LTE Over-The-Air Testing for Base Stations with R&S®FSH

Application Note

Products:

R&S®FSH4/8/13/20
R&S®FSH-K50
R&S®FSH-K50E
R&S®FSH-K51
R&S®FSH-K51E

This application note explains how to perform LTE base station measurements over the air (OTA) using the R&S®FSH4/8/13/20 handheld spectrum analyzer. It describes the required measurement setup and explains the results obtained with the different measurement modes.
To execute the tests described in this application note, the R&S®FSH4/8/13/20 handheld spectrum analyzer (from now on referred to as the FSH) needs to be equipped with an antenna and the following software options:

R&S®FSH-K50 and R&S®FSH-K50E for FDD-LTE or R&S®FSH-K51 and R&S®FSH-K51E for TD-LTE.

ROHDE&SCHWARZ

Application Note

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1 Introduction

There are a number of reasons why operators would prefer to make measurements over the air (OTA) instead of connected to the base station antenna:

1. Complexity of the measurement setup if connected to the antenna: With the wider use of tower mounted amplifiers (TMA) and remote radio heads (RRH), it is often not possible to make measurements at the base station test ports.
2. Easier access: Base stations are also often located in areas that are difficult to access, making OTA measurements more convenient.
3. Comfort: RF engineers can often make OTA measurements from their vehicles, thereby decreasing test measurement times in the field.
4. Convenience: OTA measurements can be run while the base transceiver station (BTS) is on the air; i.e. unlike connected measurements, there is no need to shut down the BTS.

The FSH handheld spectrum analyzer simplifies the execution of LTE OTA measurements in the field by synchronizing to a base station and displaying the most important RF measurements in a few seconds. In addition, the FSH supports several LTE measurement modes, including a user-configurable measurement limit display for a quick PASS/FAIL check of key performance parameters. The measurement capabilities for LTE of the digital modulation analyzer mode will be explained in detail later in this application note.

In addition to LTE-FDD/TD-LTE, the FSH supports demodulation and OTA analysis of mobile communications standards such as GSM/EDGE, WCDMA/HSPA+, TD-SCDMA, CDMA200 and EVDO.

2 Definitions of Measurements

- **Carrier frequency error**: is the offset between the transmitted frequency and the measured frequency. It is measured in Hz or in ppm (parts per million) of the carrier frequency. OFDM-based systems such as LTE are very sensitive to frequency offsets. If the carrier frequency error is above a certain threshold, it may not be possible for the mobile device to synchronize with its serving base station (BS), and this may cause a calldrop. 3GPP TS 36.104 requires that carrier frequency error be within the margins specified in Table 1.

BS class	Accuracy
Wide area BS	±0.05 ppm
Medium range BS	±0.1 ppm
Local area BS	±0.1 ppm
Home BS	±0.25 ppm

Table 1 3GPP TS 36.104, frequency error minimum requirement according to serving BS class.

To perform carrier frequency error measurements with the accuracy specified in Table 1, a GPS receiver is required which is available with the R&S®HA-Z240 option.

- **Cyclic prefix**: is a guard interval between OFDM symbols to avoid inter-symbol interference. The prefix length can be set to either “normal” (5 symbols long) or “extended” (10 symbols long). The extended prefix is normally used in cells with radius > 1.5 km (i.e. in rural areas).
- **Error vector magnitude (EVM)**: is a measure of how much a signal deviates from its ideal modulation scheme. A high EVM indicates distortions that limit the ability of the receiver to demodulate the signal properly. A high EVM is normally caused by poor RF conditions due to low signal level or interference. The LTE 3GPP standard defines EVM limits for each modulation scheme: QPSK (17.5 %), 16QAM (12.5 %), 64QAM (8 %). However, these limits are only applicable for measurements made when connected to the base station antenna, not OTA.
- **I/Q offset**: shows the power at spectral line 0 normalized to the total transmitted power. The I/Q offset may indicate a baseband DC offset or carrier leakage. Please note that the I/Q offset can be measured either if the measurements are made connected to the BTS RF port or are made OTA for a single antenna configuration (SISO).

- **OFDM symbol transmit power (OSTP)**: is the power of a symbol containing user data.
- **Physical cell identity (PCI)**: is used by the mobile device to identify its serving cell. LTE defines 504 PCIs (from 0 to 503, divided into 168 groups of 3 PCIs each).

- **Reference signal received power (RSRP)**: shows the power of the LTE reference signals over the selected bandwidth.

