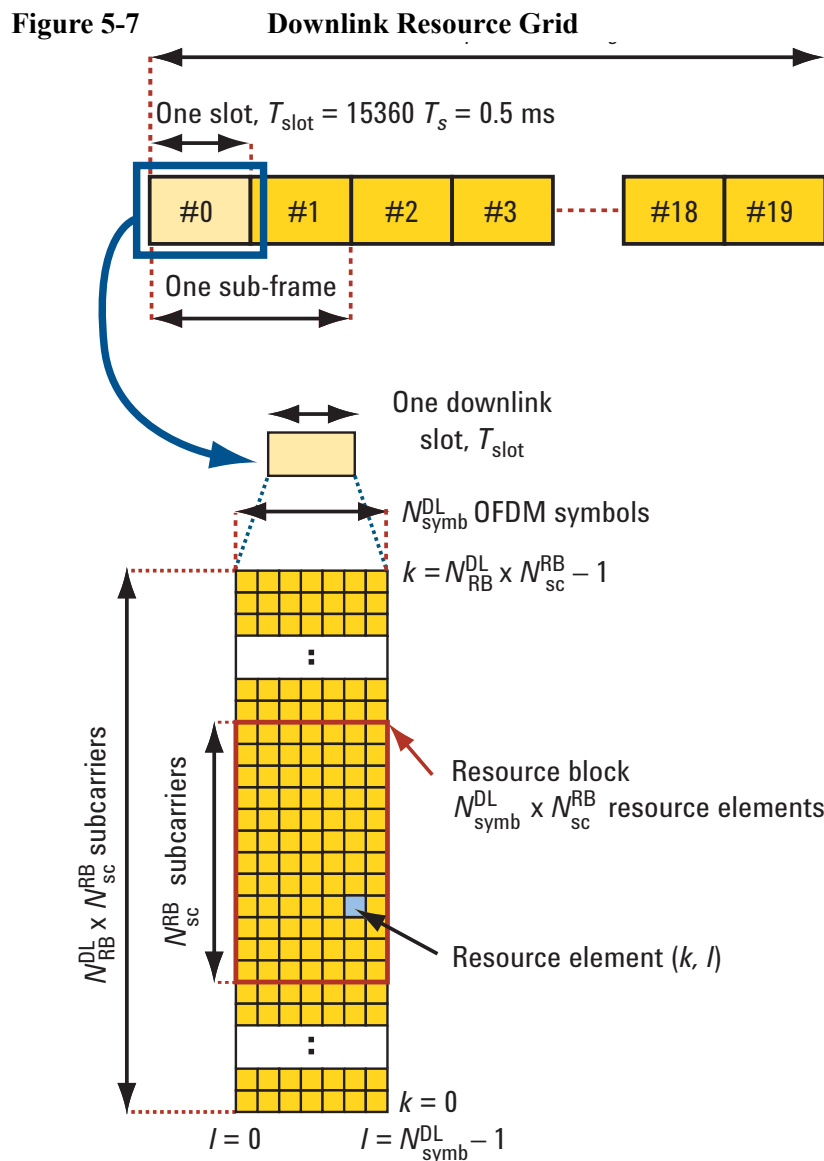


Figure 5-7 shows the downlink resource grid for a 0.5-ms timeslot which incorporates the concepts of a resource element and a resource block. A resource element is the smallest identifiable unit of transmission and consists of one subcarrier for one symbol period. However, transmissions are scheduled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

Physical Layer Channels

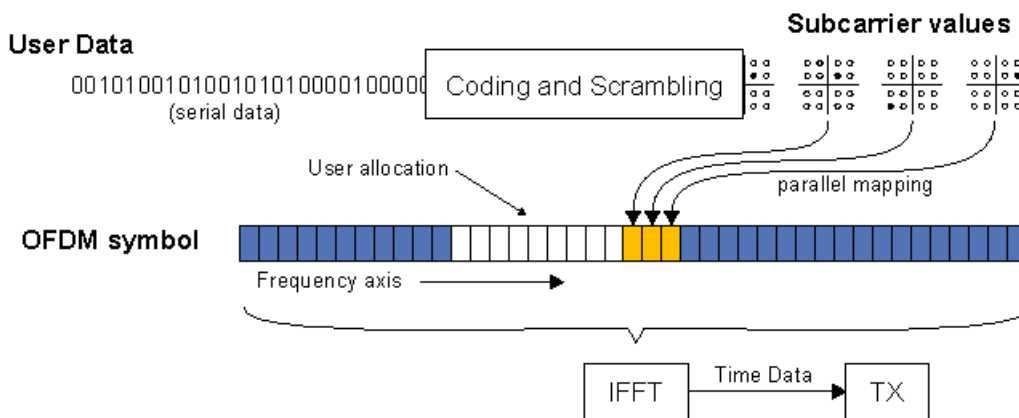
The LTE DL and UL are composed of two sets of physical layer channels: physical channels and physical signals. Physical channels carry information from higher layers and are used to carry user data,

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 5-4 on page 78](#) has information on the modulation format and purpose for each of the downlink channels and signals.

Figure 5-9 LTE Downlink Channels and Signals

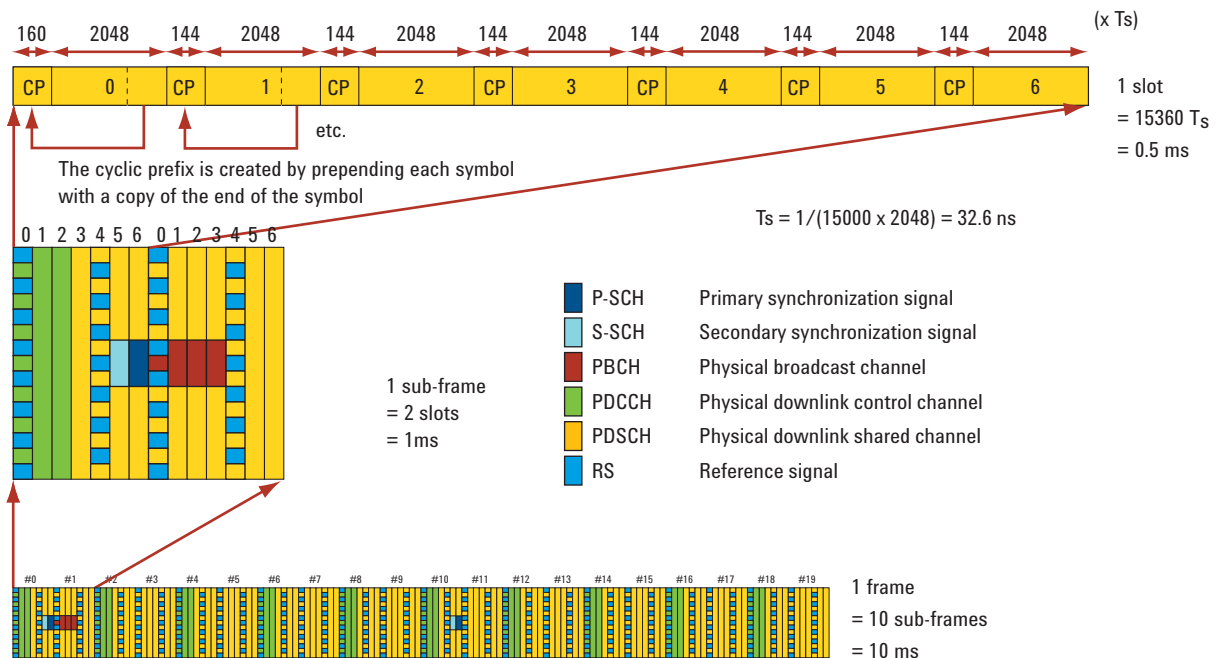
DL channels	Full name	Modulation format	Purpose
PBCH	Physical Broadcast Channel	QPSK	Carries cell-specific information
PDCCH	Physical Downlink Control Channel	QPSK	Scheduling, ACK/NACK
PDSCH	Physical Downlink Shared Channel	QPSK 16QAM 64QAM	Payload
PMCH	Physical Multicast Channel	QPSK 16QAM 64QAM	Payload 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 5-4 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

