Keysight X-Series Signal Analyzers

This manual provides documentation for the following Analyzers:

PXA Signal Analyzer N9030A

MXA Signal Analyzer N9020A

EXA Signal Analyzer N9010A

Notice: This document contains references to Agilent. Please note that Agilent's Test and Measurement business has become Keysight Technologies. For more information, go to www.keysight.com.

LTE FDD & LTE-A FDD Measurement Application Measurement Guide

KEYSIGHT TECHNOLOGIES

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Where to Find the Latest Information

Documentation is updated periodically. For the latest information about these products, including instrument software upgrades, application information, and product information, browse to one of the following URLs, according to the name of your product:

http://www.keysight.com/find/pxa

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Table of Contents

1 About the LTE FDD & LTE-A FDD Measurement Application

This chapter provides overall information on the Keysight LTE FDD & LTE-Advanced FDD Measurement Application and describes the measurements made by the analyzer.

What Does the Keysight LTE FDD & LTE-A FDD Measurement Application Do?

The LTE FDD & LTE-A FDD measurement application is a full-featured LTE FDD & LTE-A FDD 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 FDD & LTE-A FDD communications signals.

The license N9080A/B-1FP (License Type: Fixed/Perpetual. A for Windows XP platform, B for Windows 7 platform) is for LTE-Advanced TDD with one carrier measurement. And the license N9080B-2FP is for LTE-Advanced TDD with multi-carrier measurement and only available in Windows 7 platform, it also requires to have N9080A/B-1FP installed.

The measurement application supports the following standards.

- TS36.211 v.10.7.0 (2013-03) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 10)
- TS36.141 v.11.4.0 (2013-03) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) conformance testing (Release 11)
- TS36.521 v.10.5.0 (2013-03) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception conformance testing (Release 10)
- TS36.212 v.10.7.0 (2012-12) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) Physical Channels and Modulation (Release 10)
- TS36.213 v.10.9.0 (2013-03) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) Physical layer procedures (Release 10)
- TS36.214 v.10.1.0 (2011-03) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) Physical layer; Measurements (Release 10)
- TS36.101 v.11.4.0 (2013-03) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 11)
- TS36.104 v.11.4.0 (2013-03) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (Release 11)
- TS36.201 v.10.0.0 (2010-12) 3GPP TSG-RAN; Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description (Release 10)

This analyzer makes the following measurements providing power measurements and modulation analysis for the LTE & LTE-A FDD signals:

- Modulation Analysis
- Channel Power

- Adjacent Channel Power (ACP)
- Spectrum Emission Mask
- Spurious Emissions
- Occupied BW
- Power Stat CCDF
- Monitor Spectrum
- IQ Waveform (Time Domain)
- Transmit On/Off Power
- Conformance EVM

2 Making LTE FDD & LTE-A FDD Measurements

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

This chapter begins with instructions common to all measurements, and details all LTE FDD & LTE-A FDD 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 15
- "Power Measurements" on page 17
- "Modulation Analysis Measurements" on page 51
- "Conformance EVM Measurement" on page 85

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.

For the SCPI commands and a detailed description of keys and parameters, refer to N9080B LTE FDD & LTE-A FDD Measurement Application User's and Programmer's Reference.

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Setting Up and Making a Measurement

Making the Initial Signal Connection

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

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

Using Analyzer Mode and Measurement Presets

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

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

The 3 Steps to Set Up and Make Measurements

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

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

Step	Action	Notes
1. Select and Set Up the Mode	a.Press **Mode** b.Press a mode key, like **Spectrum Analyzer, LTE FDD & LTE-A FDD** or **GSM/EDGE.** c.Press **Mode Preset.** d.Press **Mode Setup**	All licensed, installed modes available are shown under the **Mode** key. Using **Mode Setup**, make any required adjustments to the mode settings. These settings will apply to all measurements in the mode.
2. Select and Set Up the Measurement	a.Press **Meas.** b.Select the specific measurement to be performed. c.Press **Meas Setup**	The measurement begins as soon as any required trigger conditions are met. The resulting data is shown on the display or is available for export. Use Meas Setup to make any required adjustment to the selected measurement settings. The settings only apply to this measurement.

Table 2-1 The 3 Steps to Set Up and Make 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.

Table 2-2 Main Keys and Functions for Making Measurements

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

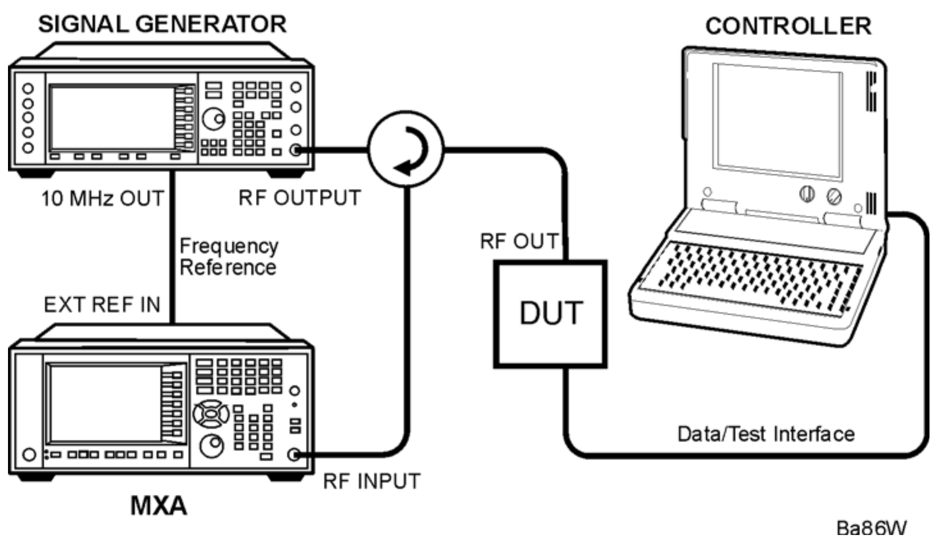
Power Measurements

This chapter explains how to make power measurements on a 3GPP LTE FDD & LTE-A FDD signal.

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

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

Figure 2-1 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 FDD & LTE-A FDD Power Measurements

Setting the Downlink Signal (Example)

This example uses a signal generated using Keysight N7624B Signal Studio for 3GPP LTE-Advanced FDD.

Direction Downlink

Frequency: 1.85 GHz

Output Power: -10 dBm

Component Carriers: 2 (CC0 E-TM1.1 and CC1 E-TM3.1)

Bandwidth: 10 MHz (50 PRB) + 10 MHz (50 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

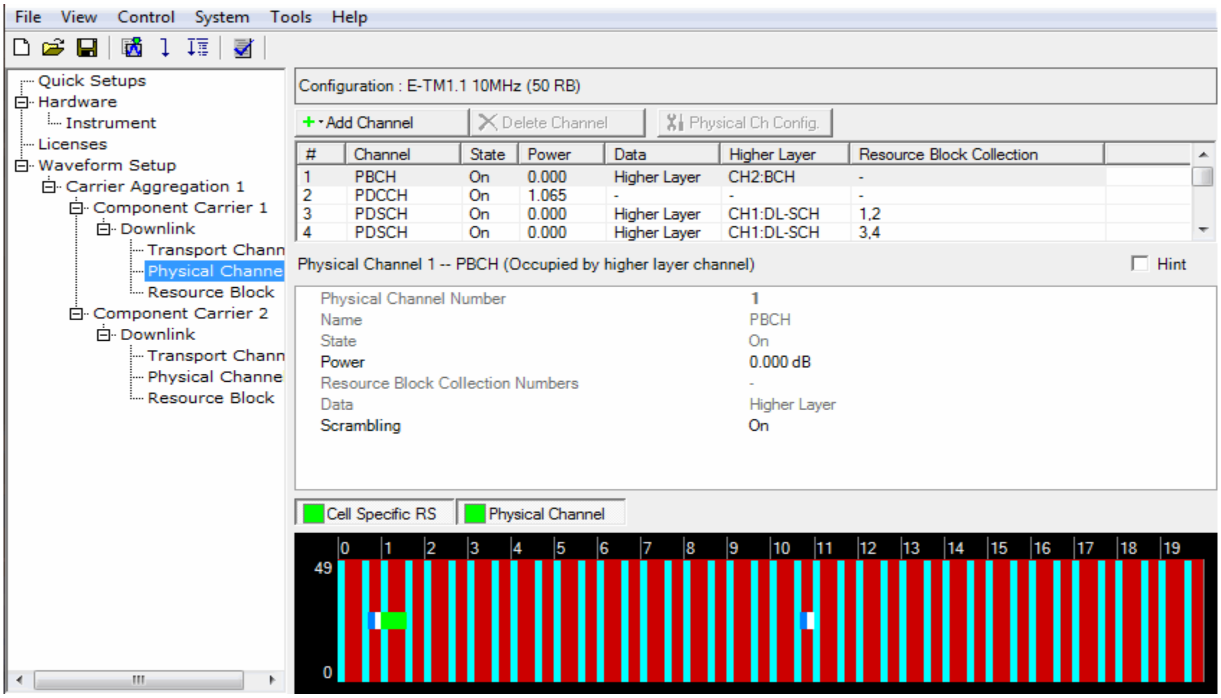
Resource Block:

•Slots = 20

•RB = 0-49

•Power = 0 dB

Figure 2-2 Signal Studio Downlink Setup Graphic Display



Common Measurement Procedure (Downlink)

NOTE	The following procedures are common and need to set up for all measurements.

Step	Action	Notes
1 Enable the LTE FDD & LTE-A FDD measurements.	Press **Mode**, **LTE FDD & LTE-A FDD**.	
2 Preset the Mode.	Press **Mode Preset.**	Only do this to return the measurement settings to a known state for all measurements in the LTE FDD & LTE-A FDD mode.
3 Set the carrier reference frequency.	Press **FREQ Channel**, **Carrier Ref Freq, 1.85**, **GHz.**	The center frequencies of carriers are defined as offset frequency from this value.
NOTE	You may need to change the Center Freq and Center Freq Offset settings to satisfy the channel spacing requirement according to the 3GPP standard.	
4 Select the direction to **Downlink**.	Press **Mode Setup**, **Direction** to be **Downlink**. Downlink is the default setting.	For uplink signal, change the direction to Uplink.
5 Configure the two component carriers.	a. Press **Mode Setup, Component Carrier Setup.** b. Press **Num Component Carriers, 2.** c. Press **Configure Component Carriers, Component Carrier, CC0**. d. Press **Freq Offset, -5 MHz.** e. Press **Bandwidth Setup, System BW, 10 MHz (50 RB)**. f. Press **Configure Component Carriers, Component Carrier, CC1**. g. Press **Freq Offset, 5 MHz.** h. Press **Bandwidth Setup, System BW, 10 MHz (50 RB)**. i. Press **Carrier Allocation, Contiguous.**	The measurement example is for contiguous carriers. If the carriers are non-contiguous, the Carrier Allocation under Component Carrier Setup needs to be set up. Press Mode Setup, Preset to Standard to preset measurement parameters besides BW. For a list of all presets effected see "Preset to Standard Settings" on page 95.

Step	Action	Notes
6 Select the predefined parameters such as Analysis Slot, Meas Interval or CP Length	Press **Mode Setup, Predefined Parameters** to set up the parameters. Configure Analysis Slot to be TS10, Meas Interval to be 13 slots. CP Length to be Normal.	Analysis Slot is defined as the first slot for analysis.

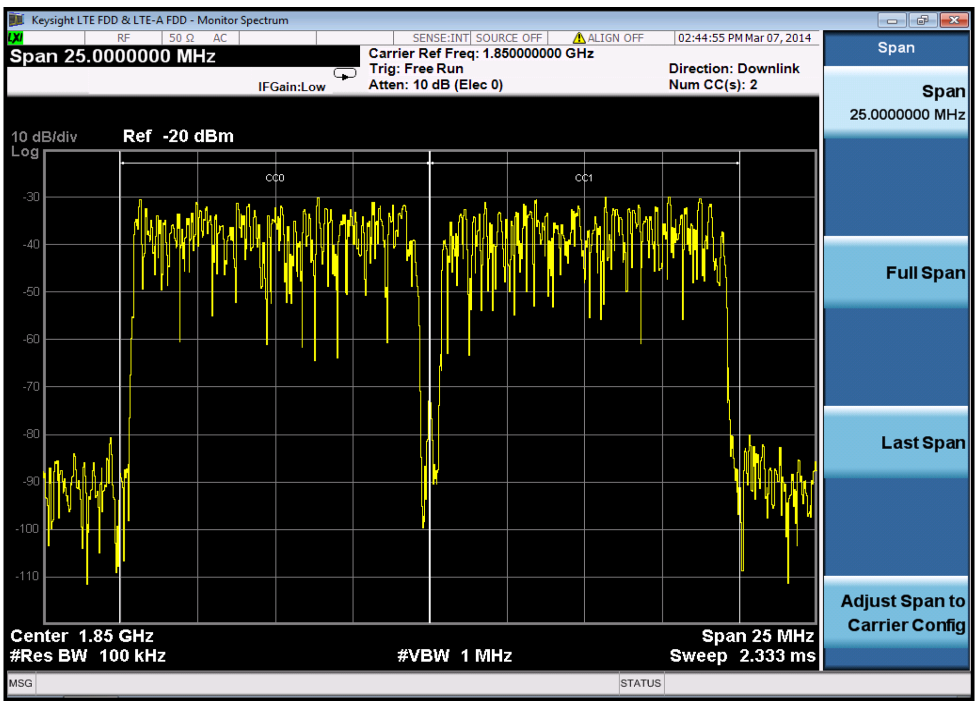
NOTE The settings under Mode Setup and Predefined Parameters are used for power measurements, which do not apply to the Modulation Analysis measurement.

Monitor Spectrum Measurement Procedure

Monitor Spectrum measurements show a spectrum domain display of the LTE & LTE-A signal. Marker functions may be used to provide Band Power, Noise and Band Interval Density measurements over the signal bandwidth.

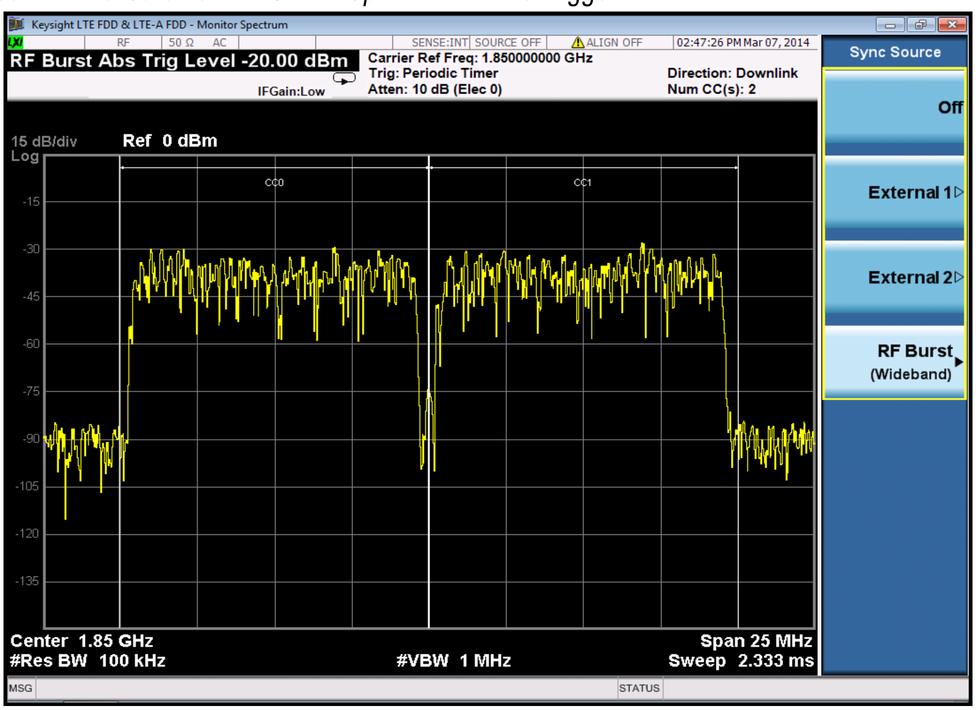
Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Initiate the Monitor Spectrum measurements.	Press **Meas**, **Monitor Spectrum**.	Monitor Spectrum measurement is the default measurement of LTE FDD & LTE-A FDD measurement application.
3 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 **25, MHz**.	The Monitor Spectrum measurement LTE default result should look like Figure 2-3.

Figure 2-3 Monitor Spectrum Measurement - Default View



Step	Action	Notes
4 To stabilize the signal display use a measurement trigger.	a. Press **Trigger, More, Periodic Timer (Frame Trigger)** to trigger the measurement with the Frame Timer. b. Press Period, 10, ms (or any multiple of 10 ms, the LTE frame period) to trigger the measurement on the frame. c. Press **Periodic Timer (Frame Trigger)** again to access the Timer Setup menu. d. Press **Sync Source** in the Timer Setup menu and select **RF Burst (Wideband)** to sync the periodic trigger to the RF Burst.	The Monitor Spectrum triggered result should look like Figure 2-4.

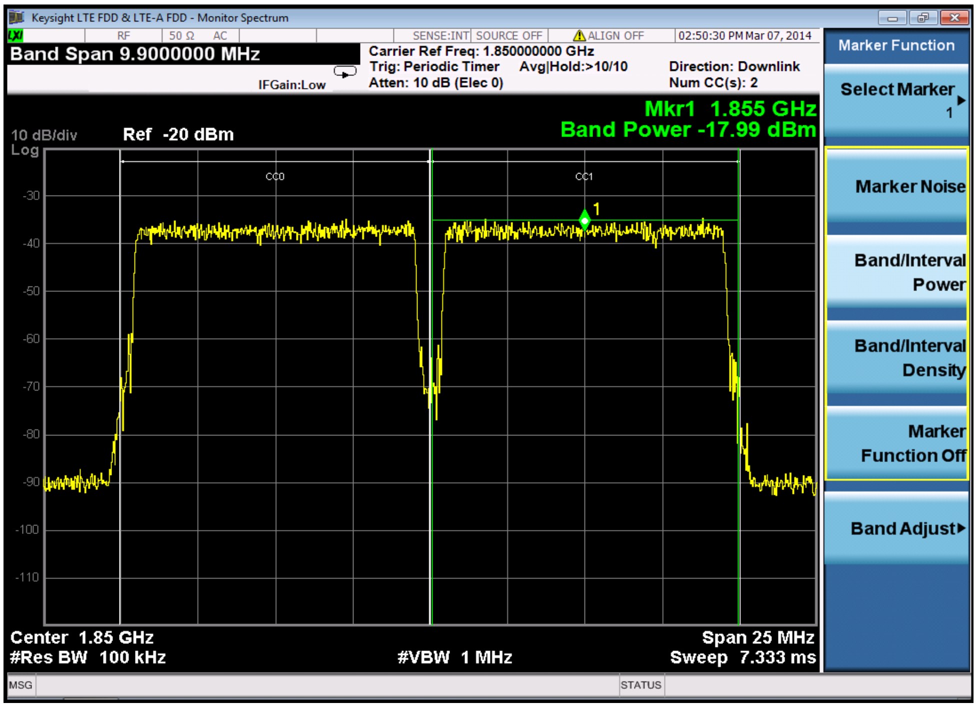
Figure 2-4 Monitor Spectrum Measurement - 25 MHz Span with Frame Trigger



5 Adjust the measurement.	Press the **Meas Setup** key to adjust **Avg Number**.	

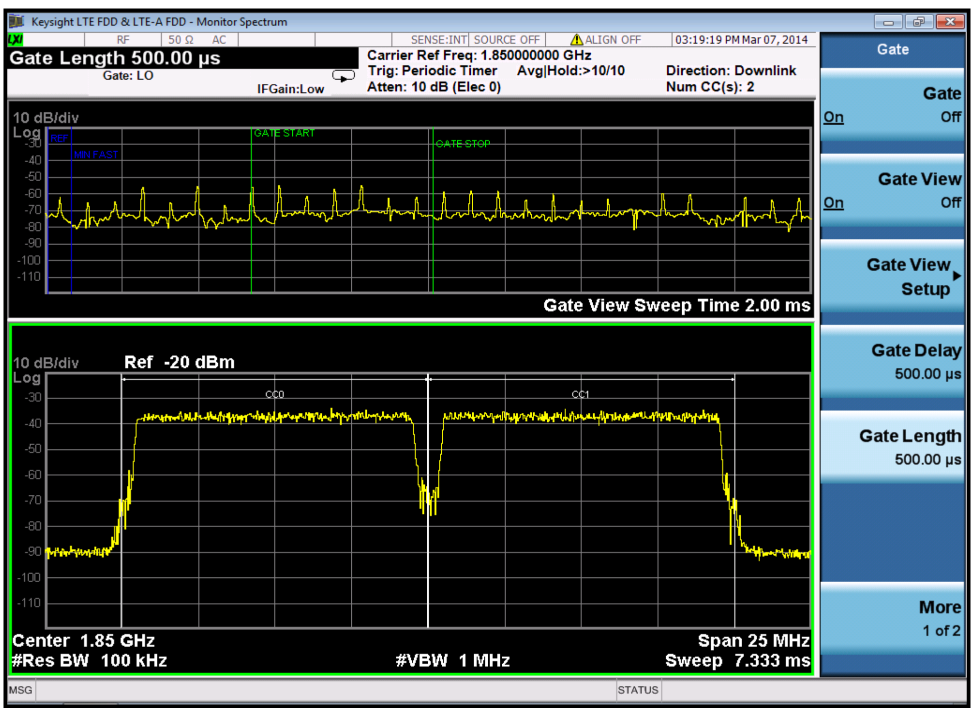
Step	Action	Notes
6 Use Band Power and other functions.	Press **Marker Function, Band Interval/Power** and select **Band Adjust.** You can use the knob to dial the marker limits to the desired setting, or enter values directly from the front panel.	The example display in Figure 2-5 shows the limits at the band edges and indicates the Band Power measurement for CC1. Other Marker Functions include Noise power measurement markers and Band Interval/Density power measurement markers.

Figure 2-5 Monitor Spectrum Measurement - Band Power Marker



Step	Action	Notes
7 Adjust Gate function and turn Gate On.	a. Press **Gate View Sweep Time** and set it to 2 ms (4 LTE slots).	Gate function that enables you measure the spectrum power over a precise interval, like an Slot or Subframe.
	b. 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.	For best results, always set **Gate Delay** to position `Gate Start` after `Max Fast` to allow the LO to “settle”. The Monitor Spectrum measurement result should look like Figure 2-6. The Gate Start and Gate Stop markers are shown in the time domain Gate View. The Spectrum display represents the average amplitude across the 10 MHz bandwidth during the single slot.
	c. Press **Gate Length** and set it to 0.5 ms, the length of an LTE slot.	
	d. Press Gate Source to select the appropriate gate source.	
	e. Press **Gate** and toggle it to **On.**	
	f. Press **Gate View (On).**	

Figure 2-6 Monitor Spectrum Measurement - Gate View



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

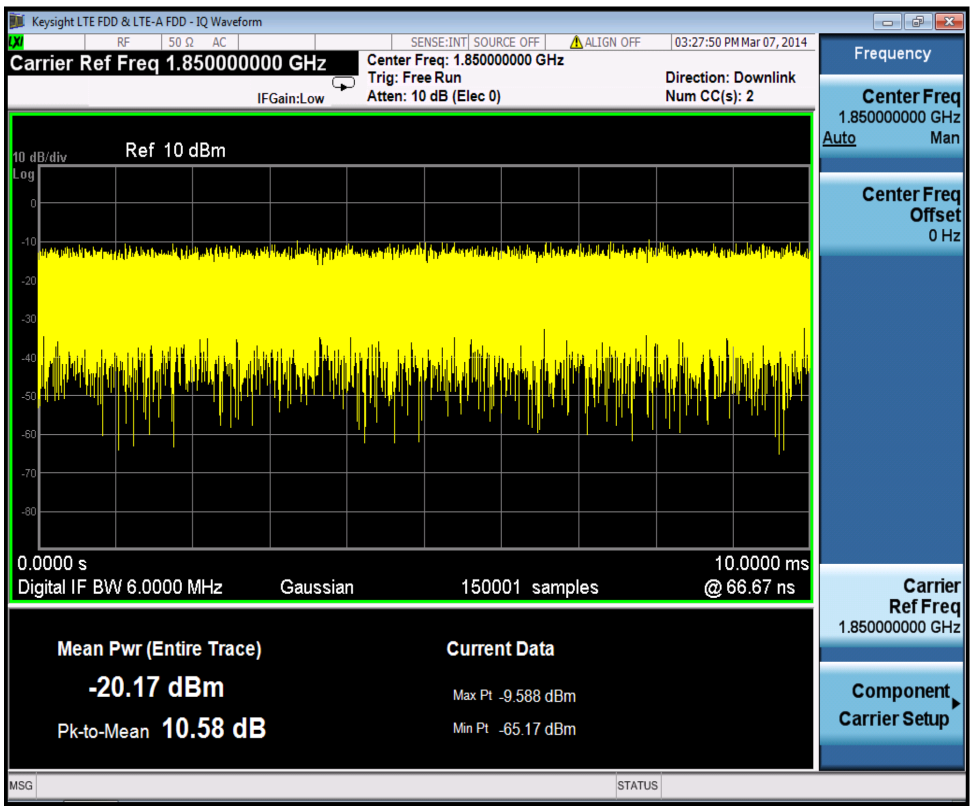
C:\Program Files\Keysight\SignalAnalysis\Infrastructure\Help\bookfiles.

IQ Waveform (Time Domain) Measurement Procedure

The measurement of I and Q modulated waveforms in the time domain disclose the voltages, which comprise the complex modulated waveform of a digital signal.

Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Initiate the IQ Waveform measurement.	Press **Meas**, **IQ Waveform**.	The default display in Figure 2-7 shows the RF Envelope with the current data. The measured values for the mean power and peak-to-mean power are shown in the text window.

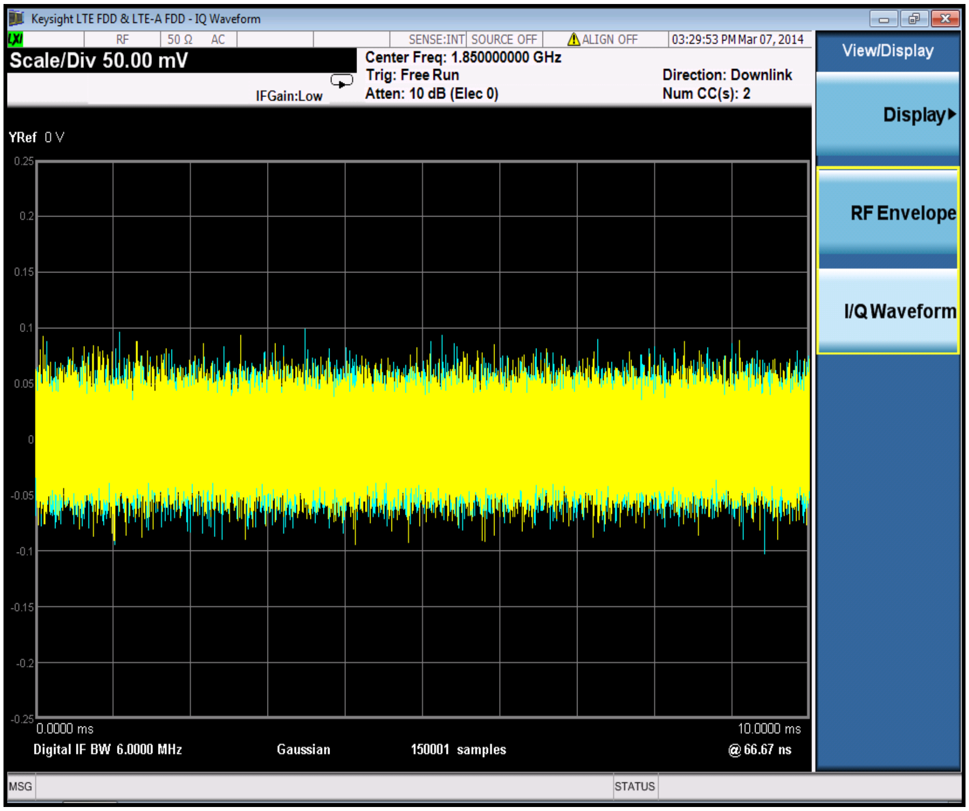
Figure 2-7 LTE FDD & LTE-A FDD Downlink IQ Waveform Measurement Result



Step	Action	Notes
3 Select the IQ Waveform view.	Press **View/Display**, **IQ Waveform**.	The IQ Waveform window provides a view of the I (yellow trace) and Q (blue trace) waveforms on the same graph in terms of voltage versus time in linear scale.

Step	Action	Notes

Figure 2-8 LTE FDD & LTE-A FDD Downlink Waveform Measurement - I/Q Waveform View



Step	Action	Notes
4 Adjust the scale.	Press the **AMPTD Y Scale** and SPAN X Scale and configure the setup until the waveforms are shown at a convenient voltage scale for viewing.	
5 Turn on Marker functions.	Press the **Maker Function** key to use Maker Noise, Band/Interval Power, Band/Interval Density and Marker Function Off. You can use Band Adjust to set the frequency span for analysis.	
6 (Optional) Change measurement parameters from their default condition.	Press the **Meas Setup** key to see the keys available to change.	

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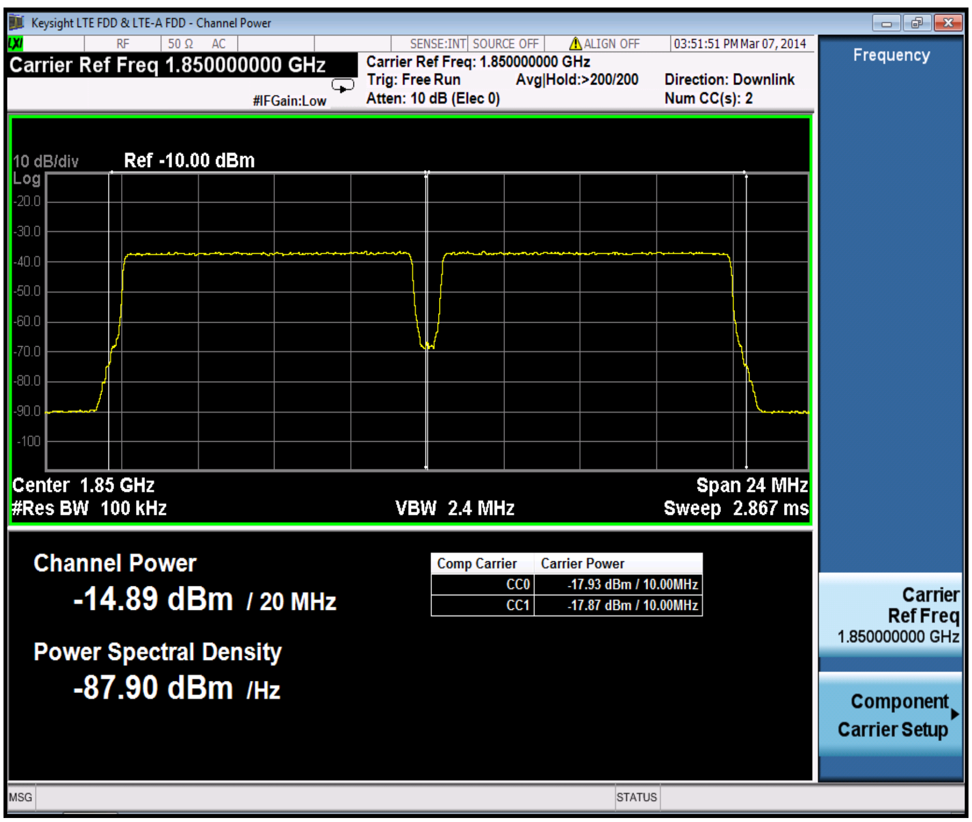
Channel Power Measurement Procedure

This test measures the total RF power present in the channel. The results are shown in a graph window and in a text window.

Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Initiate the channel power measurement.	Press **Meas**, **Channel Power**.	The Integration BW is shown within the two white lines. The Channel Power measurement result should look like Figure 2-9. The graph window and the text window show the absolute power and its mean power spectral density values.

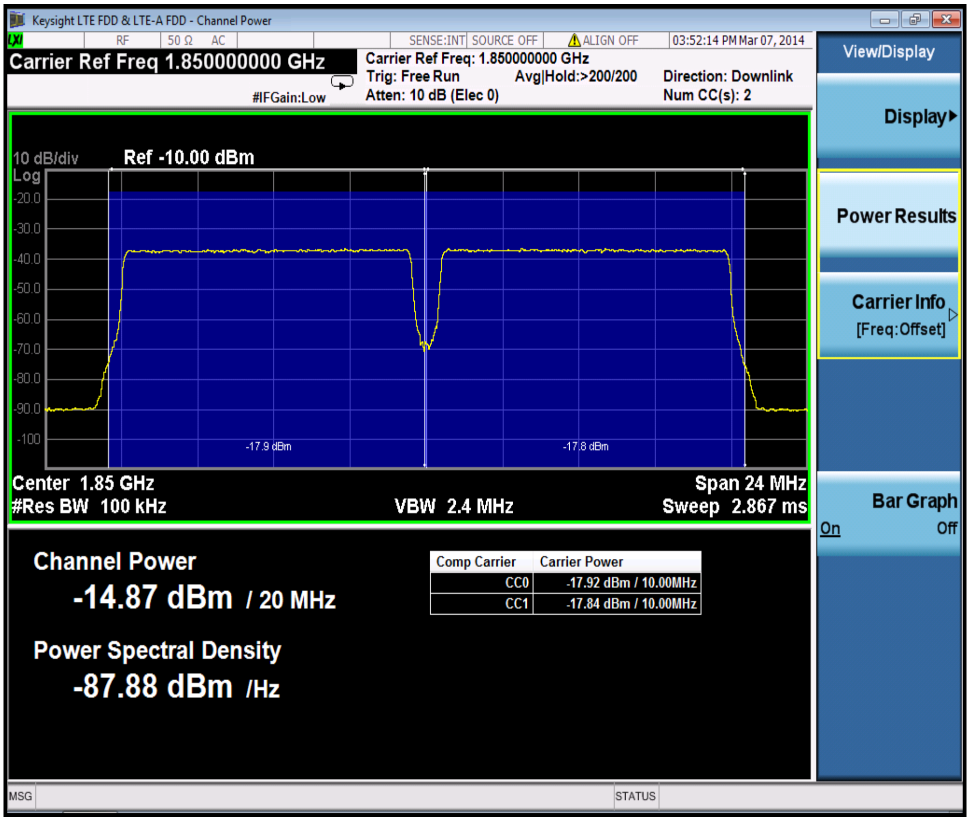
Figure 2-9 LTE FDD & LTE-A FDD Downlink Channel Power Measurement Result



Step	Action	Notes
3 (Optional) Display the Channel Power Bar Graph view.	Press **View/Display**, **Bar Graph**.	The Bar Graph view result should look like Figure 2-10.

Step	Action	Notes

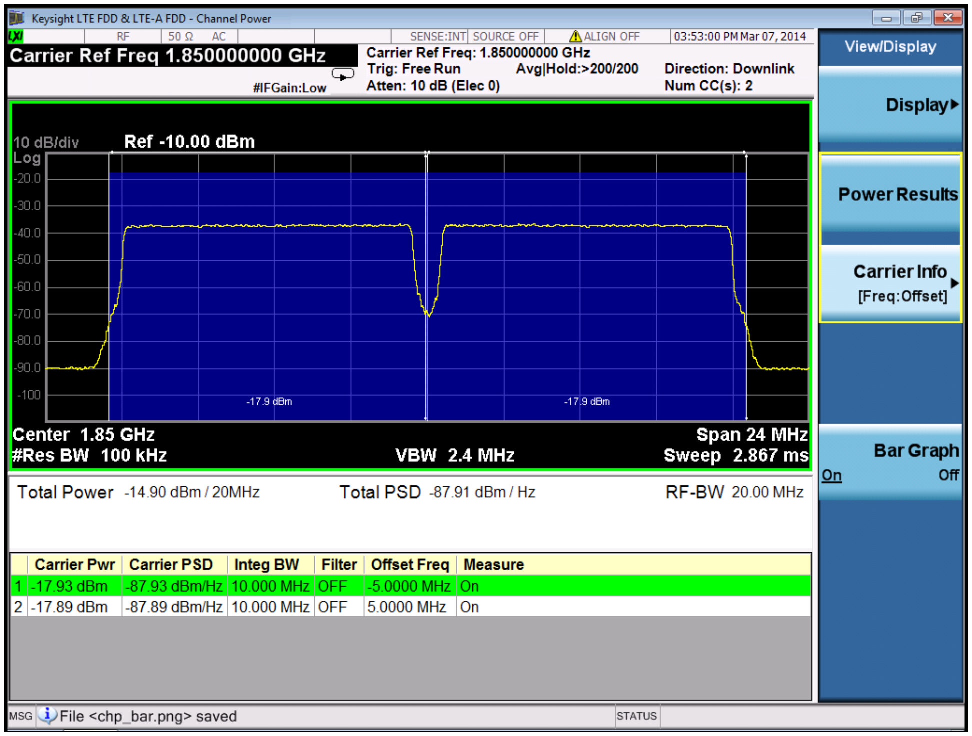
Figure 2-10 LTE FDD & LTE-A FDD Downlink Channel Power Measurement Result - Bar Graph On



Step	Action	Notes
4 Display the carrier info view.	Press **View/Display**, **Carrier Info.**	The measured component carrier power and its power spectral density are displayed in the order of component carrier index in the view window like Figure 2-11.

Step	Action	Notes

Figure 2-11 LTE FDD & LTE-A FDD Downlink Channel Power Measurement Result - Carrier Info



Step	Action	Notes
5 (Optional) Change measurement parameters from their default condition.	Press **Meas Setup** to see the keys that are available to change.	

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

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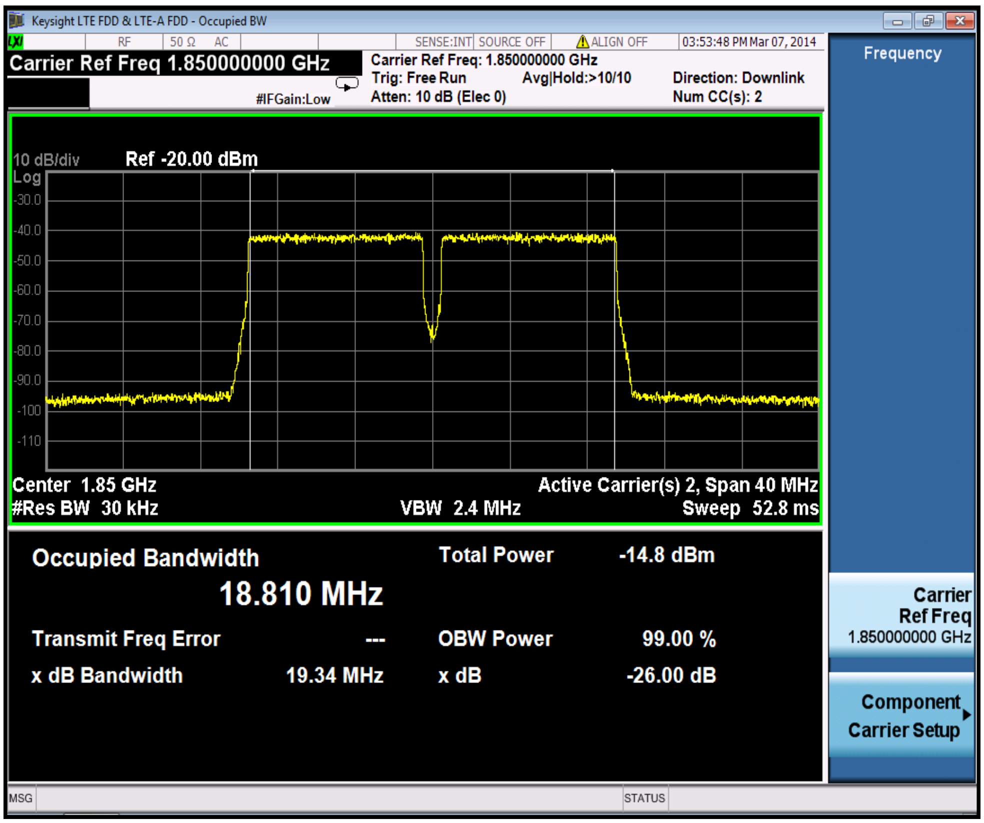
Occupied Bandwidth Measurement Procedure

The instrument measures power across the band, and then calculates its 99.0% power bandwidth.

Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Initiate the Occupied Bandwidth measurement.	Press **Meas**, **Occupied BW**.	The Occupied BW measurement results should look like Figure 2-12.

Figure 2-12 LTE FDD & LTE-A FDD Downlink Occupied BW Measurement Result



3 (Optional) Change measurement parameters from their default condition.	Press **Meas Setup** to see the keys that are available to change measurement parameters from their default condition.	

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Troubleshooting Hints

Any distortion such as harmonics or intermodulation produces undesirable power outside the specified bandwidth.