  Reference signal received quality (RSRQ): is defined as
  RSRQ = (N * RSRP) / RSSI measured over the same bandwidth,
  where N is the number of resource blocks. N depends on the measurement bandwidth (see Table 2 Number of available resource blocks vs. LTE channel).
- **Received signal strength indicator (RSSI)**: is the total power, including interferences, power of other cells and traffic. It is measured over the selected bandwidth.
- **Signal to interference and noise ratio (SINR)**: is based on the sync signal.
- **Synchronization signal power**: shows the power of the synchronization signal. The FSH can synchronize to the downlink signal in two ways:
  - PSYNC/SSYNC uses the received primary and secondary synchronization channel signals
  - Reference signal (RS) is used in the case of antennas that do not provide PSYNC / SSYNC (i.e. a single antenna is used)
- **RF channel power**: shows the power added over the selected signal bandwidth. In the case of OTA measurements, the total power includes all received signals in the channel bandwidth. The signal power outside the channel bandwidth is not included in the total power but in the *power within span*. If the power within span is higher than the RF channel power, this indicates some interference on that channel.
- **Occupied bandwidth (OBW)**: shows the bandwidth where 99 % of the RF signal power is contained.
- **Traffic activity**: indicates the percentage of traffic slots with data.

3 Physical Test Setup

3.1 Finding the Right Measurement Spot

When performing OTA measurements for LTE, observe the following guidelines:

- Select a location close to the base station, in line of sight of one of the antenna sectors and where the serving cell under test is the main server. As a rule of thumb, the SSYNC power of the serving cell should be at least 10dB higher than its neighboring cells.
- Use the same location when taking measurements at different times in order to get repeatable results. The GPS location display on the FSH facilitates this objective. In addition, the R&S®FSH-K16 geotagging option allows you to save your location on a map.

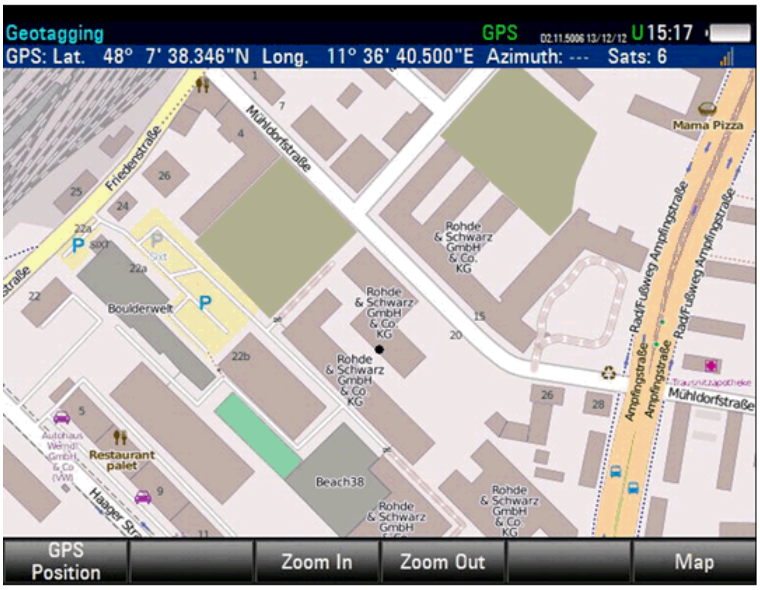

Fig. 1 GPS location on the map (using the R&S®FSH-K16 geotagging option).

- Use a directional antenna such as the R&S HL300 to aim at the BTS transmission antenna in order to minimize interference from other broadcasting base stations.

3.2 Setting up the FSH for LTE OTA Measurements

Once you are at the right location for making LTE-FDD or TD-LTE measurements over the air, you just need to perform four simple steps:

1. Select the appropriate LTE mode: in the *Dig Mod Analyzer* mode, by pressing the F3 button on the FSH front panel to enter the measurement mode for LTE-FDD or TD-LTE.

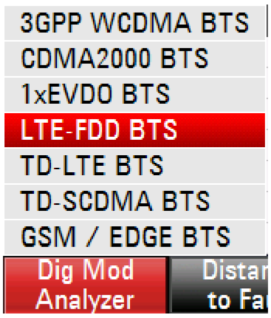

Fig. 2 Options within digital modulation analyzer mode.

2. Set the measurement frequency. FSH frequencies can be set either as frequencies (e.g. 751 MHz) or as channels (e.g. 500). The frequencies can be defined manually; the channels are defined in channel tables.

   The most important channel tables are provided with the FSH as standard.