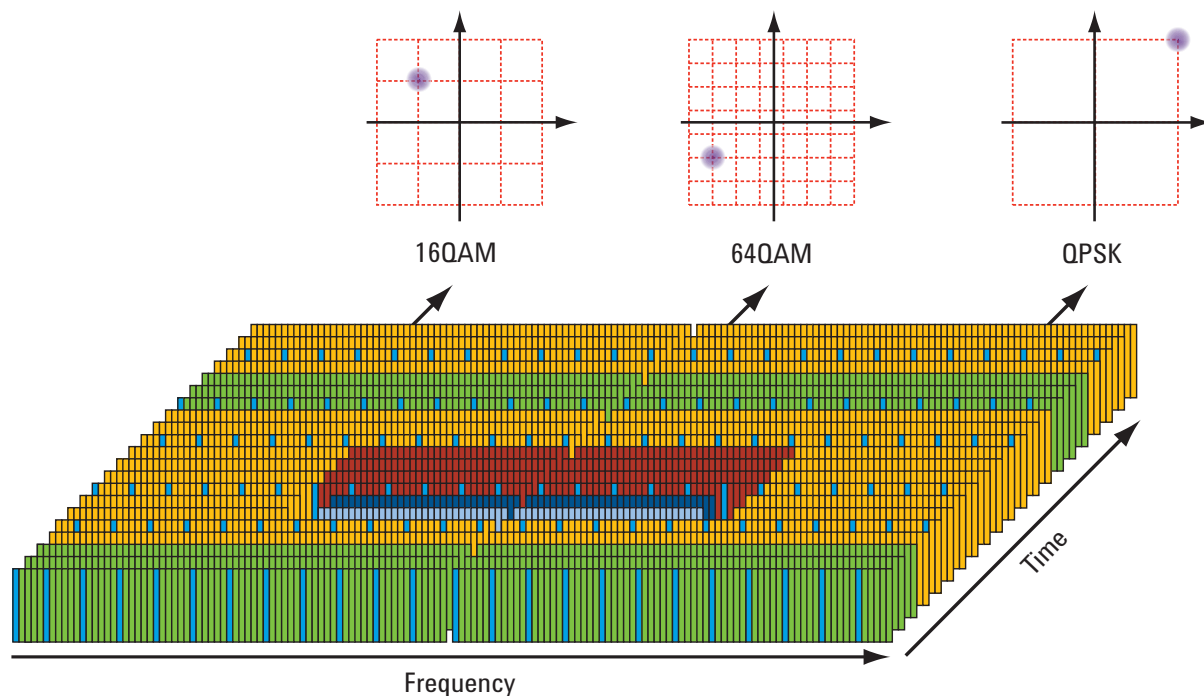


As shown in Figure 5-4, the physical mapping of the DL physical signals and channels are:

- 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



Cyclic Prefix (CP)

Table 5-6 summarizes the options for CP length and number of symbols per timeslot. The extended CP of $512 \times T_s$ ($16.67 \mu\text{s}$) 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 $1024 \times T_s$ ($33.33 \mu\text{s}$) 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

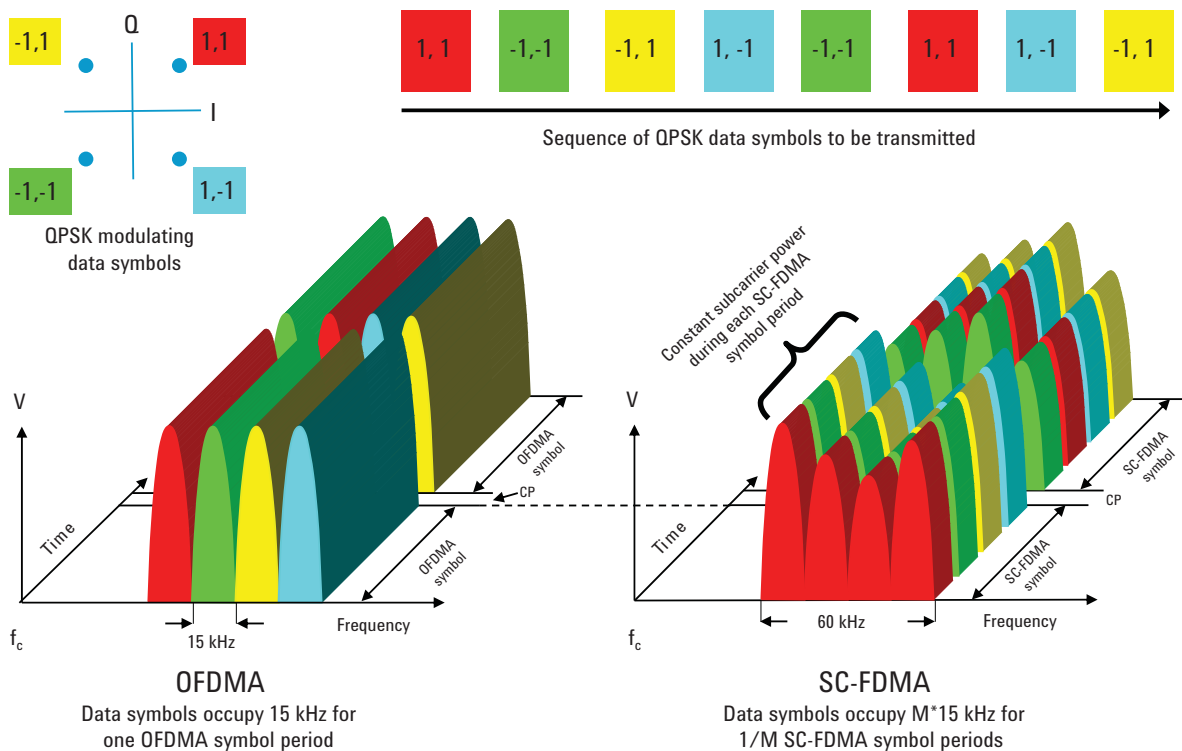
CP in T_s by Symbol Number	0	1	2	3	4	5	6
Normal $\Delta f = 15 \text{ kHz}$	160	144	144	144	144	144	144
Extended $\Delta f = 15 \text{ kHz}$	512	512	512	512	512	512	-

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)



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 $66.7 \mu\text{s}$ 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 filled 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 time-domain signals. These in turn are vector-summed to create the final 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 $M \times 15$ 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 μ s; 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

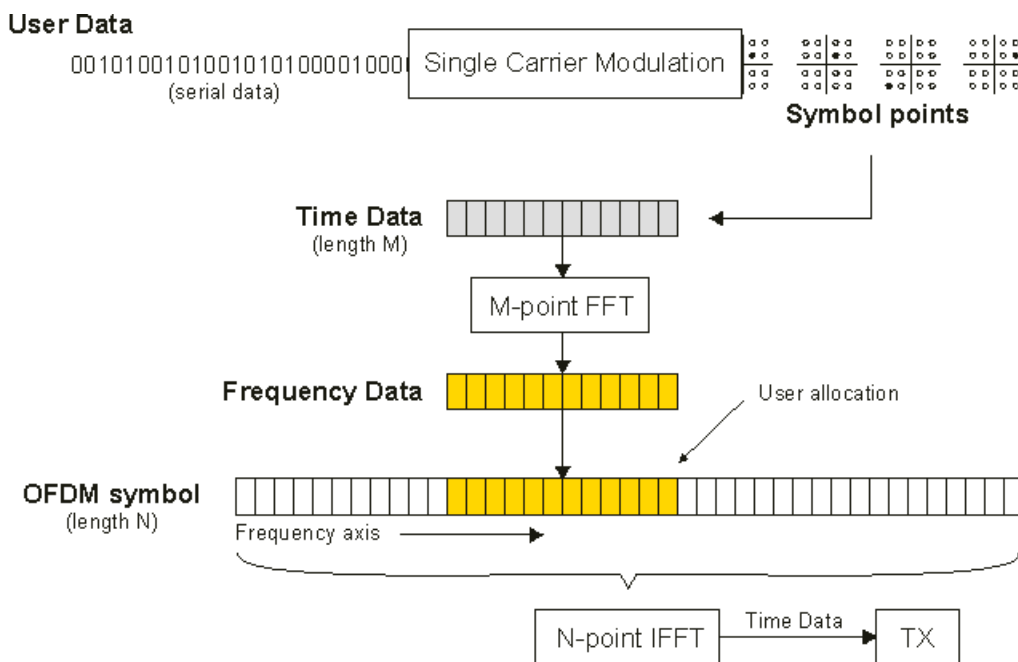


Table 5-7 summarizes the differences between the OFDMA and SC-FDMA modulation schemes. When OFDMA is analyzed one subcarrier at a time, it resembles the original data symbols. At full bandwidth, however, the signal looks like Gaussian noise in terms of its PAR statistics and the constellation. The opposite 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.