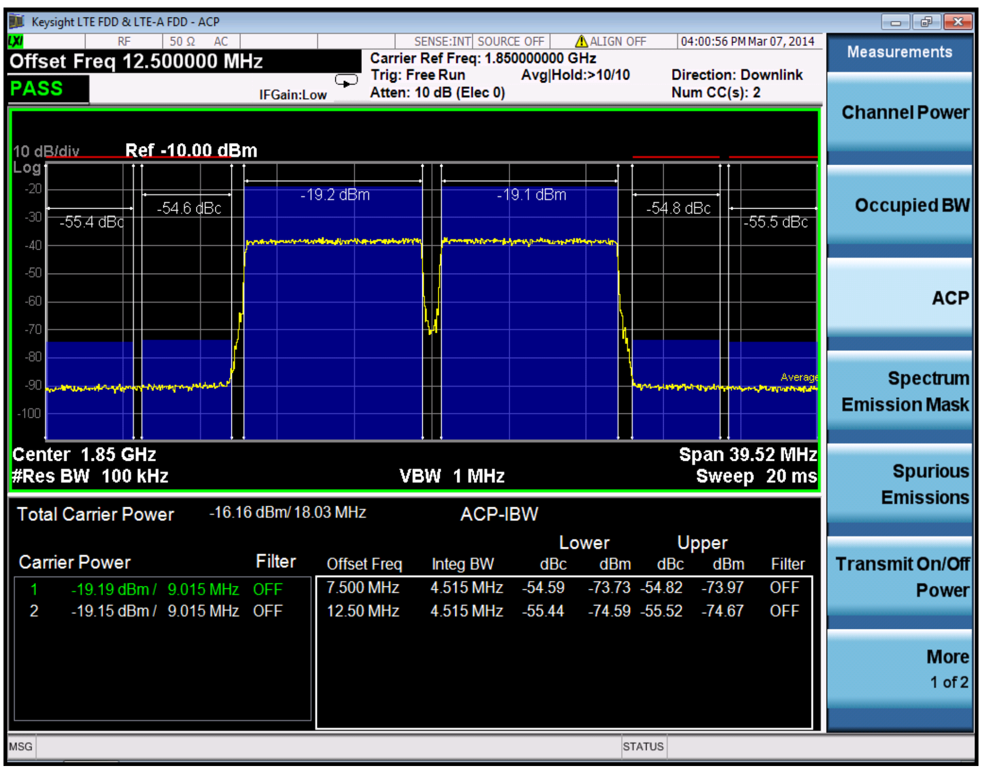
Shoulders on either side of the spectrum shape indicate spectral regrowth and intermodulation. Rounding or sloping of the top shape can indicate filter shape problems.

ACP Measurement Procedure

ACPR (Adjacent Channel Leakage Power Ratio) is a measurement of the amount of interference, or power, in an adjacent frequency channel. The results are displayed as a bar graph or as spectrum data, with measurement data at specified offsets.

Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Initial the ACP measurement.	Press **Meas**, **ACP**.	The ACP measurement results including the bar graph with the spectrum trace graph overlay should look like Figure 2-13. The graph (referenced to the total power) and a text window are displayed. The text window shows the absolute total power reference, while the lower and upper offset channel power levels are displayed in both absolute and relative readings for each component carrier.

Figure 2-13 LTE FDD & LTE-A FDD Downlink ACP Measurement Result



Step	Action	Notes
3 Recall the masks.	Press Recall, Data, Mask then Open..., a file open dialog appears. Select the appropriate test model file and click open.	The Recall function is provided for mask defined in standard 36.141 to set up the Offset/Limit parameters automatically. The other parameters will not be changed. At the bottom of the screen, there is a message to indicate which mask file is recalled.
4 Configure the limit for each offset.	Press **Meas Setup, Outer Offset/Limits and Inner Offset/Limits** to configure the settings outside and between component carriers.	Inner offsets are defined from the sub-block edges to the gap; limits from two sub-blocks overlap each other. The red dotted lines indicate the limits and the sign “PASS” or “FAIL” at the top left corner of the screen shows the result. If the result is fail, the bar of the related offset turns red.

NOTE **Noise Correction** can reduce the noise contribution of the analyzer to the measurement results as much as 10 dB. When the measured power is close to the noise floor, turning on the Noise Correction under the Meas Setup menu can make the measurement more accurate. The correction will be only valid for current measurement parameters.

CAUTION To correctly use the **Noise Correction** feature, you MUST re-calibrate the correction (set to **Off**, then **On**) after ANY measurement parameters are changed. Failure to re-calibrate the Noise Correction will provide invalid data. When **Noise Correction** is **On**, the screen annotation `NCORR` is shown below the `Input`.

Step	Action	Notes
5 (Optional) Adjust the dynamic range.	Press **AMPTD** and adjust the **Attenuation** to 0 dB.	This allows greater dynamic range for this level of input signal.

TIP For the most accurate ACP measurement results, you may be able to optimize the level of the signal measured by the analyzer. Adjust the input attenuation using the Up/Down keys, while watching the ACP levels shown at the offsets to see if the measurement results improve with another setting.

Step	Action	Notes
6 (Optional) Change measurement parameters from their default condition.	Press **Meas Setup** to see the keys that are available to change.	

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

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

Spurious Emissions Measurement Procedure

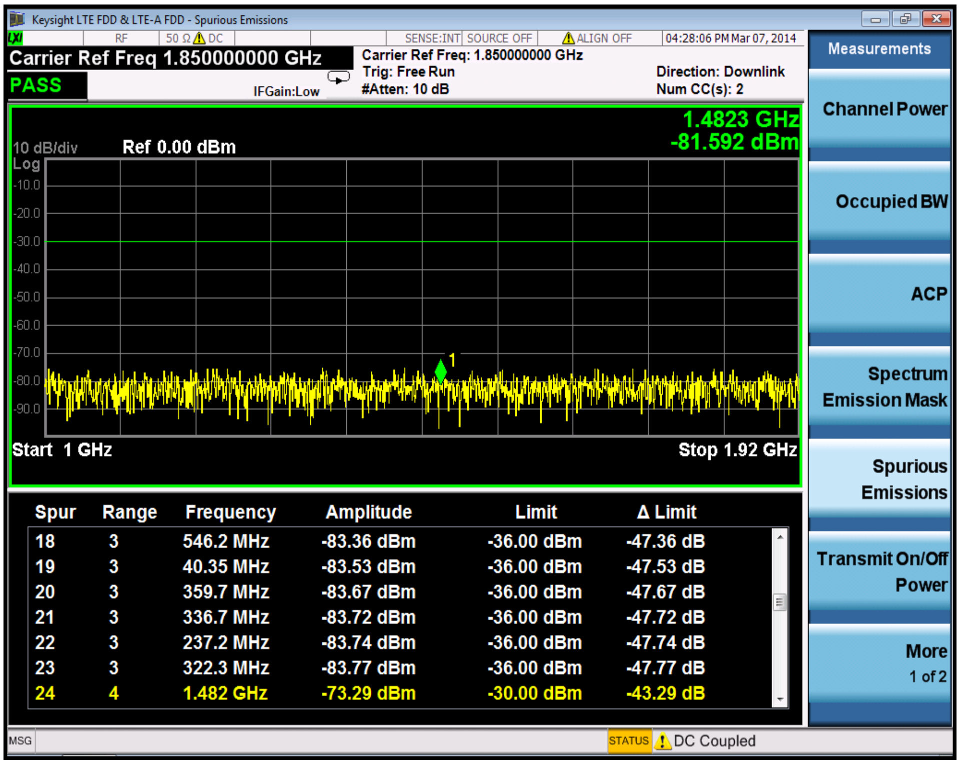
This section explains how to make the Spurious Emissions measurement on a LTE FDD & LTE-A FDD downlink signal. The measurement procedure for uplink signal is similar. This measurement identifies and determines the power level of spurious emissions in certain frequency bands.

Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Toggle the RF Coupling to DC.	Press **Input/Output**, **RF Input**, **RF Coupling**, **DC**.	In AC coupling mode, you can view signals less than 10 MHz but the amplitude accuracy is not specified. To accurately see a signal of less than 10 MHz, you must switch to DC coupling. When operating in DC coupled mode, ensure protection of the External Mixer by limiting the DC part of the input level to within 200 mV of 0 Vdc.
3 Initiate the Spurious Emission measurement.	Press **Meas**, **Spurious Emission**.	Depending on the current settings, the instrument will begin making the selected measurements. The resulting data is shown on the display. The Spurious Emissions measurement results should look like Figure 2-14. The spectrum window and the text window show the spurs that are within the current value of the Marker Peak Excursion setting of the absolute limit. Any spur that has failed the absolute limit will have an 'F' beside it. The measurement result shows the largest spur, which is yellow. You can select the other spur by pressing Meas Setup, Spur and enter the number of the spur.

NOTE If you set the Meas Type to Examine, the trace is continuously updating to show the latest spectrum range that has the worst spur. However, the table always shows the last reported trace information. Press Restart to update the table to show the latest result.

Step	Action	Notes
4 Recall the masks.	Press **Recall, Data, Mask then Open...**, a file open dialog appears. Select the appropriate mask file and click open.	The Recall function is provided for the masks defined in standard 36.141 to set up the Range Table parameters automatically. The other parameters will not be changed. At the bottom of the screen, there is a message to indicate which mask file is recalled.

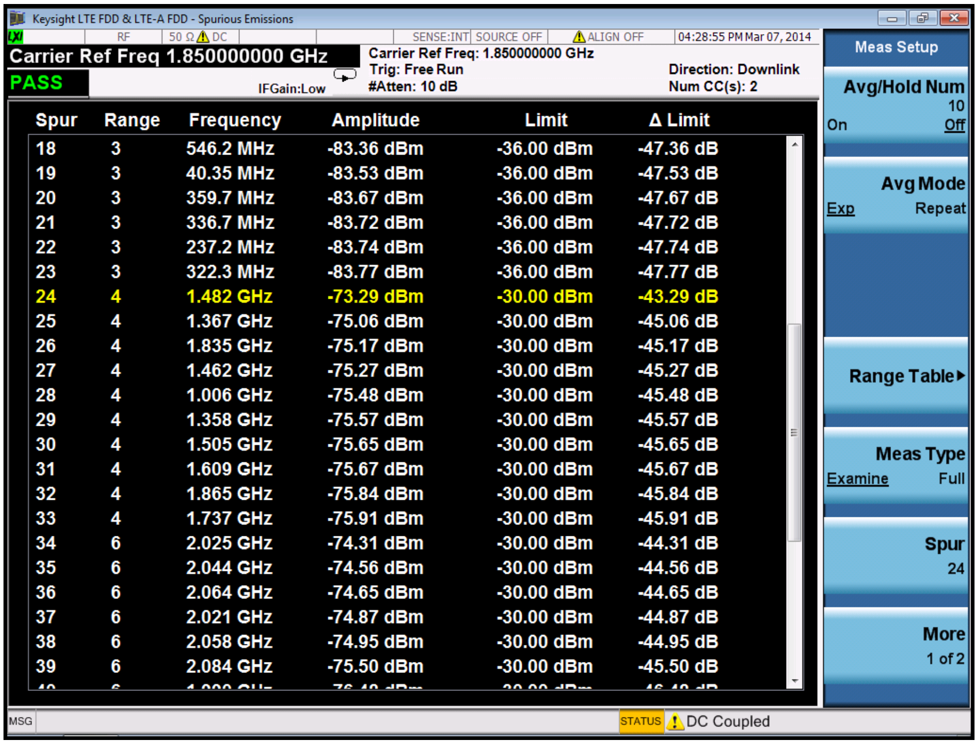
Figure 2-14 LTE FDD & LTE-A FDD Downlink Spurious Emissions Measurement - Spur Table



You can use the window control keys below the screen to zoom the result screen. See Figure 2-15.

Step	Action	Notes

Figure 2-15 LTE FDD & LTE-A FDD Downlink Spurious Emissions Measurement - Numeric Result Screen

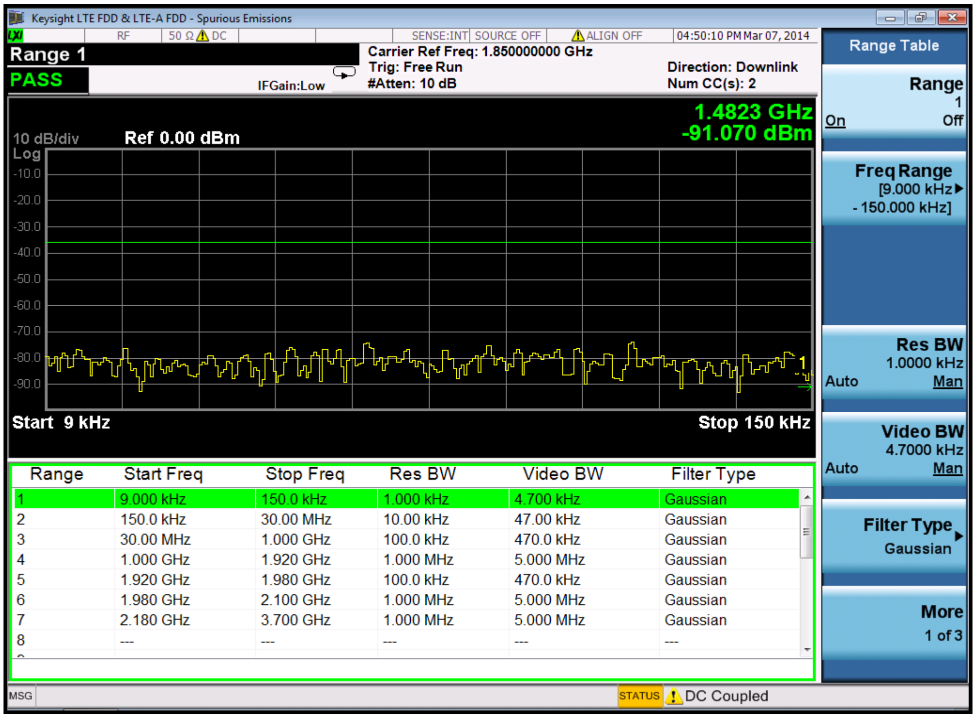


Spur	Range	Frequency	Amplitude	Limit	Δ Limit
18	3	546.2 MHz	-83.36 dBm	-36.00 dBm	-47.36 dB
19	3	40.35 MHz	-83.53 dBm	-36.00 dBm	-47.53 dB
20	3	359.7 MHz	-83.67 dBm	-36.00 dBm	-47.67 dB
21	3	336.7 MHz	-83.72 dBm	-36.00 dBm	-47.72 dB
22	3	237.2 MHz	-83.74 dBm	-36.00 dBm	-47.74 dB
23	3	322.3 MHz	-83.77 dBm	-36.00 dBm	-47.77 dB
24	4	1.482 GHz	-73.29 dBm	-30.00 dBm	-43.29 dB
25	4	1.367 GHz	-75.06 dBm	-30.00 dBm	-45.06 dB
26	4	1.835 GHz	-75.17 dBm	-30.00 dBm	-45.17 dB
27	4	1.462 GHz	-75.27 dBm	-30.00 dBm	-45.27 dB
28	4	1.006 GHz	-75.48 dBm	-30.00 dBm	-45.48 dB
29	4	1.358 GHz	-75.57 dBm	-30.00 dBm	-45.57 dB
30	4	1.505 GHz	-75.65 dBm	-30.00 dBm	-45.65 dB
31	4	1.609 GHz	-75.67 dBm	-30.00 dBm	-45.67 dB
32	4	1.865 GHz	-75.84 dBm	-30.00 dBm	-45.84 dB
33	4	1.737 GHz	-75.91 dBm	-30.00 dBm	-45.91 dB
34	6	2.025 GHz	-74.31 dBm	-30.00 dBm	-44.31 dB
35	6	2.044 GHz	-74.56 dBm	-30.00 dBm	-44.56 dB
36	6	2.064 GHz	-74.65 dBm	-30.00 dBm	-44.65 dB
37	6	2.021 GHz	-74.87 dBm	-30.00 dBm	-44.87 dB
38	6	2.058 GHz	-74.95 dBm	-30.00 dBm	-44.95 dB
39	6	2.084 GHz	-75.50 dBm	-30.00 dBm	-45.50 dB

Step	Action	Notes
5 Select the Range Table view and edit the Range Table.	Press **View/Display, Range Table**, then Meas Setup, Range Table.	You can enter the settings for up to twenty ranges. The measurement result highlights the selected range. If you want to change the settings of different ranges, you can press Meas Setup, Range Table, Range, then enter the range number you need to configure.

Step	Action	Notes

Figure 2-16 LTE FDD & LTE-A FDD Downlink Spurious Emissions Measurement - Range Table



6 (Optional) Change measurement parameters from their default condition.	Press **Meas Setup** to see the keys that are available to change.	

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

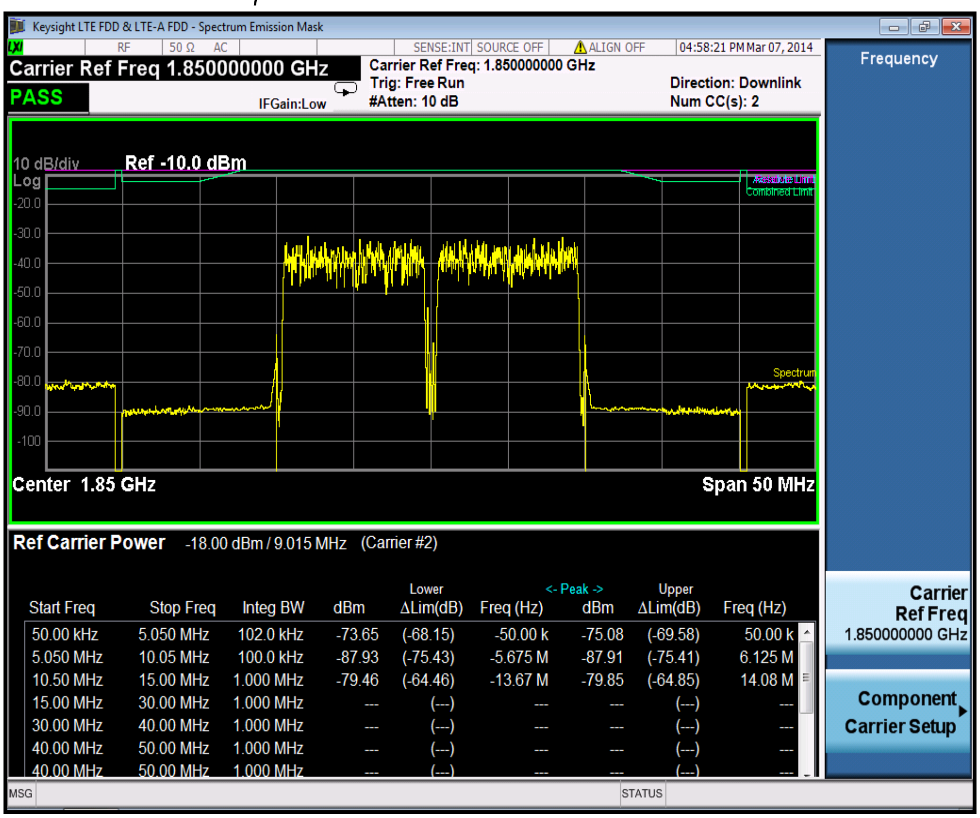
C:\Program Files\Keysight\SignalAnalysis\Infrastructure\Help\bookfiles.

Spectrum Emission Mask Measurement Procedure

SEM compares the total power level within the defined carrier bandwidth and the given offset channels on both sides of the carrier frequency, to levels allowed by the standard. Results of the measurement of each offset segment can be viewed separately.

Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Initiate the Spectrum Emission Mask measurement.	Press **Meas**, **Spectrum Emission Mask.**	The Spectrum Emission Mask measurement result should look like Figure 2-17. The text window shows the reference total power and the absolute peak power levels that correspond to the frequency bands on both sides of the reference channel. The cyan line is the absolute limit line and the purple line is the relative limit line. The limit lines are turned on by default.

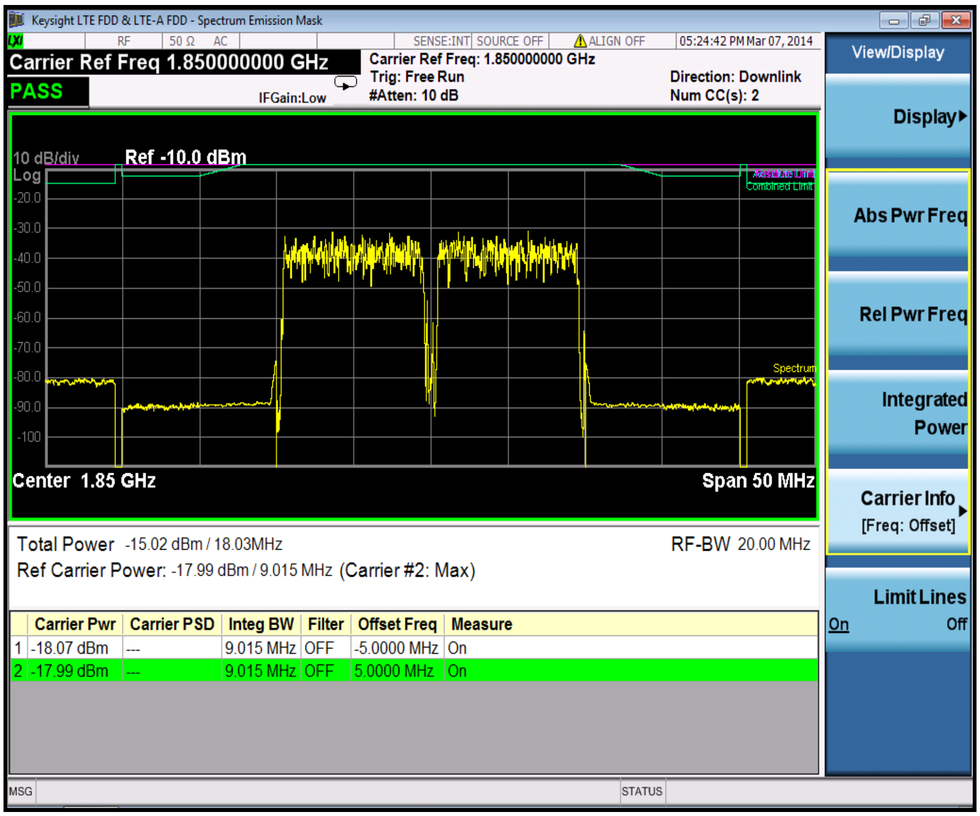
Figure 2-17 LTE FDD & LTE-A FDD Downlink Spectrum Emission Mask Measurement Result



Step	Action	Notes
NOTE	The default gate source is External 1, if you want to use another gate source, press Sweep/Control, Gate, More, Gate Source. Five types of gate sources are provided: Line, External 1, External 2, RF Burst and Periodic Timer.	
3 Recall the masks.	Press **Recall, Data, Mask then Open...**,a file open dialog appears. Select the appropriate file and click open.	The Recall function is provided for the masks defined in standard 36.141 to set up the Offset/Limit parameters automatically. The other parameters will not be changed. At the bottom of the screen, there is a message to indicate which mask file is recalled.
4 Select the desired outer offset pairs.	Press **Meas Setup**, **Outer Offset/Limit, Select Outer Offset.** Select the offset you want to turn on and press Start Freq, On. You can change the Start Freq, Stop Freq and other values for the offset.	The value of offset A, B, C is designed according to the standard and they are turned on by default. When there are many offsets to measure, you can increase the Res BW under Meas Setup, Outer Offset/Limit to increase the measurement speed.
5 Select the desired inner offset pairs.	Press **Meas Setup**, **Inner Offset/Limit, Select Inner Offset.** Select the offset you want to turn on and press Start Freq, On. You can change the Start Freq, Stop Freq and other values for the offset.	Inner offsets are defined from the sub-block edges to the gap; limits from two sub-blocks overlap each other. When there are many offsets to measure, you can increase the Res BW under Meas Setup, Inner Offset/Limit to increase the measurement speed.
6 Set up the limit.	a. Press **Meas Setup**, **Outer Offset/Limit, More, Limits then enter the limit value for each offset**. b. Press **Meas Setup**, **Inner Offset/Limit, More, Limits then enter the limit value for each offset**.	The Lower or Upper ΔLim result is the minimum margin from limit line that is decided by Fail Mask setting. There are four settings for Fail Mask: Absolute, Relative, Abs AND Rel, Abs OR Rel. ▪For Absolute mask, the Lower or Upper Lim is compared with the Absolute limit line. ▪For Relative mask, the Lower or Upper Lim is compared with the Relative limit line. ▪For Abs AND Rel mask, the Lower or Upper Lim is compared with the higher limit line. ▪For Abs OR Rel mask, the Lower or Upper Lim is compared with the lower limit line.

Step	Action	Notes
7 Select the view and measurement result.	Press **View/Display** and select the desired view.	Three types of views are provided: Absolute Peak Power & Frequency, Relative Peak Power & Frequency and Integrated Power. For each view, you can use three measurement types (select using Measure Setup, Meas Type): Total Power Reference, PSD Reference and Spectrum Peak Reference. The picture below shows the measurement result using Meas Type PSD Reference and Relative Peak Power view. Component Carrier Info Table is also provided as below.

Figure 2-18 LTE FDD & LTE-A FDD Downlink Spectrum Emission Mask Measurement Result - Carrier Info View



	Carrier Pwr	Carrier PSD	Integ BW	Filter	Offset Freq	Measure
1	-18.07 dBm	---	9.015 MHz	OFF	-5.0000 MHz	On
2	-17.99 dBm	---	9.015 MHz	OFF	5.0000 MHz	On

Step	Action	Notes
8 (Optional) Change measurement parameters from their default condition.	Press **Meas Setup** to see the keys that are available to change.	For example, you can change the **Meas Type** to **PSD Ref:** Press **Meas Setup**, Meas Type, and select **PSD Ref** to display the Integrated Power view for the spectrum emission mask measurement with a PSD reference. The PSD reference is shown below the spectrum graph in dBm/Hz. Also press Trace/Detector to change the detector type.

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

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

Troubleshooting Hints

This Spectrum Emission Mask measurement can reveal degraded or defective parts in the transmitter section of the unit under test (UUT). The following are examples of typical causes for poor performance.

- Faulty DC power supply control of the transmitter power amplifier.
- RF power controller of the pre-power amplifier stage.
- I/Q control of the baseband stage.
- Degradation in the gain and output power level of the amplifier due to the degraded gain control or increased distortion, or both.
- Degradation of the amplifier linearity or other performance characteristics.

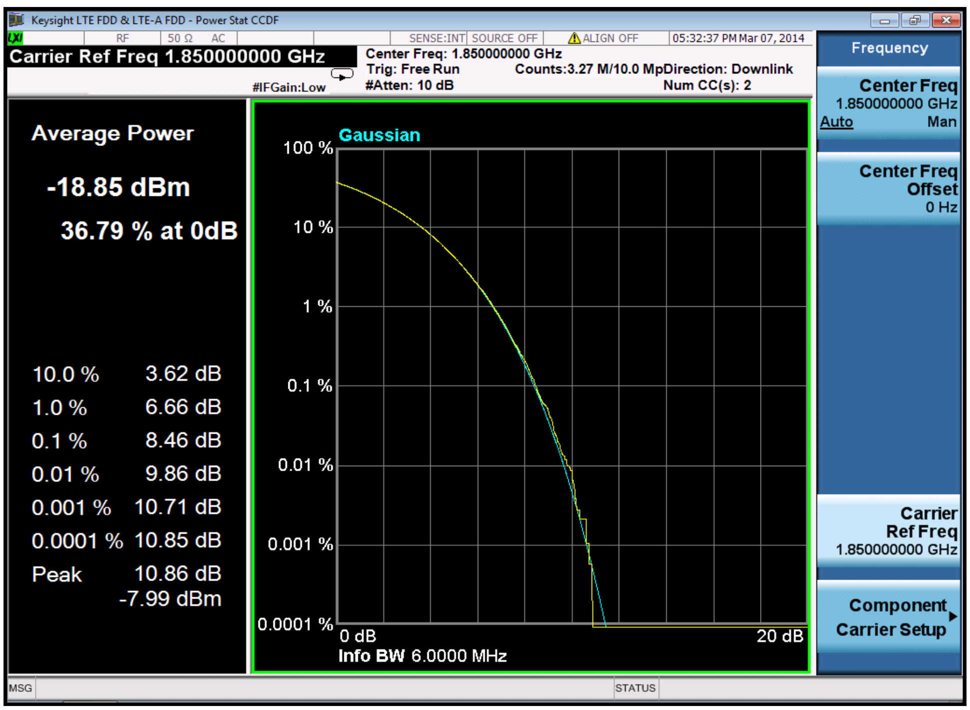
Power amplifiers are one of the final stage elements of a base or mobile transmitter and are a critical part of meeting the important power and spectral efficiency specifications. Since spectrum emission mask measures the spectral response of the amplifier to a complex wideband signal, it is a key measurement linking amplifier linearity and other performance characteristics to the stringent system specifications.

Power Statistics CCDF Measurement Procedure

Power Statistics Complementary Cumulative Distribution Function (Power Stat CCDF) curves characterize the higher level power statistics of a digitally modulated signal.

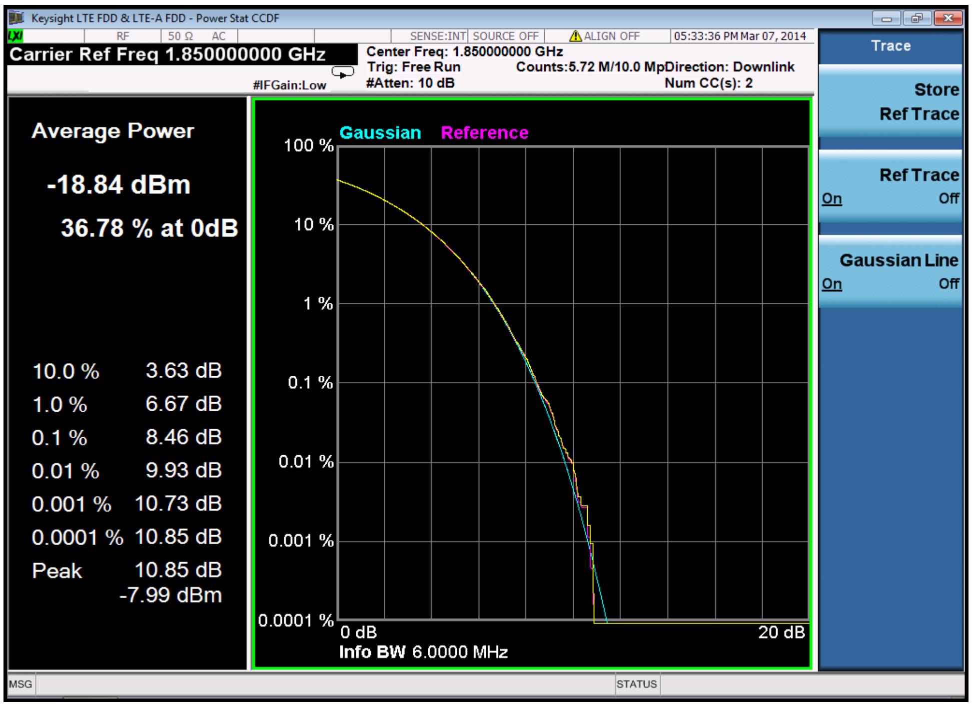
Step	Action	Notes
1 Perform the common configuration.	See "Common Measurement Procedure (Downlink)" on page 20.	It is not necessary if you already configured it in other measurements.
2 Initiate the power statistics CCDF measurement.	Press **Meas**, **Power Stat CCDF**.	The CCDF measurement result should look like Figure 2-19. The blue line is the Gaussian trace and the yellow line is the measurement result. The Info BW is the channel bandwidth that will be used for data acquisition, the default value is 6 MHz. You can manually change the Info BW under the BW menu.

Figure 2-19 LTE FDD & LTE-A FDD Downlink Power Statistics CCDF Measurement Result



Step	Action	Notes
3 Turn reference trace on.	Press **Trace/Detector**, **Ref Trace (On)** to represent the user-definable reference trace (violet line).	The reference trace is the same as the measurement trace. You can use the Store Ref Trace key to copy the currently measured curve as the reference trace. It will not change until you store the reference trace again or choose another mode. The CCDF measurement result with the reference trace should look like Figure 2-20.

Figure 2-20 LTE & LTE-A FDD Downlink Power Statistics CCDF Result - Reference Trace On



Step	Action	Notes
4 Optimize the measurement for your signal level.	Press **Meas Setup**, **IF Gain** to optimize the measurement for your signal level. If you have a very high or low level signal, selecting **Low Gain** or **High Gain** can improve your accuracy. The default is **Auto**.	

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

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

Troubleshooting Hints

The power statistics CCDF measurement can assist in setting the signal power specifications for design criteria for systems, amplifiers, and other components. For example, it can help determine the optimum operating point to adjust each code timing for appropriate peak or average power ratio, or both, for the transmitter.

Transmit On/Off Power Measurement Procedure

The test is to verify that the transmitter off power and transmitter transient periods are within the limit of the minimum requirement for LTE & LTE-A uplink signal.

Setting the Uplink Signal

In this example, Keysight N7624B Signal Studio for 3GPP LTE-Advanced FDD, is used to generate the waveform for testing.

Center Frequency: 1.75 GHz

Output Power: –10 dBm (at analyzer input)

Component Carriers: 2 (CC0 and CC1)

Channel Configuration: QPSK 10MHz (50 RB)

System Bandwidth: 10 MHz (50 RB) + 10 MHz (50 RB)

Antennas: 1

Cyclic Prefix: Normal

Transport Channel: UL-SCH = On, 0 dB, Channel Numbers 1-6

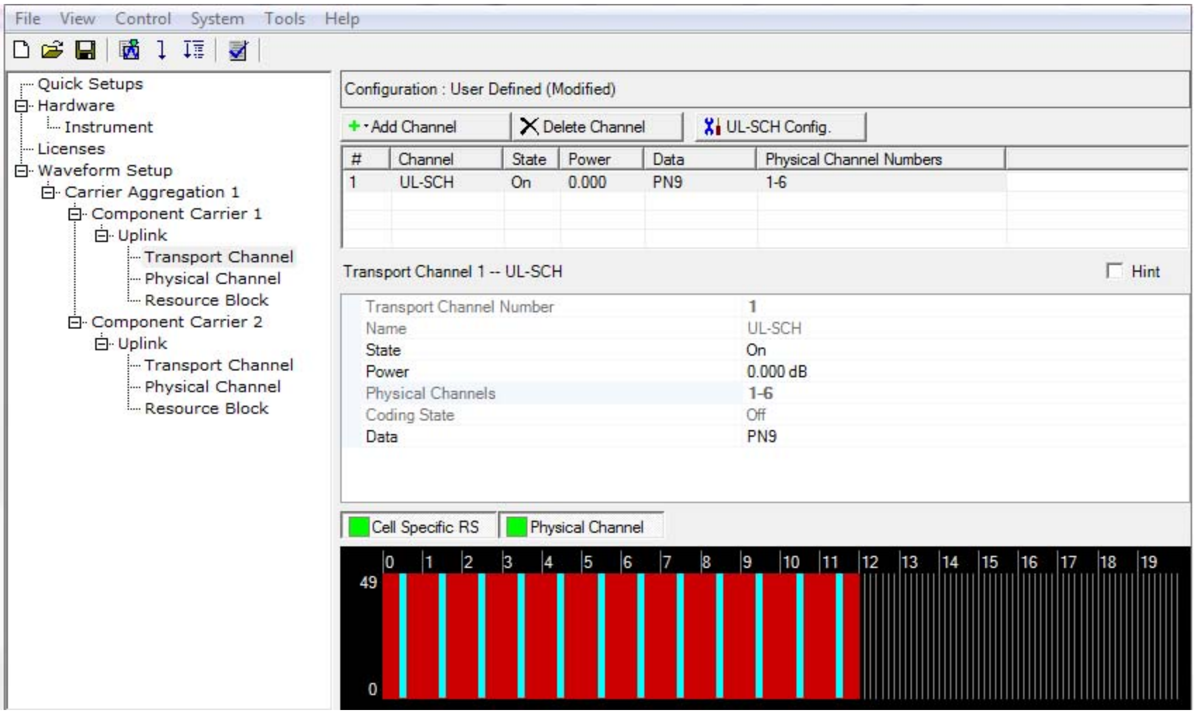
Physical Channel: PUSCH = On, 0 dB, 10 Channels, RB 1-2, ..., 11-12

Resource Block: Slot = 0-11

Power = 0 dB

PUSCH RB = 0-49

Figure 2-21 Signal Studio Mapping (Uplink Signal)



Measurement Procedure

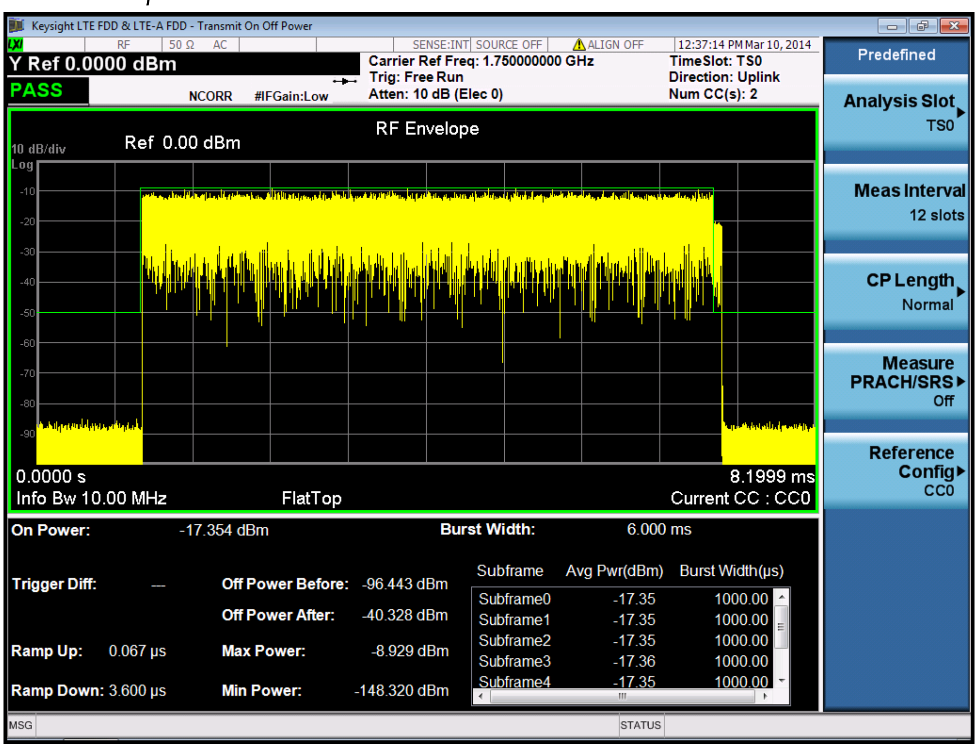
Step	Action	Notes
1 Enable the LTE FDD & LTE-A FDD measurements.	Press **Mode**, **LTE FDD & LTE-A FDD**.	
2 Preset the Mode.	Press **Mode Preset**.	Only do this to return the measurement settings to a known state for all measurements in the LTE & LTE-A FDD mode.
3 Select the direction to **Uplink**.	Press **Mode Setup**, **Radio**, **Direction** to be **Uplink**. Downlink is the default setting.	
4 Set the carrier reference frequency.	Press **FREQ Channel**, **Carrier Ref Freq, 1.75**, **GHz**.	The center frequencies of carriers are defined as offset frequency from this value.
NOTE You may need to change the Center Freq and Center Freq Offset settings to satisfy the channel spacing requirement according to the 3GPP standard.		
5 Configure the two component carriers.	a. Press **FREQ Channel, Component Carrier Setup**. b. Press **Num Component Carriers, 2**. c. Press **Configure Component Carriers, Component Carrier, CC0**. d. Press **Freq Offset, -5 MHz**. e. Press **Bandwidth Setup, System BW, 10 MHz (50 RB)**. f. Press **Configure Component Carriers, Component Carrier, CC1**. g. Press **Freq Offset, 5 MHz**. h. Press **Bandwidth Setup, System BW, 10 MHz (50 RB)**. i. Press **Carrier Allocation, Contiguous**.	The measurement example is for contiguous carriers. If the carriers are non-contiguous, the Carrier Allocation under Component Carrier Setup needs to be set up.

Step	Action	Notes
6 Select the predefined parameters such as Analysis Slot, Meas Interval or CP Length	Press **Mode Setup, Predefined Parameters** to set up the parameters. Configure Analysis Slot to be TS0, Meas Interval to be 12 slots. CP Length to be Normal.	Analysis Slot is defined as the first slot for analysis.
7 Initiate the Transmit On/Off Power measurement.	Press **Meas**, **Transmit On/Off Power.**	The Transmit On/Off Power measurement result should look like Figure 2-22. Sometimes the result for Burst Width and Ramp Down displays “---”. That is because the measured burst is not a complete burst. The Off Power shows “---” because the transmitter off period is not detected within the Meas Interval.

NOTE The default setup of the Transmitter On/Off Power measurement is Single. Do not use Cont to let the analyzer continuously sweep. The attenuator and preamplifier performs adjustment in every sweep. If you turn Cont on, the device lifetime will be influenced.