   To select an LTE channel table, click "Channel" in the frequency mode menu. After the *Channel* of *Freq Mode* is selected, a list of LTE channel bands (refer to Fig. 3) will be displayed, from which you can choose the right LTE frequency band.

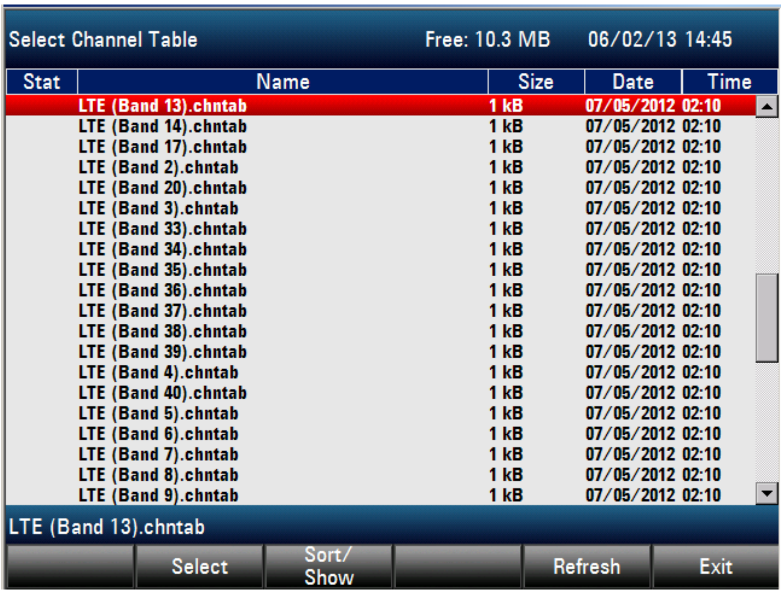

Fig. 3 LTE channel bands within channel table.

Once the frequency band has been selected, you can select the right frequency channel.

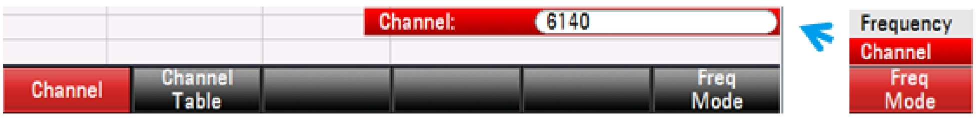

Fig. 4 Frequency mode and channel selection.

It is especially important to set the correct measurement frequency. Otherwise the FSH may not be able to synchronize with the BTS.

Once the correct frequency has been set, click AMP and then the level adjust button in order to set the frontend amplifier gain to the optimum level.

3. Set the antenna configuration: For OTA measurements, you can choose between SISO, MIMO 2x2 and MIMO 4x4 Over-The-Air antenna configurations, according to the BTS configuration.

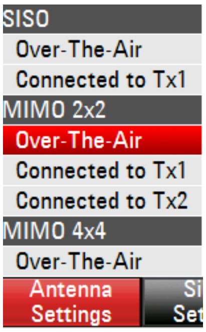

Fig. 5 LTE antenna mode configurations.

4. Set the LTE signal settings: The LTE signal bandwidth must be set manually. You can choose between 1.4 MHz (6 RB), 3 MHz (15 RB), 5 MHz (25 RB), 10 MHz (50 RB), 15 MHz (75 RB) and 20 MHz (100 RB). Most network operators have deployed 10 MHz systems first. This selection is shown in Fig. 6 below.

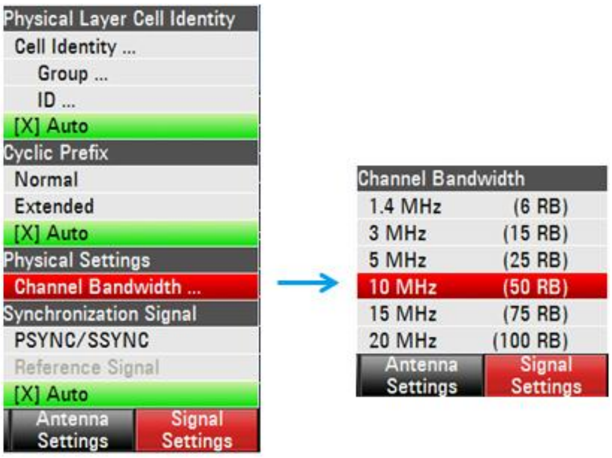

Fig. 6 LTE channel bandwidth configuration.

The FSH detects the physical layer cell identity (PCI), the cyclic prefix and the synchronization signal automatically by default. However, it is also possible to set these manually in order to select a specific cell. Setting up these parameters manually will also help to speed up the synchronization to the base station.