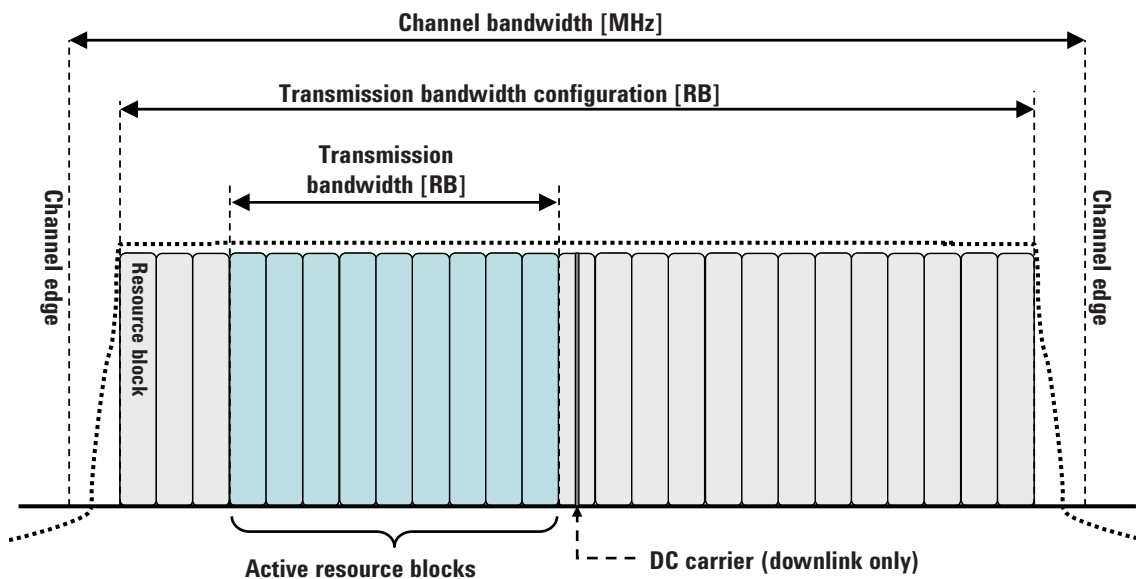
Table 5-7 Analysis of OFDMA and SC-FDMA at Different Bandwidths

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 μ s	Not meaningful (Gaussian)	Not meaningful (Gaussian)	Same as data symbol at 66.7 μ s

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 configuration 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

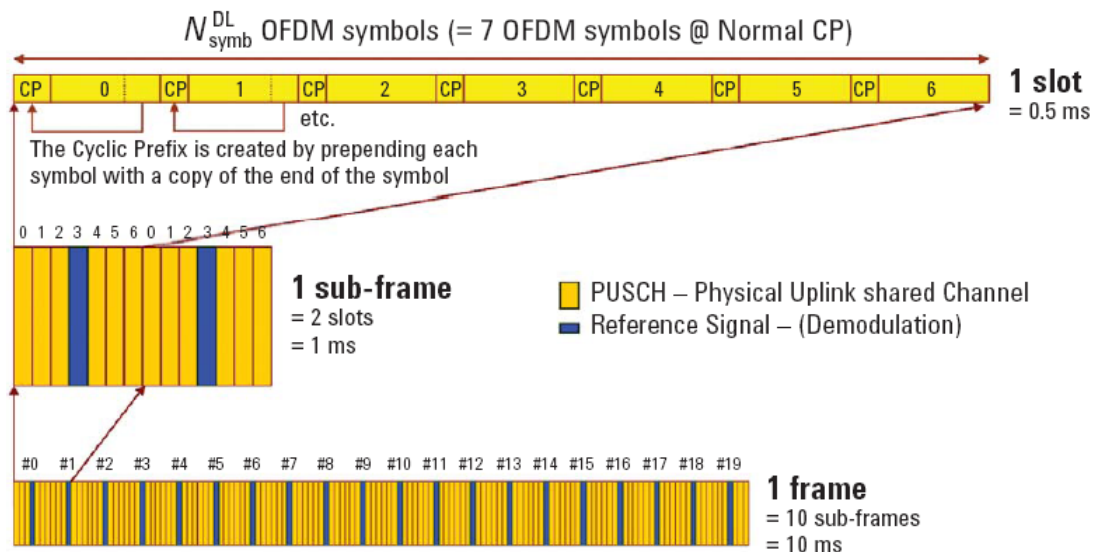
UL signals	Full name	Modulation sequence	Purpose
DM-RS	Demodulation Reference Signal	uth root Zadoff-Chu	Used for synchronization to the UE and UL channel estimation
S-RS	Sounding Reference Signal	Zadoff-Chu	Used to monitor propagation conditions with UE.

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

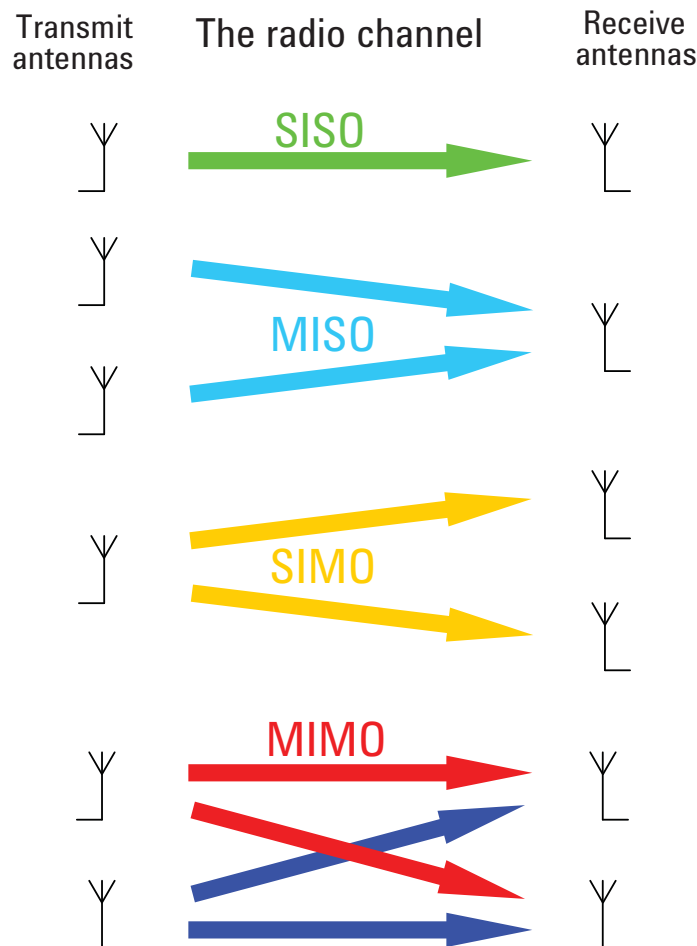


Overview of Multiple Antenna Techniques (MIMO)

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.