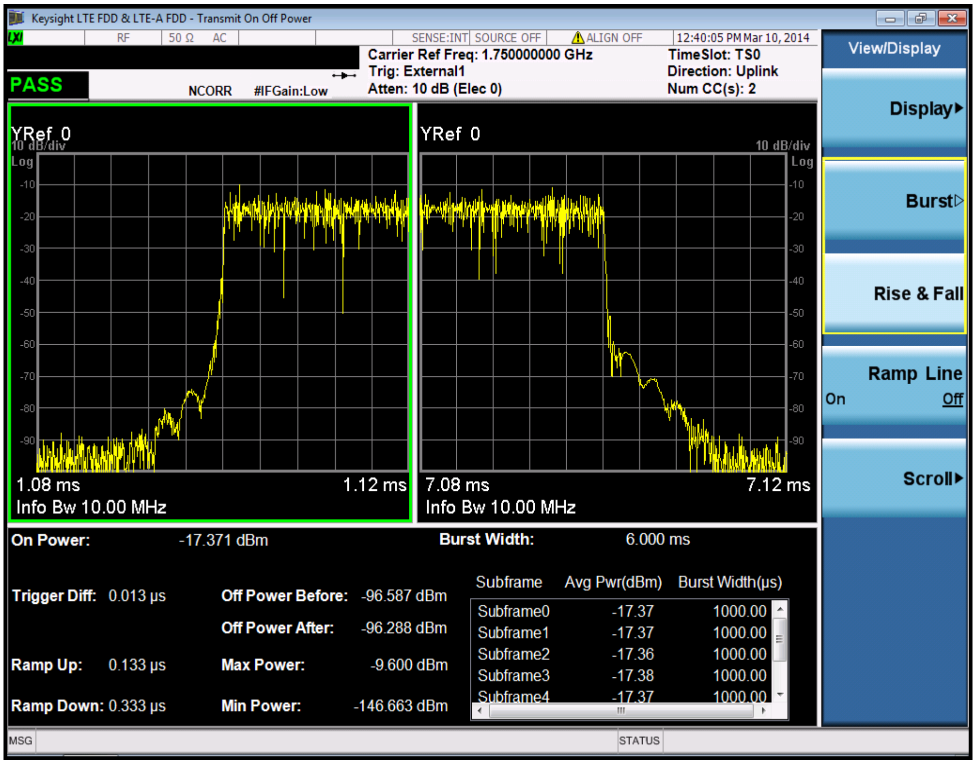
NOTE Each time the parameter is modified, you need to press Restart or Single to initiate a sweep. The yellow mark (*) on the top right indicates a Restart or Single sweep was not performed after the parameters were changed and the results are invalid.

Figure 2-22 LTE FDD & LTE-A FDD Uplink Transmit On/Off Power Measurement Result



Step	Action	Notes
8 Select Rise & Fall view.	Press **View/Display, Rise & Fall.**	You can observe the details during the ramp up and down period in the Rise & Fall view.

Figure 2-23 LTE FDD & LTE-A FDD Uplink Transmit On/Off Power Measurement Result - Rise & Fall view



9 (Optional) Change measurement parameters from their default condition.	Press **Meas Setup** to see the keys that are available to change.	

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

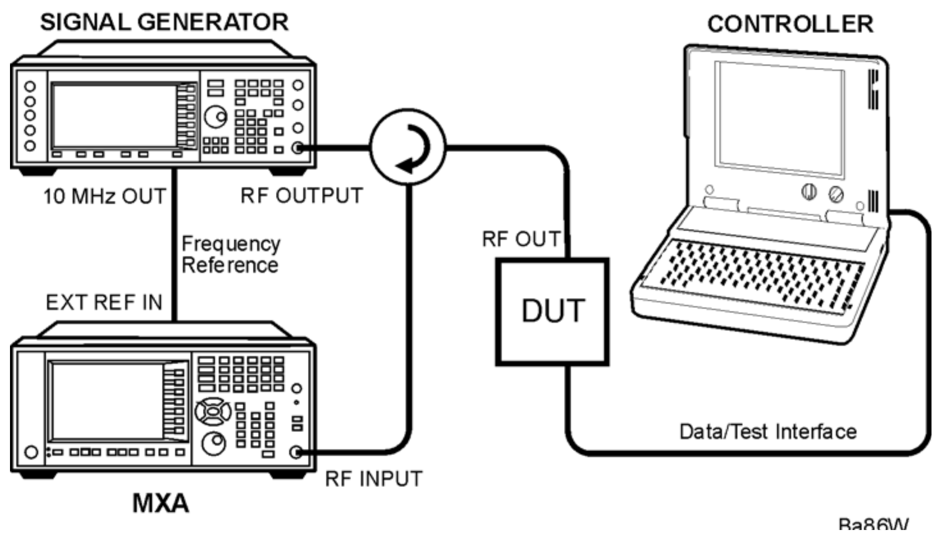
C:\Program Files\Keysight\SignalAnalysis\Infrastructure\Help\bookfiles.

Modulation Analysis Measurements

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

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

Figure 2-24 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 FDD & LTE-A FDD Downlink Measurements

Setting the Downlink Signal (Example)

This example uses a signal generated by Keysight N7624B Signal Studio for 3GPP LTE-Advanced FDD.

Direction Downlink

Frequency: 1.85 GHz

Output Power: -10 dBm

Bandwidth 10 MHz (50 PRB) + 10 MHz (50 PRB)

Component Carriers: 2 (CC0, CC1)

Channel Configuration: Full-Filled QPSK 10 MHz (50 PRB) + Full-Filled 16 QAM 10 MHz (50 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

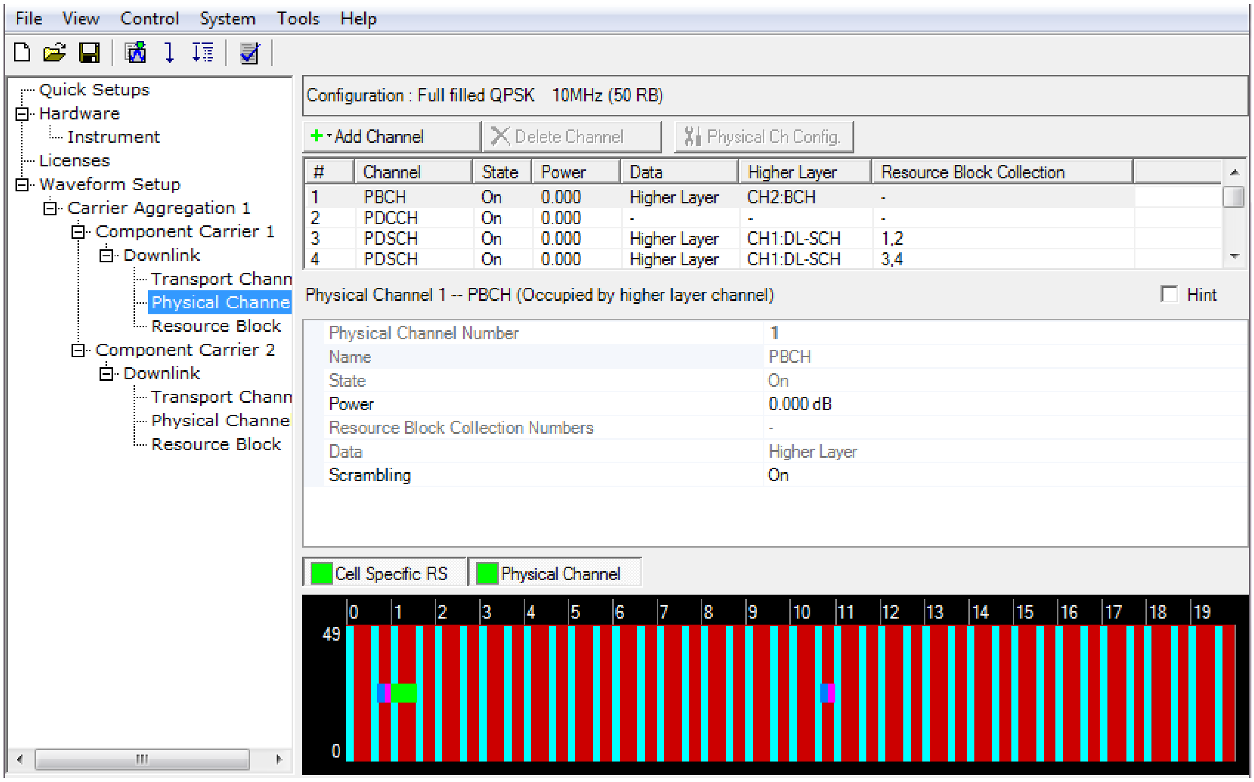
Resource Block:

•Slots = 20

•RB = 0-49

•Power = 0 dB

Figure 2-25 Signal Studio Downlink Setup Graphic Display



Downlink Measurement Procedure - RB Auto Detect On

The LTE & LTE-A 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 & LTE-A DL signal.

NOTE If an LTE & LTE-A 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 58.

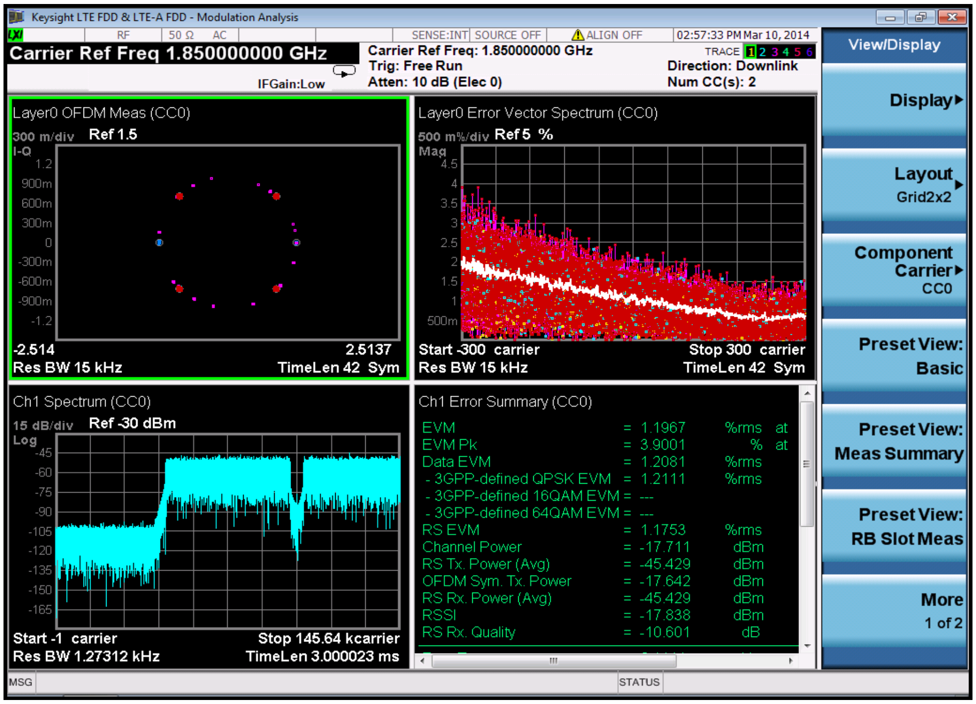
Step	Action	Notes
1 Enable the LTE & LTE-A FDD measurements.	Press **Mode**, **LTE FDD & LTE-A FDD.**	
2 Preset the Mode.	Press **Mode Preset.**	Only do this to return the measurement settings to a known state for all measurements in the LTE FDD & LTE-A FDD mode.
3 Initiate the Modulation Analysis measurement.	Press **Meas**, **Modulation Analysis.**	
4 Set the center frequency.	Press **FREQ Channel**, **Carrier Ref Freq, 1.85**, **GHz.**	
5 Select the direction to **Downlink**.	Press **Mode Setup**, **Direction** to be **Downlink.** Downlink is the default setting.	

Step	Action	Notes
6 Configure the two component carriers.	a. Press **Mode Setup, Component Carrier Setup**. b. Press **Num Component Carriers, 2.** c. Press **Configure Component Carriers, Component Carrier, CC0**. d. Press **Freq Offset, -5 MHz.** e. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** f. Press **Configure Component Carriers, Component Carrier, CC1.** g. Press **Freq Offset, 5 MHz.** h. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** i. Press **Carrier Allocation, Contiguous**.	Press Mode Setup, Preset to Standard to preset measurement parameters besides BW. For a list of all presets effected see "Preset to Standard Settings" on page 95.
7 Recall the EVM setup file.	Press **Recall**, **Data**, **Component Carrier Setup, CC0, (or CC1)** then **Open...,** a file open dialog appears, under D:\Users\Administrator(Instrument)\Documents\LTEAFDD\data\evmsetup folder, select the appropriate test model file and click open. This will apply the RB setup and related parameters quickly. The other parameters will not be changed.	If the signal is E-URTA Test Models E-TM1.1, E-TM2, E-TM3.1, E-TM3.2 or E-TM3.3 in 3GPP standard, you can recall the EVM parameter setting directly.

TIP If the configuration for CC1 is the same as CC0, you may directly use **Meas Setup, Component Carrier, CC0, Copy CC0 to, CC1.**

Step	Action	Notes
8 View the result for CC0.	Press **View/Display, CC For Preset Views, CC0** then Preset View: Basic.	The demodulation result for CC0 should look like Figure 2-26.

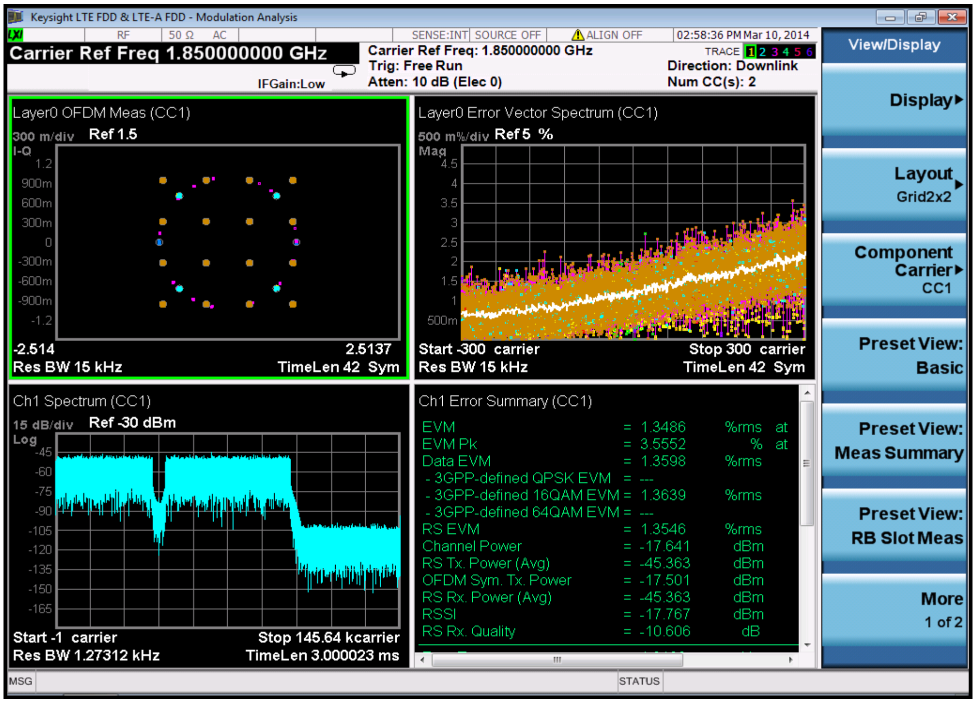
Figure 2-26 LTE & LTE-A FDD Downlink Modulation Accuracy Measurement Result (CC0, 10 MHz bandwidth)



Step	Action	Notes
9 View the result for CC1.	Press **View/Display, CC For Preset Views, CC1** then Preset View: Basic.	The demodulation result for CC1 should look like Figure 2-27.

Step	Action	Notes

Figure 2-27 LTE & LTE-A FDD Downlink Modulation Accuracy Measurement Result (CC1, 10 MHz bandwidth)



10 Select views and measurement result.	Press **View/Display** to select different views. See "Selecting Different Measurement Results Views" on page 62.	
11 You can now view individual signal and Channel results.	See "To View Individual User or Channel (C-RS example):" on page 69.	
12 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 58.	

Downlink Measurement Procedure - RB Auto Detect Off

The LTE & LTE-A 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 & LTE-A DL signal. For more information see "Downlink Measurement Procedure - RB Auto Detect On" on page 54.

NOTE If an LTE & LTE-A 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	Action	Notes
1 Enable the LTE & LTE-A FDD measurements.	Press **Mode**, **LTE FDD & LTE-A FDD**.	
2 Preset the Mode.	Press **Mode Preset**.	
3 Initiate the Modulation Analysis measurement.	Press **Meas**, **Modulation Analysis**.	
4 Set the center frequency.	Press **FREQ Channel**, **Carrier Ref Freq, 1.85**, **GHz**.	
5 Select the direction to **Downlink**.	Press **Mode Setup**, **Direction** to be **Downlink**. Downlink is the default setting.	

Step	Action	Notes
6 Configure the two component carriers.	a. Press **Mode Setup, Component Carrier Setup**. b. Press **Num Component Carriers, 2.** c. Press **Configure Component Carriers, Component Carrier, CC0**. d. Press **Freq Offset, -5 MHz.** e. Press **Bandwidth Setup, System BW, 10 MHz (50 RB)**. f. Press **Configure Component Carriers, Component Carrier, CC1**. g. Press **Freq Offset, 5 MHz.** h. Press **Bandwidth Setup, System BW, 10 MHz (50 RB)**. i. Press **Carrier Allocation, Contiguous**.	Press Mode Setup, Preset to Standard to preset measurement parameters besides BW. For a list of all presets effected see “Preset to Standard Settings” on page 95.
7 Select the component carrier to be configured.	Press **Meas Setup, Component Carrier, CC0.**	Then the parameters under Meas Setup will be used for CC0.
8 Turn Auto Detect Off.	Press **Meas Setup**, **Chan Profile Setup, Detection** to toggle RB Auto Detect to **Man.**	

NOTE To perform the following procedure, it is easier to use a USB mouse connected to the instrument.

If a mouse is not available, you can use the Tab key repeatedly until the required table cell or check box is selected and the key menu appears, then enter the value from the front panel. Also, press Enter to activate the knob function, then you can move the focus quickly using the knob. If you finish the setup, you can select OK, or Cancel by pressing the Cancel (Esc) key on the front panel.

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

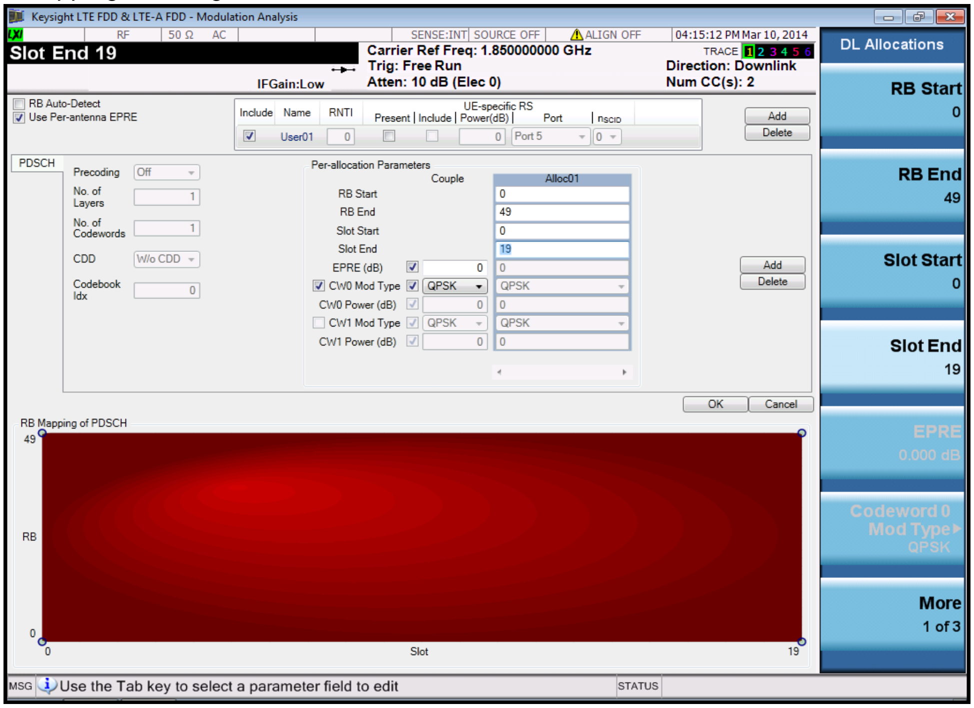
Step	Action	Notes
9 Set up the User Mapping table.	a. Press **Meas Setup**, **Chan Profile Setup, More, Edit User Mapping**. For Downlink signals, only PDSCH mapping is required. b. Press **Add** to allocate a new User to the signal. Users are assigned a number in order of their appearance. you can add up to 25 Users to a signal. c. Use the mouse to select the `Include` checkbox before `User1`. d. Check the `CW0 Mod Type` checkbox, then select the modulation using the pull-down menu. This example uses `QPSK, the default selection`. e. Select the field "`No Allocations Defined`". When it is selected it will have a blue background. f. Press **Add** to add to begin entering Downlink allocations. g. Enter values for **RB Start, RB End, Slot Start**, and **Slot End**. This example uses values of RB Start = 0, RB End = 49, Slot Start = 0, Slot End= 19. h. Repeat d through h as needed for all Users. i. Click OK to save the settings and exit the User Mapping table.	

TIP When the allocation is selected, there are four circles in the four corner of the block. You can directly drag the circles to allocate the RB.

TIP If you want to copy all autodetected allocations into the Resource Block Editor, press Copy Auto -> Manual, then each autodetected modulation group will be assigned to a user. When RB Auto Detect Mode is set to Power Based, User_01 will contain resource blocks with QPSK; User_02 will contain resource blocks with 16QAM; and User_03 will contain resource blocks with 64QAM.

Step	Action	Notes

Figure 2-28 Editing User Mapping - Adding PDSCH Downlink Allocations



Step	Action	Notes
10 Select the other component carrier to be configured.	Press **Meas Setup, Component Carrier, CC1.** and repeat the above procedure from ”Turn Auto Detect Off.”	

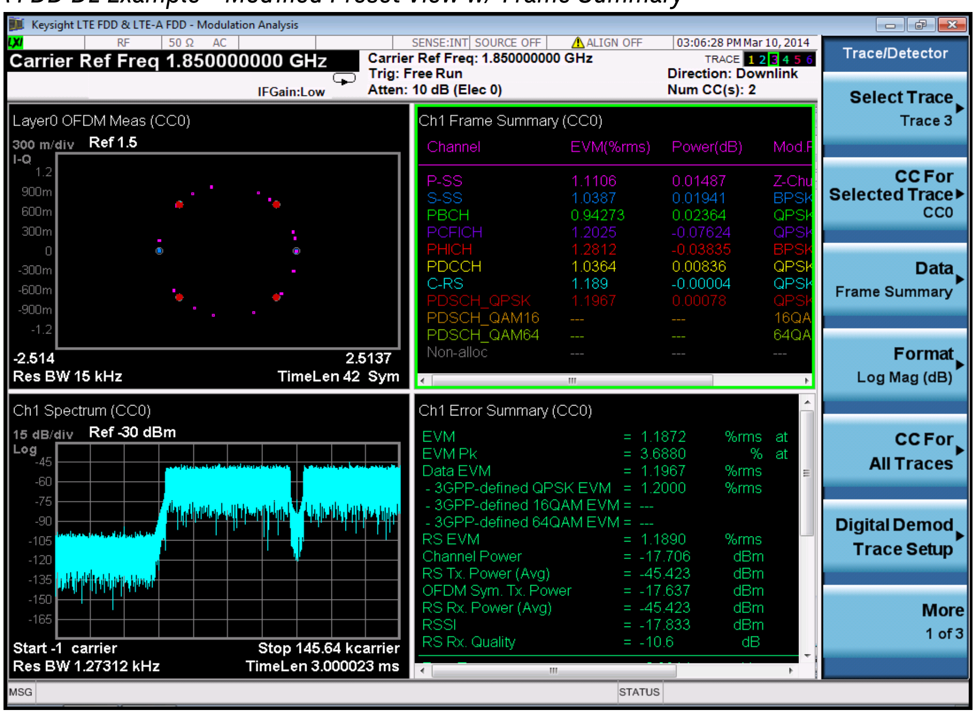
TIP If the configuration for CC1 is the same as CC0, you may directly use **Meas Setup, Copy CC0 to, CC1.**

Step	Action	Notes
11 Select views and measurement result.	Press **View/Display** to select different views. See “Selecting Different Measurement Results Views” on page 62.	
12 You can now view individual signal and Channel results.	See “To View Individual User or Channel (C-RS example):” on page 69.	

Selecting Different Measurement Results Views

Step	Action	Notes
13 Change the traces displayed in any preset view.	Press **Trace/Detector**, **Select Trace, Trace 3**, **Data, CC0, Tables, Frame Summary** to display the Frame data summary in the Trace 3 position. See Figure 2-29.	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. In View/Display, Layout, you may configure the windows to Grid2x3 or Grid3x2. There is a wide variety of data traces available for display. You may even combine CC0 and other component carriers measurement traces in one display. For more information on the available data traces see the Data topic in the Trace/Detector section in the **LTE FDD & LTE-A FDD Measurement Application User's and Programmer's Guide.**

Figure 2-29 LTE & LTE-A FDD DL Example - Modified Preset View w/ Frame Summary



Step	Action	Notes
14 Select Meas Summary view.	Press **View/Display**, **Preset View: Meas Summary** to display a Stack 2 view of the Error and Frame summary result windows. See Figure 2-30.	

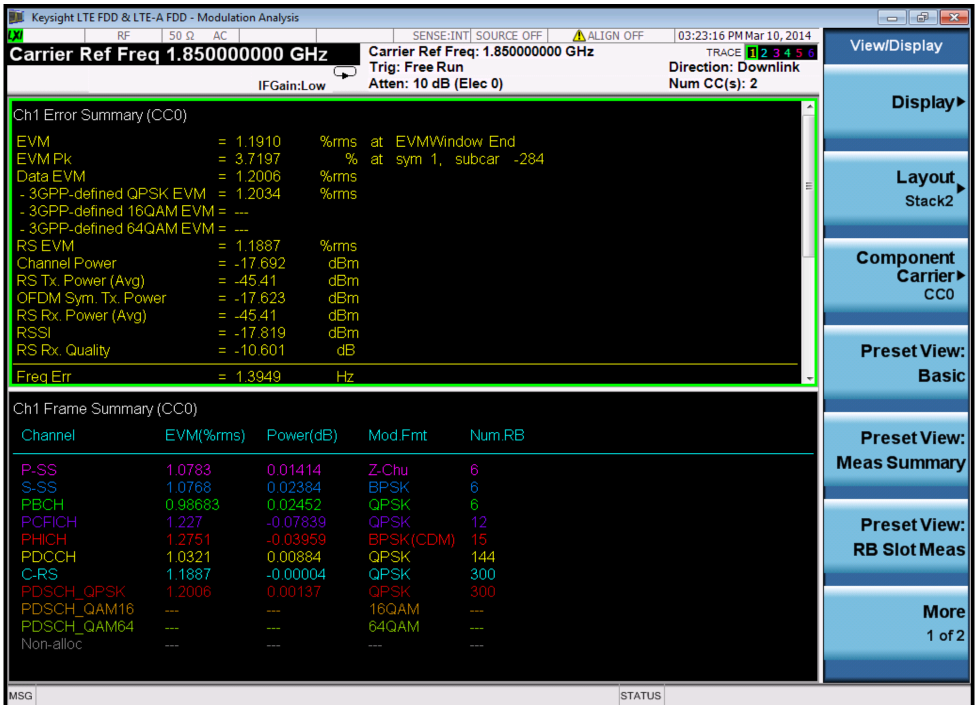


Figure 2-30 Modulation Analysis Measurement Result - Meas Summary Preset View

Step	Action	Notes
15 Select RB Slot Meas view.	Press **View/Display**, **Preset View: RB Slot Meas** to display the traces in units of RBs and Slots. See Figure 2-31.	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.

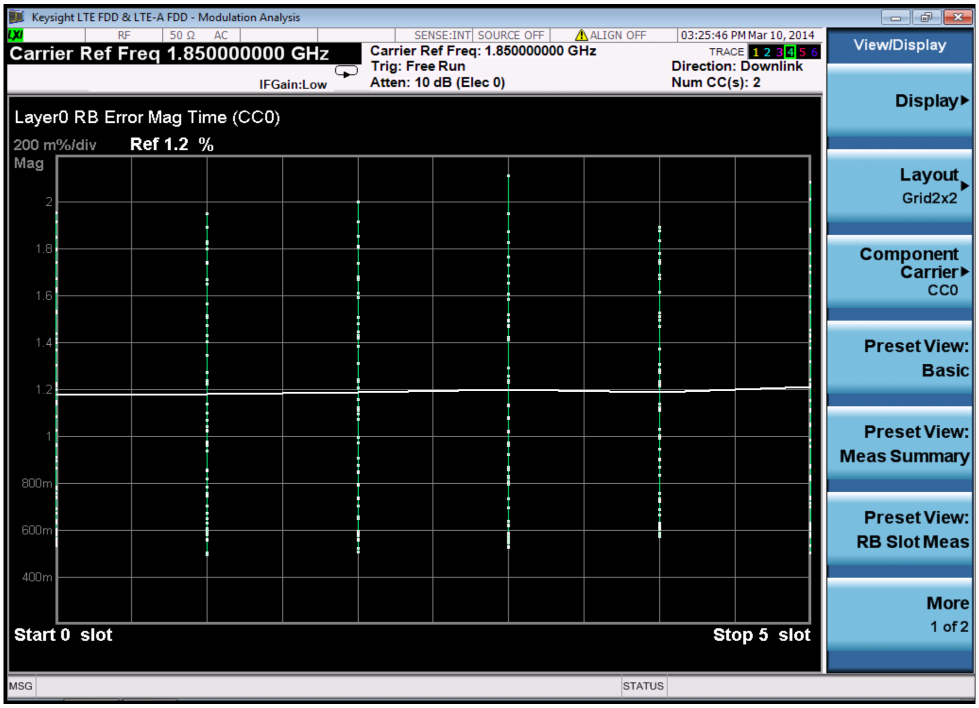
Step	Action	Notes

Figure 2-31 Modulation Analysis Measurement Result - RB Slot Meas Preset View

16 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. See Figure 2-32.	You can also press **Trace/Detector**, **Trace, Select Trace, Trace 3**, then **Zoom** to display the RB Error Mag Spectrum graph.

Step	Action	Notes

Figure 2-32 Modulation Analysis Measurement Result - RB Error Mag Spectrum

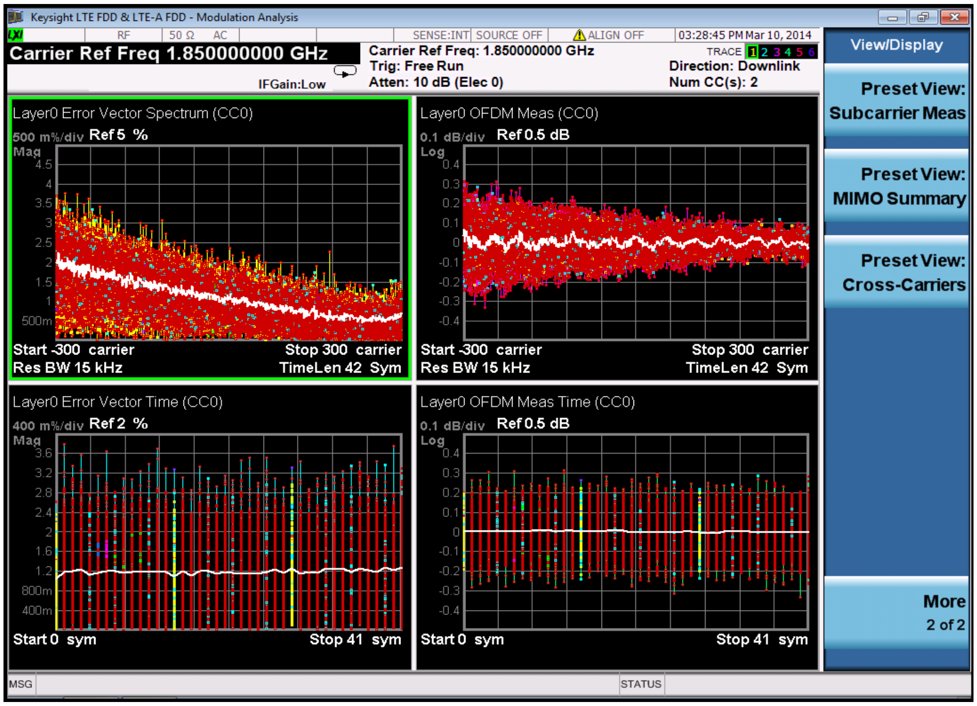


TIP The RB Error Mag Spectrum graph is especially useful to determine whether there are any individual slots or RBs with excessive EVM.

Step	Action	Notes
17 Select Subcarrier Meas view.	Press **View/Display**, **Preset View: Subcarrier Meas** to display a view of the Subcarrier measurement result windows. See Figure 2-33.	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	Action	Notes

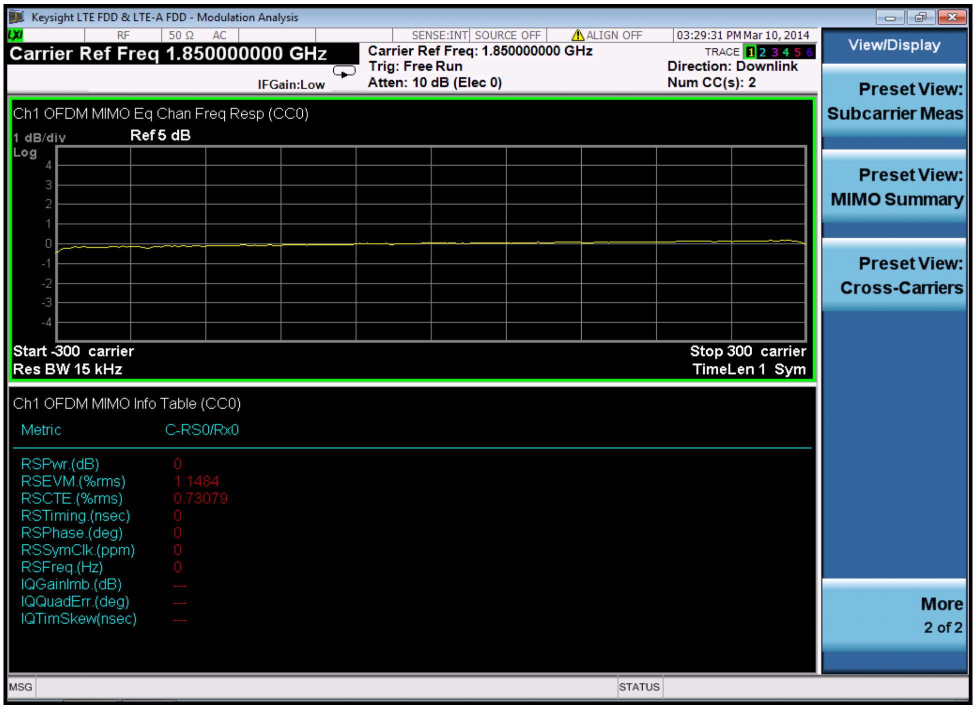
Figure 2-33 Modulation Analysis Measurement Result - Subcarrier Meas Preset View



Step	Action	Notes
18 Select MIMO Summary view.	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. See Figure 2-34.	

Step	Action	Notes

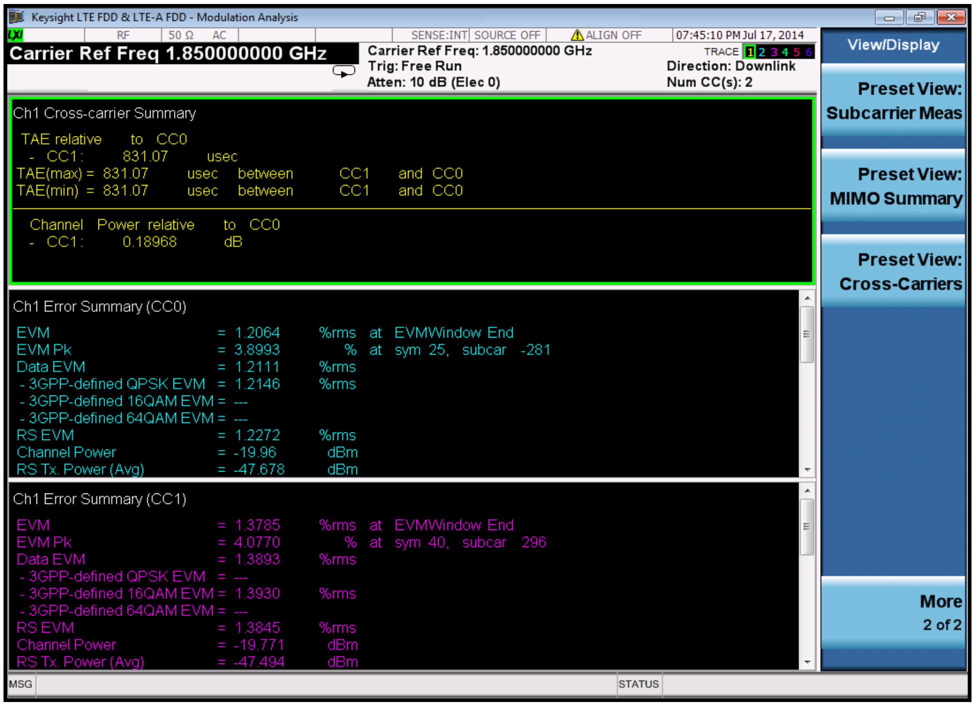
Figure 2-34 Modulation Analysis Measurement Result - MIMO Summary Preset View



Step	Action	Notes
19 Select Cross Carriers view.	Press **View/Display**, **Preset View: Cross-Carriers** to display Error Summary of each Component Carrier and Cross-Carriers Summary information about the Time Alignment Error (TAE) and Channel Power for each component carrier (CCx) relative to the selected Reference Component Carrier (Reference CC). See Figure 2-35.	

Step	Action	Notes

Figure 2-35 Modulation Analysis Measurement Result - Cross Carriers Preset View



To View Individual User or Channel (C-RS example):

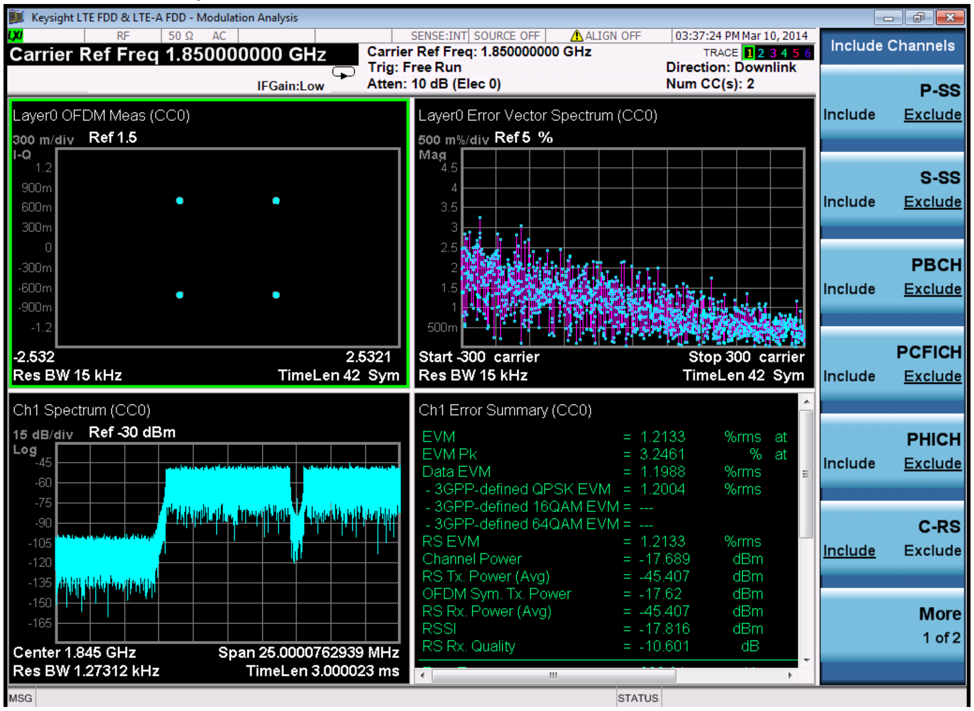
The default measurement setting for Channel Profile is to Include all Users and Channels. Displaying individual signals and Channels will make defects more obvious and will allow specific investigation of your modulation parameters.

Step	Action	Notes
1 Display the Basic View measurement results.	Press **View/Display, Preset View: Basic**.	
2 To view the channels that are included in the measurement.	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.
3 Exclude all the channels.	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.
4 Select the C-RS to be analyzed.	Press **Include Channels, C-RS** to toggle C-RS to Include to show only the Reference signal in the measurement results displayed.	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 C-RS. Your measurement result should like Figure 2-36.

NOTE If you have multiple users, you may use **Meas Setup, Channel Profile Setup, More, Include Users** to choose which user is included in the measurement.