Once the measurement has been set up, you can toggle between seven LTE measurement displays to analyze the measurement results: *Spectrum Overview*, *Result Summary*, *Constellation Diagram*, *Resource Allocations*, *BTS Scanner*, *Limits* and *Isotropic Antenna*. The results obtained in each measurement display will be explained in the next section.

Please note that the BTS scanner, the constellation diagram and the resource allocation display require the extended options R&S®FSH-K50E (FDD) and R&S®FSH-K51E (TDD).

4 Measurement Results

This section explains the different measurement functions available for LTE signal analysis.

4.1 Spectrum Overview

The Spectrum Overview screen shows the measured LTE spectrum. It helps the user to make a first check of the LTE signal, including a coarse estimation of the carrier frequency and basic spectrum measurements such as RF channel power, occupied bandwidth and power within span without switching back to the spectrum mode.

The channel bandwidth limits are shown by vertical lines; markers can be set to measure frequencies and levels as shown in Fig. 7 below.

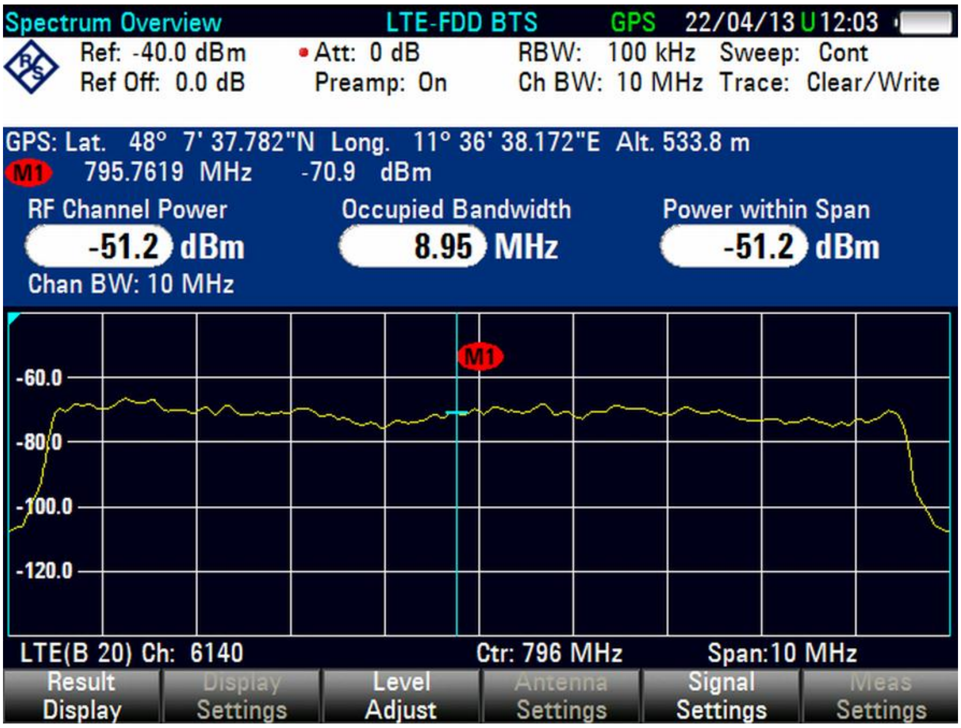

Fig. 7 LTE-FDD spectrum overview.

For TD-LTE measurements, you have to set Config 0 to 6 of *UL/DL Configuration* under the *Signal Settings* button.

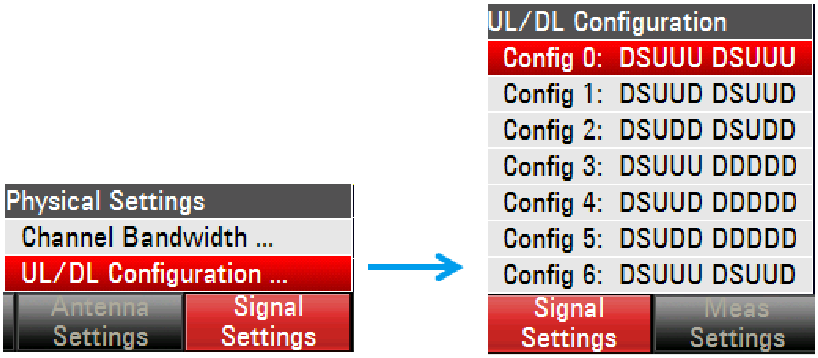

Fig. 8 UL/DL configuration settings for TD-LTE.