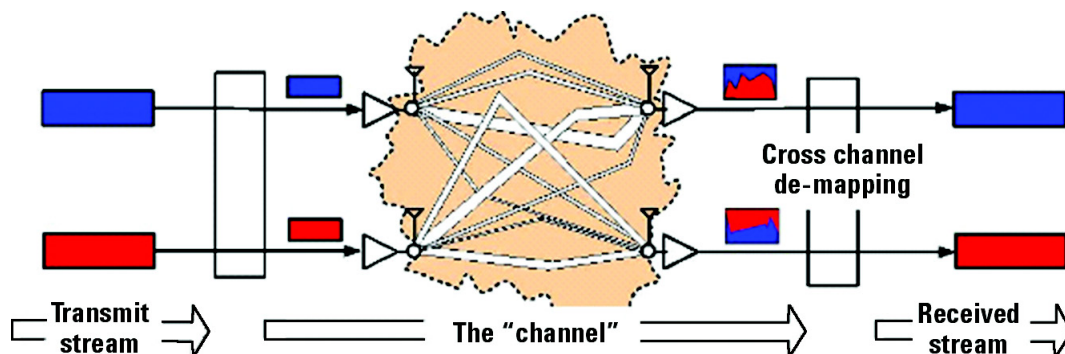
SIMO - The third mode shown in [Figure 5-17](#) is single input multiple output (SIMO), which—in contrast to MISO—uses one transmitter and two or more receivers. SIMO is often referred to as receive diversity. Similar to transmit diversity, it is particularly well suited for low SNR conditions in which 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. $SIMO + MISO \neq MIMO$. 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 identifiable so that each receiver can determine what combination of transmissions has been received. This identification 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 significantly 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.

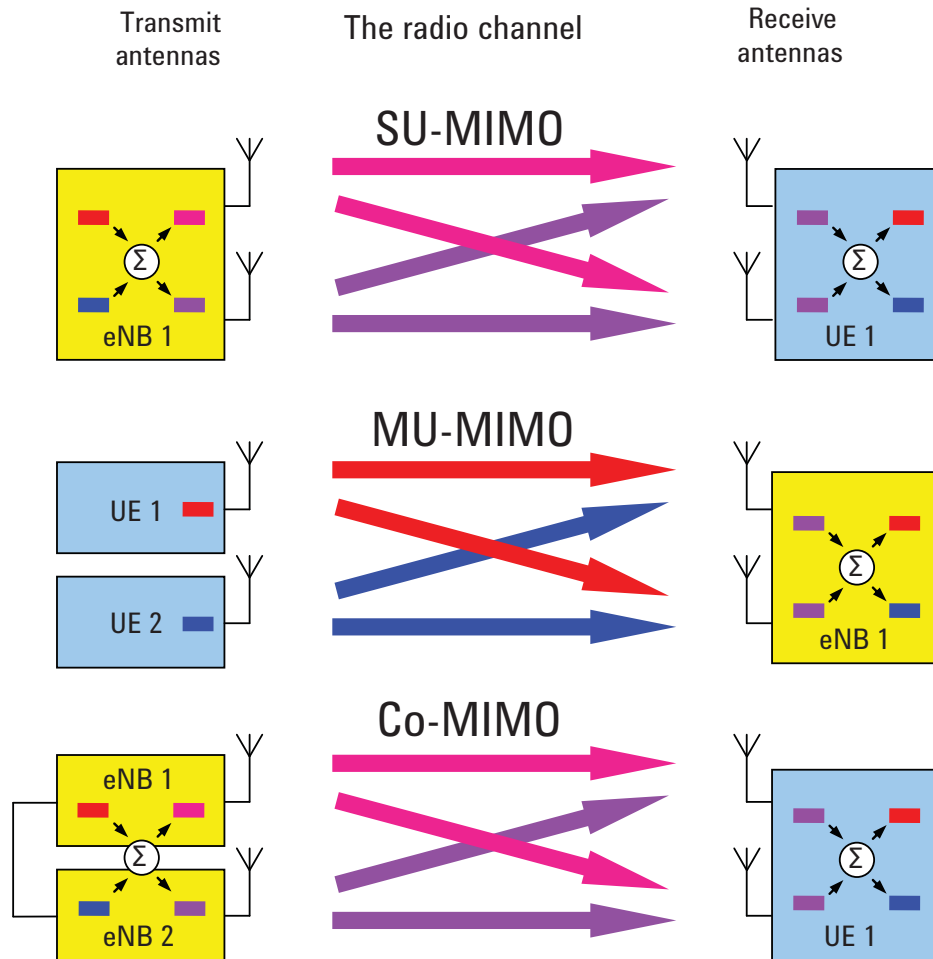
The theoretical gains from MIMO are a function of the number of transmit and receive antennas, the radio propagation conditions, the ability of the transmitter to adapt to the changing conditions, and the SNR. The ideal case is one in which the paths in the radio channel are completely uncorrelated, 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 on page 90](#).

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™ specifications 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 significant potential for increased performance. Co-MIMO is also possible in the uplink but is fundamentally more difficult 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 challenges.

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.

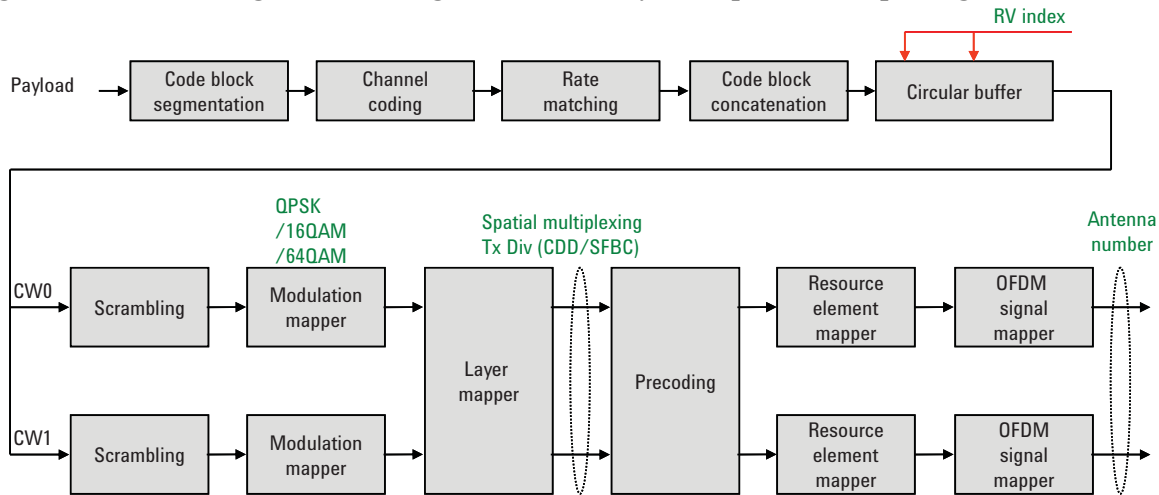
The most advanced form of multiple antenna techniques is probably the combination of beamforming with MIMO. In this mode MIMO techniques could be used on sets of antennas, each of which comprises a beamforming array. Given that beamforming with only two antennas has limited gains, the advantage of combining 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 Multiple Antenna 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 configurations. 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 identified 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 artificial 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 μ s 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.

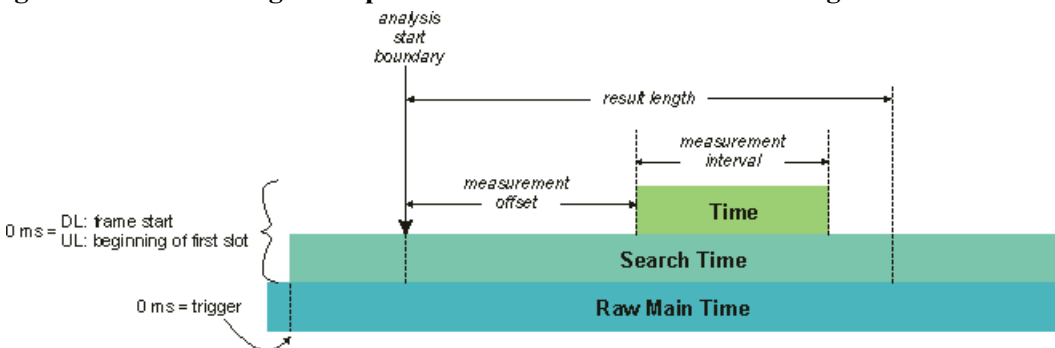
Capturing Signals for Measurement

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 by the 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.