Step	Action	Notes

Figure 2-36 Modulation Analysis Measurement Result - Downlink Example (Basic Preset View) - Include C-RS Channel Only



Step	Action	Notes
5 Select non allocated channels.	Press **Meas Setup, Chan Profile, Include Channels, More, 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 guide "**Instrument Messages**", which is provided on the Documentation CD ROM, and in the instrument here:

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

Making LTE Uplink Measurements

Setting the Uplink Signal (Example)

This example uses a signal generated by Keysight N7624B Signal Studio for 3GPP LTE FDD.

Direction Uplink

Frequency: 1.75 GHz

Output Power: -10 dBm

Bandwidth 10 MHz (50 PRB) + 10 MHz (50 PRB) Contiguous

Component Carriers: 2 (CC0, CC1)

Antennas 1

Transport Channel:

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

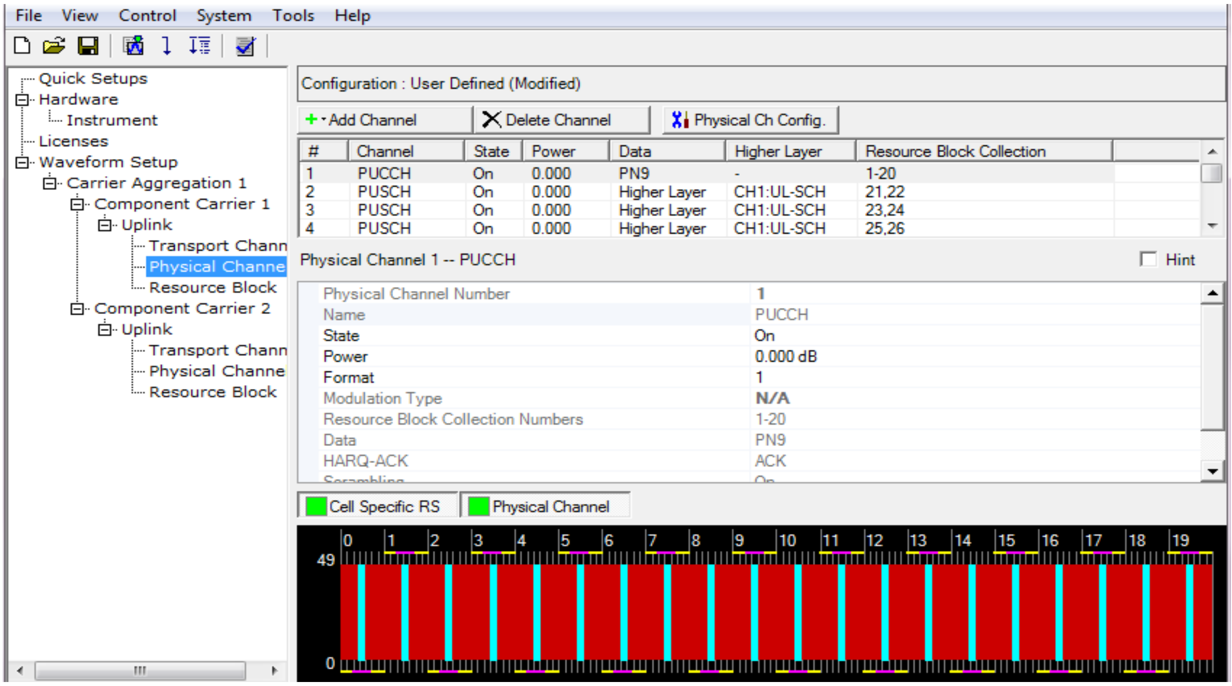
Physical Channels:

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

Resource Block:

- Slots = 20 (1-19)
- PUSCH RB = 5-44
- PUCCH RB = 0, 49
- Power = 0 dB

Figure 2-37 Signal Studio Uplink Setup Graphic Display



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

NOTE To perform the following procedure, it is easier to use a USB mouse connected to the instrument.

If a mouse is not available, you can use the Tab key repeatedly until the required table cell or check box is selected and the key menu appears, then enter the value from the front panel. Also, press Enter to activate the knob function, then you can move the focus quickly using the knob. If you finish the setup, you can select OK, or Cancel by pressing the Cancel (Esc) key on the front panel.

Step	Action	Notes
1 Enable the LTE & LTE-A FDD measurements.	Press **Mode**, **LTE FDD & LTE-A FDD**.	
2 Preset the Mode.	Press **Mode Preset**.	Only do this to return the measurement settings to a known state for all measurements in the LTE & LTE-A FDD mode.
3 Select the direction to **Uplink**.	Press **Mode Setup**, **Direction** to be **Uplink**. Downlink is the default setting.	
4 Set the carrier reference frequency.	Press **FREQ Channel**, **Carrier Ref Freq, 1.75**, **GHz**.	The center frequencies of carriers are defined as offset frequency from this value.

NOTE You may need to change the Center Freq and Center Freq Offset settings to satisfy the channel spacing requirement according to the 3GPP standard.

Step	Action	Notes
5 Configure the two component carriers.	a. Press **Mode Setup, Component Carrier Setup**. b. Press **Num Component Carriers, 2.** c. Press **Configure Component Carriers, Component Carrier, CC0**. d. Press **Freq Offset, -5 MHz.** e. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** f. Press **Configure Component Carriers, Component Carrier, CC1.** g. Press **Freq Offset, 5 MHz.** h. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** i. Press **Carrier Allocation, Contiguous**.	The measurement example is for contiguous carriers. If the carriers are non-contiguous, the Carrier Allocation under Component Carrier Setup needs to be set up. Press Mode Setup, Preset to Standard to preset measurement parameters besides BW. For a list of all presets effected see "Preset to Standard Settings" on page 95.
6 Select the predefined parameters such as Analysis Slot, Meas Interval or CP Length	Press **Mode Setup, Predefined Parameters** to set up the parameters. Configure Analysis Slot to be TS4, Meas Interval to be 6 slots. CP Length to be Normal.	Analysis Slot is defined as the first slot for analysis.
7 Choose one of the two procedures depends on auto or manual measurement.	For analysis of no specific user, you can use demodulator auto-detect feature, the measurement provides a composite result of all Channels and Users, go to "LTE & LTE-A UL - RB Auto Detect On" on page 75. If you want to analyze individual user, you need to define the user mapping manually, go to "LTE & LTE-A UL - RB Auto Detect Off" on page 77.	

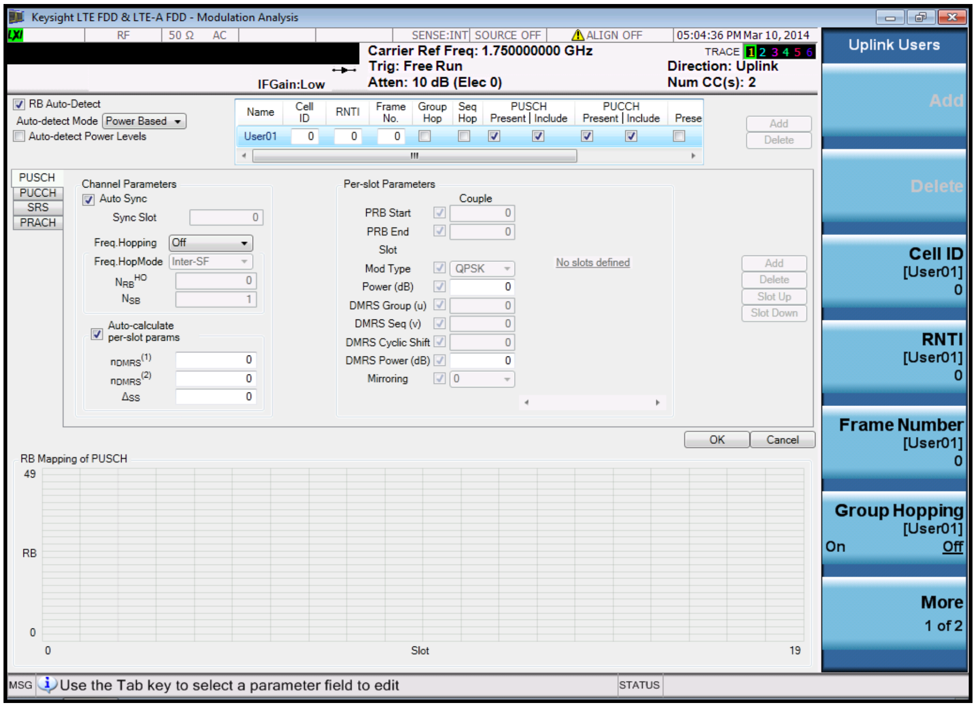
LTE & LTE-A UL - RB Auto Detect On

For analysis of PUSCH or PUSCH with unique slots, you must set **RB Auto Detect** to **Off** and manually set all User Mapping allocations. See: "LTE & LTE-A UL - RB Auto Detect Off" on page 77.

Step	Action	Notes
1 Complete the initial procedure.	See "Common UL Setup Steps (RB Auto Detect On or Off)" on page 73.	
2 Select the component carrier to be configured.	Press **Meas Setup, Component Carrier, CC0.**	Then the parameters under Meas Setup will be used for CC0.
3 Access the User Mapping table.	a. Press **Meas Setup**, **Chan Profile Setup, Edit User Mapping**. b. Select RB Auto Detect and configure the parameters of User01. In this example Cell ID is 0, PUSCH and PUCCH are selected. c. Check Present in Signal and Include in Analysis for both PUSCH and PUCCH. d. Check Auto Sync for PUSCH and PUCCH. Also you can enter the sync slot manually. e. Check the Auto-calculate per-slot params checkbox for PUSCH and PUCCH and enter the nDMRS. f. Click OK to save the settings and exit the User Mapping table,	PUSCH and PUCCH are transmitted exclusively from one UE, however PUSCH, PUCCH and SRS can be analyzed at the same time. PRACH needs to be analyzed separately, if you select PRACH, the others PUSCH, PUCCH and SRS will be grayed out. When RB Auto-Detect is On, only one user (User01) can be included in the analysis. You can not add any other users. The Figure 2-38 shows the configuration for User Mapping when RB Auto-Detect is On.

Step	Action	Notes

Figure 2-38 Editing Uplink User Mapping - RB Auto Detect On



4 View measurement result.	Press **View/Display** to see different views. See "Viewing Measurement Results" on page 80.	
5 You can now view individual signal and Channel results.	See "To View Individual User or Channel (C-RS example):" on page 69.	
6 If you want to change any allocations of Users or Slots you must turn Auto Detect off.	See: "LTE & LTE-A UL - RB Auto Detect Off" on page 77.	

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

To save the State settings in a file permanently:
Press **Save, State, to File...** and select a file name for recall later.
Press **Recall, State** and select a register or file to be recalled.

LTE & LTE-A UL - RB Auto Detect Off

In this example, two users (one with PUSCH and the other with PUCCH) are configured for uplink modulation analysis.

For analysis of PUSCH and PUCCH with no unique slots, you can set **RB Auto Detect** to **ON**. See: "LTE & LTE-A UL - RB Auto Detect On" on page 75.

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.

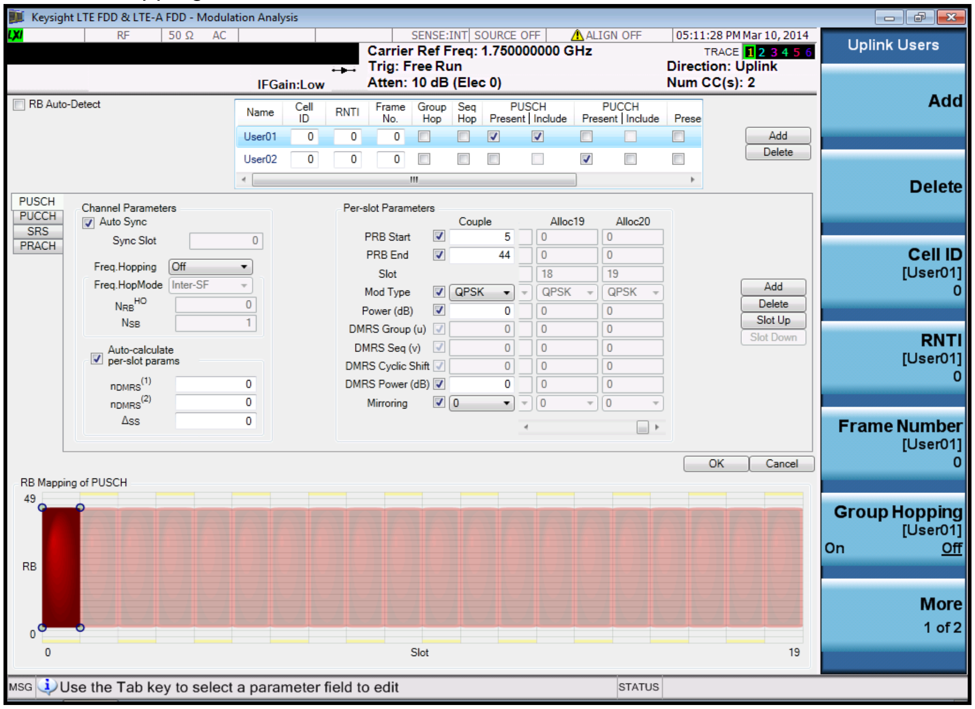
Step	Action	Notes
1 Complete the initial procedure.	See "Common UL Setup Steps (RB Auto Detect On or Off)" on page 73.	
2 Select the component carrier to be configured.	Press **Meas Setup, Component Carrier, CC0**.	Then the parameters under Meas Setup will be used for CC0.
3 Turn RB Auto Detect to OFF.	Press **Meas Setup**, **Chan Profile Setup, and toggle Detection to Man**.	

Step	Action	Notes
4 Access the User Mapping table.	a. Press **Meas Setup**, **Chan Profile Setup, Edit User Mapping**. b. Press Add, `User01` will be shown as active in the setup table at the top row. Press Add again to add User02. c. For `User01`, check "Present" for PUSCH (means User01 has PUSCH), in PUSCH tab, you can configure the parameters for PUSCH. d. Set the **Sync Slot** value if not equal to zero. The default setting for **Sync Slot** is Auto Sync. e. Set Couple Values in the `Couple` column. This allow you to couple the values across all slots for checked values. f. 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 values of RB Start = 5, RB End = 44. g. Click the `No slots defined` field. 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. h. Check "Include" for PUSCH in User01. i. For `User02`, check "Present" in Signal for PUCCH, in PUCCH tab, you can configure the parameters for PUCCH. This example uses the default value of First RB = 0, and all other Pre-Slot Parameter defaults. j. Click the `No subframes defined` field. The same as User01, press **Add** to create a new Slot for User02. Continue to press Add until you have added 19 more Slots, for a total of 20, to correspond with the example signal. k. Check the Auto-calculate per-slot params checkbox and enter the nDMRS. l. Click OK to save the settings and exit the User Mapping table,	

NOTE You can not Include in Analysis of PUCCH for User02. Because PUSCH for User01 is Include in Analysis. When RB Auto-Detect is Off, only one user can be included in the analysis at the same time.

Step	Action	Notes

Figure 2-39 Editing Uplink User Mapping - RB Auto Detect Off



Step	Action	Notes
5 Select the other component carrier to be configured.	Press **Meas Setup, Component Carrier, CC1.** and repeat the above procedure from ”Turn RB Auto Detect to OFF.”	

TIP If the configuration for CC1 is the same as CC0, you may directly use **Meas Setup, Copy CC0 to, CC1.**

Step	Action	Notes
6 View measurement result.	Press **View/Display** to see different views. See “Viewing Measurement Results” on page 80.	

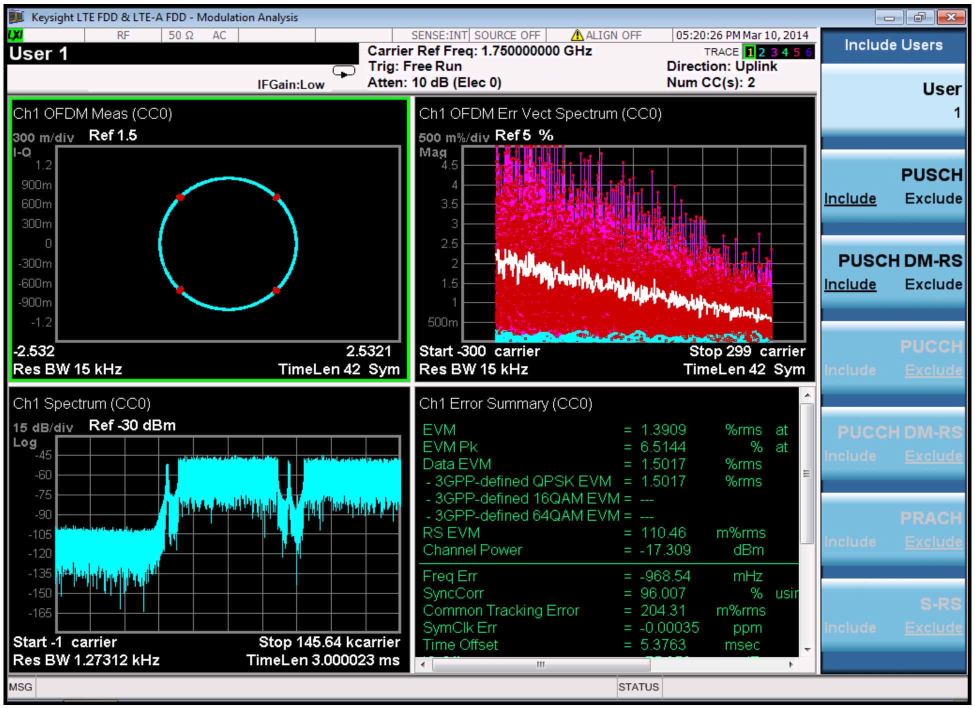
TIP You can save your settings as a recallable State:
Press **Save, State**, and select a **Register** to store the measurement settings. These settings are subject to reset by a power cycle.

To save the State settings in a file permanently:
Press **Save, State, to File...** and select a file name for recall later.
Press **Recall, State** and select a register or file to be recalled.

Viewing Measurement Results

Step	Action	Notes
7 View the result for CC0.	Press **View/Display, CC For Preset Views, CC0** then Preset View: Basic.	For this example, User01 (PUSCH) is included in the demodulation and User02 (PUCCH) is excluded.

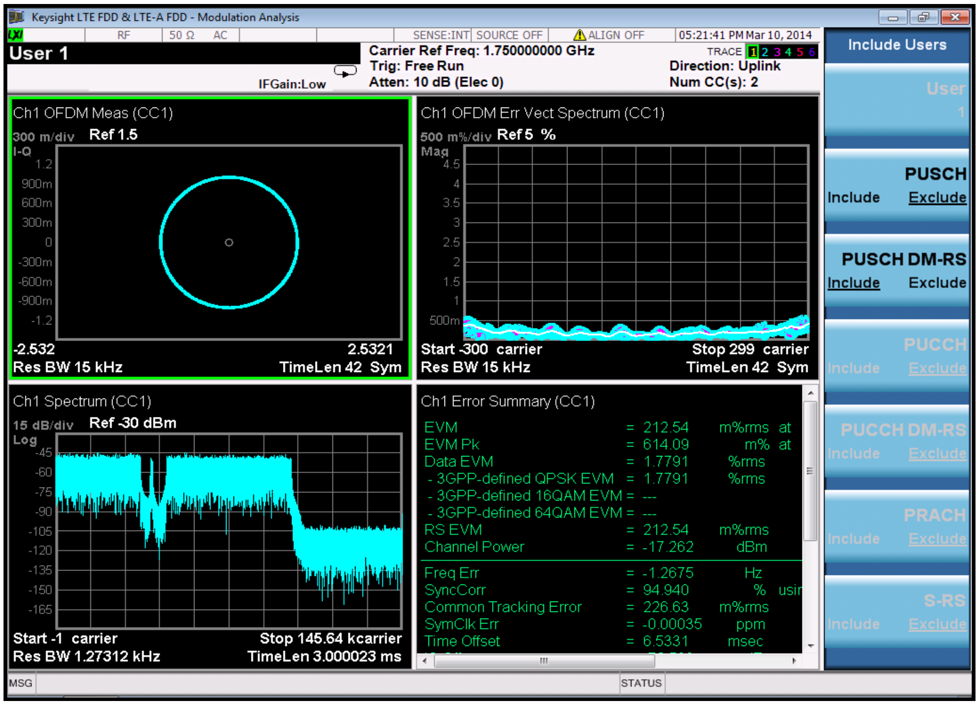
Figure 2-40 LTE & LTE-A FDD Modulation Analysis Measurement Result - UL CC0 User01



Step	Action	Notes
8 Exclude all the channels.	Press **Meas Setup, Chan Profile Setup, 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.
9 To view the users that are included in the measurement.	Press **Meas Setup, Chan Profile Setup, Include Users** to see the menu allowing you include or exclude signals and Channels in the carrier.	
10 View the result for CC1.	Press **View/Display, CC For Preset Views, CC1** then Preset View: Basic.	The demodulation result (only include PUSCH DM-RS) for CC1 should look like Figure 2-41.

Step	Action	Notes

Figure 2-41 LTE & LTE-A FDD Modulation Analysis Measurement Result - UL CC1 PUSCH DM-RS



Step	Action	Notes
11 Select different views.	You can now view data traces and use different Preset Views to display measurement results. See “Selecting Different Measurement Results Views” on page 62.	

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

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

Troubleshooting Measurements

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

PROBLEM describes some common problems and possible solutions.

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

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

Conformance EVM Measurement

This section explains how to make the Conformance EVM measurement on a LTE FDD & LTE-A FDD signal. For the detailed instruction about this measurement, see "LTE & LTE-A Conformance EVM Measurement Concepts" on page 191.

"Making LTE & LTE-A Downlink Conformance EVM Measurement" on page 85

"Making LTE & LTE-A Uplink Conformance EVM Measurement" on page 90

Making LTE & LTE-A Downlink Conformance EVM Measurement

For signal setting, see "Setting the Downlink Signal (Example)" on page 52.

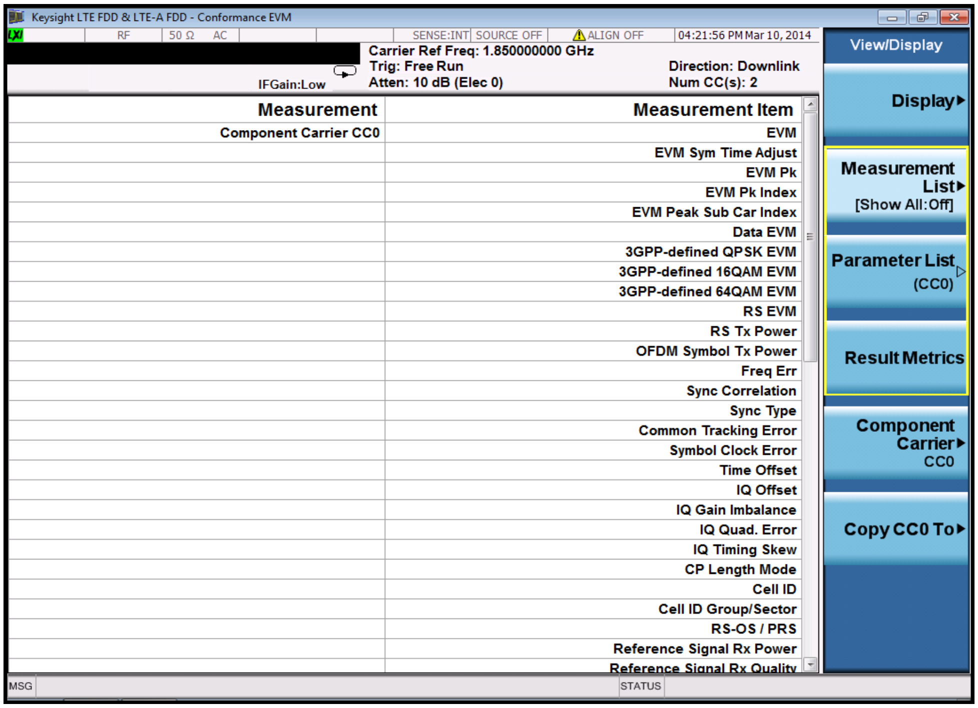
Measurement Procedure

Step	Action	Notes
1 Enable the LTE & LTE-A FDD measurements.	Press **Mode**, **LTE FDD & LTE-A FDD.**	
2 Preset the Mode.	Press **Mode Preset**.	Only do this to return the measurement settings to a known state for all measurements in the LTE FDD & LTE-A FDD mode.
3 Initiate the Modulation Analysis measurement.	Press **Meas**, **Modulation Analysis.**	
4 Set the center frequency.	Press **FREQ Channel**, **Carrier Ref Freq, 1.85**, **GHz.**	
5 Select the direction to **Downlink**.	Press **Mode Setup**, **Direction** to be **Downlink.** Downlink is the default setting.	

Step	Action	Notes
6 Configure the two component carriers.	a. Press **Mode Setup, Component Carrier Setup**. b. Press **Num Component Carriers, 2**. c. Press **Configure Component Carriers, Component Carrier, CC0**. d. Press **Freq Offset, -5 MHz.** e. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** f. Press **Configure Component Carriers, Component Carrier, CC1**. g. Press **Freq Offset, 5 MHz.** h. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** i. Press **Carrier Allocation, Contiguous**.	Press Mode Setup, Preset to Standard to preset measurement parameters besides BW. For a list of all presets effected see "Preset to Standard Settings" on page 95.
7 Recall the EVM setup file.	Press **Recall**, **Data**, **Component Carrier Setup, CC0, (or CC1)** then **Open...,** a file open dialog appears, under D:\Users\Administrator(Instrument)\Documents\LTEAFDD\data\evmsetup folder, select the appropriate test model file and click open. This will apply the RB setup and related parameters quickly. The other parameters will not be changed.	If the signal is E-URTA Test Models E-TM1.1, E-TM2, E-TM3.1, E-TM3.2 or E-TM3.3 in 3GPP standard, you can recall the EVM parameter setting directly.
8 Initial Conformance EVM measurement.	Press **Meas, Conformance EVM.**	
9 Set up other measurement parameters.	You need to send SCPI commands or change parameter settings in Parameter List view (under View/Display).	If you have already configured the setting in Modulation Analysis measurements in this example, you can simply use Copy from Modulation function to automatically apply the parameter values to Conformance EVM. Press **Meas Setup, Copy from Mod Analysis**.

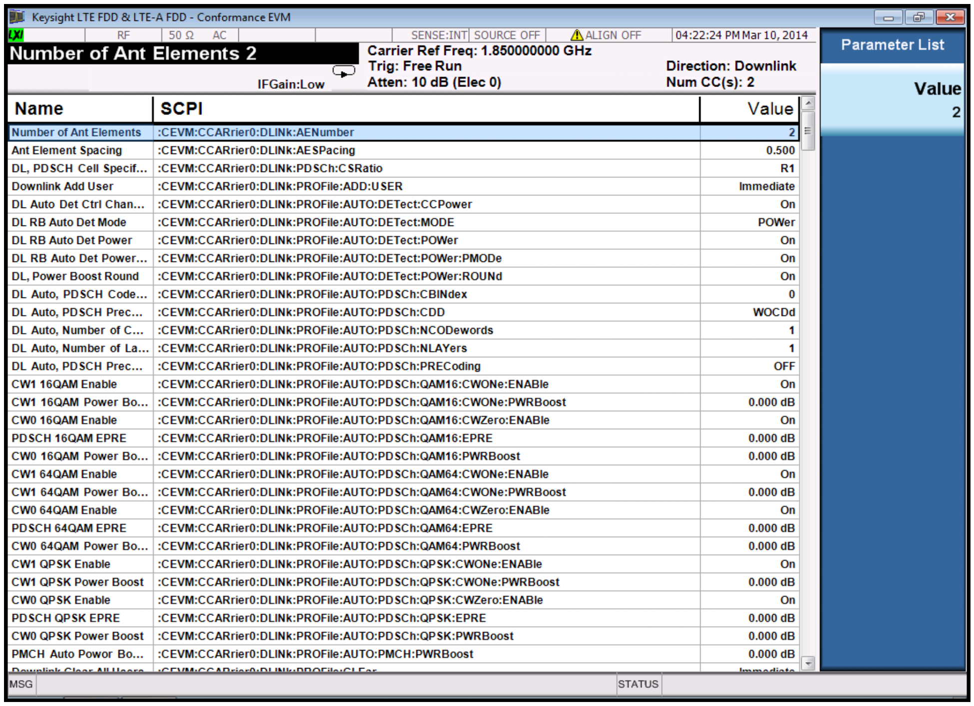
Step	Action	Notes
TIP	If the configuration for CC1 is the same as CC0, you may directly use **View/Display, Component Carrier, CC0, Copy CC0 to, CC1**.	
10 Select views.	Press **View/Display** to select different views: **Measurement List, Parameter List, and Result Metrics.**	

Figure 2-42 LTE & LTE-A FDD Downlink Conformance EVM Measurement List



Step	Action	Notes

Figure 2-43 LTE & LTE-A FDD Downlink Conformance EVM Parameter List

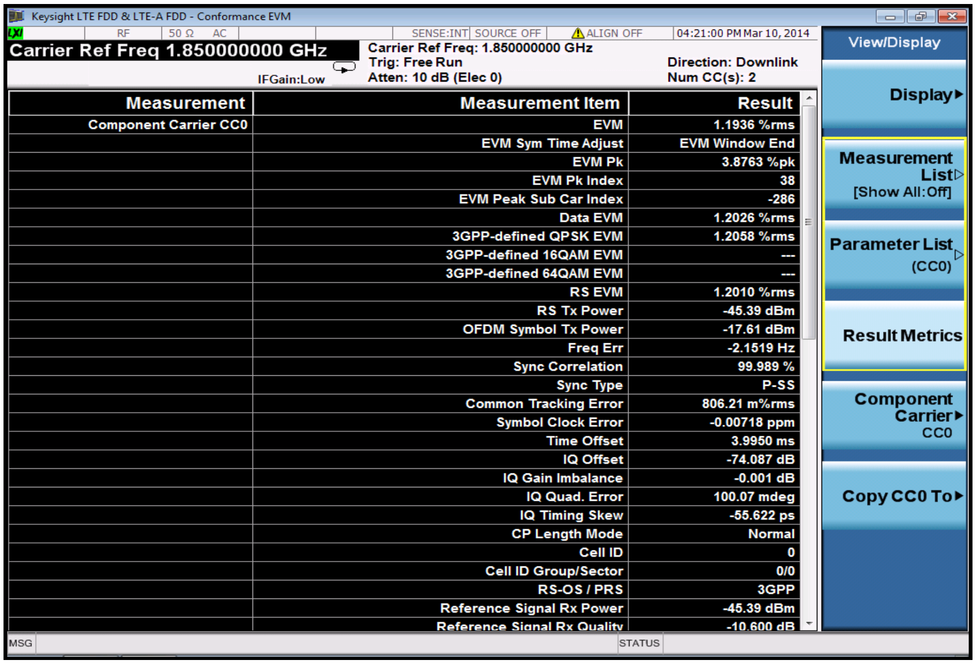


NOTE The parameter name, related SCPI and value are listed in the Parameter List view in a tabular format. You can send the SCPI to change the parameters or you can manually change them by selecting the parameter using the knob or up and down arrows then enter the value using front panel keys.

For other Component Carrier settings, press View/Display, Component Carrier then select the carrier (such as CC1), the Parameter List will be changed to CC1.

Step	Action	Notes

Figure 2-44 LTE & LTE-A FDD Downlink Conformance EVM Result Metrics



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

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

Making LTE & LTE-A Uplink Conformance EVM Measurement

This section explains how to make the Conformance EVM measurement on a LTE FDD uplink signal. For detailed instruction about this measurement, see "LTE & LTE-A Conformance EVM Measurement Concepts" on page 191.

Setting the Uplink Signal (Example)

For signal setting, see "Setting the Uplink Signal (Example)" on page 71.

Measurement Procedure

Step	Action	Notes
1 Enable the LTE & LTE-A FDD measurements.	Press **Mode**, **LTE FDD & LTE-A FDD.**	
2 Preset the Mode.	Press **Mode Preset.**	Only do this to return the measurement settings to a known state for all measurements in the LTE FDD & LTE-A FDD mode.
3 Select the direction to **Uplink**.	Press **Mode Setup**, **Direction** to be **Uplink.** Downlink is the default setting.	
4 Set the carrier reference frequency.	Press **FREQ Channel**, **Carrier Ref Freq, 1.75**, **GHz.**	The center frequencies of carriers are defined as offset frequency from this value.

NOTE You may need to change the Center Freq and Center Freq Offset settings to satisfy the channel spacing requirement according to the 3GPP standard.

Step	Action	Notes
5 Configure the two component carriers.	a. Press **Mode Setup, Component Carrier Setup**. b. Press **Num Component Carriers, 2**. c. Press **Configure Component Carriers, Component Carrier, CC0**. d. Press **Freq Offset, -5 MHz.** e. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** f. Press **Configure Component Carriers, Component Carrier, CC1**. g. Press **Freq Offset, 5 MHz.** h. Press **Bandwidth Setup, System BW, 10 MHz (50 RB).** i. Press **Carrier Allocation, Contiguous**.	The measurement example is for contiguous carriers. If the carriers are non-contiguous, the Carrier Allocation under Component Carrier Setup needs to be set up. Press Mode Setup, Preset to Standard to preset measurement parameters besides BW. For a list of all presets effected see “Preset to Standard Settings” on page 95.
6 Initial Conformance EVM measurement.	Press **Meas, Conformance EVM**.	
7 Set up other measurement parameters.	You need to send SCPI commands or change parameter settings in Parameter List view (under View/Display).	If you have already configured the setting in the Modulation Analysis measurements, you can simply use Copy from Modulation function to automatically apply the parameter values to Conformance EVM. Press **Meas Setup, Copy from Mod Analysis.**
8 Select views.	Press **View/Display** to select different views: **Measurement List, Parameter List, and Result Metrics.**	

Step	Action	Notes

Figure 2-45 LTE & LTE-A Uplink Conformance EVM Measurement List

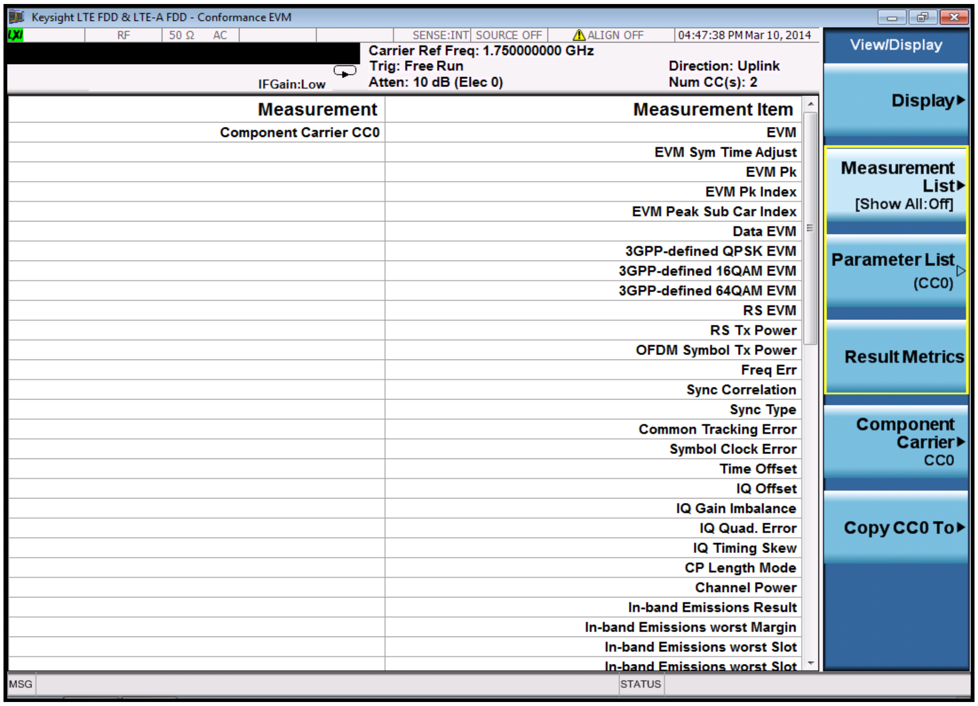
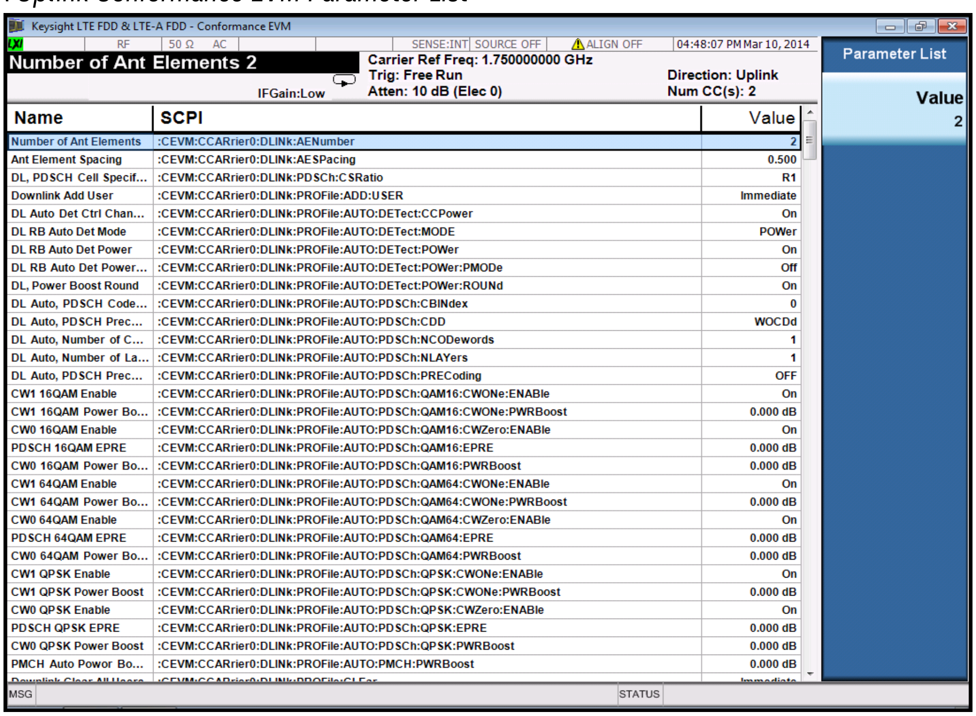
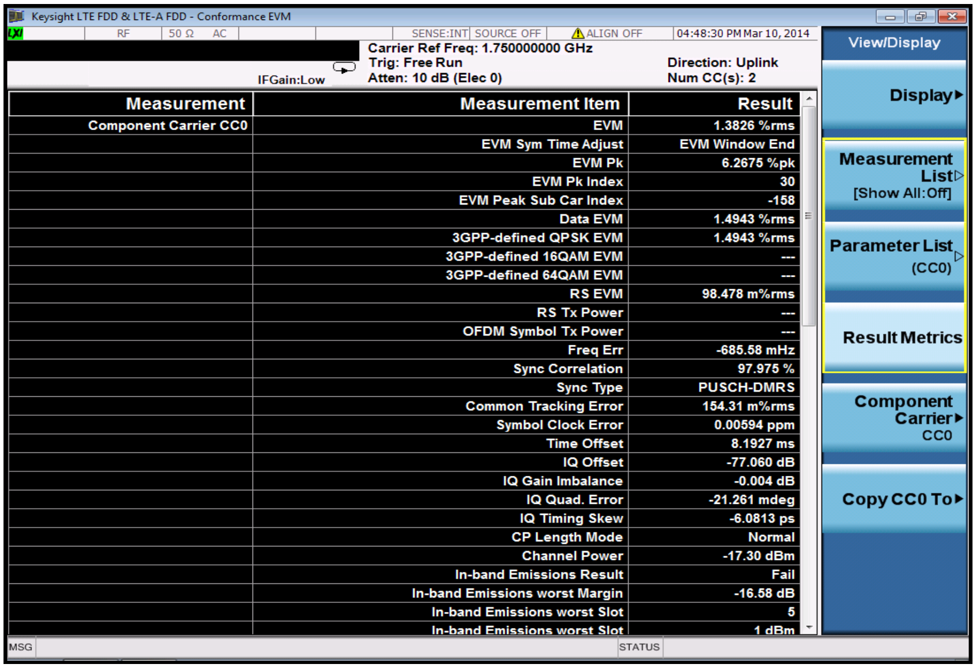


Figure 2-46 LTE & LTE-A Uplink Conformance EVM Parameter List



Step	Action	Notes
NOTE	The parameter name, related SCPI and value are listed in the Parameter List view in a tabular format. You can send the SCPI to change the parameters or you can manually change them by selecting the parameter using the knob or up and down arrows then enter the value using front panel keys. For other Component Carrier settings, press View/Display, Component Carrier then select the carrier (such as CC1), the Parameter List will be changed to CC1.	
TIP	If you want to imply CC0 Parameter List to CC1, press View/Display, Component Carrier, CC0, then Copy CC0 to, CC1.	

Figure 2-47 LTE & LTE-A Uplink Conformance EVM Result Metrics



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

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

Preset to Standard Settings

The following tables summarizes the default value using Mode Setup, Preset to Standard for Power measurement.

Table 2-3 Channel Power Preset to Standard Value

Bandwidth	IntegBW
1.4MHz	1.4MHz
3MHz	3MHz
5MHz	5MHz
10MHz	10MHz
15MHz	15MHz
20MHz	20MHz

RBW, VBW, SPAN and Sweep Time will be determined by IntegBW automatically.