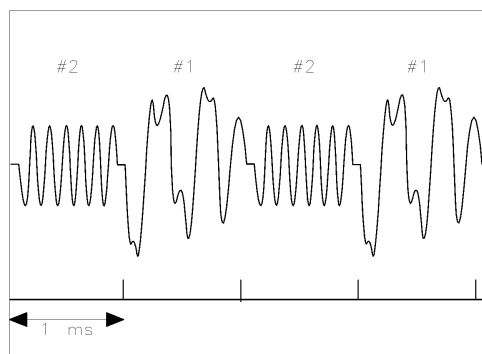
Time Gating Concepts

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 1. 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 1. Simplified Digital Mobile-Radio Signal in Time Domain

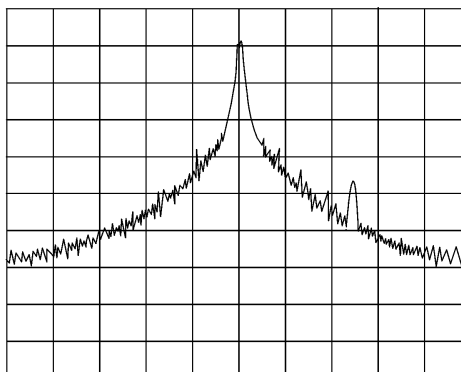


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We want to measure the unique frequency spectrum of each transmitter.

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 2. The signal analyzer shows the combined spectrum; you cannot tell which part of the spectrum results from which signal.

Figure 2. Frequency Spectra of the Combined Radio Signals



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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 3](#).

Figure 3. Time-Gated Spectrum of Radio 1

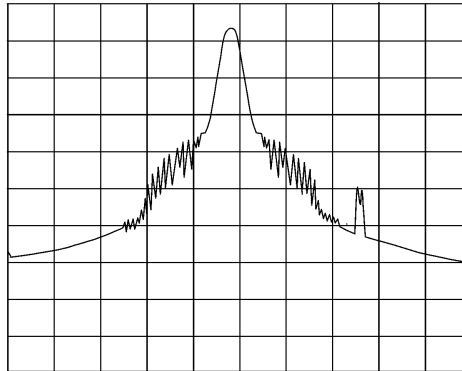
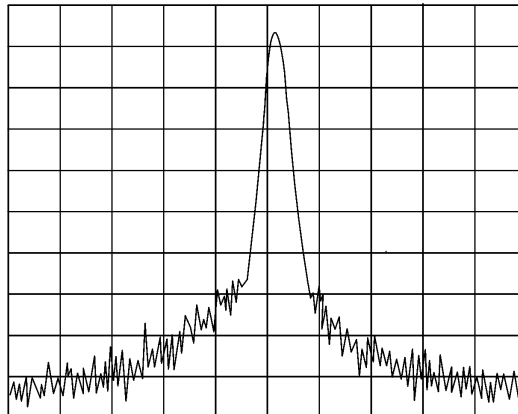


Figure 4. Time-Gated Spectrum of Radio 2



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 7. and Figure 6. 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.

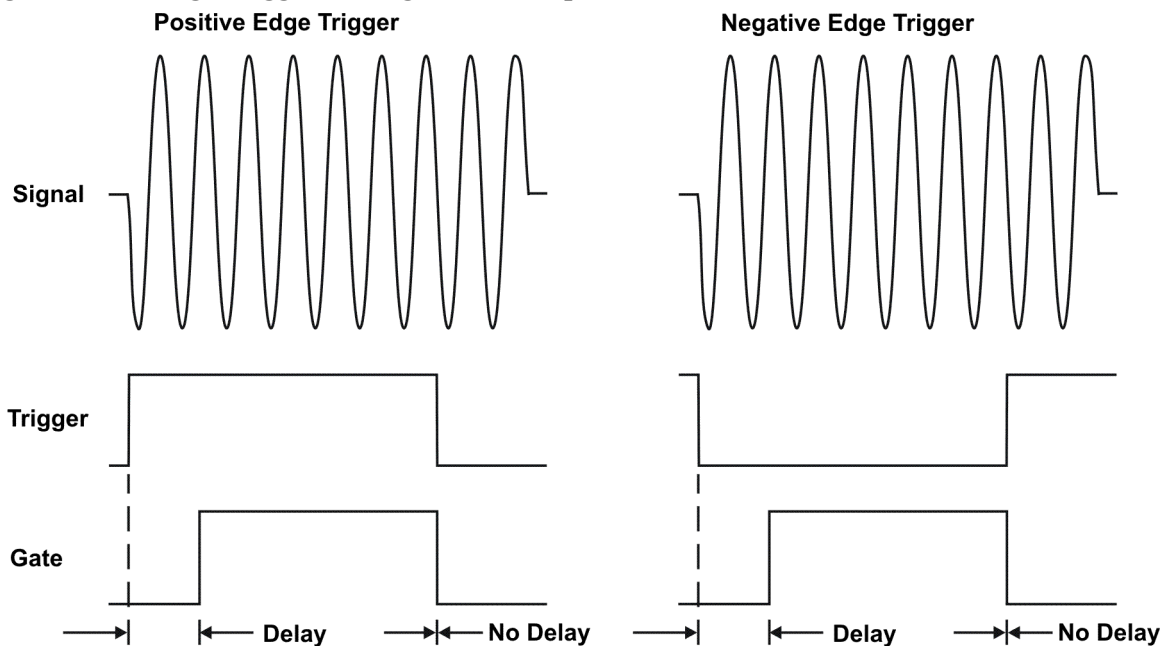
There are typically two main types of gating conditions, *edge* and *level*:

- 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.).

- 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. 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

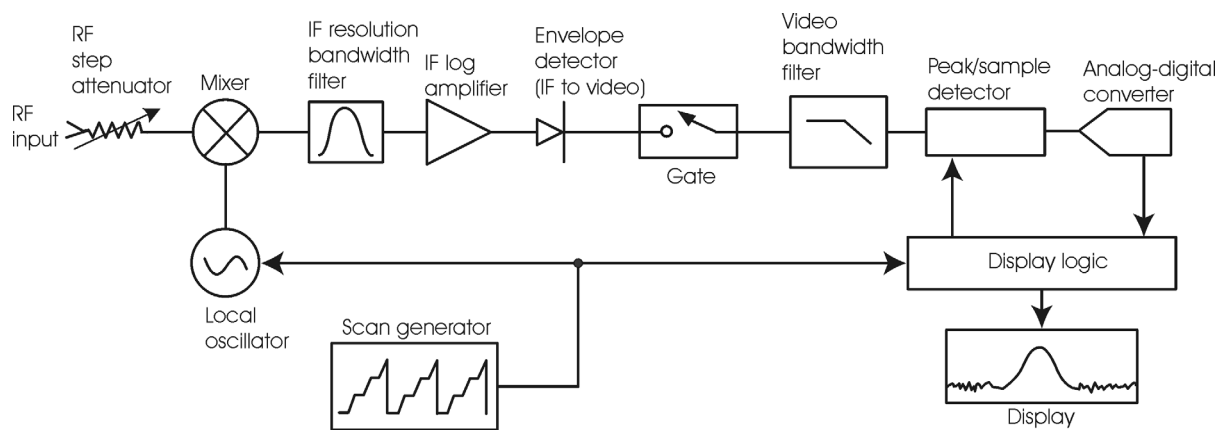
Gated video may be thought of as a simple gate switch, which connects the signal to the input of the signal analyzer. When the gate is “on” (under the Gate menu) the gate is passing a signal. When the gate

is “off,” the gate is blocking the signal. Whenever the gate is passing a signal, the analyzer sees the signal. In [Figure 6](#), 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.

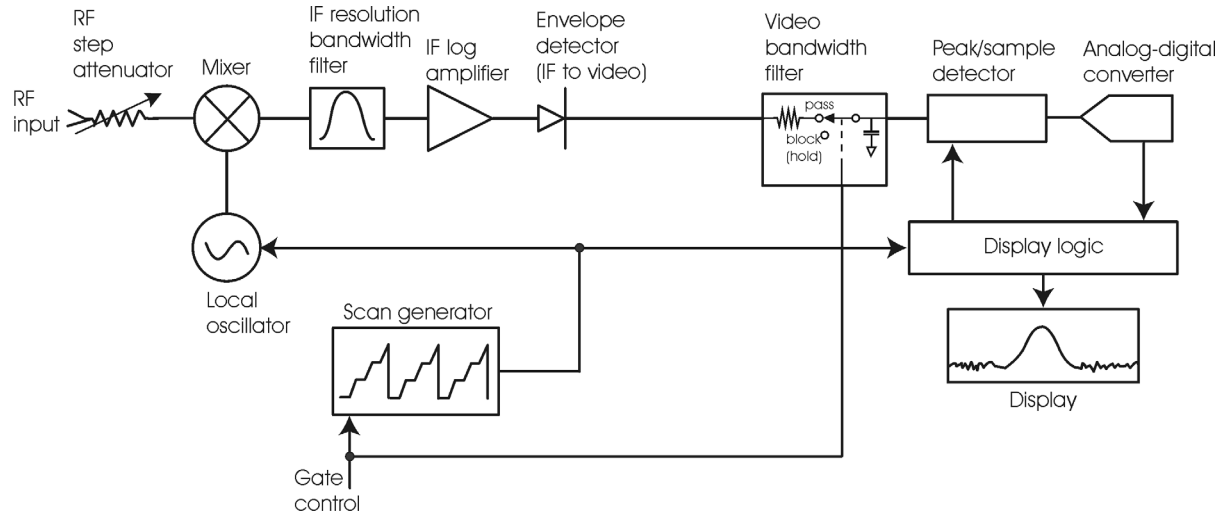
Figure 6. Gated Video Signal Analyzer Block Diagram



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 7](#) 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 7. 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.

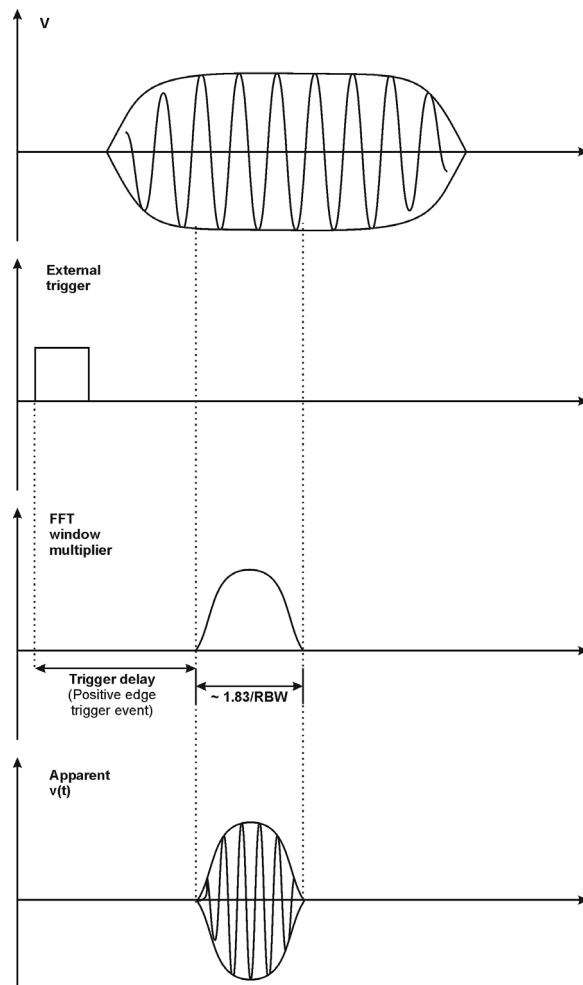
The process of making a spectrum measurement with FFTs is inherently a “gated” process, in that the spectrum is computed from a time record of short duration, much like a gate signal in swept-gated analysis.

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

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

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 8. 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).

Concepts

Time Gating Concepts

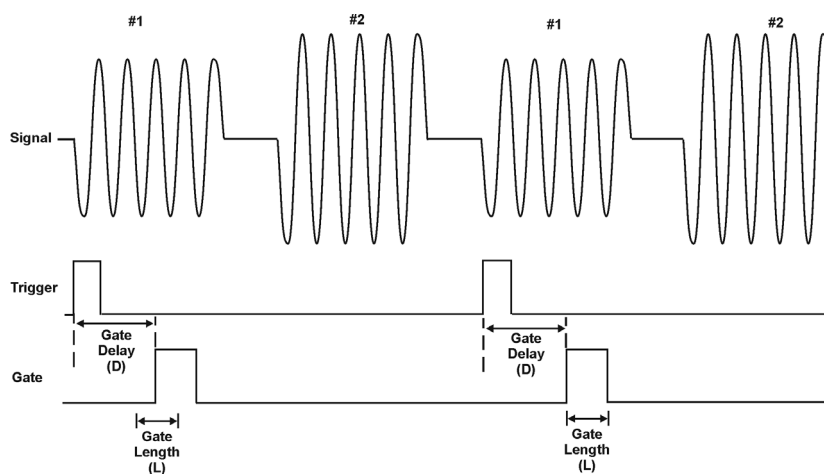
The timing interactions between the three signals are best understood if you observe them in the time domain (see [Figure 9](#)).

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.

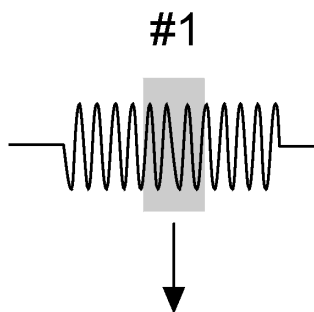
To measure signal 1, the gate must be on only during the pulses from signal 1. The gate will be off at all other times, thus excluding all other signals. To position the gate, set the gate delay and gate length, as shown in [Figure 9](#), so that the gate is on only during some central part of the pulse. 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 9. Timing Relationship of Signals During Gating



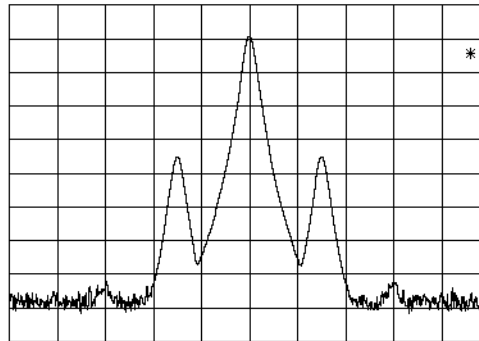
Once the signal analyzer is set up to perform the gate measurement, the spectrum of signal 1 is visible and the spectrum of signal 2 is excluded, as shown in [Figure 11](#). In addition, when viewing signal 1, you also will have eliminated the pulse spectrum generated from the pulse edges. Gating has allowed you to view spectral components that otherwise would be hidden.

Figure 10. Signal within pulse #1 (time-domain view)



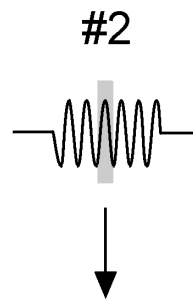
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Figure 11. Using Time Gating to View Signal 1 (spectrum view)



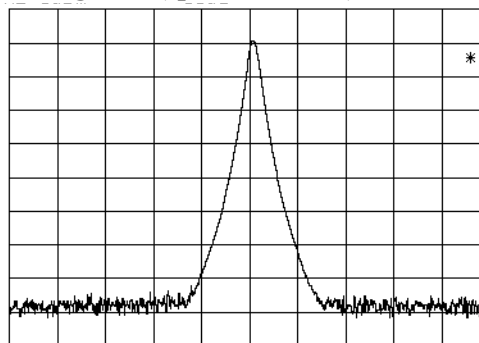
Moving the gate so that it is positioned over the middle of signal 2 produces a result as shown in [Figure 13](#). Here, you see only the spectrum within the pulses of signal 2; signal 1 is excluded.

Figure 12. Signal within pulse #2 (time-domain view)



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Figure 13. 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.