Table 2-4 Occupied Bandwidth Preset to Standard Value

Bandwidth	**RBW**	**SPAN**	**Limit**
1.4MHz	30KHz	20MHz	1.4MHz
3MHz	30KHz	20MHz	3MHz
5MHz	30KHz	20MHz	5MHz
10MHz	30KHz	20MHz	10MHz
15MHz	30KHz	20MHz	15MHz
20MHz	30KHz	25MHz	20MHz

VBW and Sweep Time will be determined automatically.

Table 2-5 *ACP Preset to Standard Value (2-1)*

Direction	**Bandwidth**	**Meas Noise BW**	**Carrier Spacing**	**Offset**	**Offset Freq**	**Offset IntegBW**	**RBW**	**VBW**	**Filter**
Downlink	1.4MHz	1.095MHz	1.4MHz	A	1.4MHz	1.095MHz	100kHz	Auto	None
				B	2.8MHz	1.095MHz	100kHz	Auto	None
	3MHz	2.715MHz	3MHz	A	3MHz	2.715MHz	100kHz	Auto	None
				B	6MHz	2.715MHz	100kHz	Auto	None
	5MHz	4.515MHz	5MHz	A	5MHz	4.515MHz	100kHz	Auto	None
				B	10MHz	4.515MHz	100kHz	Auto	None
	10MHz	9.015MHz	10MHz	A	10MHz	9.015MHz	100kHz	Auto	None
				B	20MHz	9.015MHz	100kHz	Auto	None
	15MHz	13.515MHz	15MHz	A	15MHz	13.515MHz	100kHz	Auto	None
				B	30MHz	13.515MHz	100kHz	Auto	None
	20MHz	18.015MHz	20MHz	A	20MHz	18.015MHz	100kHz	Auto	None
				B	40MHz	18.015MHz	100kHz	Auto	None
	Bandwidth	Meas Noise BW	Carrier Spacing	Offset	Offset Freq	Offset IntegBW	RBW	VBW	Filter

Table 2-5 *ACP Preset to Standard Value (2-1)*

Direction	Band width	Meas Noise BW	Carrier Spacing	Offset	Offset Freq	Offset IntegBW	RBW	VBW	Filter
Uplink	1.4MHz	1.08MHz	1.4MHz	A	1.4MHz	1.08MHz	100kHz	Auto	None
				B	2.8MHz	1.08MHz	100kHz	Auto	None
	3MHz	2.7MHz	3MHz	A	3MHz	2.7MHz	100kHz	Auto	None
				B	6MHz	2.7MHz	100kHz	Auto	None
	5MHz	4.5MHz	5MHz	A	5MHz	4.5MHz	100kHz	Auto	None
				B	10MHz	4.5MHz	100kHz	Auto	None
	10MHz	9MHz	10MHz	A	10MHz	9MHz	100kHz	Auto	None
				B	20MHz	9MHz	100kHz	Auto	None
	15MHz	13.5MHz	15MHz	A	15MHz	13.5MHz	100kHz	Auto	None
				B	30MHz	13.5MHz	100kHz	Auto	None
	20MHz	18MHz	20MHz	A	20MHz	18MHz	100kHz	Auto	None
				B	40MHz	18MHz	100kHz	Auto	None

Table 2-6 *ACP Preset to Standard Value (2-2)*

Direction	Band	Offset	Abs Limit	Rel Limit	Fail Mask
Downlink	1.4MHz	A	–14.61	0dB	AND
		B	–14.61	0dB	AND
	3MHz	A	–10.66	0dB	AND
		B	–10.66	0dB	AND
	5MHz	A	–8.45	0dB	AND
		B	–8.45	0dB	AND
	10MHz	A	–5.45	0dB	AND
		B	–5.45	0dB	AND
	15MHz	A	–3.69	0dB	AND
		B	–3.69	0dB	AND
	20MHz	A	–2.44	0dB	AND
		B	–2.44	0dB	AND

Table 2-6 ACP Preset to Standard Value (2-2)

Direction	Band	Offset	Abs Limit	Rel Limit	Fail Mask
	Band	Offset		Rel Limit	Fail Mask
Uplink	1.4MHz	A	–50.0	0dB	AND
		B	–50.0	0dB	AND
	3MHz	A	–50.0	0dB	AND
		B	–50.0	0dB	AND
	5MHz	A	–50.0	0dB	AND
		B	–50.0	0dB	AND
	10MHz	A	–50.0	0dB	AND
		B	–50.0	0dB	AND
	15MHz	A	–50.0	0dB	AND
		B	–50.0	0dB	AND
	20MHz	A	–50.0	0dB	AND
		B	–50.0	0dB	AND

Table 2-7 Spectrum Emission Mask Preset to Standard Value (2-1)

Band wid th	Direction	Integ BW	Span	Sweep Time	Res BW	Video BW	VBW/RBW
1.4MHz	Downlink	1095000	1.4MHz	Auto	Auto	Auto	Auto
3MHz	Downlink	2715000	3MHz	Auto	Auto	Auto	Auto
5MHz	Downlink	4515000	5MHz	Auto	Auto	Auto	Auto
10MHz	Downlink	9015000	10MHz	Auto	Auto	Auto	Auto
15MHz	Downlink	13515000	15MHz	Auto	Auto	Auto	Auto
20MHz	Downlink	18015000	20MHz	Auto	Auto	Auto	Auto
Band wid th	Direction	Integ BW	Span	Sweep Time	Res BW	Video BW	VBW/RBW
1.4MHz	Uplink	1080000	1.4MHz	Auto	Auto	Auto	Auto
3MHz	Uplink	2700000	3MHz	Auto	Auto	Auto	Auto
5MHz	Uplink	4500000	5MHz	Auto	Auto	Auto	Auto
10MHz	Uplink	9000000	10MHz	Auto	Auto	Auto	Auto

Table 2-7 Spectrum Emission Mask Preset to Standard Value (2-1)

15MHz	Uplink	13500000	15MHz	Auto	Auto	Auto	Auto
20MHz	Uplink	18000000	20MHz	Auto	Auto	Auto	Auto

Table 2-8 Spectrum Emission Mask Preset to Standard Value (2-2)

BW	Offset	Offset side	Offset Define	Start Freq	Stop Freq	RBW	VBW	VBW/ RBW	Sweep	Limit ABS Start	Limit ABS Stop
Downlink											
1.4 MHz	A	Both	ETOC	0.05MHz	1.45MHz	51KHz	Auto	Man (0.01)	Auto	+0.5dBm	–9.5dBm
	B	Both	ETOC	1.45MHz	2.85MHz	100KHz	Auto	Man (0.01)	Auto	–9.5dBm	AUTO
	C	Both	ETOC	3.3MHz	15MHz	1MHz	Auto	Man (0.01)	Auto	–15dBm	AUTO
3MHz	A	Both	ETOC	0.05MHz	3.05MHz	51KHz	Auto	Man (0.01)	Auto	–3.5dBm	–13.5dBm
	B	Both	ETOC	3.05MHz	6.05MHz	100KHz	Auto	Man (0.01)	Auto	–13.5dBm	AUTO
	C	Both	ETOC	6.5MHz	15MHz	1MHz	Auto	Man (0.01)	Auto	–15dBm	-AUTO
5MHz	A	Both	ETOC	0.05MHz	5.05MHz	51KHz	Auto	Man (0.01)	Auto	–5.5dBm	–12.5dBm
	B	Both	ETOC	5.05MHz	10.05MHz	100KHz	Auto	Man (0.01)	Auto	–12.5dBm	AUTO
	C	Both	ETOC	10.5MHz	15MHz	1MHz	Auto	Man (0.01)	Auto	–15dBm	AUTO
10MHz	A	Both	ETOC	0.05MHz	5.05MHz	51KHz	Auto	Man (0.01)	Auto	–5.5dBm	–12.5dBm
	B	Both	ETOC	5.05MHz	10.05MHz	100KHz	Auto	Man (0.01)	Auto	–12.5dBm	AUTO
	C	Both	ETOC	10.5MHz	15MHz	1MHz	Auto	Man (0.01)	Auto	–15dBm	AUTO

Table 2-8 Spectrum Emission Mask Preset to Standard Value (2-2)

BW	Offset	Offset side	Offset Define	Start Freq	Stop Freq	RBW	VBW	VBW/ RBW	Sweep	Limit ABS Start	Limit ABS Stop
15M Hz	A	Both	ETOC	0.05MHz	5.05MHz	51KHz	Auto	Man (0.01)	Auto	–5.5dBm	–12.5d Bm
	B	Both	ETOC	5.05MHz	10.05M Hz	100KHz	Auto	Man (0.01)	Auto	–12.5dB m	AUTO
	C	Both	ETOC	10.5MHz	15MHz	1MHz	Auto	Man (0.01)	Auto	–15dBm	AUTO
20M Hz	A	Both	ETOC	0.05MHz	5.05MHz	51KHz	Auto	Man (0.01)	Auto	–5.5dBm	–12.5d Bm
	B	Both	ETOC	5.05MHz	10.05M Hz	100KHz	Auto	Man (0.01)	Auto	–12.5dB m	-AUTO
	C	Both	ETOC	10.5MHz	15MHz	1MHz	Auto	Man (0.01)	Auto	–15dBm	AUTO
Uplink											
1.4 MHz	A	Both	ETOC	15.00 kHz	985.0 kHz	15KHz	Auto	Man (0.01)	Auto	–11.50 dBm	AUTO
	B	Both	ETOC	1.50 MHz	4.50 MHz	510KHz	Auto	Man (0.01)	Auto	–8.50 dBm	AUTO
	C	Both	ETOC	5.50 MHz	5.50MHz	1MHz	Auto	Man (0.01)	Auto	–23.50 dBm	AUTO
3MH z	A	Both	ETOC	15.00 kHz	985.0 kHz	15KHz	Auto	Man (0.01)	Auto	–8.50	AUTO
	B	Both	ETOC	1.50 MHz	2.00MHz	510KHz	Auto	Man (0.01)	Auto	–8.50dB m	AUTO
	C	Both	ETOC	3.00 MHz	3.00MHz	1MHz	Auto	Man (0.01)	Auto	–23.50d Bm	AUTO
5MH z	A	Both	ETOC	15.00 kHz	985.0 kHz	15KHz	Auto	Man (0.01)	Auto	–13.50d Bm	AUTO
	B	Both	ETOC	1.50 MHz	4.5MHz	510KHz	Auto	Man (0.01)	Auto	–8.5dBm	AUTO
	C	Both	ETOC	5.50MHz	5.50MHz	1MHz	Auto	Man (0.01)	Auto	–11.5dB m	AUTO
	D	Both	ETOC	6.5MHz	9.5MHz	1MHz	Auto	Man (0.01)	Auto	–23.50d Bm	AUTO

Table 2-8 Spectrum Emission Mask Preset to Standard Value (2-2)

BW	Offset	Offset side	Offset Define	Start Freq	Stop Freq	RBW	VBW	VBW/ RBW	Sweep	Limit ABS Start	Limit ABS Stop
10M Hz	A	Both	ETOC	15.00 kHz	985.0 kHz	15KHz	Auto	Man (0.01)	Auto	−16.5dBm	AUTO
	B	Both	ETOC	1.50 MHz	4.5MHz	510KHz	Auto	Man (0.01)	Auto	−8.5dBm	AUTO
	C	Both	ETOC	5.50 MHz	9.50MHz	1MHz	Auto	Man (0.01)	Auto	−11.50dBm	AUTO
	D	Both	ETOC	10.50MHz	14.5MHz	1MHz	Auto	Man (0.01)	Auto	−23.50dBm	AUTO
15M Hz	A	Both	ETOC	15.00 kHz	985.0 kHz	15KHz	Auto	Man (0.01)	Auto	−18.50dBm	AUTO
	B	Both	ETOC	1.50 MHz	4.5MHz	510KHz	Auto	Man (0.01)	Auto	−8.50dBm	AUTO
	C	Both	ETOC	5.50MHz	14.50MHz	1MHz	Auto	Man (0.01)	Auto	−11.50dBm	AUTO
	D	Both	ETOC	15.50MHz	19.5MHz	1MHz	Auto	Man (0.01)	Auto	−23.5dBm	AUTO
20M Hz	A	Both	ETOC	15.00 kHz	985.0 kHz	15KHz	Auto	Man (0.01)	Auto	−19.50dBm	AUTO
	B	Both	ETOC	1.50 MHz	4.5MHz	510KHz	Auto	Man (0.01)	Auto	−8.50dBm	AUTO
	C	Both	ETOC	5.50MHz	19.50MHz	1MHz	Auto	Man (0.01)	Auto	−11.50dBm	AUTO
	D	Both	Both	20.50MHz	24.50MHz	1MHz	Auto	Man (0.01)	Auto	−23.5dBm	AUTO

Table 2-9 Power Stat CCDF Preset to Standard Value

Band wid th	Info BW
1.4MHz	1.5MHz
3MHz	4MHz
5MHz	6MHz
10MHz	25MHz
15MHz	25MHz

Table 2-9 Power Stat CCDF Preset to Standard Value

Bandwidth	Info BW
20MHz	25MHz

Table 2-10 Modulation Analysis Measurement Preset to Standard Value

Parameter	Preset Value
Bandwidth	The selected standard bandwidth
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
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 Slot	as many slots as possible up to 2 slots
Measurement Offset Slot	0 slots, 0 symbol-times
Include Non Allocation?	EXCLud
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

Table 2-10 *Modulation Analysis Measurement Preset to Standard Value*

Parameter	**Preset Value**
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 Diversity / MIMO	Control Chan Precoding: Off
	Shared Chan Precoding: Off
Downlink	
Detection	Selected
Include QPSK	Selected
Include 16QAM	Selected
Include 64QAM	Selected
PDSCH	
Power Boost (dB)	0
Uplink	
Detection	Selected
Cell ID	0
Group Hopping	Cleared
Seq Hopping	Cleared
Include PUSCH	Selected

Table 2-10 Modulation Analysis Measurement Preset to Standard Value

Parameter	**Preset Value**
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
Power (dB)	0
DMRS Group (u)	0
DMRS Power (dB)	0
LTE Downlink Control Channel Properties (Edit Control Params...) defaults	
Parameter	Preset Value
P-SS Power Boost	0.65 dB

Table 2-10 Modulation Analysis Measurement Preset to Standard Value

Parameter	**Preset Value**
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 Constant	Selected
PHICH Power Boost	0 dB
Despread IQ Orthogonal Sequence Index	Cleared
PHICH Allocation	Ng 1
PHICH Duration	Normal

3 Interpreting Error Codes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4 Concepts

This chapter presents an overview of the 3GPP LTE communications system including both LTE & LTE-A FDD and TDD. It also provides what's new in LTE-Advanced and its key technologies. The details on how various measurements are performed by the instrument are described in measurement concepts section. 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 a new modulation scheme called single carrier frequency division multiple access (SC-FDMA) used in the LTE uplink.

There are two types of frame structure in the LTE standard, Type 1 and Type 2. LTE Type 1 uses Frequency Division Duplexing (uplink and downlink separated by frequency), and LTE Type 2 uses Time Division Duplexing (uplink and downlink separated in time). This overview covers both LTE Type 1 FDD signals and LTE Type 2 TDD signals described in the March 2009 release of the standard.

LTE is designed to provide the following features:

- Increased downlink and uplink peak data rates, as shown in Table 4-1 and Table 4-2. 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 FDD and TDD air interface and in ideal radio conditions with allowance for signaling overheads.
- Scalable bandwidth from 1.4, 3.0, 5, 10, 15, 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 4-1 LTE FDD Downlink Peak Data Rates (64QAM)

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

Table 4-2 LTE FDD Uplink Peak Data Rates (Single Antenna)

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

LTE Specification Documents

Release 7 of the 3GPP specifications included the study phase of LTE. As a result of this study, requirements were published in TR 25.913 for LTE in terms of objectives, capability, system performance, deployment, E-UTRAN architecture and migration, radio resource management, complexity, cost, and service.

E-UTRA, E-UTRAN, and the EPC are defined in the 36-series of 3GPP Release 8:

- 36.100 series, covering radio specifications and evolved Node B (eNB)
- 36.200 series, covering layer 1 (physical layer) specifications
- 36.300 series, covering layer 2 and 3 (air interface signaling) specifications
- 36.400 series, covering network signaling specifications
- 36.500 series, covering user equipment conformance testing
- 36.800 and 36.900 series, which are technical reports containing background information

The latest version of the 36-series documents can be found at http://www.3gpp.org/ftp/specs/archive/36_series/.

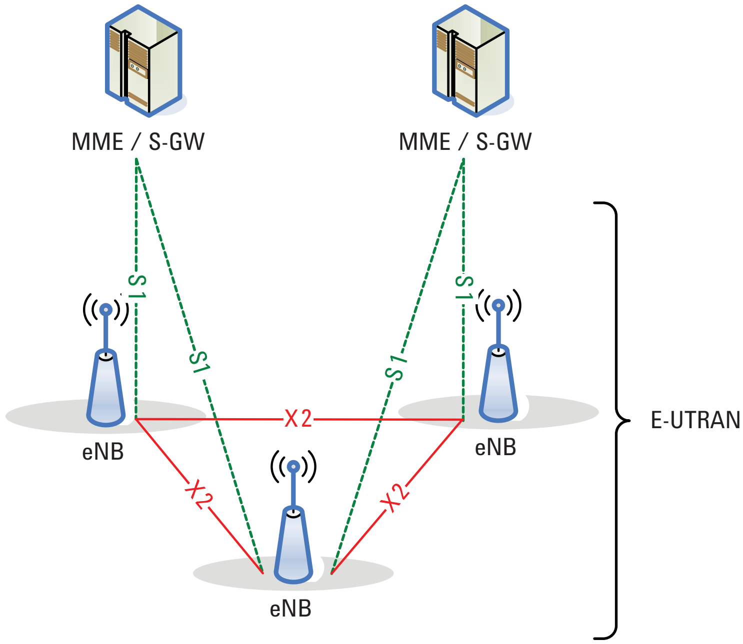
LTE Network Architecture

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 4-1. 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).

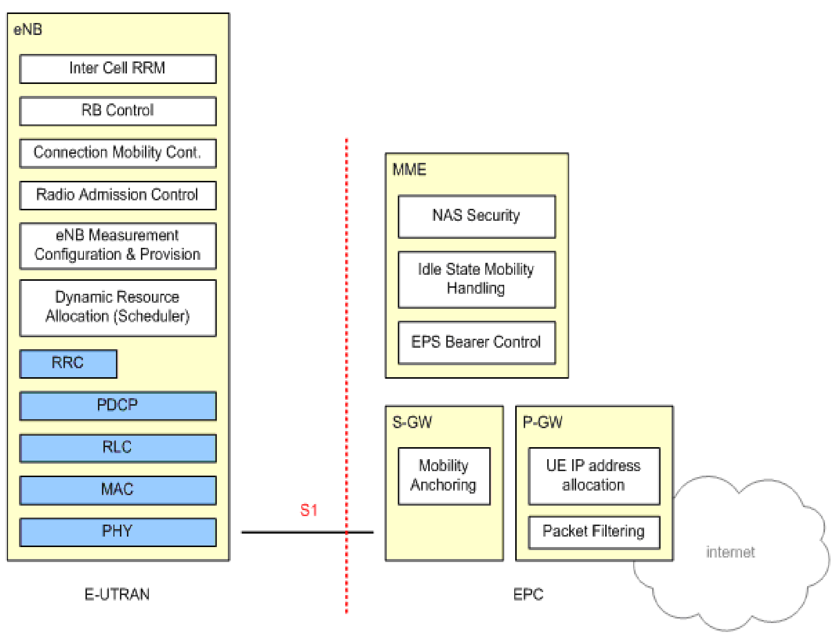
The E-UTRAN is connected to the EPC through the S1 interface, which connects the eNBs to the mobility management entity (MME) and serving gateway (S-GW) elements through a “many-to-many” relationship.

Figure 4-1 LTE architecture with E-UTRAN (TS 36.300 V8.8.0 Figure 4-1)



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 4-2.

Figure 4-2 Functional split between E-UTRAN and EPC (TS 36.300 V8.8.0 Figure 4.1-1)



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, ETWS 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 P-GW hosts these functions:

- Packet filtering
- UE IP address allocation

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 36.300 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.

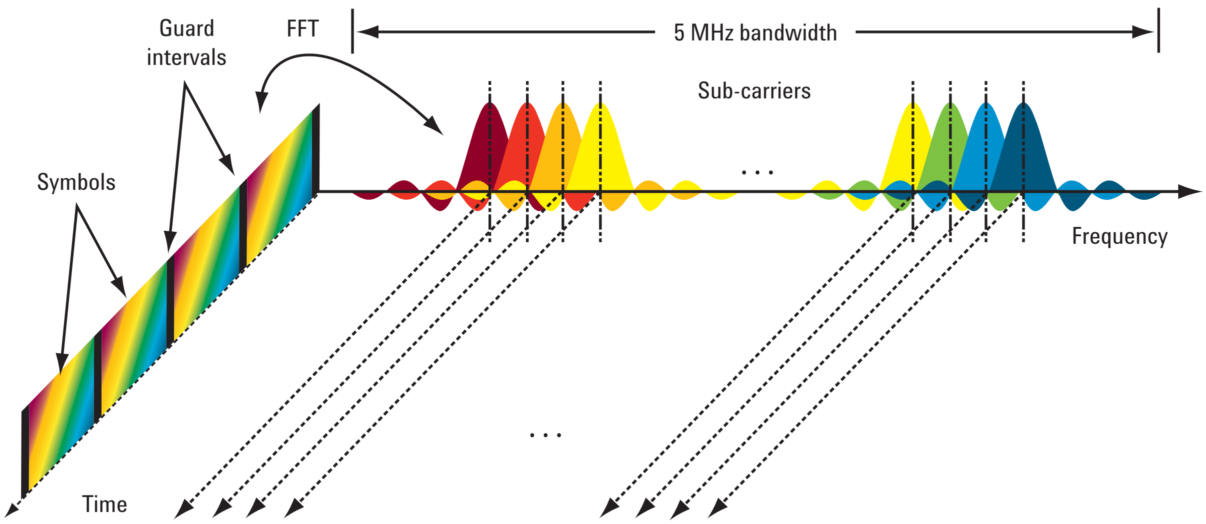
OFDM vs. CDMA

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 4-3 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 4-3 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:

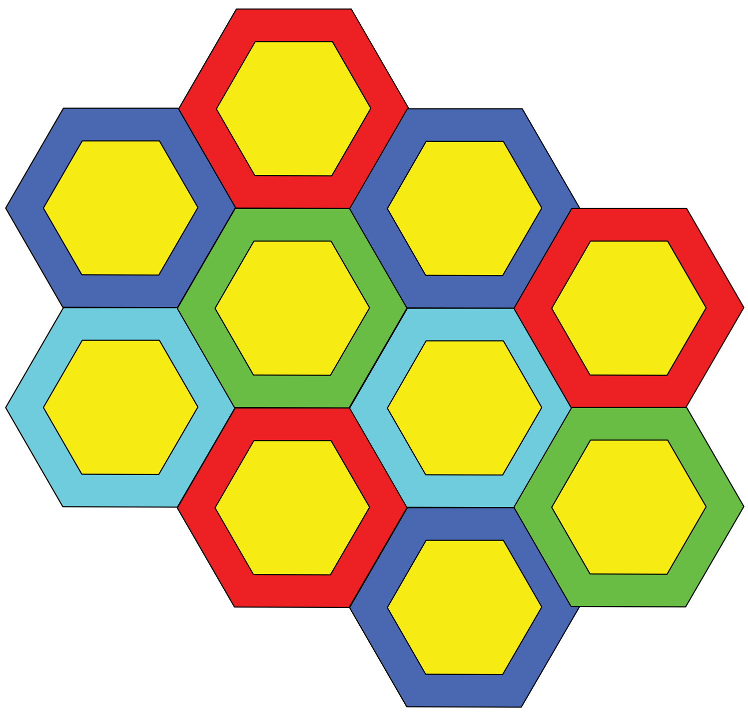
- OFDM can easily be scaled up to wide channels that are more resistant to fading.
- OFDM channel equalizers are much simpler to implement than are CDMA equalizers, as the OFDM signal is represented in the frequency domain rather than the time domain.
- OFDM can be made completely resistant to multi-path 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 4-4 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 4-4 Example of Frequency Planning to Avoid Inter-Cell Interference at the Cell Edges



The main differences between CDMA and OFDM are shown in Table 4-3.

Table 4-3 Comparison of CDMA and OFDM

Attribute	CDMA	OFDM
Transmission Bandwidth	Full system bandwidth	Variable up to full system bandwidth

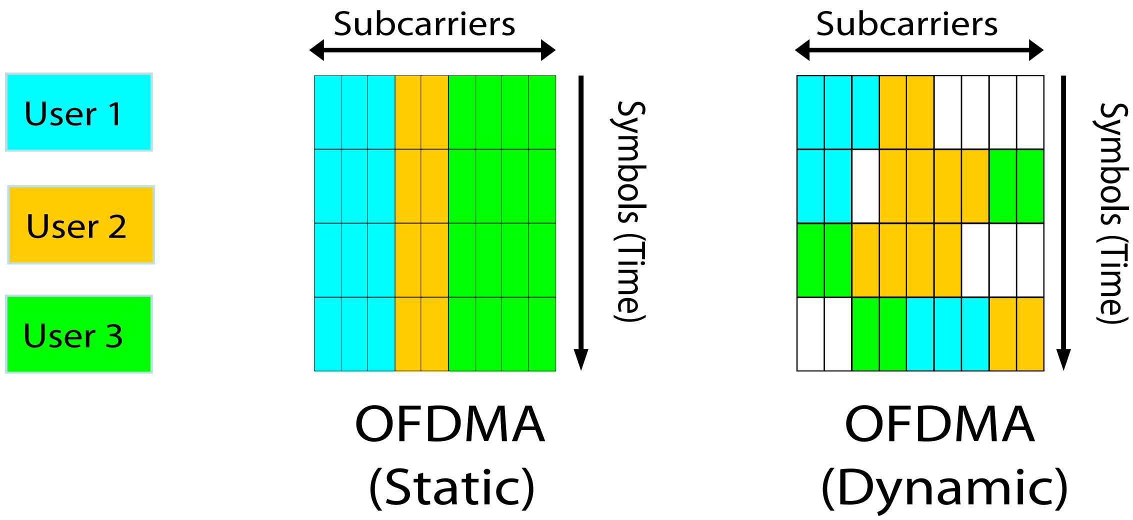
Table 4-3 Comparison of CDMA and OFDM

Attribute	CDMA	OFDM
Symbol period	Very short – inverse of system bandwidth	Very long - defined by subcarrier spacing and independent of system spacing
Separation of users	Orthogonal spreading codes	Frequency and time

Adding TDMA to OFDM to Create ODFMA

With standard OFDM, very narrow UE-specific transmissions can suffer from narrowband fading and interference. That is why for the downlink 3GPP chose OFDMA, which incorporates elements of time division multiple access (TDMA). OFDMA allows subsets of the subcarriers to be allocated dynamically among the different users on the channel, as shown in Figure 4-5. 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.

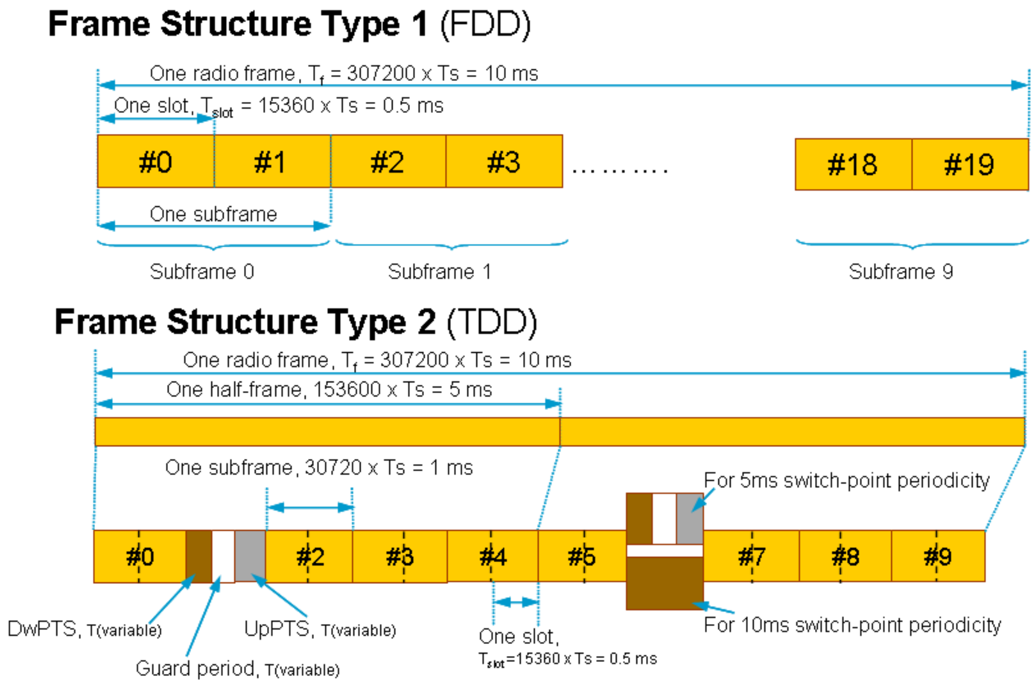
Figure 4-5 Comparison of Static and Dynamic OFDMA Subcarrier Allocation



LTE Frame Structure

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). The frame structure type 1 and type 2 are shown in Figure 4-6.

Figure 4-6 LTE Frame Structure



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.

In TDD mode, each radio frame is 10 ms long and consists of two half frames. Each half frame contains 5 subframes. There are seven defined uplink-downlink configuration shown in Table 4-4. "D" denotes the subframe is reserved for downlink transmissions, "U" denotes the subframe is reserved for uplink transmissions and subframe #1 and sometimes subframe #6 consist of three special fields: Downlink Pilot Timeslot (DwPTS), Guard Period (GP) and Uplink Timeslot (UpPTS). Table 4-4 shows the configuration of special subframe.

Table 4-4 LTE TDD Uplink-Downlink Configurations

Uplink-Dowlink Configuration	Switch-Point Periodicity	Subframe Number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D

Table 4-4 LTE TDD Uplink-Downlink Configurations

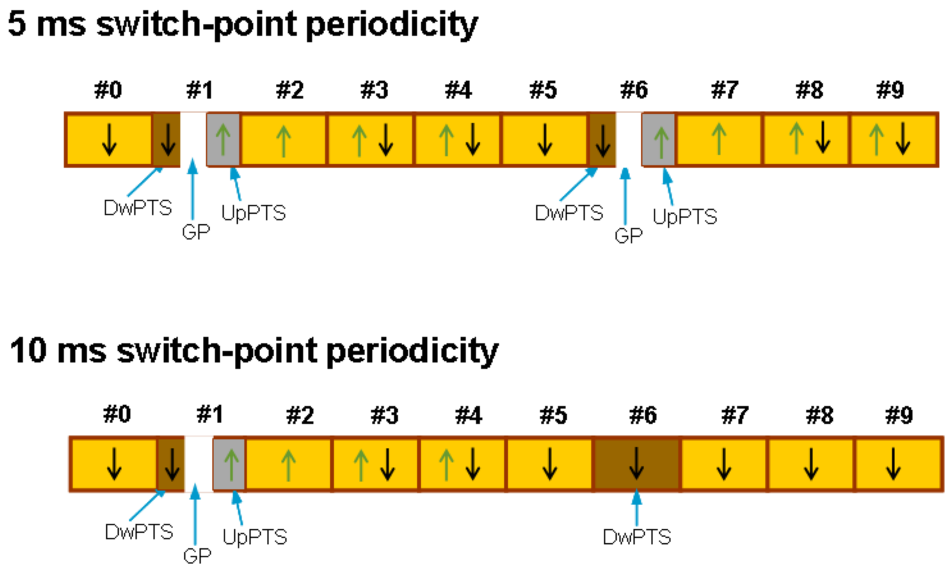
Uplink-Dowlink Configuration	**Switch-Point Periodicity**	**Subframe Number**									
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

Table 4-5 LTE TDD Special Subframe Configurations (DwPTS/GP/UpPTS)

Special subframe configuration	Normal cyclic prefix in downlink			Extended cyclic prefix in downlink		
	DwPTS	UpPTS		DwPTS	UpPTS	
		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink
0	$6592 \cdot T_s$	$2192 \cdot T_s$	$2560 \cdot T_s$	$7680 \cdot T_s$	$2192 \cdot T_s$	$2560 \cdot T_s$
1	$19760 \cdot T_s$			$20480 \cdot T_s$		
2	$21952 \cdot T_s$			$23040 \cdot T_s$		
3	$24144 \cdot T_s$			$25600 \cdot T_s$		
4	$26336 \cdot T_s$			$7680 \cdot T_s$	$4384 \cdot T_s$	$5120 \cdot T_s$
5	$6592 \cdot T_s$	$4384 \cdot T_s$	$5120 \cdot T_s$	$20480 \cdot T_s$		
6	$19760 \cdot T_s$			$23040 \cdot T_s$		
7	$21952 \cdot T_s$			-	-	-
8	$24144 \cdot T_s$			-	-	-

The flexible assignment for downlink or uplink slot in a frame enables asymmetric data rates. Depending on the switch-point periodicity of 5 ms or 10 ms, there can be one or two changes of direction within the frame. See Figure 4-7.

Figure 4-7 LTE TDD Switch-point Periodicity



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 4-6.

Table 4-6 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 4-7.

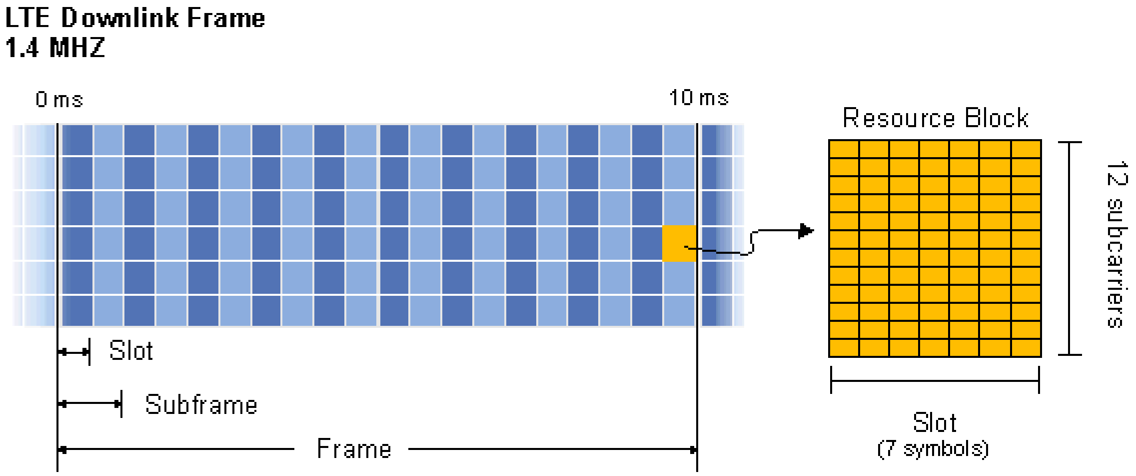
Table 4-7 LTE Time Units

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 4-8. 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 4-8 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 4-9. 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 4-6 on page 120.

Figure 4-9 Downlink Resource Grid

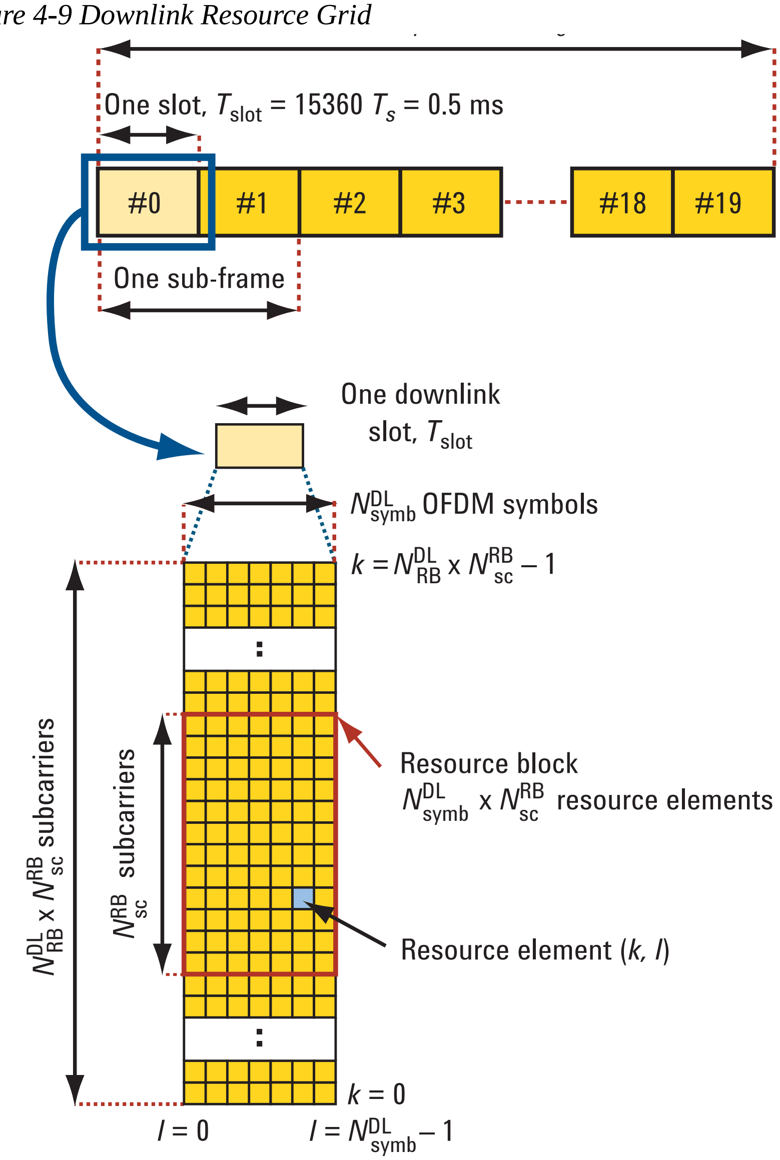


Figure 4-9 shows the downlink resource grid for a 0.5-ms timeslot, which incorporates the concepts of a resource element and a resource block. A resource element is the smallest identifiable unit of transmission and consists of one subcarrier for one symbol period. However, transmissions are scheduled in larger units called resource blocks, which comprise 12 adjacent subcarriers for a period of one 0.5-ms timeslot.

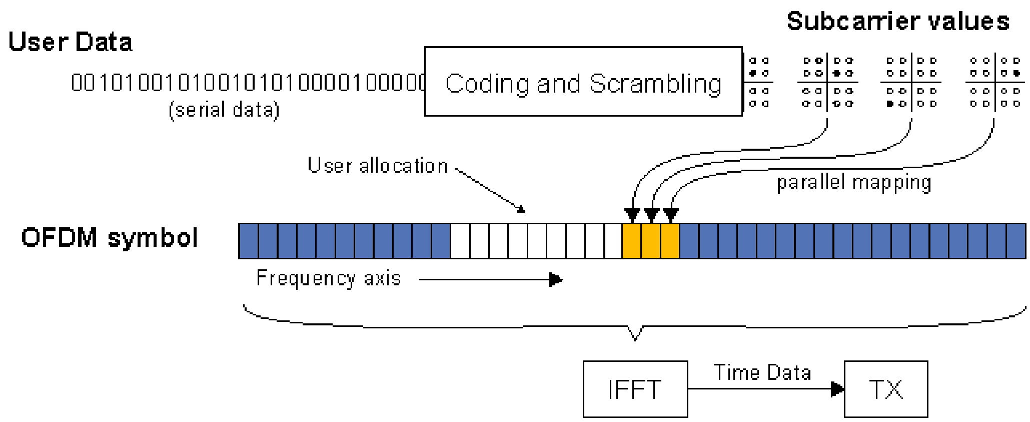
Physical Layer Channels

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 4-18). 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 4-10 illustrates this process.

Figure 4-10 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 4-11 has information on the modulation format and purpose for each of the downlink channels and signals.

Figure 4-11 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).

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) that is associated with transmission of PUSCH or PUCCH, and sounding reference signal (S-RS) that is not associated with transmission of PUSCH or PUCCH. Figure 4-12 below has information on the modulation format and purpose for each of the uplink channels and signals.