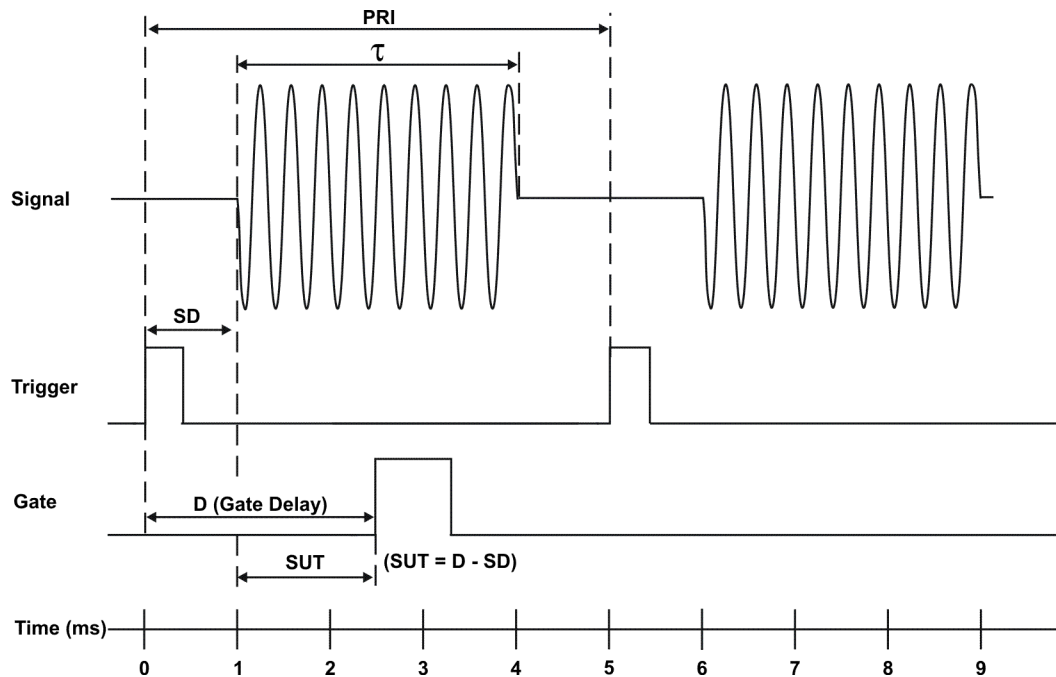
Step 1. Determine how your signal under test appears in the time domain and how it is synchronized to the trigger signal.

Concepts
Time Gating Concepts

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 14. Time-domain Parameters



In Figure 14., 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 $(\text{sweep points} - 1) * (\text{PRI} - \tau)$.

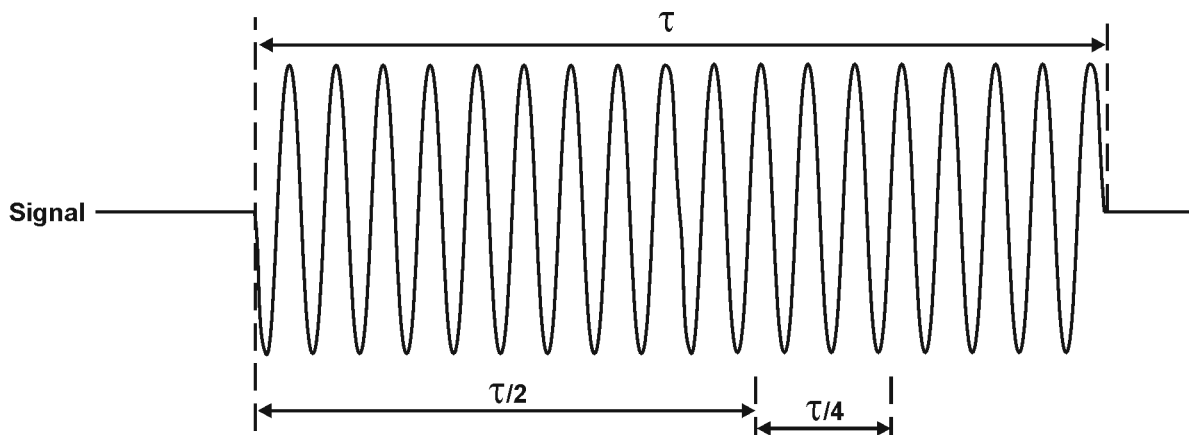
Step 3. Locate the signal under test on the display of the signal analyzer. Set the center frequency and span to view the signal characteristics that you are interested in measuring. Although the analyzer is not yet configured for correct gated measurements, you will want to determine the approximate 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 15](#).

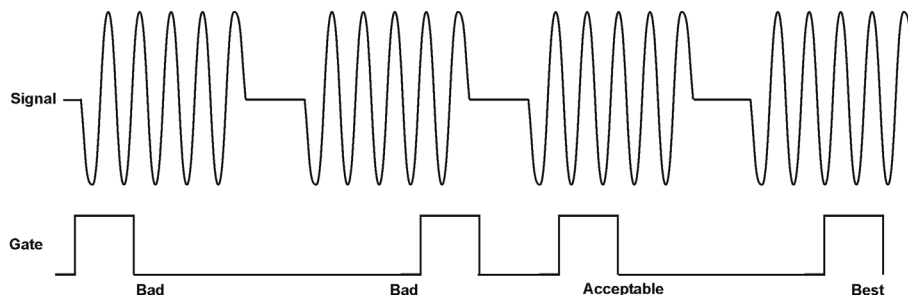
Figure 15. Positioning the Gate



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 16. Best Position for Gate



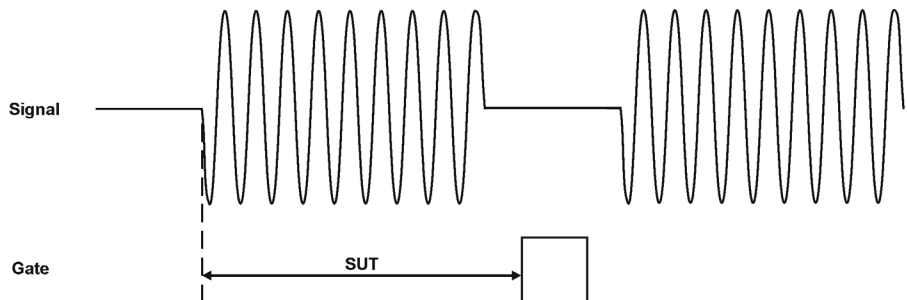
As a general rule, you will obtain the best measurement results if you position the gate relatively late within the signal of interest, but without extending the gate over the trailing pulse edge or signal transition. Doing so maximizes setup time and provides the resolution bandwidth filters of the 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 $3.84/\text{resolution bandwidth}$ (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 17. Setup Time for Interpulse Measurement

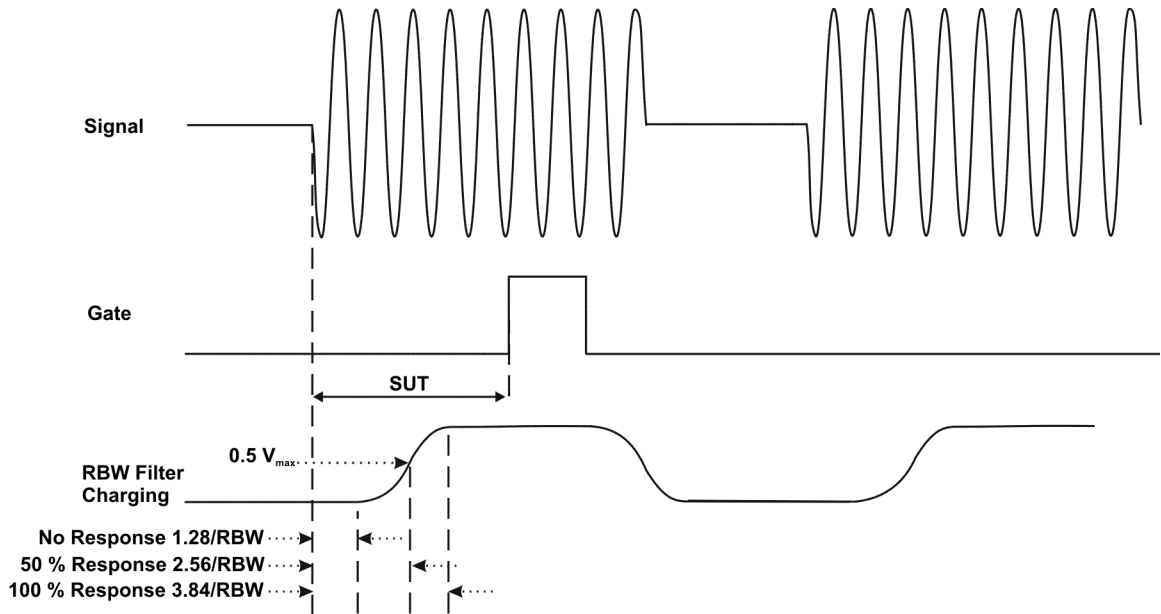


Step 5. The resolution bandwidth will need to be adjusted for gated LO and gated video. The video bandwidth will only need to be adjusted for gated video.

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 18. 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.

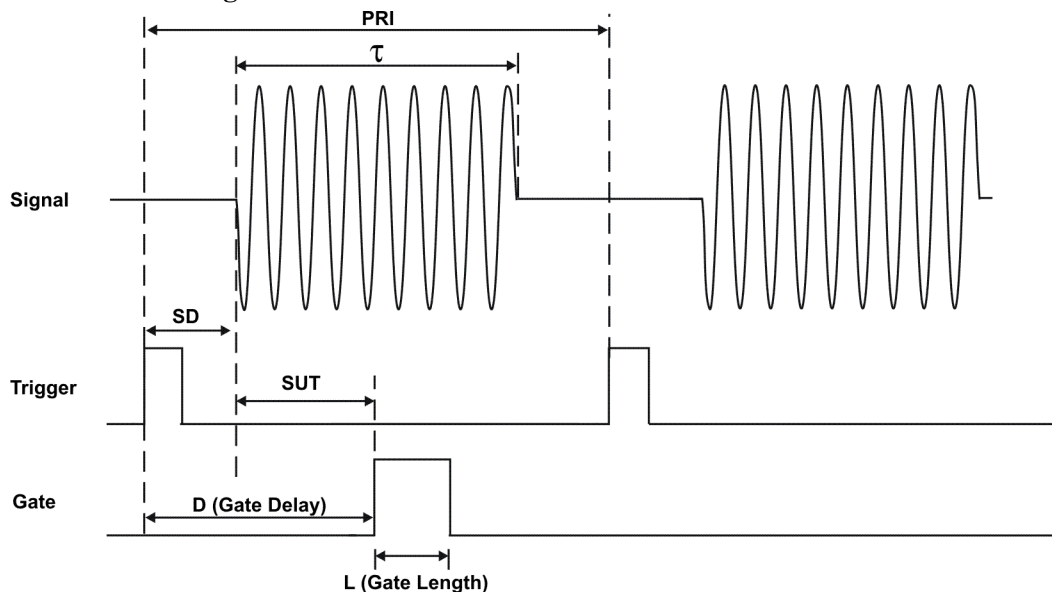
“Quick Rules” for Making Time-Gated Measurements

This section summarizes the rules described in the previous sections.

Table 1. 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) × 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): $Gate\ Length = 0.7 \times \tau/4$	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 19. 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 2 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 2. Suggested Initial Settings for Known Pulse Width (τ) and Zero Signal Delay

Pulse width (τ)	Gate Delay ($SD + \tau/5$)	Resolution Bandwidth ($>19.5/\tau$)	Gate Length ($0.7 \times \tau/4$)
4 μ s	0.8 μ s	4.875 MHz	0.7 μ s
10 μ s	2 μ s	1.95 MHz	1.753 μ s
50 μ s	10 μ s	390 kHz	8.75 μ s
63.5 μ s	12.7 μ s	307 kHz	11.11 μ s
100 μ s	20 μ s	195 kHz	17.5 μ s
500 μ s	100 μ s	39 kHz	87.5 μ s
1 ms	200 μ s	19.5 kHz	0.175 μ s
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
100 ms	20 ms	195 Hz	17.5 ms
≥ 130 ms	26 ms	151 Hz	22.75 ms

Table 3. 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

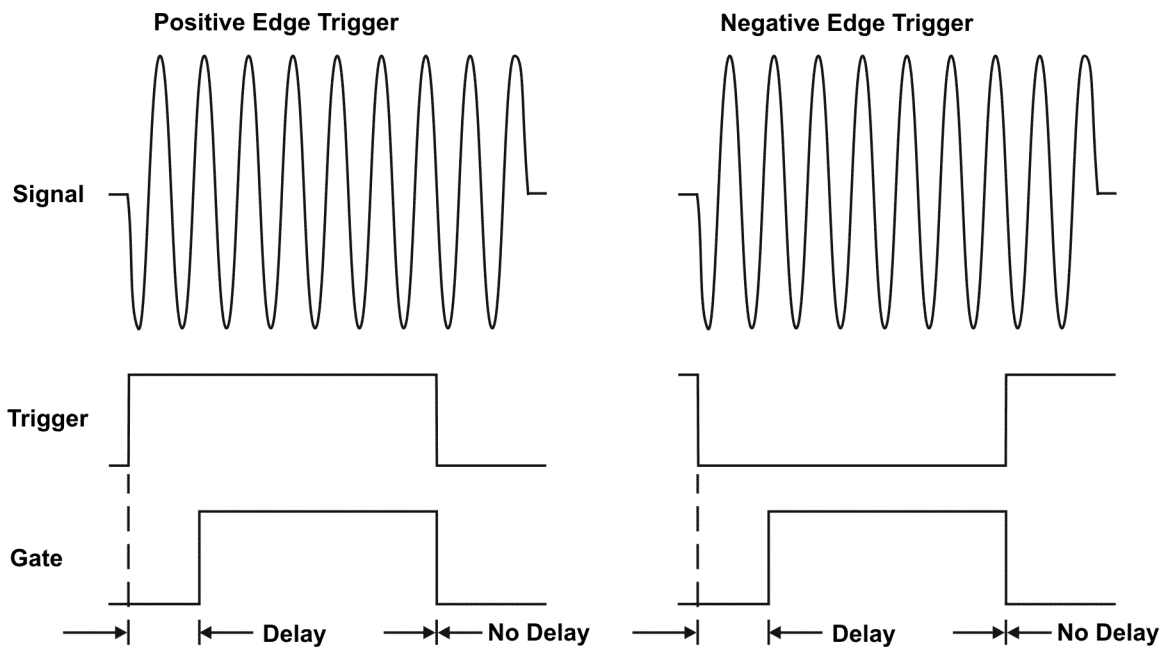
Depending on the trigger signal that you are working with, you can trigger the gate in one of two separate modes: edge or level. This gate-trigger function is separate from the normal external trigger capability of the signal analyzer, which initiates a sweep of a measurement trace based on an external 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 20 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 20. 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

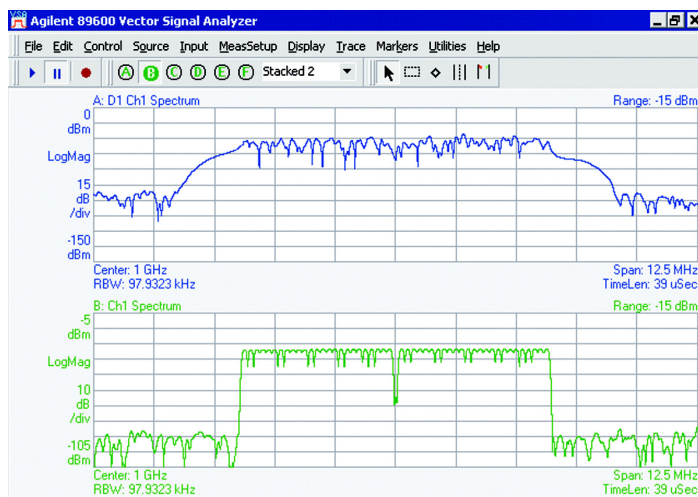
Concepts

Measuring the Frequency Spectrum

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 [Figure 5-22 on page 116](#), 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 5-22 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 successfully 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.

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/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 prefix
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

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List of Acronyms

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 specification
TTA Telecommunications Technology Association
TTI Transmission time interval
UCI Uplink control indicator
UE User equipment

Concepts
List of Acronyms

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

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