Figure 4-12 LTE Uplink Channels and Signals

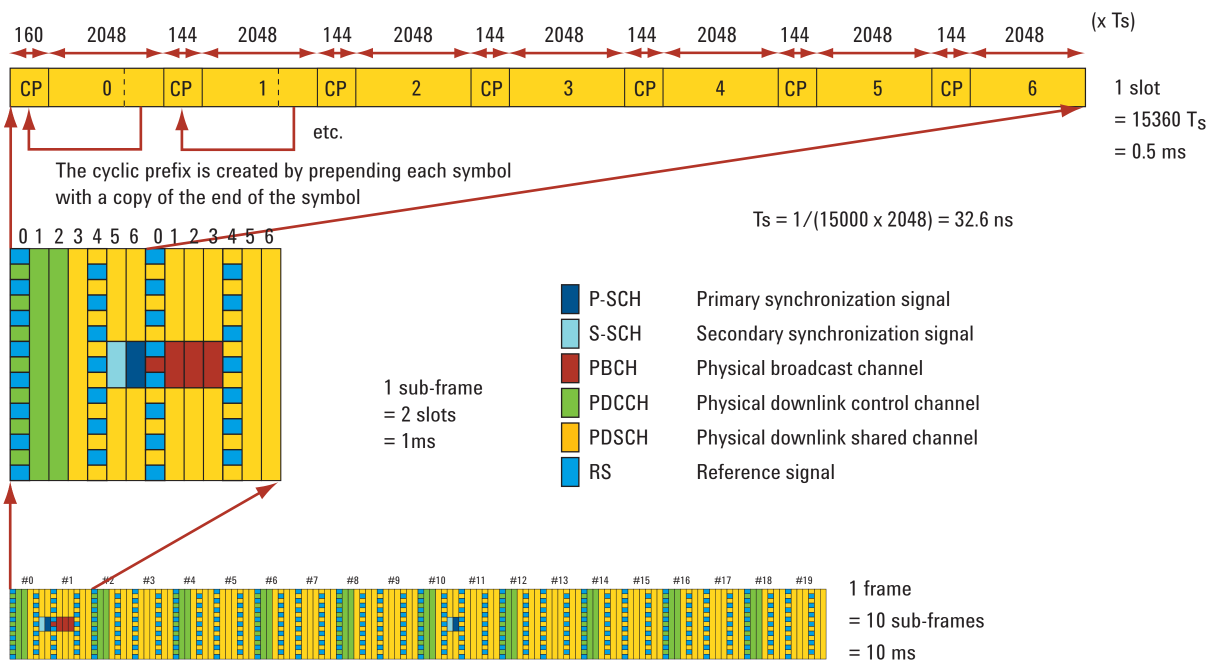
UL channels	Full name	Modulation format	Purpose
PRACH	Physical Random Access Channel	**QPSK**	Call setup
PUCCH	Physical Uplink Control Channel	**BPSK, QPSK**	Scheduling, ACK/NACK
PUSCH	Physical Uplink Shared Channel	**QPSK 16QAM 64QAM**	Payload
UL signals	**Full name**	**Modulation sequence**	**Purpose**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

Physical Signals and Channels Mapping

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.

Figure 4-13 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 4-13 DL FDD Type 1 Frame Structure

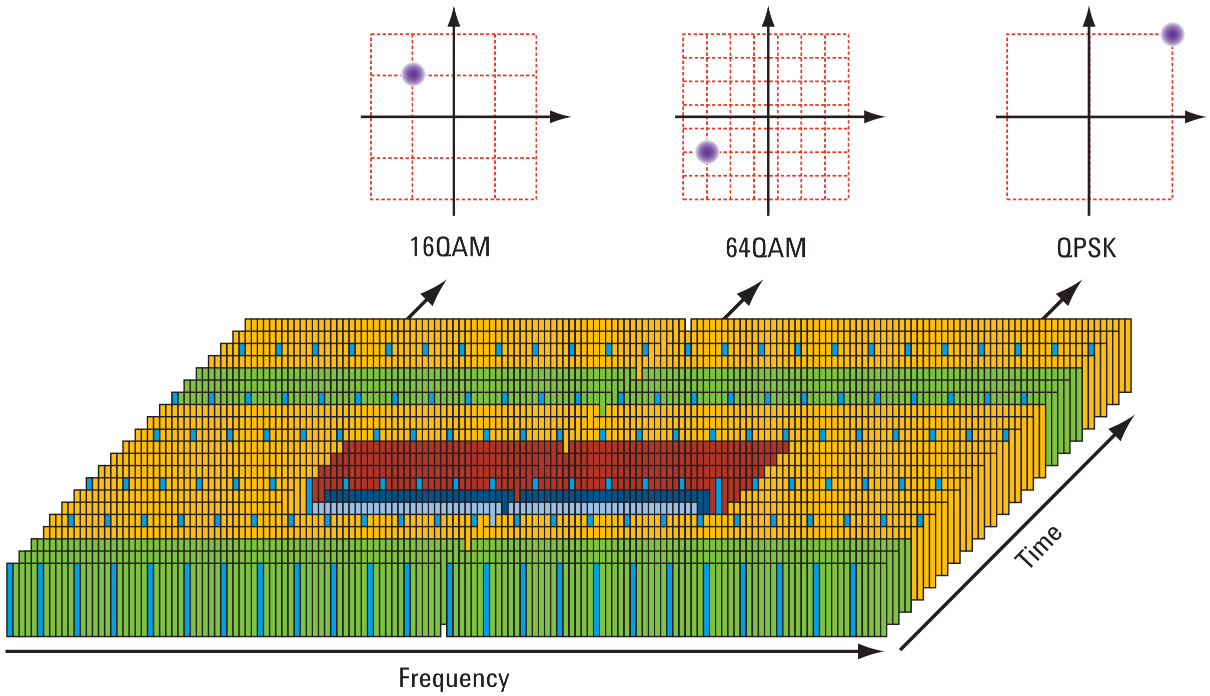


The physical mapping of the DL physical signals and channels are:

- 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 4-14 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 4-14 Downlink Frame Structure 1 Showing Subframe vs. Frequency



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 4-15 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 4-15 Uplink Type 1 FDD Frame Structure

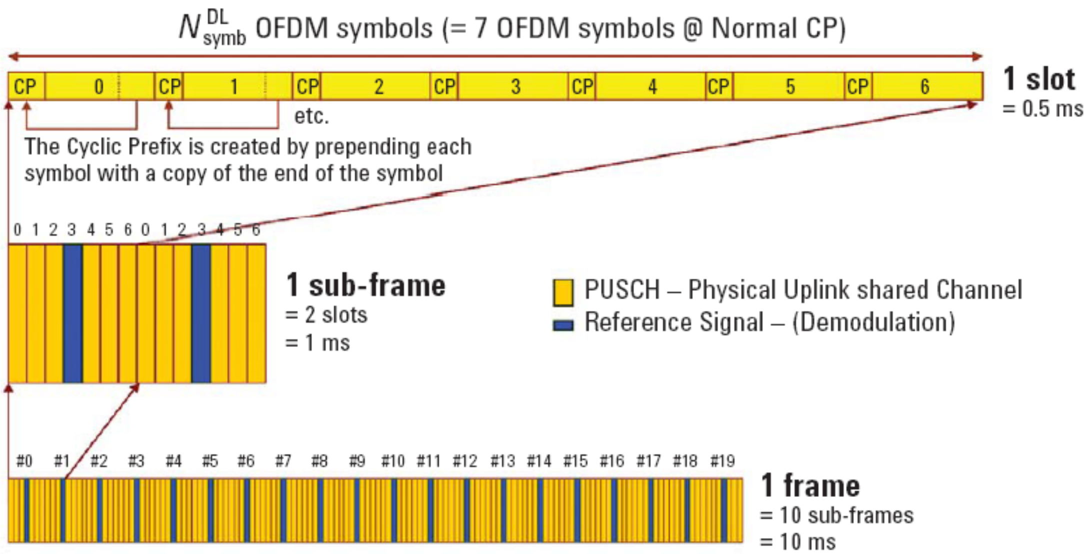


Figure 4-16 and Figure 4-17 are 5 ms and 10 ms TDD switch point periodicity physical signals and channels mapping.

- P-SCH is transmitted in the central 62 subcarriers at the third symbol of slot 2 and slot 12.
- S-SCH is transmitted in the last symbol of slot 1 and slot 11.
- Reference signal is transmitted at symbol #0 and symbol #4 in each slot.
- PBCH is transmitted at the first four symbols in slot 1.
- PDCCH is transmitted at the first three symbols in every subframe.
- PDSCH is transmitted on any assigned OFDM subcarriers not occupied by any of the above channels and signals

Figure 4-16 LTE TDD 5 ms Switch Periodicity Mapping

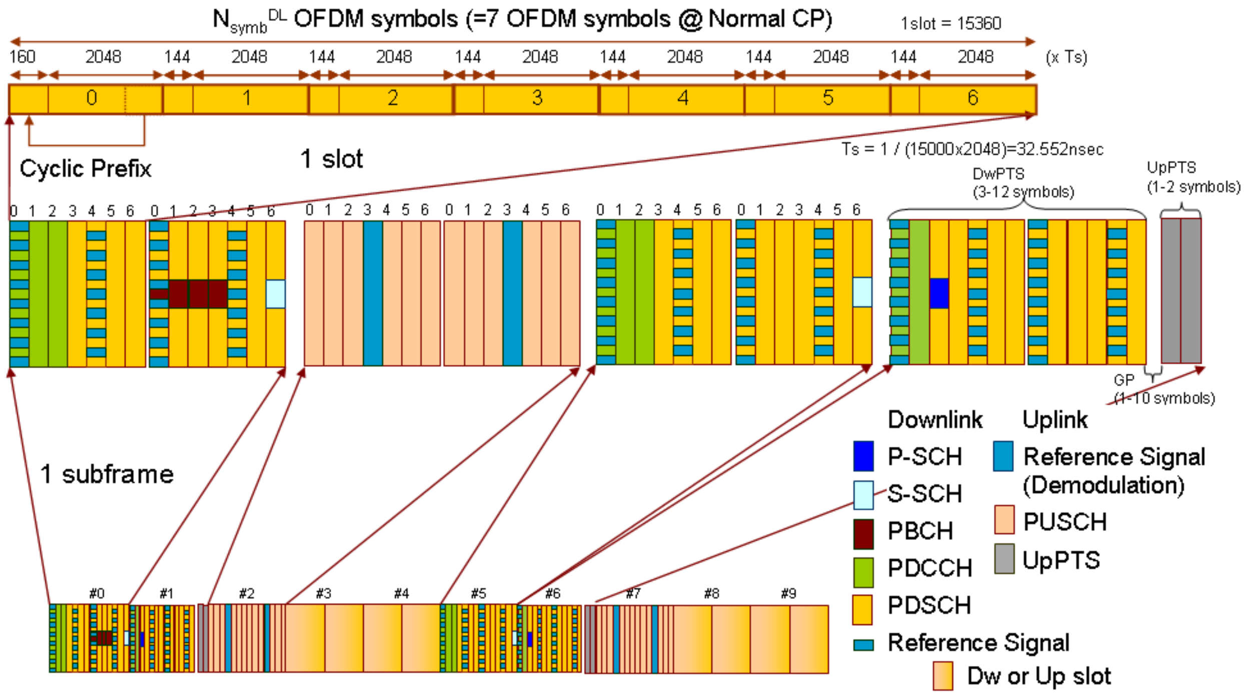
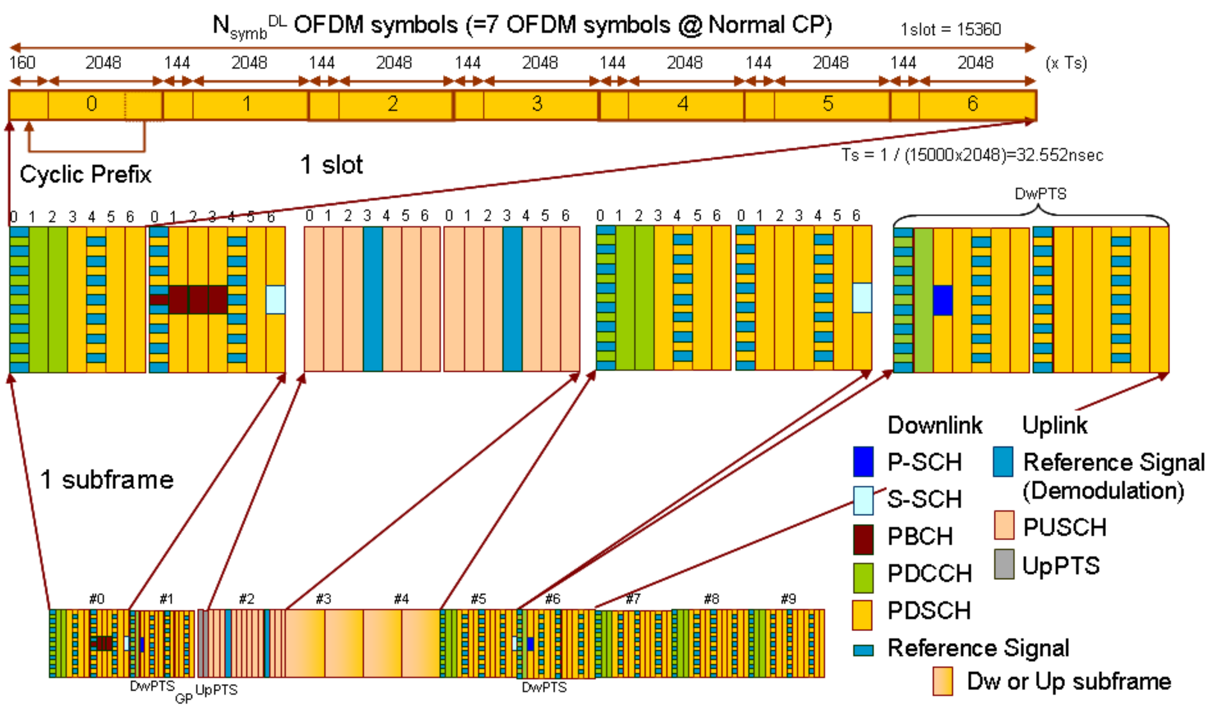


Figure 4-17 LTE TDD 10 ms Switch Periodicity Mapping



Cyclic Prefix (CP)

Table 4-8 and Table 4-9 summarizes the options for CP length and number of symbols per timeslot. The extended CP of 512 x Ts (16.67 µs) is available for use in larger cells and provides protection for up to a 5-km delay spread. The price for this increased protection is a reduction in system capacity since the extended CP allows for only six symbols per timeslot. The longest protection from delay spread is achieved when using the extended CP of 1024 x Ts (33.33 µs) with the optional 7.5-kHz subcarrier spacing for eMBMS. This enables transmissions from multiple cells to be combined in a Multicast/Broadcast over Single Frequency Network (MBSFN) with protection from delay spread of up to 10 km. This very long CP means there are only three symbols per timeslot, but this capacity loss is counteracted by the doubling up of the subcarriers.

Table 4-8 Cyclic Prefix Configurations for DL

CP in Ts by Symbol Number	0	1	2	3	4	5	6
Normal Δf = 15 kHz	160	144	144	144	144	144	144
Extended Δf = 15 kHz	512	512	512	512	512	512	-
Extended Δf = 7.5 kHz	1024	1024	1024	-	-	-	-

Table 4-9 Cyclic Prefix Configurations for UL

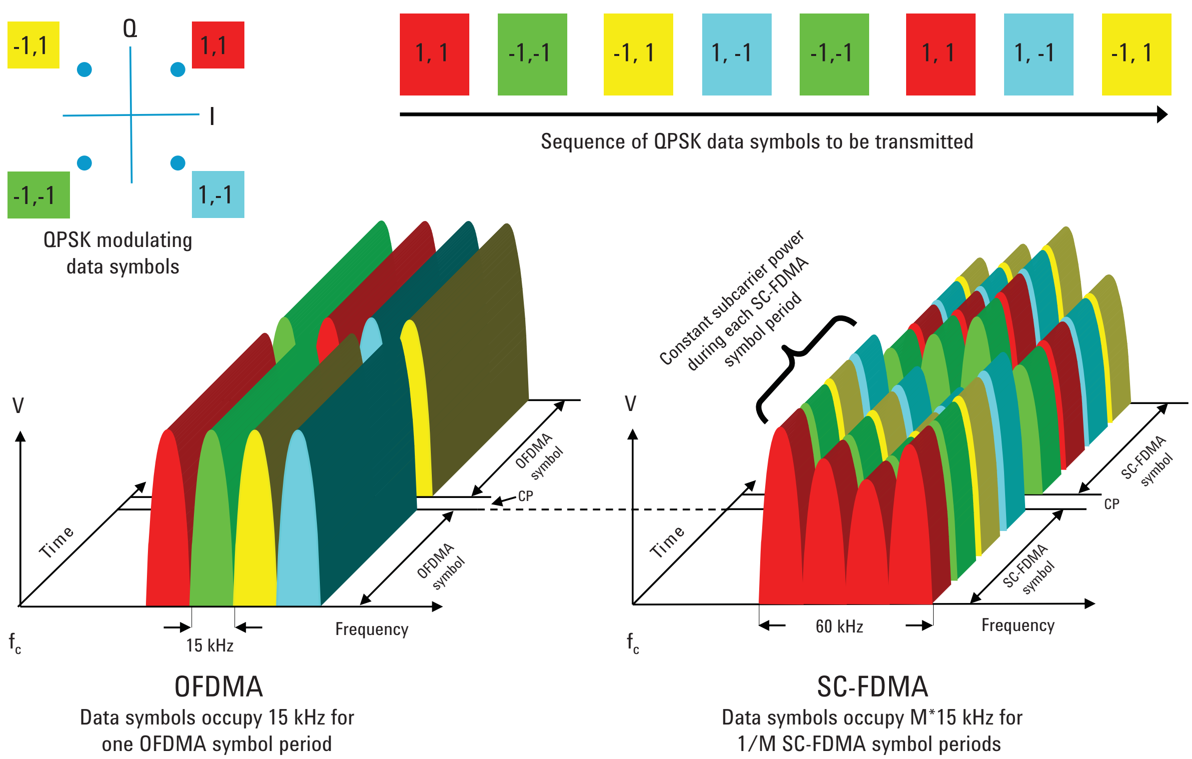
CP in Ts by Symbol Number	0	1	2	3	4	5	6
Normal Δf = 15 kHz	160	144	144	144	144	144	144
Extended Δf = 15 kHz	512	512	512	512	512	512	-

Multiple Access Technology in the Uplink: SC-FDMA

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

A graphical comparison of OFDMA and SC-FDMA as shown in Figure 4-18 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 4-18 Comparison of OFDMA (DL) and SC-FDMA (UL)



On the left side of Figure 4-18, M adjacent 15 kHz subcarriers—already positioned at the desired place in the channel bandwidth—are each modulated for the OFDMA symbol period of 66.7 µs by one QPSK data symbol. In this four subcarrier example, four symbols are taken in parallel. These are QPSK data symbols so only the phase of each subcarrier is modulated and the subcarrier power remains constant between symbols. After one OFDMA symbol period has elapsed, the CP is inserted and the next four symbols are transmitted in parallel. For visual clarity, the CP is shown as a gap; however, it is actually 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 4-18. The most obvious difference between the two schemes is that OFDMA transmits the four QPSK data symbols in parallel, one per subcarrier, while SC-FDMA transmits the four QPSK data symbols in series at four times the rate, with each data symbol occupying M x 15 kHz bandwidth.

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

SC-FDMA maps the data onto a single carrier modulation format (QPSK, QAM16, or QAM64). Then it takes the time domain set of symbols, performs an FFT, and maps the frequency domain values to the subcarriers that are assigned to the user. Then it takes an IFFT of the entire OFDM symbol and transmits the resulting time data. Figure 4-19 illustrates this process.

Figure 4-19 Uplink Modulation - Bits to SC-TDMA Carrier Allocation

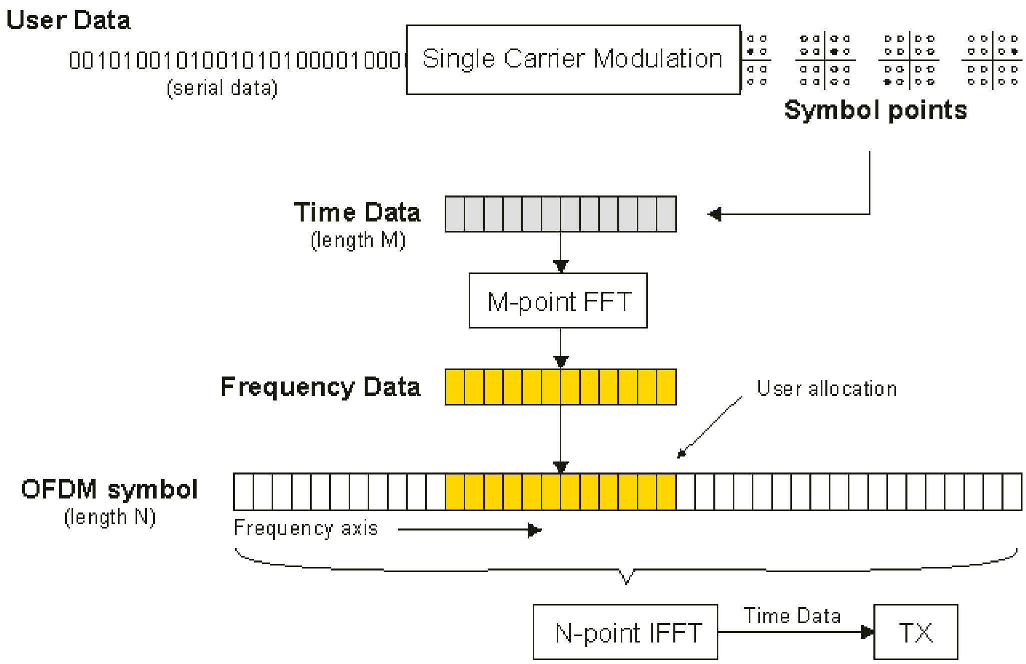


Table 4-10 summarizes the differences between the OFDMA and SC-FDMA modulation schemes. When OFDMA is analyzed one subcarrier at a time, it resembles the original data symbols. At full bandwidth, however, the signal looks like Gaussian noise in terms of its PAR statistics and the constellation. The opposite 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.

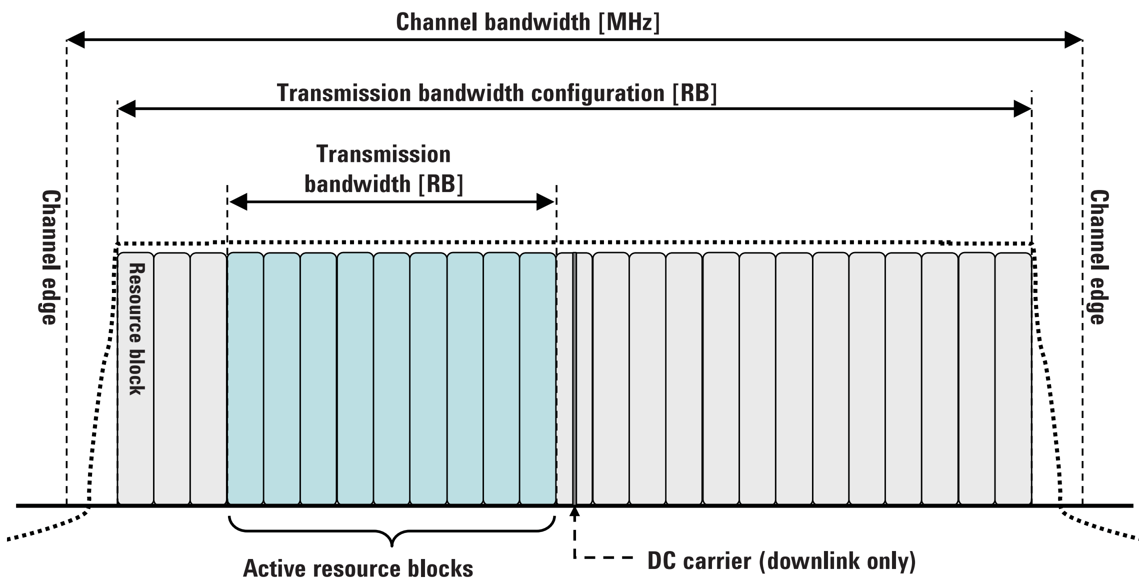
Table 4-10 Analysis of OFDMA and SC-FDMA at Different Bandwidths

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

Examining the SC-FDMA Signal

Unlike the eNB (base station transmitter), the UE does not normally transmit across the entire channel bandwidth. A typical uplink configuration with the definition of terms is shown in Figure 4-20.

Figure 4-20 SC-FDMA Channel BW and Transmission BW Configuration

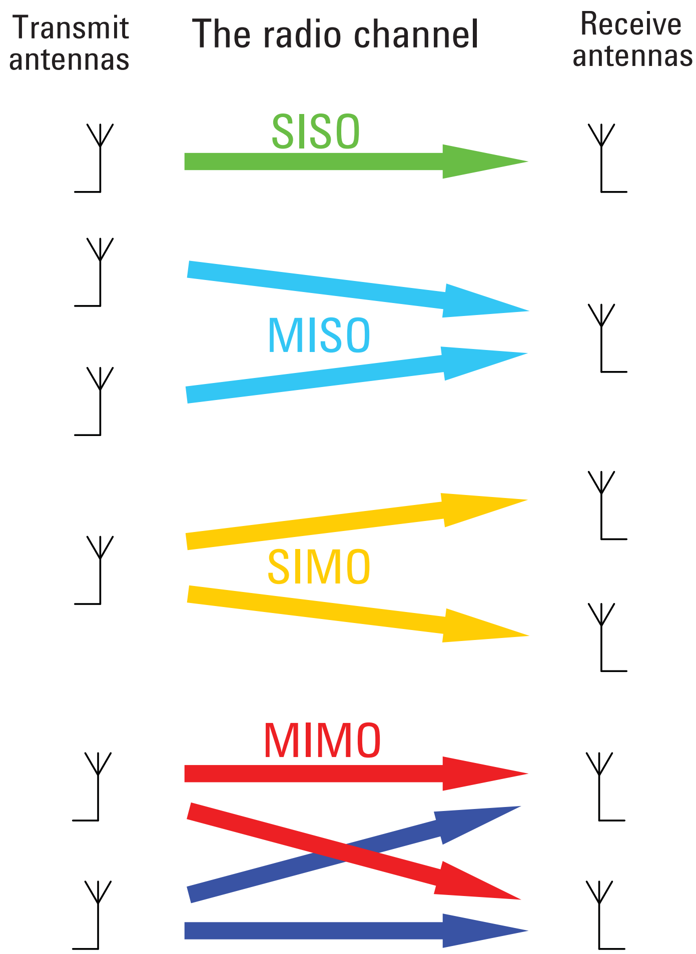


Overview of Multiple Antenna Techniques (MIMO)

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 4-21 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 4-21 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 4-21 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.

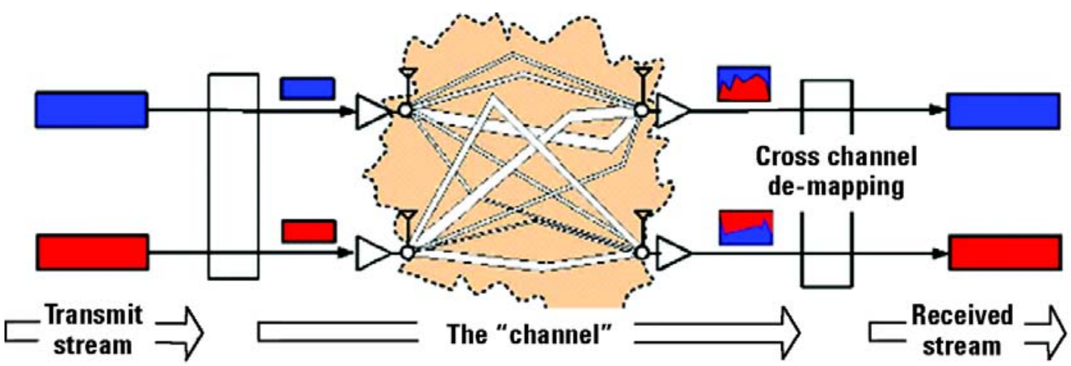
SIMO - The third mode shown in Figure 4-21 is single input multiple output (SIMO), which—in contrast to MISO—uses one transmitter and two or more receivers. SIMO is often referred to as receive diversity. Similar to transmit diversity, it is particularly well suited for low SNR conditions in which a theoretical gain of 3 dB is possible when two receivers are used. As with transmit diversity, there is no change in the data rate since only one data stream is transmitted, but coverage at the cell edge is improved due to the lowering of the usable SNR.

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

One other crucial factor for MIMO operation is that the transmissions from each antenna must be uniquely 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 4-22.

Figure 4-22 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 pre64

-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.

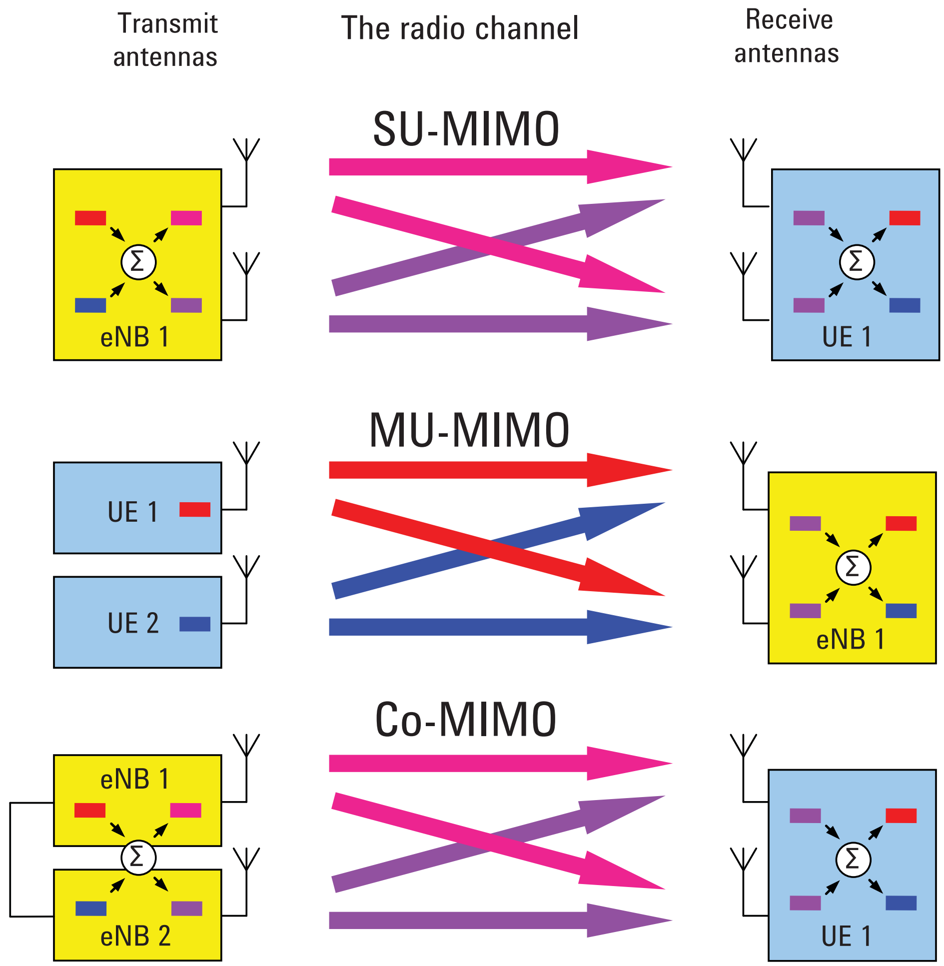
The theoretical gains from MIMO are a function of the number of transmit and receive antennas, the radio propagation conditions, the ability of the transmitter to adapt to the changing conditions, and the SNR. The ideal case is one in which the paths in the radio channel are completely uncorrelated, 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 4-22 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 4-22 on page 136.

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 4-23 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 4-23 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 4-23, 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 4-23 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 challenge.

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

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

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

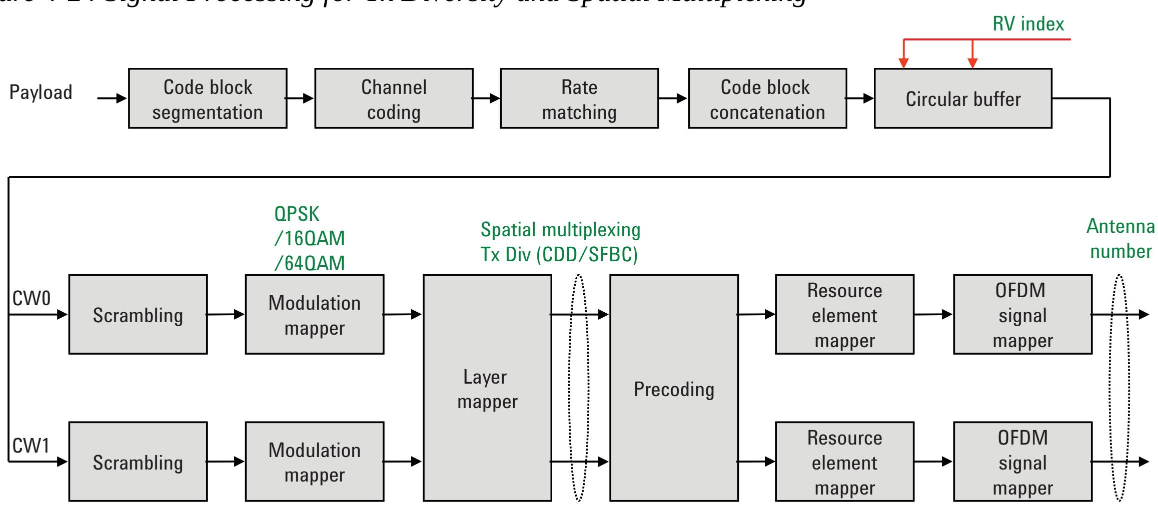
LTE Downlink Multiple Antenna Schemes

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 4-24 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 4-24 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 4-24.

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 µs for the 1.4 MHz channel. For the widest channels using the small delay will be a challenge because the required time shift is very close to the limits of antenna timing calibration. It is possible to apply a small delay CDD to the entire cell, including the RS. Doing so would make the CDD transparent to the UE but worsen the performance of channel quality indicator (CQI) reporting for those UE that would otherwise provide frequency-selective CQI reports.

LTE Uplink Multiple Antenna 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.

LTE-Advanced

LTE-Advanced (LTE-A) is the project name of the evolved version of LTE that is being developed by 3GPP. LTE-A will meet or exceed the requirements of the International Telecommunication Union (ITU) for the fourth generation (4G) radio communication standard known as IMT-Advanced. LTE-Advanced is being specified initially as part of Release 10 of the 3GPP specifications, with a functional freeze targeted for March 2011. The LTE specifications will continue to be developed in subsequent 3GPP releases.

In the feasibility study for LTE-Advanced, 3GPP determined that LTE-Advanced would meet the ITU-R requirements for 4G. The results of the study are published in 3GPP Technical Report (TR) 36.912. Further, it was determined that 3GPP Release 8 LTE could meet most of the 4G requirements apart from uplink spectral efficiency and the peak data rates. These higher requirements are addressed with the addition of the following LTE-Advanced features:

- Wider bandwidths, enabled by carrier aggregation
- Higher efficiency, enabled by enhanced uplink multiple access and enhanced multiple antenna transmission (advanced MIMO techniques)

Other performance enhancements are under consideration for Release 10 and beyond, even though they are not critical to meeting 4G requirements:

- Coordinated multipoint transmission and reception (CoMP)
- Relaying
- Support for heterogeneous networks
- LTE self-optimizing network (SON) enhancements
- Home enhanced-node-B (HeNB) mobility enhancements
- Fixed wireless customer premises equipment (CPE) RF requirements

LTE-Advanced Specification Documents

Release 10 of the 3GPP specifications included the study item, requirements, study phase technical report, study item final status report, physical layer aspects and so on.

E-UTRA, E-UTRAN, and the EPC are defined in the 36-series of 3GPP Release 10:

- 36.100 series, covering radio specifications and evolved Node B (eNB)
- 36.200 series, covering layer 1 (physical layer) specifications
- 36.300 series, covering layer 2 and 3 (air interface signaling) specifications
- 36.400 series, covering network signaling specifications
- 36.500 series, covering user equipment conformance testing
- 36.800 and 36.900 series, which are technical reports containing background information

The latest version of the 36-series documents can be found at http://www.3gpp.org/ftp/specs/archive/36_series/.

IMT-Advanced and LTE-Advanced

Release 10 is a 3GPP proposal for the International Telecommunications Union Radiocommunication Sector (ITU-R) International Telecommunicaionts Advanced (IMT-Advanced) program. ITU-R defined the requirements for IMT-Advanced and 3GPP defined requirements for LTE-Advanced to meet or exceed the ITU-R requirements. 3GPP undertook a feasibility study that proposed LTE-Advanced as an IMT-Advanced candidate technology. 3GPP then created work items to develop the many detailed specification in Release 10 to define LTE-Advanced.

The ITU's high level requirements for IMT-Advanced:

• A high degree of common functionality worldwide while retaining the flexibility to support a wide range of local services and applications in a costefficient manner

• Compatibility of services within IMT and with fixed networks

• Capability for interworking with other radio systems

• High quality mobile services

• User equipment suitable for worldwide use

• User-friendly applications, services, and equipment

• Worldwide roaming capability

• Enhanced peak data rates to support advanced mobile services and applications (in the downlink, 100 Mbps for high mobility and 1 Gbps for low mobility).

The requirements for LTE-Advanced (based on the ITU requirements for 4G and on 3GPP operators' own requirements for advancing LTE):

• Continual improvement to the LTE radio technology and architecture

• Scenarios and performance requirements for interworking with legacy radio access technologies

• Backward compatibility of LTE-Advanced with LTE. An LTE terminal should be able to work in an LTE-Advanced network and vice versa. Any exceptions will be considered by 3GPP.

• Account taken of recent World Radiocommunication Conference (WRC-07) decisions regarding new IMT spectrum as well as existing frequency bands to ensure that LTE-Advanced geographically accommodates available spectrum for channel allocations above 20 MHz. Also, requirements must recognize those parts of the world in which wideband channels are not available.

Item	Subcategory	LTE target	LTE-Advanced target	IMT-Advanced target
Peak spectral efficiency (b/s/Hz)	Downlink	16.3 (4x4 MIMO)	30 (up to 8x8 MIMO)	15 (4x4 MIMO)
	Uplink	4.32 (64QAM SISO)	15 (up to 4x4 MIMO)	6.75 (2x4 MIMO)
Downlink cell spectral efficiency (b/s/Hz), 3 km/h, 500 m ISD	2x2 MIMO	1.69	2.4	
	4x2 MIMO	1.87	2.6	2.6
	4x4 MIMO	2.67	3.7	
Uplink cell spectral efficiency (b/s/Hz), 3 km/h, 500 m ISD	1x2 MIMO		1.2	1.8
	2x4 MIMO		2.0	
Downlink celledge user spectral efficiency (b/s/Hz) 5 percentile, 10 users, 500 m ISD	2x2 MIMO	0.05	0.07	
	4x2 MIMO	0.06	0.09	0.075
	4x4 MIMO	0.08	0.12	
Uplink celledge user spectral efficiency (b/s/Hz) 5 percentile, 10 users, 500 m ISD	1x2 MIMO		0.04	0.05
	2x4 MIMO		0.07	

LTE-Advanced Key Technologies

The key three LTE-Advanced technologies, as proposed to ITU are:

• Carrier aggregation which enables transmission bandwidth extension to support deployment bandwidths of up to 100 MHz

• Enhanced uplink multiple access where clustering of user data and simultaneous control and data transmission is supported

• Enhanced multiple antenna transmission where 8 streams are supported for downlink (vs. 4 in Release 8) and up to 4 streams supported for uplink (verses no single user MIMO support in Release 8).

Carrier Aggregation

How we can meet the peak data rate targets of 1Gpbp in the downlink and 500 Mbps in the uplink? At the moment, LTE supports channel bandwidths up to 20 MHz, and it is unlikely that spectral efficiency can be improved much beyond current LTE performance targets. Therefore the only way to achieve significantly higher data rates is to increase the channel bandwidth. IMT-Advanced sets the upper limit at 100 MHz, with 40 MHz the expectation for minimum performance. And it is most unlikely to have up to 100MHz wide contiguous bandwidth so LTE-Advanced uses carrier aggregation to address the lack of large contiguous spectrum.

Carrier aggregation is one of the key features of LTE-Advanced and is likely to be one of the earliest deployed technologies of LTE-Advanced.

The main principal of carrier aggregation is to extend the maximum transmission bandwidth to up to 100 MHz and this is done by aggregating up to 5 LTE carriers, each of which has a maximum bandwidth of 20 MHz. When carriers are aggregated, each carrier is referred to as a component carrier.

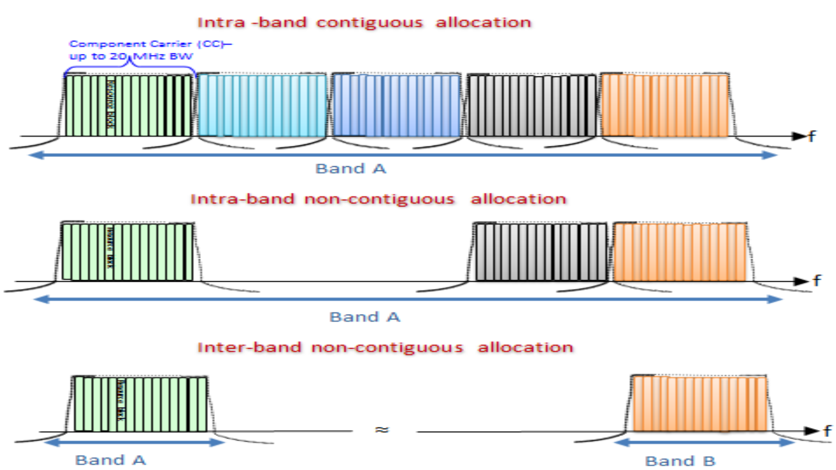
In addition to meeting the peak data rate targets, there are other additional motivations behind carrier aggregation:

One motivation is to help with an efficient use of fragmented spectrum, this is regardless of the peak data rate. In practice, this is more important since there are large variety of fragmented spectrum operators and CA allows aggregation of these fragmented spectrum to provide high data rate services even though they don't own a single wideband spectrum allocation.

The other motivation is inter-cell interference management and this is beneficial in a heterogeneous deployment where cells of different power levels and coverage areas are supported.

Three aggregation scenarios are possible, depending on the spectrum availability of the operators. Aggregated component carriers (CCs) can be contiguous or non-contiguous and both within a single frequency band or two different frequency bands.

Figure 4-25 Three Scenarios of Carrier Aggregation



The top image shows single band or intraband contiguous CA with 5, 20MHz CCs. This is a less likely scenario given frequency allocations today, however it can be possible when new spectrum bands like 3.5 GHz are allocated in the future in various parts of the world. From implementation perspective, this type of aggregation is the least challenging in terms of hardware implementation.

The middle image shows us non-contiguous allocation in the same frequency band also known as intraband Non-Contiguous CA. This can be a case where the middle carriers are loaded with other users or network sharing is considered.

Finally the bottom image shows us non-contiguous allocation in different frequency bands also known as interband Non-Contiguous CA and this is the most realistic scenario given the spectrum service providers have (especially for FDD). One of the drawbacks of this scenario is the complexity of the RF front end of user equipment. The antenna size, power amplifier, filters etc. might not be compatible among the different radio bands.

Enhanced uplink multiple access

Today’s LTE uplink is based on SC-FDMA, a powerful technology that combines many of the flexible aspects of OFDM with the low peak to average power ratio (PAPR) of a single carrier system. However, SC-FDMA requires carrier allocation across a contiguous block of spectrum and this prevents some of the scheduling flexibility inherent in pure OFDM.

LTE-Advanced enhances the uplink multiple access scheme by adopting clustered SC-FDMA, also known as discrete Fourier transform spread OFDM (DFT-S-OFDM). This scheme is similar to SC-FDMA but has the advantage that it allows noncontiguous (clustered) groups of subcarriers to be allocated for transmission by a single UE, thus enabling uplink frequency-selective scheduling and better link performance. Clustered SC-FDMA was chosen in preference to pure OFDM to avoid a significant increase in PAPR. It will help satisfy the requirement for increased uplink spectral efficiency while maintaining backward-compatibility with LTE.

In the process of mapping the symbols to the subcarriers, with SC-FDMA, the symbols are all mapped to adjacent subcarriers, however with clustered SC-FDMA, the symbols are mapped in two or more non-adjacent groups. The initial specifications decide to limit the number of SC-FDMA clusters to two, which will provide some improved spectral efficiency over single cluster when transmitting through a frequency-selective channel with more than one distinct peak.

In Release 8 the user data carried on the physical uplink shared channel (PUSCH) and the control data carried on the physical uplink control channel (PUCCH) are time-multiplexed. In Release 10, LTE-Advanced allows the PUSCH and the PUCCH to be transmitted simultaneously. It has some latency and scheduling advantages though it does make the PAPR higher than the Release 8 cases. Simultaneous PUCCH/PUSCH are contained within one component carrier, and should not be confused with carrier aggregation, which involves multiple component carriers.

Enhanced multiple antenna transmission

In Release 8, LTE downlink supports a maximum of four spatial layers of transmission (4x4, assuming four UE receivers) and the uplink a maximum of one per UE (1x2, assuming an eNB diversity receiver). And multiple antenna transmission is not supported in order to simplify the baseline UE, although multiple user spatial multiplexing (MU-MIMO) is supported. In the case of MU-MIMO, two UEs transmit on the same frequency and time, and the eNB has to differentiate between them based on their spatial properties. With this multi-user approach to spatial multiplexing, gains in uplink capacity are available but single user peak data rates are not improved.

To improve single user peak data rates and to meet the ITU-R requirement for spectrum efficiency, LTE-Advanced specifies up to eight layers in the downlink which, with the requisite eight receivers in the UE, allows the possibility in the downlink of 8x8 spatial multiplexing. The UE will be specified to support up to four transmitters allowing the possibility of up to 4x4 transmission in the uplink when combined with four eNB receivers.

Center Frequency and Carrier Ref Frequency

In most applications, Center Frequency is generally where the carrier center is located at and thus plays a very important role. However, in LTE & LTE-A TDD/FDD mode, the measurements are done based on carrier center frequencies and its bandwidths, both of which are calculated or obtained according to the carriers' configuration. The Center Frequency parameter defined here only for the Monitor Spectrum, IQ Waveform and CCDF measurements, because these three are general type measurements and focus on a certain frequency range, which may be the entire BS RF bandwidth, a frequency range of one of the component carriers or a range far away from the component carriers to see spurious. The center frequency in these three measurements has a different meaning, therefore it should be a separate setting from Carrier Ref Frequency.

Carrier center frequencies are defined using offsets from Carrier Ref Frequency which determines absolute frequency locations, which can be set as both absolute and relative frequency from the carrier reference frequency.

Since Center Frequency is only used in those three measurements, Monitor Spectrum, IQ Waveform and CCDF, this key only appears on Chan/Freq menus of these measurements.

Carrier Configuration

LTE-Advanced TDD/FDD are multi-carriers mode. This section describes how component carriers are configured. First it is required to specify how many component carriers are used in LTE-Advanced TDD/FDD measurements using Num Component Carrier key on Component Carrier Setup menu. Each component carrier is configured based on the selected component carrier. The available component carrier indexes is determined from the total number of the component carriers. The Configure Component Carriers menu groups the parameters to be set per carrier shown as below:

- Measure Carrier

  Specifies whether LTE-Advanced FDD/TDD measurements expect active carrier at this frequency. This parameter doesn't affect RF bandwidth calculation.

- Frequency Offset from Carrier Ref Freq

  Specifies carrier center frequency from Carrier Ref Freq.

- Bandwidth

  Specifies RF bandwidth for the selected component carrier.

- UL/DL Config

  Specifies the downlink and uplink allocation for LTE-Advanced TDD (TDD only).

- Dw/GP/UP Length

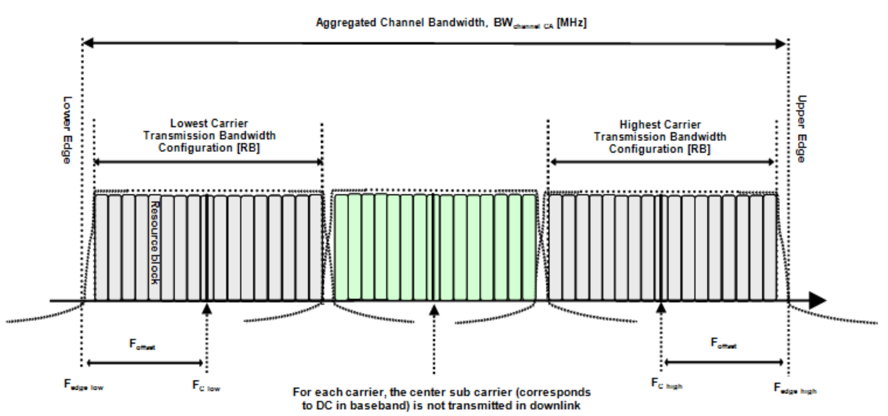
  Specifies DwPTS/GP/UpPTS length for LTE-Advanced TDD special subframe (TDD only).

RF Bandwidth

Each component carrier in LTE-Advanced system is back-compatible with the LTE standards, so the channel bandwidth and transmission bandwidth of each component carrier still apply to the LTE standards.

The following Figure illustrates the aggregated channel bandwidth for intra-band contiguous aggregation.

Figure 4-26 Definition of Aggregated Channel Bandwidth for intra-band carrier aggregation



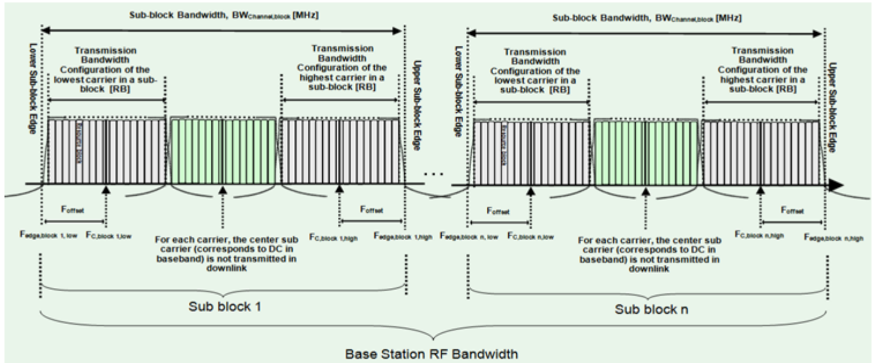
The lower edge of the Aggregated Channel Bandwidth (BWChannel_CA) is defined as Fedge_low = FC_low - Foffset. The upper edge of the aggregated channel bandwidth is defined as Fedge_high = FC_high + Foffset.

The Aggregated Channel Bandwidth, BWChannel_CA, is defined as follows:

BWChannel_CA = Fedge_high - Fedge_low [MHz]

The following Figure illustrates the sub-block bandwidth for intra-band non-contiguous aggregation.

Figure 4-27 Definition of Sub-blockBandwidth for intra-band non-contiguous spectrum



The lower sub-block edge of the Sub-block Bandwidth (BWChannel,block) is defined as Fedge,block,low = FC,block,low - Foffset. The upper sub-block edge of the Sub-block Bandwidth is defined as Fedge,block,high = FC,block,high + Foffset. The Sub-block Bandwidth, BWChannel,block, is defined as follows:

BWChannel,block = Fedge,block,high - Fedge,block,low [MHz]

The receiver and transmitter RF requirements shall apply from the frequency reference point with Foffset from the carrier center frequency of the lowest/highest carriers received/transmitted.

The Foffset is defined in 3GPP TS36.104 for BS below:

Channel Bandwidth of the Lowest or Highest Carrier: BWChannel[MHz]	Foffset[MHz]
5, 10, 15, 20	BWChannel/2
1.4, 3	FFS (For Further Study)

The Foffset is defined in 3GPP TS 36.101 for UE below:

Foffset = 0.18NRB /2 + BWGB [MHz]

where NRB is the transmission bandwidth configurations for the lowest and highest assigned component carrier respectively. BWGB denotes the Nominal Guard Band and is defined in following Table:

CA Bandwidth Class	Aggregated Transmission Bandwidth Configuration	Maximum number of CC	Nominal Guard Band BWGB
A	NRB,agg <=100	1	0.05BWChannel
B	NRB,agg <=100	2	FFS (For Further Study)

CA Bandwidth Class	Aggregated Transmission Bandwidth Configuration	Maximum number of CC	Nominal Guard Band BWGB
C	100 < NRB,agg <= 200	2	0.05max(BWChannel(1),BWChannel(2))
D	200 < NRB,agg <= [300]	FFS (For Further Study)	FFS (For Further Study)
E	[300] < NRB,agg <= [400]	FFS (For Further Study)	FFS (For Further Study)
F	[400] < NRB,agg <= [500]	FFS (For Further Study)	FFS (For Further Study)

NOTE: BWChannel(1) and BWChannel(2) are channel bandwidths of two E-UTRA component carriers. NRB,agg is the number of the aggregated RBs within the fully allocated Aggregated Channel bandwidth.

Channel Spacing

The channel spacing between carriers will depend on the deployment scenario, the size of the frequency block available and the channel bandwidths. The nominal channel spacing between two adjacent E-UTRA carriers is defined as following:

Nominal Channel spacing = (BWChannel(1) + BWChannel(2))/2

For intra-band contiguously aggregated carriers the channel spacing between adjacent component carriers shall be multiple of 300 kHz.

The nominal channel spacing between two adjacent aggregated E-UTRA carriers is defined as follows:

$$\text{Nominal channel spacing} = \left\lfloor \frac{BW_{Channel(1)} + BW_{Channel(2)} - 0.1\left|BW_{Channel(1)} - BW_{Channel(2)}\right|}{0.6} \right\rfloor 0.3$$

where BWChannel(1) and BWChannel(2) are the channel bandwidths of the two respective E-UTRA component carriers . The channel spacing for intra-band contiguous carrier aggregation can be adjusted to any multiple of 300 kHz less than the nominal channel spacing to optimize performance in a particular deployment scenario.

Channel Raster

The channel raster is 100 kHz for all bands, which means that the carrier center frequency must be an integer multiple of 100 kHz.

Component Carrier Power Measurement Bandwidth and Filter

The component carrier powers are measured with the predefined bandwidths and filter states. The measurement bandwidth of the component carrier measured can be set to the predefined value in its corresponding measurements, the predefined measurement bandwidths for BS and UE are given based on their channel bandwidths:

Table 4-11 BS Component Carrier power measurement bandwidth (MHz)

	LTE Bandwidth (MHz)					
	1.4	3	5	10	15	20
ACP Meas Noise BW	1.095	2.715	4.515	9.015	13.515	18.015
SEM Integ BW	1.095	2.715	4.515	9.015	13.515	18.015
CHP Integ BW	1.4	3	5	10	15	20

Table 4-12 UE Component Carrier power measurement bandwidth (MHz)

	LTE Bandwidth (MHz)					
	1.4	3	5	10	15	20
ACP Meas Noise BW	1.08	2.7	4.5	9	13.5	18
SEM Integ BW	1.08	2.7	4.5	9	13.5	18
CHP Integ BW	1.4	3	5	10	15	20

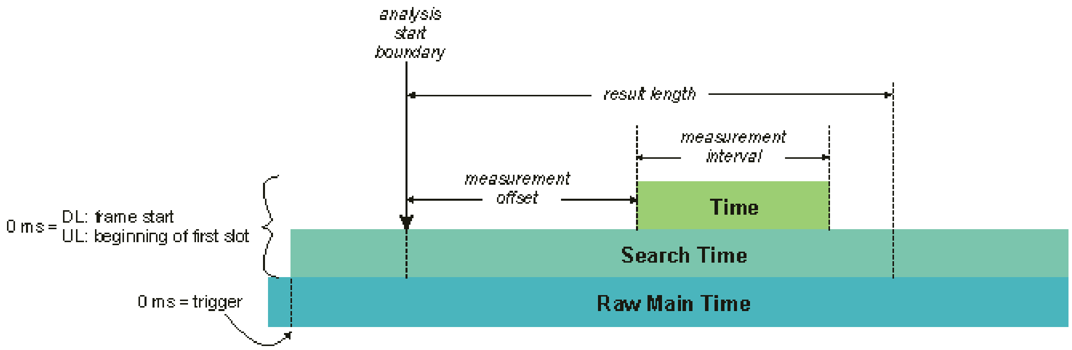
Capturing Signals for Measurement

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 4-28 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.

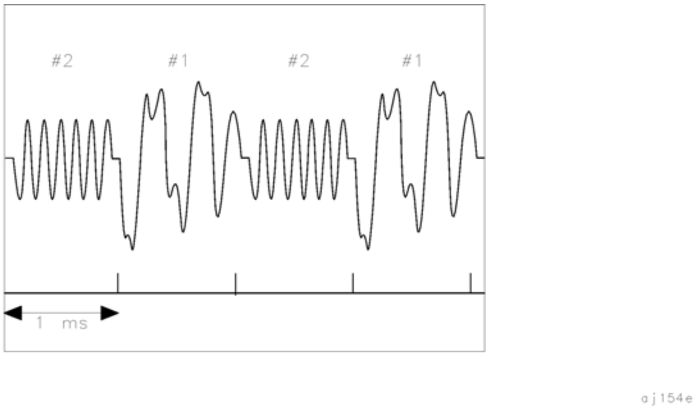
Time Gating Concepts

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 4-29 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.

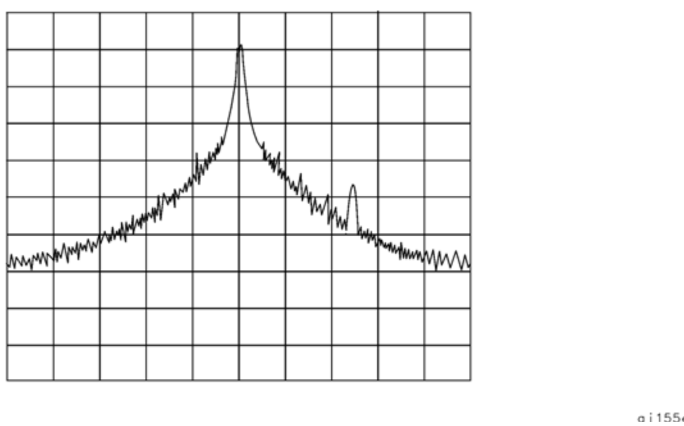
Figure 4-29 Simplified Digital Mobile-Radio Signal in Time Domain



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

A signal analyzer without time gating cannot do this. By the time the signal analyzer has completed its measurement sweep, which lasts about 50 ms, the radio transmissions switch back and forth 25 times. Because the radios are both transmitting at the same frequency, their frequency spectra overlap, as shown in Figure 4-30 The signal analyzer shows the combined spectrum; you cannot tell which part of the spectrum results from which signal.

Figure 4-30 Frequency Spectra of the Combined Radio Signals



Time gating allows you to see the separate spectrum of radio 1 or radio 2 to determine the source of the spurious signal, as shown in Figure 4-31

Figure 4-31 Time-Gated Spectrum of Radio 1

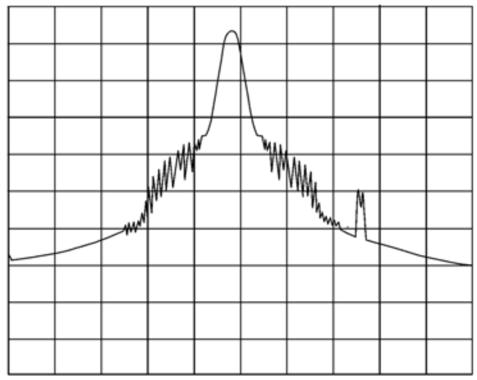
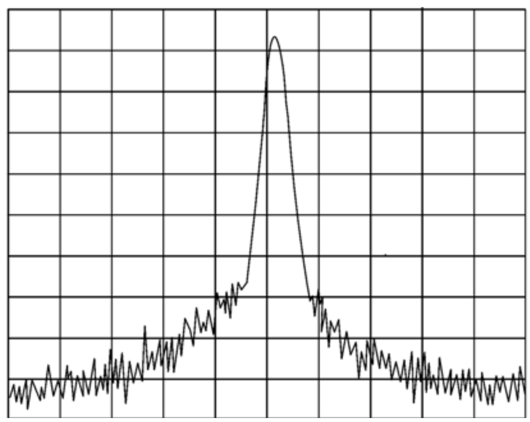


Figure 4-32 Time-Gated Spectrum of Radio 2



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 4-35 and Figure 4-34 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.

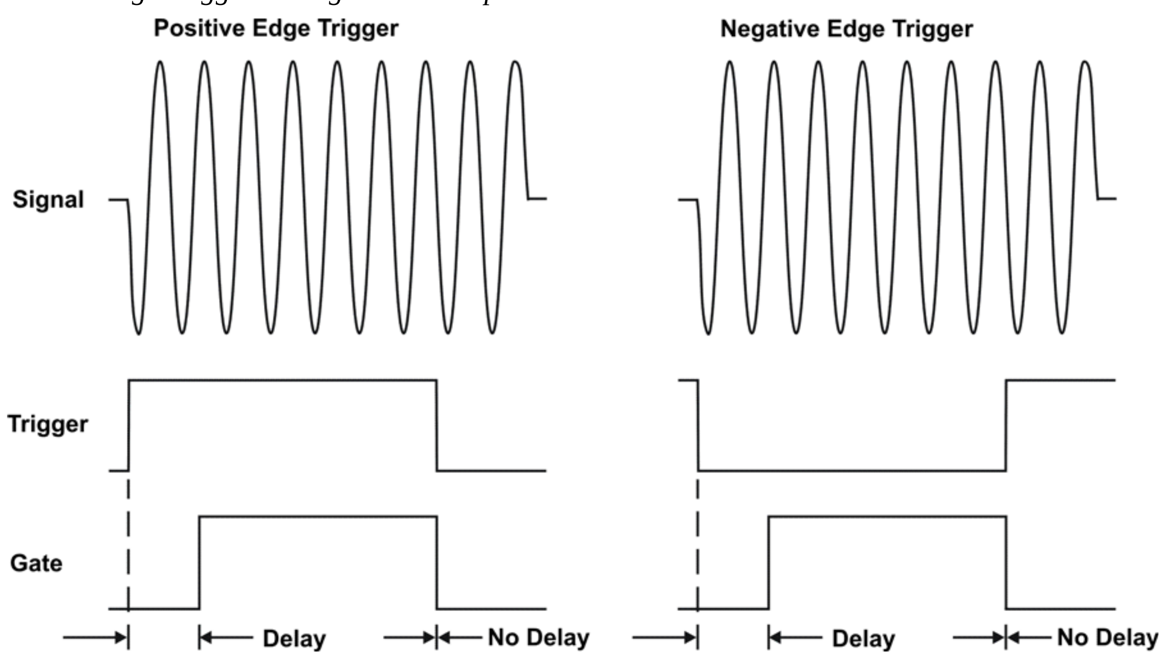
There are typically two main types of gating conditions, **edge** and **level**:

- 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 4-33).

- 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 4-33 Edge Trigger Timing Relationships



With Keysight signal analyzers, there are three different implementations for time gating: gated LO, gated video and gated FFT.

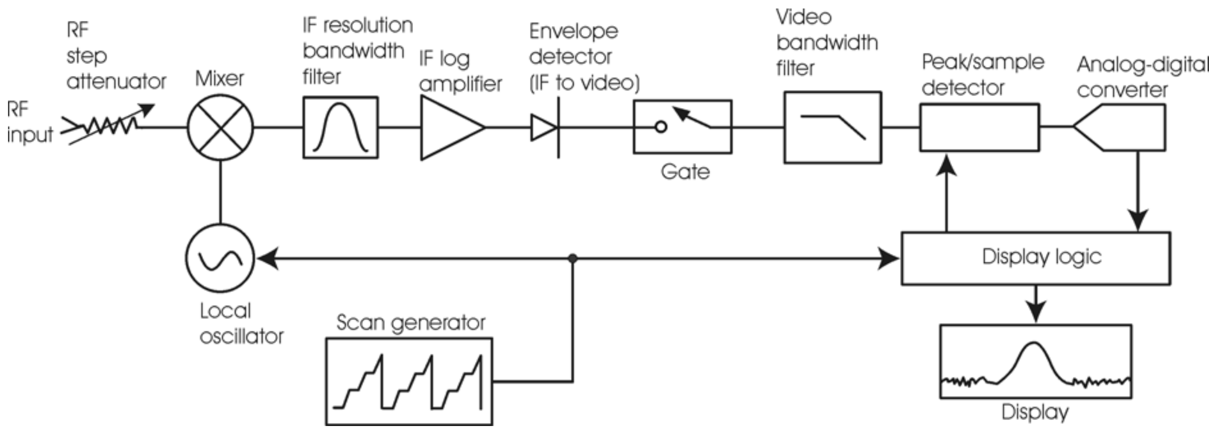
Gated Video Concepts

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 4-34 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.

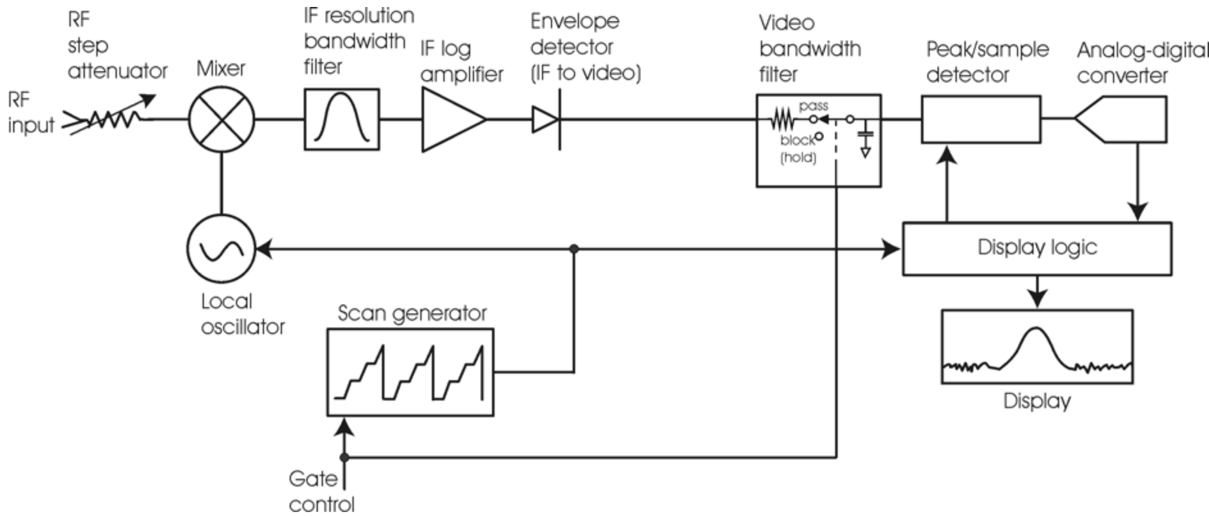
Figure 4-34 Gated Video Signal Analyzer Block Diagram



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 4-35 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 4-35 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.

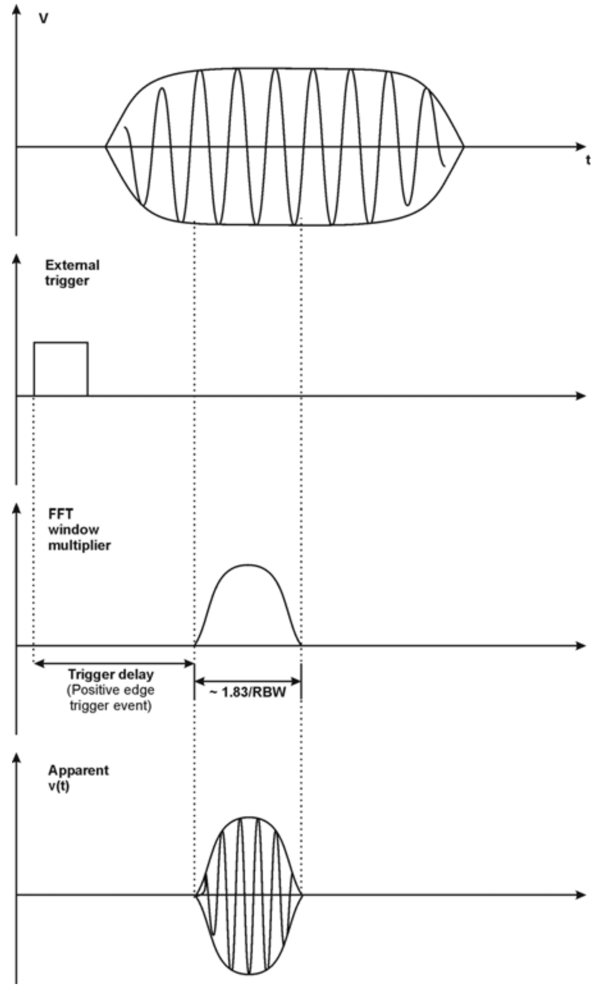
The process of making a spectrum measurement with FFTs is inherently a "gated" process, in that the spectrum is computed from a time record of short duration, much like a gate signal in swept-gated analysis.

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

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

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 4-36 Gated FFT Timing Diagram



Time Gating Basics (Gated LO and Gated Video)

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

- Trigger condition - Usually an external transistor-transistor logic (TTL) periodic signal for edge triggering and a high/low TTL signal for level triggering.
- Gate delay - The time after the trigger condition is met when the gate begins to pass a signal.
- Gate length - The gate length setting determines the length of time a gate begins to pass a signal.

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

- The composite of the two pulsed-RF signals.
- The gate trigger signal (a periodic TTL level signal).

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

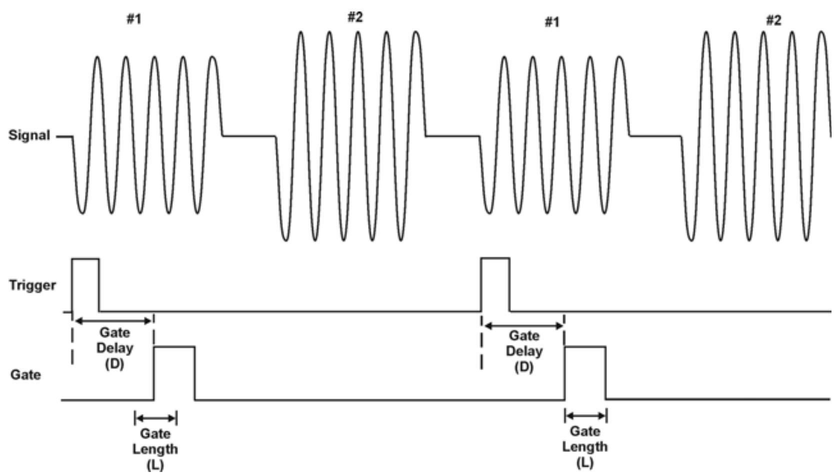
The timing interactions between the three signals are best understood if you observe them in the time domain (see Figure 4-37).

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 4-37, 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 4-37 Timing Relationship of Signals During Gating



Once the signal analyzer is set up to perform the gate measurement, the spectrum of signal 1 is visible and the spectrum of signal 2 is excluded, as shown if Figure 4-39 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 4-38 Signal within pulse #1 (time-domain view)

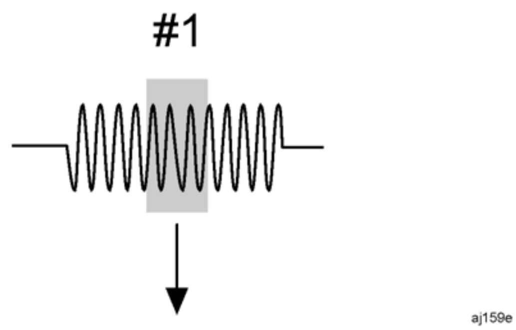
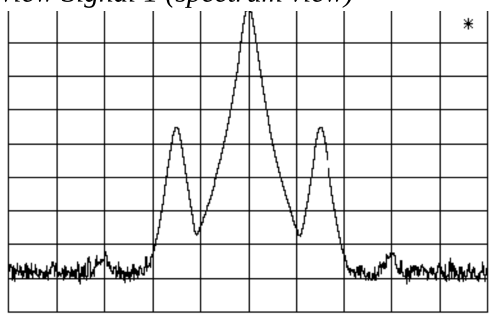


Figure 4-39 Using Time Gating to View Signal 1 (spectrum view)



Moving the gate so that it is positioned over the middle of signal 2 produces a result as shown in Figure 4-41 Here, you see only the spectrum within the pulses of signal 2; signal 1 is excluded.

Figure 4-40 Signal within pulse #2 (time-domain view)

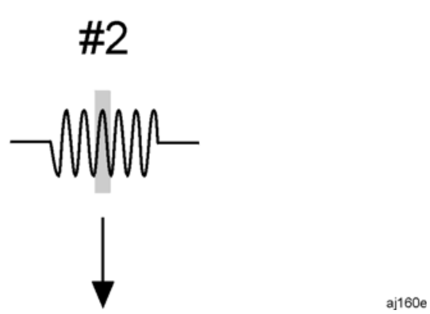
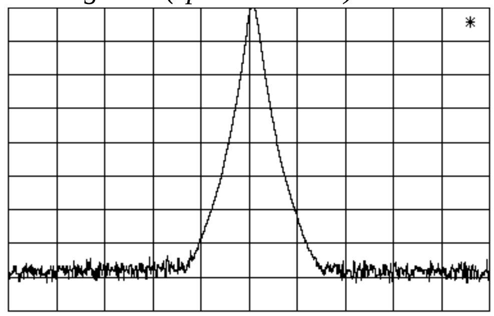


Figure 4-41 Using Time Gating to View Signal 2 (spectrum view)



Measuring a Complex/Unknown Signal

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

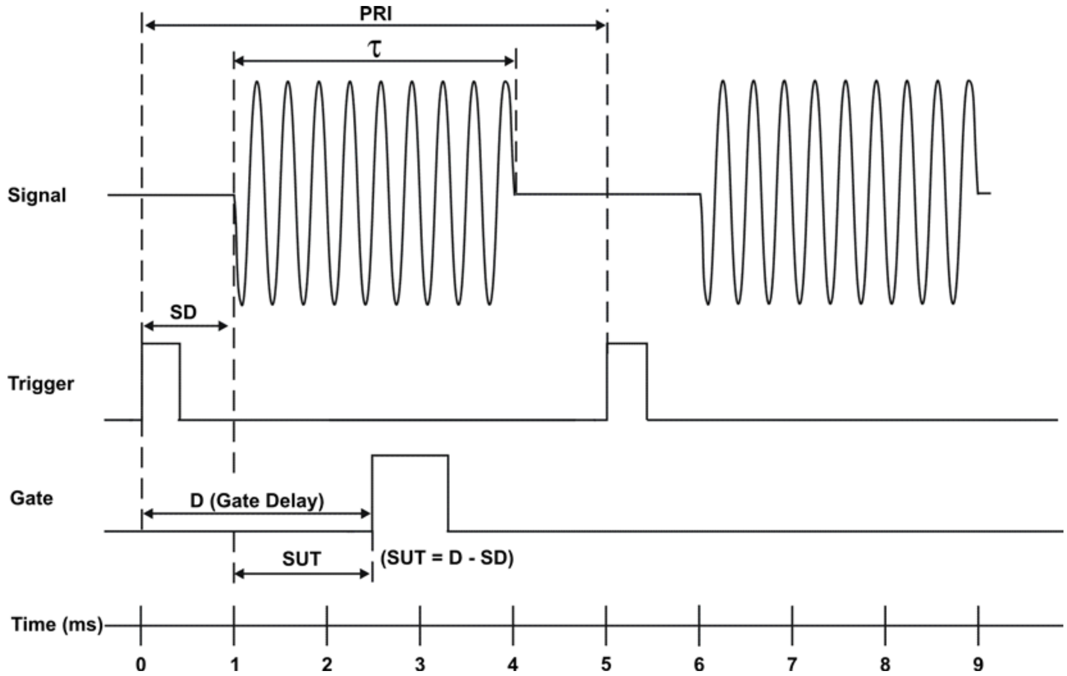
This example shows you how to use time gating to measure a very specific signal. Most signals requiring time gating are fairly complex and in some cases extra steps may be required to perform a measurement.

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

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

- Trigger type (edge or level triggering)
- Pulse repetition interval (PRI), which is the length of time between trigger events (the trigger period).
- Pulse width, or τ
- Signal delay (SD), which is the length of time occurring between the trigger event and when the signal is present and stable. If your trigger occurs at the same time as the signal, signal delay will be zero.

Figure 4-42 *Time-domain Parameters*



In Figure 4-42, the parameters are:

- Pulse repetition interval (PRI) is 5 ms.
- Pulse width (τ) is 3 ms.
- Signal delay (SD) is 1 ms for positive edge trigger (0.6 ms for negative edge trigger).
- Gate delay (D) is 2.5 ms.
- Setup time (SUT) is 1.5 ms.

Step 2. Set the signal analyzer sweep time:

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

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

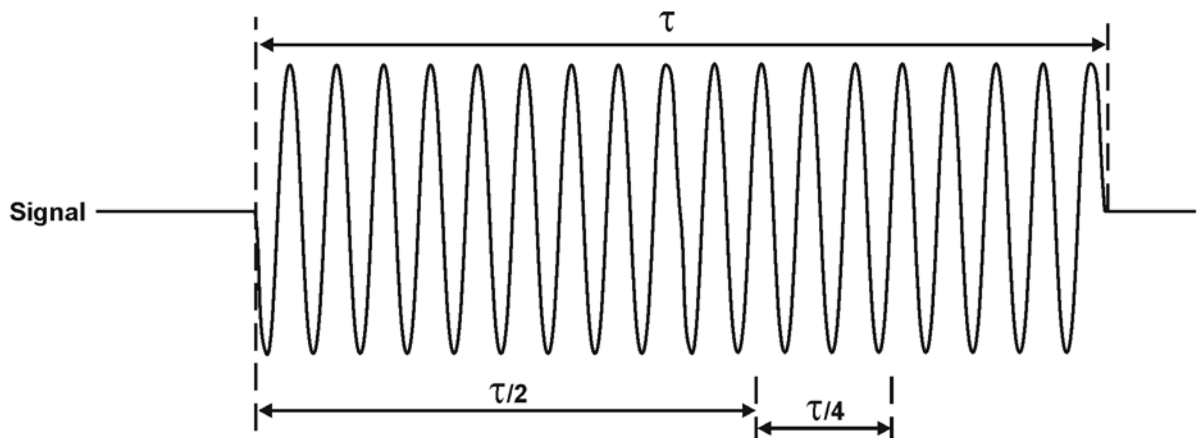
Step 3. Locate the signal under test on the display of the signal analyzer. Set the center frequency and span to view the signal characteristics that you are interested in measuring. Although the analyzer is not yet configured for correct gated measurements, you will want to determine the approximate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

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

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

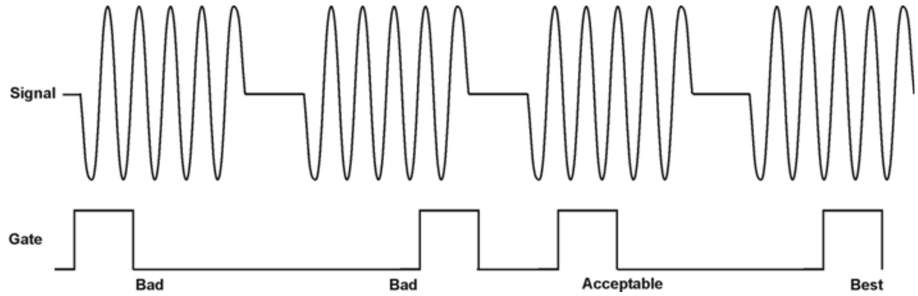
Generally, the gate should be positioned over a part of the signal that is stable, not over a pulse edge or other transition that might disturb the spectrum. Starting the gate at the center of the pulse gives a setup time of about half the pulse width. Setup time describes the length of time during which that signal is present and stable before the gate comes on. The setup time (SUT) must be long enough for the RBW filters to settle following the burst-on transients. Signal delay (SD) is the length of time after the trigger, but before the signal of interest occurs and becomes stable. If the trigger occurs simultaneously with the signal of interest, SD is equal to zero, and SUT is equal to the gate delay. Otherwise, SUT is equal to the gate delay minus SD. See Figure 4-43

Figure 4-43 *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 4-44 *Best Position for Gate*



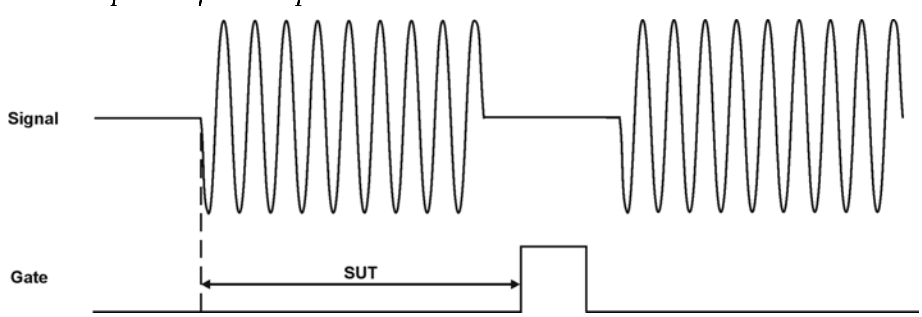
As a general rule, you will obtain the best measurement results if you position the gate relatively late within the signal of interest, but without extending the gate over the trailing pulse edge or signal transition. Doing so maximizes setup time and provides the resolution bandwidth filters of the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

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

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

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

Figure 4-45 *Setup Time for Interpulse Measurement*

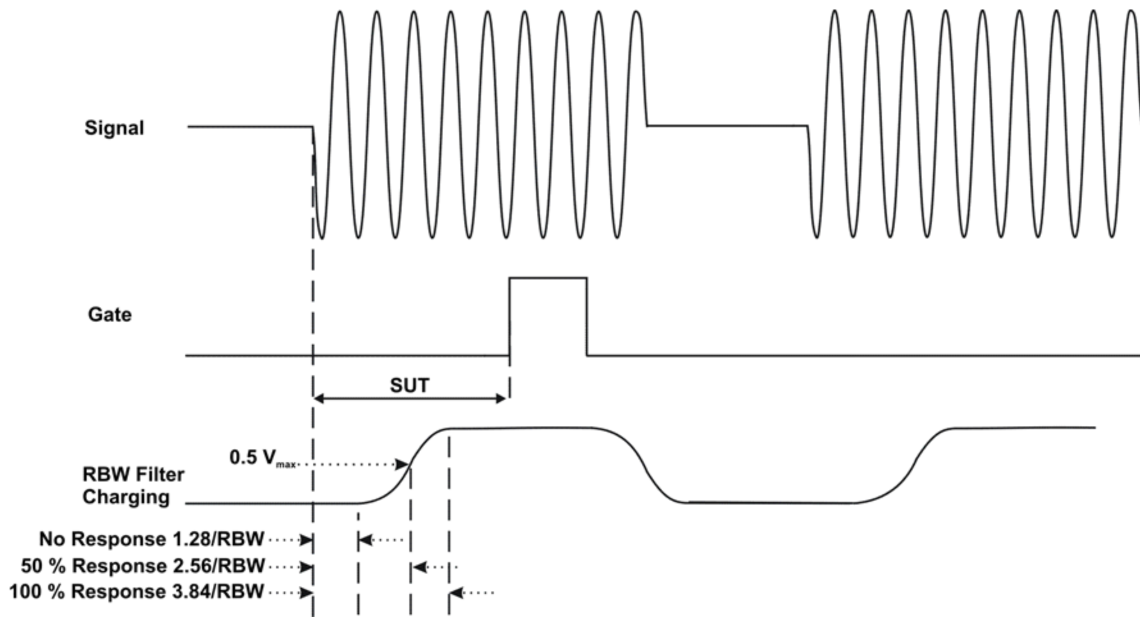


Step 5. The resolution bandwidth will need to be adjusted for gated LO and gated video. The video bandwidth will only need to be adjusted for gated video.

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 4-46 *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 > 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.

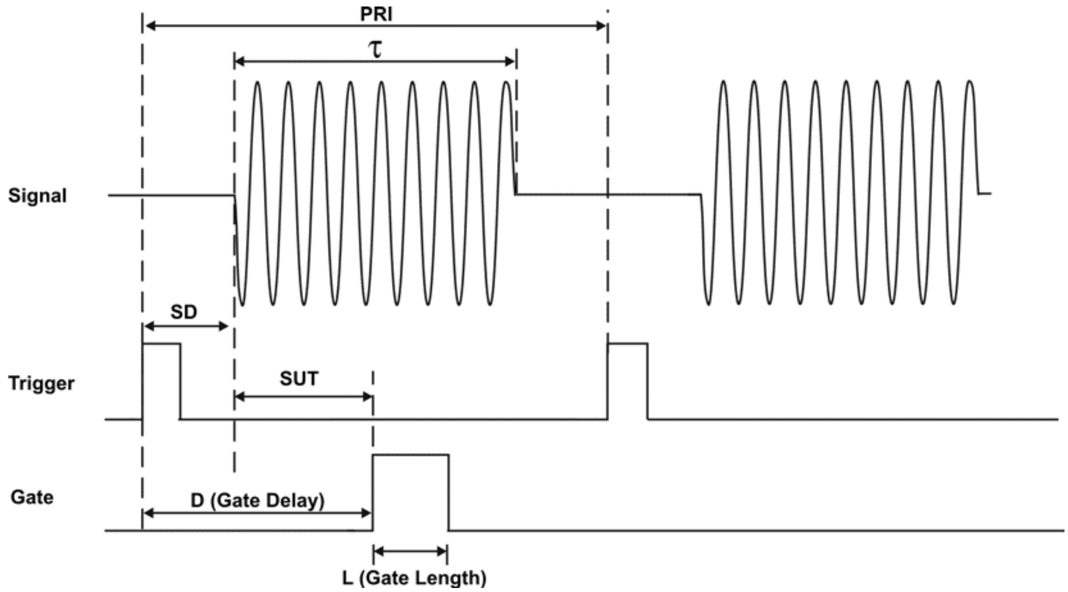
"Quick Rules" for Making Time-Gated Measurements

This section summarizes the rules described in the previous sections.

Table 4-13 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 + τ/5	The gate delay must be set so that the gating captures the pulse. If the gate delay is too short or too long, the gating can miss the pulse or include resolution bandwidth transient responses.
Gate Length	The gate length minimum is equal to one-fourth the pulse width (maximum about one-half): Gate Length = 0.7 x τ/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/τ	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 4-47 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 4-14 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 4-14 Suggested Initial Settings for Known Pulse Width (τ) and Zero Signal Delay

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

Table 4-14 Suggested Initial Settings for Known Pulse Width (τ) and Zero Signal Delay

Pulse width (τ)	**Gate Delay (SD + τ/5)**	**Resolution Bandwidth (>19.5/τ)**	**Gate Length (0.7 x τ/4)**
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 4-15 *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

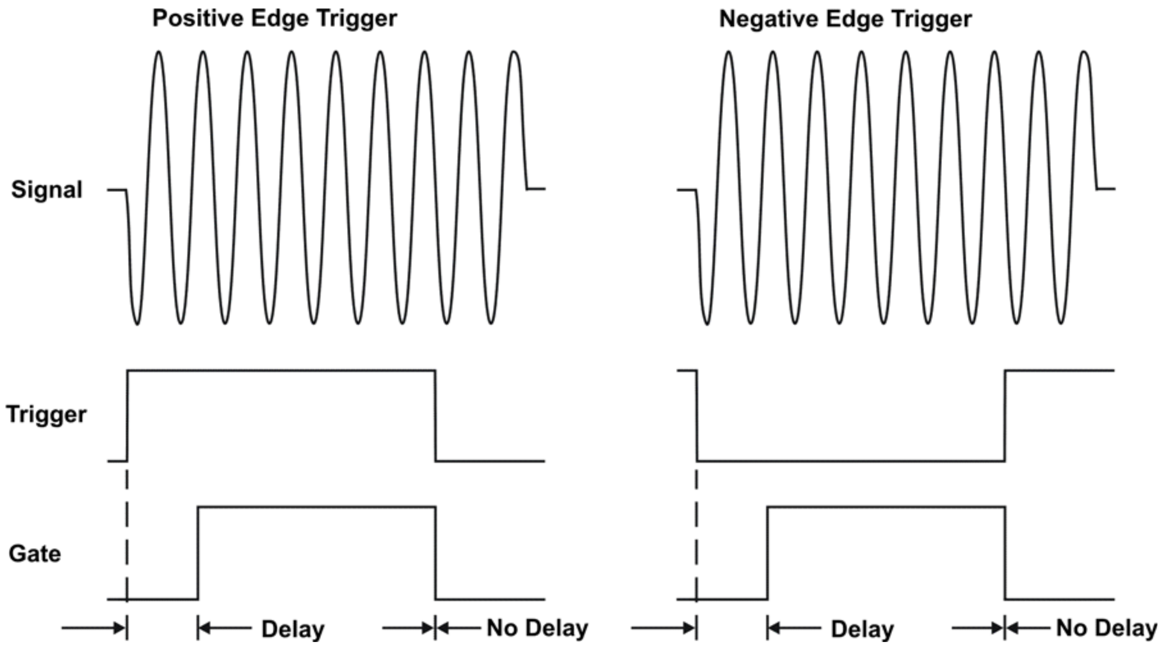
Depending on the trigger signal that you are working with, you can trigger the gate in one of two separate modes: edge or level. This gate-trigger function is separate from the normal external trigger capability of the signal analyzer, which initiates a sweep of a measurement trace based on an external 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 4-48 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 4-48 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 Keysight Technologies Application Note 1303, Spectrum Analyzer Measurements and Noise, in the section on Peak-detected Noise and TDMA ACP Measurements.

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

Measuring the Frequency Spectrum

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

Measuring the Wideband Spectrum

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

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

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

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

Measuring the Narrowband Spectrum

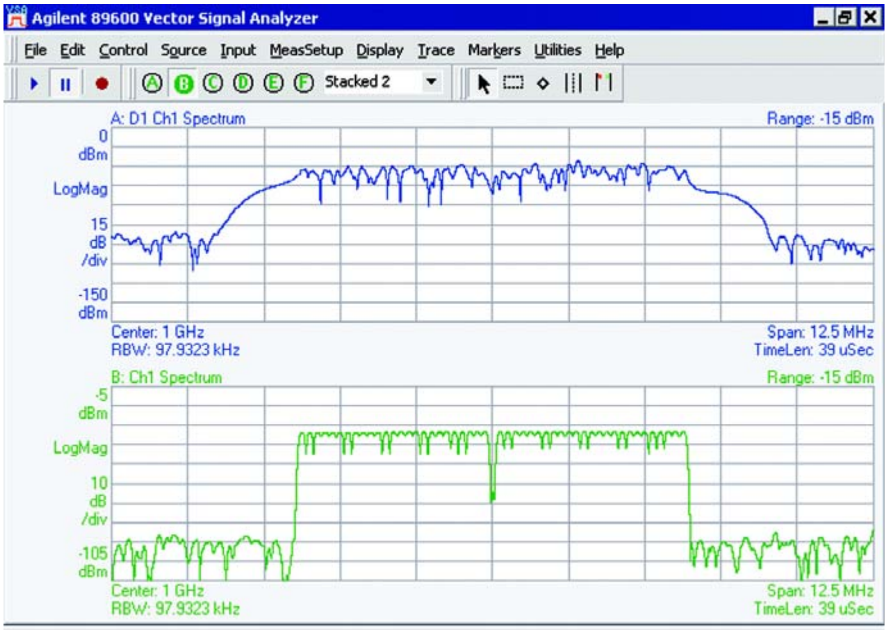
For narrowband spectrum analysis of the LTE signal, the instrument's frequency span should be set to approximately 1.1 times the nominal bandwidth of the signal. Alternately the span can be configured to match the bandwidth of a typical LTE front-end filter. Using a frequency span close to a typical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

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

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

Time-variant signals such as LTE signals often require spectral analysis over a smaller portion of the entire waveform, for example, during a subframe. In this case, the measurement needs to be stabilized using the trigger control in the analyzer. Triggering the analyzer can easily be accomplished and the details will be provided in the next section. The importance of triggering for a time-variant waveform can be seen in Figure 4-49 on page 177, 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 4-49 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 Keysight 89600).



LTE & LTE-A Measurement Concepts

The following sections describe the purpose, measurement method for the LTE & LTE-A measurements.

- "Channel Power Measurement Concepts" on page 179
- "Occupied Bandwidth Measurement Concepts" on page 180
- "Adjacent Channel Power (ACP) Measurement Concepts" on page 181
- "Power Statistics CCDF Measurement Concepts" on page 183
- "Spurious Emissions Measurement Concepts" on page 185
- "Spectrum Emission Mask Measurement Concepts" on page 186
- "Transmit On/Off Measurement Concepts" on page 187
- "LTE & LTE-A Modulation Analysis Measurement Concepts" on page 188
- "IQ Waveform Measurement Concepts" on page 189
- "Monitor Spectrum (Frequency Domain) Measurement Concepts" on page 190
- "LTE & LTE-A Conformance EVM Measurement Concepts" on page 191

Channel Power Measurement Concepts

Purpose

The Channel Power measurement is a common test used in the wireless industry to measure the total transmitted power of a radio within a defined frequency channel. This procedure measures the total power within the defined channel for LTE. This measurement is applied to design, characterize, evaluate, and verify transmitters and their components or devices for LTE uplink and downlink signals.

Measurement Method

The Channel Power measurement reports the total transmitted power and the calculated power spectral density within the integration bandwidth. It takes a sweep and the measurement acquires power in the channel.

The power calculation method used to determine the channel power is a traditional method known as the integration bandwidth (IBW) method. The measurement uses the frequency sweep mode, the RBW filter is set narrow relative to the desired integration bandwidth. You can change the RBW and VBW setings.It is important to correctly set the RBW before making this measurement, because if the RBW filter setting is too narrow the signal will be under-sampled and not all of the signal power will be measured. If the setting is too wide, it will reduce the accuracy of the Channel Power measurement.

Span keys are not supported in LTE-Advanced FDD/TDD channel power because the span is calculated automatically from integration bandwidths pre-defined for all formats. In FREQ Channel, Component Carrier Setup, Configure Component Carriers, Bandwidth, the CHP Integ BW parameter is added and the LTE-Advanced FDD/TDD CHP measurement uses these values to calculate carrier powers. Preset values of these bandwidth parameters, see “Component Carrier Power Measurement Bandwidth and Filter” on page 152.

To improve repeatability, you can increase the number of averages. The channel power graph is shown in the graph window, while the absolute channel power in dBm and the mean power spectral density in dBm/Hz are shown in the text window.

Because the signal under test is bursted, CHP measurements must be made in synchronized fashion with the burst timing in order to get a useful sample in the time domain during the “on” portion of the signal. This is accomplished using Time Gating (Gate ON). The sweep timing is synchronized with the signal when time gating is on. However, if the sweep time is too short, due to the synchronization, each measurement in the frequency domain can capture only the corresponding portion of the signal in time domain. In this case, an increase of the Avg Number will have no effect on the measurement deviation from one trace update to the next. To reduce this variation, the sweep time must be increased.

Occupied Bandwidth Measurement Concepts

Purpose

Occupied bandwidth measurements express the percentage of the transmitted power within a specified bandwidth. This percentage is typically 99%.

The spectrum shape of a LTE signal can give useful qualitative insight into transmitter operation. Any distortion to the spectrum shape can indicate problems in transmitter performance.

Measurement Method

The instrument uses sweep mode to capture the data and the total power within the measurement frequency span is integrated for its 100% of power. The frequencies of 0.5% of the total power are then calculated to get 99.0% bandwidth.

The LTE-Advanced FDD/TDD supports the auto span mode whatever the transmission type is single carrier or multi-carrier. The active carrier(s) are detected for the span calculation.

Because the signal under test is bursted, the measurement must be made in synchronized fashion with the burst timing in order to get a useful sample in the time domain during the “on” portion of the signal. This is accomplished using Time Gating (Gate ON).

Adjacent Channel Power (ACP) Measurement Concepts

Purpose

Adjacent Channel Power (ACP), is the power contained in a specified frequency channel bandwidth relative to the total carrier power. It may also be expressed as a ratio of power spectral densities between the carrier and the specified offset frequency band.

As a composite measurement of out-of-channel emissions, ACP combines both in-band and out-of-band specifications to provide useful figures-of-merit for spectral regrowth and emissions produced by components and circuit blocks without the rigor of performing a full spectrum emissions mask measurement.

To maintain a quality call by avoiding channel interference, it is important to measure and reduce any adjacent channel leakage power transmitted from a mobile phone. The characteristics of adjacent channel leakage power are mainly determined by the transmitter design, particularly the low-pass filter.

Measurement Method

This ACP measurement analyzes the total power levels within the defined carrier bandwidth and at given frequency offsets on both sides of the carrier frequency. This measurement requires the user to specify measurement bandwidths of the carrier channel and each of the offset frequency pairs. Each pair may be defined with unique measurement bandwidths.

For Meas Method of RBW, it uses an appropriate RBW and capture all of the power in the carrier channel and the offsets. For Meas Method of integration bandwidth (IBW), the channel integration bandwidth is analyzed using the user defined resolution bandwidth (RBW), which is much narrower than the channel bandwidth. The measurement computes an average power of the channel over a specified number of data acquisitions, automatically compensating for resolution bandwidth and noise bandwidth.

If **Total Pwr Ref** is selected as the measurement type, the results are displayed as relative power in dBc and as absolute power in dBm. If **PSD Ref** (Power Spectral Density Reference) is selected, the results are displayed as relative power in dB, and as absolute power in dBm/Hz.

Because the signal under test is bursted, the measurement must be made in synchronized fashion with the burst timing in order to get a useful sample in the time domain during the “on” portion of the signal. This is accomplished using Time Gating (Gate ON).

In FREQ Channel, Component Carrier Setup, Configure Component Carriers, Bandwidth, the ACP Measurement Noise BW parameter is added and the LTE-Advanced FDD/TDD ACP measurement uses these values to calculate carrier powers. Preset values of these Measurement Noise BW, see “Component Carrier Power Measurement Bandwidth and Filter” on page 152.

Intermodulation test is supported in this measurement. Offsets whose entire or part of frequency range is covered by the intermodulation interference frequency range specified by the parameters under the Mode Setup, Intermod menu are excluded from the limit test when interference power present is on.

Power Statistics CCDF Measurement Concepts

Purpose

Many of the digitally modulated signals appear noise-like in the time and frequency domain. This means that statistical measurements of the signals can be a useful characterization. Power Complementary Cumulative Distribution Function (CCDF) curves characterize the higher-level power statistics of a digitally-modulated signal. The curves can be useful in determining design parameters for digital communications systems.

The power statistics CCDF measurement can be affected by many factors. For example, modulation filtering, modulation format, combining the multiple signals at different frequencies, number of active codes and correlation between symbols on different codes with spread spectrum systems. These factors are all related to modulation and signal parameters. External factors such as signal compression and expansion by non-linear components, group delay distortion from filtering, and power control within the observation interval also affect the measurement.

CCDF curves can help you in several situations:

- To determine the headroom required when designing a component.
- To confirm the power statistics of a given signal or stimulus. CCDF curves allow you to verify if the stimulus signal provided by another design team is adequate. For example, RF designers can use CCDF curves to verify that the signal provided by the digital signal processing (DSP) section is realistic.
- To confirm that a component design is adequate or to troubleshoot your subsystem or system design, you can make CCDF measurements at several points of a system. For example, if the ACLR of a transmitter is too high, you can make CCDF measurements at the input and output of the PA. If the PA design is correct, the curves will coincide. If the PA compresses the signal, the PAR of the signal is lower at the output of the PA.

Measurement Method

The power measured in power statistics CCDF curves is actually instantaneous envelope power defined by the equation:

$$P = (I^2 + Q^2)/Z_0$$

(where I and Q are the quadrature voltage components of the waveform and Zo is the characteristic impedance).

A CCDF curve is defined by how much time the waveform spends at or above a given power level. The percent of time the signal spends at or above the level defines the probability for that particular power level. To make the power statistics CCDF measurement, the instrument uses digital signal processing (DSP) to sample the input signal in the channel bandwidth.

The Gaussian distribution line as the band-limited gaussian noise CCDF reference line, the user-definable reference trace, and the currently measured trace can be displayed on a semi-log graph. If the currently measured trace is above the user reference trace, it means that the higher peak power levels against the average power are included in the input signal.

Spurious Emissions Measurement Concepts

Purpose

Spurious signals can be caused by different combinations of signals in the transmitter. The spurious emissions from the transmitter should be minimized to guarantee minimum interference with other frequency channels in the system. Harmonics are distortion products caused by nonlinear behavior in the transmitter. They are integer multiples of the transmitted signal carrier frequency.

This measurement verifies the frequency ranges of interest are free of interference by measuring the spurious signals specified by the user defined range table.

Measurement Method

The table-driven measurement has the flexibility to set up custom parameters such as frequency, span, resolution bandwidth, and video bandwidth.

For each range that you specify and activate, the analyzer scans the band using the specified Range Table settings. Then using the Peak Excursion and Peak Threshold values determines which spurs to report.

As each band is swept, any signal which is above the Peak Threshold value and has a peak excursion of greater than the Peak Excursion value will be added to a list of spurs displayed in the lower results window. A total of 200 spurs can be recorded for one measurement, with a limit of 10 spurs per frequency range. To improve repeatability, you can increase the number of averages.

From the spurs in the list, those with peak amplitude greater than the Absolute Limit for that range will be logged as a measurement failure and denoted by an 'F' in the 'Amplitude' column of the table. If no spurs are reported, but the measured trace exceeds the limit line for any range, the fail flag is set to fail.

This measurement has the ability to display two traces using different detectors on the display simultaneously. All spur detection and limit line testing are only applied to the trace associated with Detector 1, which will be colored yellow. The trace associated with Detector 2 will be colored cyan.

If the sweep time for the range exceeds 2 seconds, a flashing message “Sweeping...Please Wait” will appear in the annunciator area. This advises you that the time to complete the sweep is between 2 and 2000 seconds, and is used as without it the display would appear stagnant and you may think the measurement is not functional.

The intermodulation test is supported in this measurement. The intermodulation interference frequency range specified by the parameters under the Mode Setup, Intermod menu is excluded from the measurement when interference power present is on.

Spectrum Emission Mask Measurement Concepts

Purpose

Spectrum Emission Mask measurements include the in-band and out-of-band spurious emissions. It is the power contained in a specified frequency bandwidth at certain offsets relative to the total carrier power. It may also be expressed as a ratio of power spectral densities between the carrier and the specified offset frequency band.

As a composite measurement of out-of-channel emissions, the spectrum emission mask measurement combines both in-band and out-of-band specifications to provide useful figures-of-merit for spectral regrowth and emissions produced by components and circuit blocks without the rigor of performing a full spectrum emissions mask measurement.

Measurement Method

The spectrum emission mask measurement measures spurious signal levels in up to 6 pairs of offset/region frequencies and relates them to the carrier power. The reference channel integration bandwidth method is used to measure the carrier channel power and offset/region powers. When “Offset” is selected, spectrum emission mask measurements are made, relative to the carrier channel frequency bandwidth. When “Region” is selected, spurious emission absolute measurements are made, set by specifying start and stop RF frequencies.

The channel integration bandwidth is analyzed using the user defined resolution bandwidth (RBW), which is much narrower than the channel bandwidth. The measurement computes an average power of the channel or offset/region over a specified number of data acquisitions, automatically compensating for resolution bandwidth and noise bandwidth.

This measurement requires the user to specify measurement bandwidths of the carrier channel and each of the offset/region frequency up to 12 (A - L). Each offset may be defined with unique measurement bandwidths. The results are displayed both as relative power in dBc, and as absolute power in dBm.

Under FREQ Channel, Component Carrier Setup, Configure Component Carriers, Bandwidth, the SEM Integ BW parameter is added and the LTE-Advanced FDD/TDD SEM measurement uses these values to calculate carrier powers. Preset values of these Measurement Integ BW, see “Component Carrier Power Measurement Bandwidth and Filter” on page 152.

Transmit On/Off Measurement Concepts

Purpose

The Transmit On/Off measurement measures the mean transmit power and examines the time domain burst shape to determine the power rise and fall fits within the defined mask. The limit mask is configurable.

Measurement Method

There are two key results: transmitter off power and transmitter transient period.

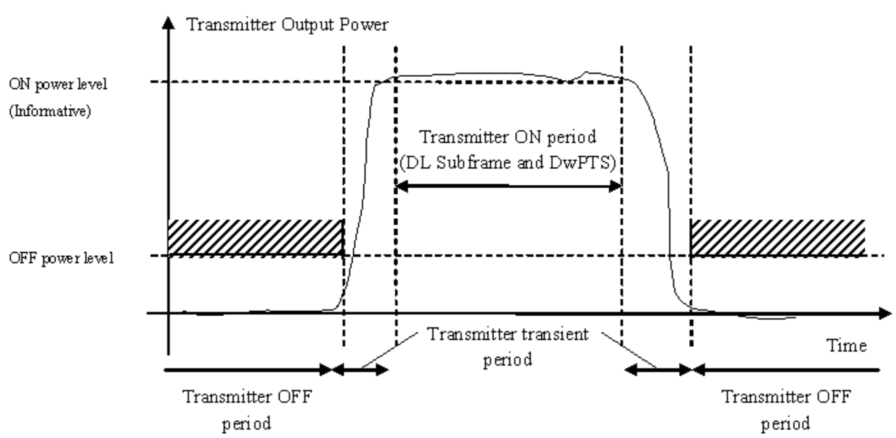
- Transmitter Off Power

  Transmitter OFF power is defined as the mean power measured over [70 us] filtered with a square filter of bandwidth equal to the transmission bandwidth configuration of the BS (BWConfig) centred on the assigned channel frequency during the transmitter OFF period. The transmitter OFF power spectral density shall be less than -85 dBm/MHz.

- Transmitter Transient Period

  Transmitter transient period is the time period during which the transmitter is changing from the OFF period to the ON period or vice versa. The transmitter transient period is illustrated in figure below. The transmitter transient period should be shorter than 17 us.

Figure 4-50 LTE TDD Transmitter Transient Period



For averaged measurements, the user may specify the number of sweeps over which to average the result. This means that for an average number of 10, the power results are obtained from each trace, converted to linear (voltage squared), and then averaged with the previous average result before being displayed. The running average count and (the log of) the true averaged linear power will be displayed after each measurement sweep.

LTE & LTE-A Modulation Analysis Measurement Concepts

Purpose

The Modulation Analysis measurement provides LTE & LTE-A modulation analysis capabilities, it can demodulate both uplink and downlink signals, which may consist of up to 5 aggregated component carriers. Once required parameters are specified, the demodulator will automatically lock onto the signal. The measurement is based on the acquisition of IQ Pairs.

Measurement Method

The functionality in LTE & LTE-A measurement is fully compatible with LTE Modulation Analysis measurement for each CC. It also has auto range function which LTE Modulation Analysis measurement does not have.

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 and uplink signals that makes measurement of all parameters automatically.

IQ Waveform Measurement Concepts

Purpose

The waveform measurement is a generic measurement for viewing the input signal waveforms in the time domain. This measurement is how the instrument performs the zero span functionality found in traditional spectrum analyzers.

Basic mode waveform measurement data may be displayed using either a Signal Envelope window, or 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 making a waveform measurement is that it allows you to view complex components of the same signal without changing settings or measurements.

The waveform measurement can be used to perform general purpose power measurements in the time domain with excellent accuracy.

Measurement Method

The instrument makes repeated power measurements at a set frequency, similar to the way a swept-tuned spectrum analyzer makes zero span measurements. The input analog signal is converted to a digital signal, which then is processed into a representation of a waveform measurement. The measurement relies on a high rate of sampling to create an accurate representation of a time domain 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.

Measurement Method

The analyzer sweeps the LO to generate a heterodyned IF signal which can be detected for the purpose of analyzing the signal content of a range of frequencies. The x-axis of the display is frequency, the Y Axis is amplitude.

LTE & LTE-A Conformance EVM Measurement Concepts

Purpose

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

Measurement Method

All available measurement parameters are accessible through RUI (SCPI). CEVM doesn't have softkeys for setting parameters except for some common keys. Basically it has three views: Measurement List view, Parameter List view and Result Metrics view. These views are in tabular form.

Differences from LTE & LTE-A Modulation Analysis Measurement

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

For example,

EVM [:SENSe]:EVM:CCAR0:PROFile:AUTO:DETect ON|OFF

CEVM [:SENSe]:CEVM:CCAR0:PROFile:AUTO:DETect ON|OFF

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

- The results displayed on Error Summary in the EVM measurement are also available in CEVM. On the other hand, the other results such as Frame Summary, symbols, and various traces are not available in CEVM.
- For Trigger Setting, CEVM also applies xSA-based SCPI commands.
- The parameter “Update” concept in EVM doesn’t exist in CEVM. Any users and allocation changes take effect immediately. Same applies to “Ignore” commands.
- For IF BW setting, EVM uses the command “[:SENSe]:FREQuency:SPAN,” and CEVM uses “[:SENSe]:CEVM:IFBW”. Since IF BW is automatically set whenever the Demod Bandwidth is changed, the user doesn’t have to change it.
- Some SCPI commands in EVM are not available in CEVM, see “SCPI Commands available in EVM are not supported in CEVM” on page 191. Some SCPI commands are newly added in CEVM, see “SCPI Commands only available in CEVM” on page 196.

SCPI Commands available in EVM are not supported in CEVM

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

- [:SENSe]:EVM:CCAR{0:4}:AVERage:FAST
- [:SENSe]:EVM:CCAR{0:4}:AVERage:FAST:URATe
- [:SENSe]:EVM:CCAR{0:4}:AVERage:FAST:URATe:AUTO
- [:SENSe]:EVM:CCAR{0:4}:AVERage:TCONtrol
- [:SENSe]:EVM:CCAR{0:4}:AVERage:TYPE

Copy Auto Detection to Manual function is not implemented in CEVM.

- [:SENSe]:EVM:CCAR{0:4}:PROFile:COPY[:IMMediate]

Decoding capabilities are not implemented in CEVM.

- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:PBCH
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:PCFich
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:PDCCh
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:PDSCh
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUSCh
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUCCh
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:DFINclude
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:RNTI:MINimum:RA
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:RNTI:MAXimum:RA
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:RNTI:MINimum:TPC
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:RNTI:MAXimum:TPC
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:DFTWo:PRONe
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:DFTWo:PRTWo
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:DFTWo:PRTHree
- [:SENSe]:EVM:CCAR{0:4}:DLINk:DECode:DFTWo:PRFour
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUSCh:HARQ:ISIZe
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUSCh:HARQ:OFFSet
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUSCh:RI:ISIZe
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUSCh:RI:OFFSet
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUSCh:CQI:ISIZe
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUSCh:CQI:OFFSet
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUCCh:HARQ:ISIZe
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUCCh:CQI:ISIZe
- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:PUCCh:CQI:ISIZe:AUTO

- [:SENSe]:EVM:CCAR{0:4}:ULINk:DECode:ANFMode
- [:SENSe]:EVM:CCAR{0:4}:REPort:DB
- [:SENSe]:EVM:CCAR{0:4}:REPort:POWer:RELative
- [:SENSe]:EVM:CCAR{0:4}:TIME:SCALe:FACTor
- [:SENSe]:EVM:CCAR{0:4}:ULINk:PROFile:AUTO:PUSCh:MODulation:TYPE
- [:SENSe]:EVM:CCAR{0:4}:DLINk:SYNC:CPLength:AUTO
- [:SENSe]:EVM:CCAR{0:4}:ULINk:SYNC:CPLength:AUTO
- [:SENSe]:EVM:CCAR{0:4}:DLINk:UERS:WEIGhts:RIFormat
- [:SENSe]:EVM:CCAR{0:4}:DLINk:UERS:WEIGhts:DISPlay

These display related commands are not available in CEVM.

- :DISPlay:EVM:CCAR{0:4}:AFPoints
- :DISPlay:EVM:CCAR{0:4}:ANNotation:TITLe:DATA
- :DISPlay:EVM:CCAR{0:4}:FANNotation
- :DISPlay:EVM:TRACe(1:4):COPY/nquery/
- :DISPlay:EVM:TRACe(1:4):DDEMod:ALINe
- :DISPlay:EVM:TRACe(1:4):DDEMod:EYE:COUNt
- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol
- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol:FORMat
- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol:SHAPe
- :DISPlay:EVM:TRACe(1:4):DDEMod:SYMBol:SIZE
- :DISPlay:EVM:TRACe(1:4):DDEMod:UNIT:FREQuency
- :DISPlay:EVM:TRACe(1:4):DDEMod:UNIT:TIME
- :DISPlay:EVM:TRACe(1:4):FEED
- :DISPlay:EVM:TRACe(1:4):FORMat
- :DISPlay:EVM:TRACe(1:4):FORMat:DELay:APERture
- :DISPlay:EVM:TRACe(1:4):FORMat:PHASe:OFFSet
- :DISPlay:EVM:TRACe(1:4):FORMat:PHASe:UNWRap:REFerence
- :DISPlay:EVM:TRACe(1:4):RLINe
- :DISPlay:EVM:TRACe(1:4):VHCenter
- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:COUPle
- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:RLEVel
- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:RPOSition

- :DISPlay:EVM:TRACe(1:4):X[:SCALe]:SPAN
- :DISPlay:EVM:TRACe(1:4):Y:LRATio
- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:AUTO:ONCE/nquery/
- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:PDIVision
- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:RLEVel
- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:RLEVel:AUTO
- :DISPlay:EVM:TRACe(1:4):Y[:SCALe]:RPOSition
- :DISPlay:EVM:TRACe(1:4):Y:UNIT?/qonly/
- :DISPlay:EVM:TRACe(1:4):Y:UNIT:PREFerence
- :DISPlay:EVM:VIEW:PRESet/nquery/
- :DISPlay:EVM:WINDow:FORMat

These DATA related commands are not available in CEVM.

- :CALCulate:EVM:DATA(1:4)?/qonly/
- :CALCulate:EVM:DATA(1:4):HEADer:NAMes?/qonly/
- :CALCulate:EVM:DATA(1:4):HEADer[:NUMBer]?/qonly/
- :CALCulate:EVM:DATA(1:4):HEADer:STRing?/qonly/
- :CALCulate:EVM:DATA(1:4):HEADer:TYPE?/qonly/
- :CALCulate:EVM:DATA(1:4):NAMes?/qonly/
- :CALCulate:EVM:DATA(1:4):POINts?/qonly/
- :CALCulate:EVM:DATA(1:4):RAW?/qonly/
- :CALCulate:EVM:DATA(1:4):RAW:COMPlex?/qonly/
- :CALCulate:EVM:DATA(1:4):RAW:POINts?/qonly/
- :CALCulate:EVM:DATA(1:4):TABLe:NAMes?/qonly/
- :CALCulate:EVM:DATA(1:4):TABLe[:NUMBer]?/qonly/
- :CALCulate:EVM:DATA(1:4):TABLe:STRing?/qonly/
- :CALCulate:EVM:DATA(1:4):TABLe:UNIT?/qonly/

These MARKer related commandsare not available in CEVM.

- :CALCulate:EVM:MARKer(1:12):AOFF/nquery/
- :CALCulate:EVM:MARKer(1:12):CFORmat
- :CALCulate:EVM:MARKer(1:12):COUPle[:STATe]
- :CALCulate:EVM:MARKer(1:12):CPSearch[:STATe]
- :CALCulate:EVM:MARKer(1:12):FCOunt[:STATe]

- :CALCulate:EVM:MARKer(1:12):FCOunt:X?/qonly/
- :CALCulate:EVM:MARKer(1:12):FUNCtion
- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:CENTer
- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:LEFT
- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:RIGHt
- :CALCulate:EVM:MARKer(1:12):FUNCtion:BAND:SPAN
- :CALCulate:EVM:MARKer(1:12):FUNCtion:BDENsity:CTYPe
- :CALCulate:EVM:MARKer(1:12):FUNCtion:BPOWer:CTYPe
- :CALCulate:EVM:MARKer(1:12):MAXimum/nquery/
- :CALCulate:EVM:MARKer(1:12):MAXimum:LEFT/nquery/
- :CALCulate:EVM:MARKer(1:12):MAXimum:NEXT/nquery/
- :CALCulate:EVM:MARKer(1:12):MAXimum:PREVious/nquery/
- :CALCulate:EVM:MARKer(1:12):MAXimum:RIGHt/nquery/
- :CALCulate:EVM:MARKer(1:12):MINimum/nquery/
- :CALCulate:EVM:MARKer(1:12):MODE
- :CALCulate:EVM:MARKer(1:12):POSition
- :CALCulate:EVM:MARKer(1:12):REFerence
- :CALCulate:EVM:MARKer(1:12):TABLe[:STATe]
- :CALCulate:EVM:MARKer(1:12):TRACe
- :CALCulate:EVM:MARKer(1:12):X
- :CALCulate:EVM:MARKer(1:12):X:POSition
- :CALCulate:EVM:MARKer(1:12):X:UNIT?/qonly/
- :CALCulate:EVM:MARKer(1:12):Y:IMAGinary
- :CALCulate:EVM:MARKer(1:12):Y[:REAL]
- :CALCulate:EVM:MARKer(1:12):Y:UNIT?/qonly/
- :CALCulate:EVM:MARKer(1:12):Z
- :CALCulate:EVM:MARKer(1:12):Z:UNIT?/qonly/

These TRACe related commandsare not available in CEVM.

- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:BANDwidth|BWIDth:INTegration
- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:FILTer:RRC:ALPHa
- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:FILTer:RRC:STATe

- :CALCulate:EVM:TRACe(1:4):ACPower:CARRier:FREQuency
- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:FILTer:RRC:STATe
- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:BANDwidth|BWIDth:INTegration
- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:FILTer:RRC:ALPHa
- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:FREQuency
- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:RCARrier
- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:RCARrier:TEST
- :CALCulate:EVM:TRACe(1:4):ACPower:OFFSet:LIST:STATe
- :CALCulate:EVM:TRACe(1:4):ACPower:STATe
- :CALCulate:EVM:TRACe(1:4):OBWidth:CENTroid?/qonly/
- :CALCulate:EVM:TRACe(1:4):OBWidth:LIMit:FBLimit
- :CALCulate:EVM:TRACe(1:4):OBWidth:LIMit[:TEST]
- :CALCulate:EVM:TRACe(1:4):OBWidth:PERCent
- :CALCulate:EVM:TRACe(1:4):OBWidth:STATe

SCPI Commands only available in CEVM

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

- [:SENSe]:CEVM:IFBW

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

- [:SENSe]:CEVM:METHod
- [:SENSe]:CEVM:EVM:COPY[:IMMediate]
- [:SENSe]:CEVM:CCAR:SELected
- [:SENSe]:CEVM:CCAR:COPY
- [:SENSe]:CEVM:DLINk:RESult
- [:SENSe]:CEVM:ULINk:RESult

Other Sources of Measurement Information

Additional measurement application information is available through your local Keysight 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
  Keysight part number 5989-8931EN

- Technical Overview

  Keysight Technologies Solutions for 3GPP LTE
  Keysight part number 5989-6133EN

- Application Note 1298

  Digital Modulation in Communications Systems - An Introduction
  Keysight part number 5965-7160E

- Application Note

  Characterizing Digitally Modulated Signals with CCDF Curves
  Keysight part number 5968-5858E

- Application Note

  HSDPA RF Measurements for User Equipment
  Keysight 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 Keysight design and test products for LTE visit
  http://www.keysight.com/find/lte

Instrument Updates at www.keysight.com

These web locations can be used to access the latest information about the instrument, including the latest firmware version.

http://www.keysight.com/find/pxa
http://www.keysight.com/find/mxa
http://www.keysight.com/find/exa

List of Acronyms

3G 3rd Generation

3GPP 3rd Generation Partnership Project

ACLR Adjacent channel leakage ratio

ACPR Adjacent channel power ratio

ACS Adjacent channel selectivity

ADS Advanced Design System

AMC Adaptive modulation and coding

A-MPR Additional maximum power reduction

ARQ Automatic repeat request

BCCH Broadcast control channel

BTS Base transceiver station

CDD Cyclic delay diversity

CCDF Complementary cumulative distribution function

CDMA Code division multiple access

CFI Control format indicator

Co-MIMO Cooperative MIMO

CP Cyclic prefi x

CPICH Common pilot channel

CPRI Common public radio interface

CQI Channel quality indicator

CRC Cyclic redundancy check

DCI Downlink control indicator

DFT Discrete Fourier transform

DFT-SOFDM Discrete Fourier transform spread OFDM

DL Downlink (base station to subscriber transmission)

DL-SCH Downlink shared channel

D-PHY 500 Mbps physical layer

DSP Digital signal processing

DT Development toolset

DVSA Digital vector signal analysis

EDA Electronic design automation

E-DCH Enhanced dedicated channel

E-UTRAN Evolved UMTS terrestrial radio access network

eMBMS Evolved multimedia broadcast multicast service

eNB Evolved Node B

EPC Evolved packet core

EPRE Energy per resource element

ETSI European Telecommunications Standards Institute

E-UTRA Evolved UTRA

E-UTRAN Evolved UTRAN

EVM Error vector magnitude

FDD Frequency division duplex

FFT Fast Fourier transform

FRC Fixed reference channel

FS1 Frame structure type 1

FS2 Frame structure type 2

GSM Global system for mobile communication

HARQ Hybrid automatic repeat request

HDL Hardware description language

HI HARQ indicator

HSDPA High speed downlink packet access

HSPA High speed packet access

HSUPA High speed uplink packet access

IFFT Inverse FFT

IOT Interoperability test

IP Internet protocol

LO Local oscillator

LTE Long term evolution

MAC Medium access control

MBMS Multimedia broadcast multicast service

MBSFN Multicast/broadcast over single-frequency network

MCH Multicast channel

MIMO Multiple input multiple output

MISO Multiple input single output

MME Mobility management entity

MOP Maximum output power

MPR Maximum power reduction

MU-MIMO Multiple user MIMO

NAS Non-access stratum

OBSAI Open base station architecture interface

OFDM Orthogonal frequency division multiplexing

OFDMA Orthogonal frequency division multiple access

PAPR Peak-to-average power ratio

PAR Peak-to-average ratio

PBCH Physical broadcast channel

P-CCPCH Primary common control physical channel

PCFICH Physical control format indicator channel

PCH Paging channel

PDCCH Physical downlink control channel

PDCP Packet data convergence protocol

PDSCH Physical downlink shared channel

PHICH Physical hybrid ARQ indicator channel

PHY Physical layer

PRACH Physical random access channel

PMCH Physical multicast channel

PMI Pre-coding matrix indicator

P-SCH Primary synchronization signal

PUCCH Physical uplink control channel

PUSCH Physical uplink shared channel

QAM Quadrature amplitude modulation

QPSK Quadrature phase shift keying

RACH Random access channel

RAT Radio access technology

RB Resource block

RF Radio frequency

RFDE RF design environment

RLC Radio link control

RMC Reference measurement channel

RNC Radio network controller

RRC Radio resource control

RRM Radio resource management

RS Reference signal

RSCP Received signal code power

RSRP Reference signal received power

RSRQ Reference signal received quality

RSSI Received signal strength indicator

SAE System architecture evolution

SAP Service access point

SC-FDMA Single carrier frequency division multiple access

SFBC Space-frequency block coding

S-GW Serving gateway

SIMO Single input multiple output

SISO Single input single output

SNR Signal-to-noise ratio

SRS Sounding reference signal

S-SCH Secondary synchronization signal

SU-MIMO Single user MIMO

TDD Time division duplex

TDMA Time division multiple access

TR Technical report

TrCH Transport channel

TS Technical specifi cation

TTA Telecommunications Technology Association

TTI Transmission time interval

UCI Uplink control indicator

UE User equipment

UL Uplink (subscriber to base station transmission)

UL-SCH Uplink shared channel

UMB Ultra-mobile broadband

UMTS Universal mobile telecommunications system

UTRA Universal terrestrial radio access

UTRAN Universal terrestrial radio access network

VSA Vector signal analyzer

W-CDMA Wideband code division multiple access