4.2 Result Summary

The Result Summary screen gives an overview of the most important LTE downlink configuration data and the measurement results that show the performance of the selected frequency channel.

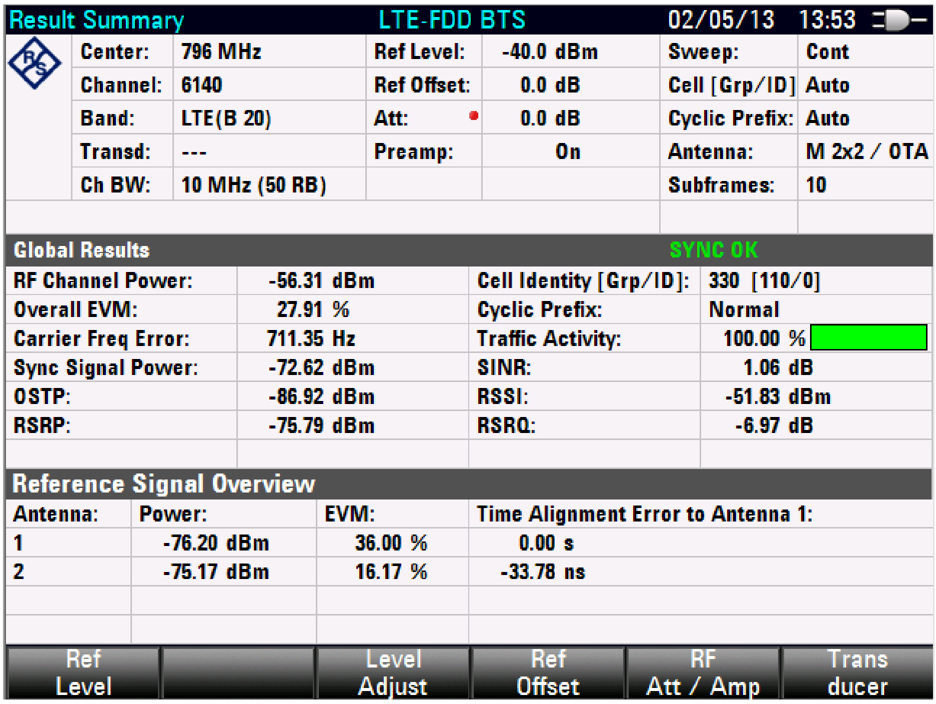

Fig. 9 Result summary for LTE OTA MIMO 2x2 antenna.

The upper part of the screen displays some basic settings of the analyzer and some settings specific to the 3GPP LTE standard.

- The parameters *Center*, *Channel* and *Band* are related to the selected carrier frequency. Optionally the antenna transducer factors can be selected.

- The parameter *Ch BW* shows the selected base channel bandwidth and number of resource blocks (RB).
- *Cell [Grp/ID]* and *Cyclic Prefix* can be set to be detected automatically by the FSH (the default setting is “Auto”). These parameters can also be set manually.
- *Antenna* shows the selected antenna configuration.
- *Subframes* shows the number of subframes the FSH records and analyzes during a single sweep. This parameter can be set by the user as a number between 1 and 10. The default value is 10 (10 subframes = 1 frame) as defined in the standard.

The Global Results section shows the most important measurement results of the composite signal, such as Carrier Frequency Error, Sync Signal Power, OSTP, RSRP, Cell Identity [Grp/ID], Cyclic Prefix, Traffic Activity, SINR, RSSI, RSRQ and I/Q offset.

These results evaluate the total signal over the number of subframes that have been set by the user. The global results also contain information about the quality of the measured signal.

The overall EVM includes all signal components, regardless of the modulation or channel type.

A more detailed description of the measurement parameters is given in section 2.

The results displayed at the bottom of the result summary depend on the selected antenna configurations.

For LTE OTA measurements, you can select between SISO, MIMO 2x2 and MIMO 4x4 antenna configurations as described in section 3.2.

Fig. 9 shows the results for a MIMO 2x2 over-the-air antenna configuration, which is currently the most common configuration used in LTE base stations.

The reference signal overview shown in Fig. 9 contains the power and EVM for each antenna (two in this case). The power values are normalized to one resource element or one subcarrier respectively. The FSH evaluates the results over all resource blocks and subframes. The time alignment error between both antennas is also displayed.

4.3 Constellation Diagram

The Constellation Diagram screen shows the LTE signal constellation, visually indicating the modulation quality and the received signal EVM.

Different colors are used to represent the different modulation schemes used (e.g. QPSK, 16QAM, 64QAM).

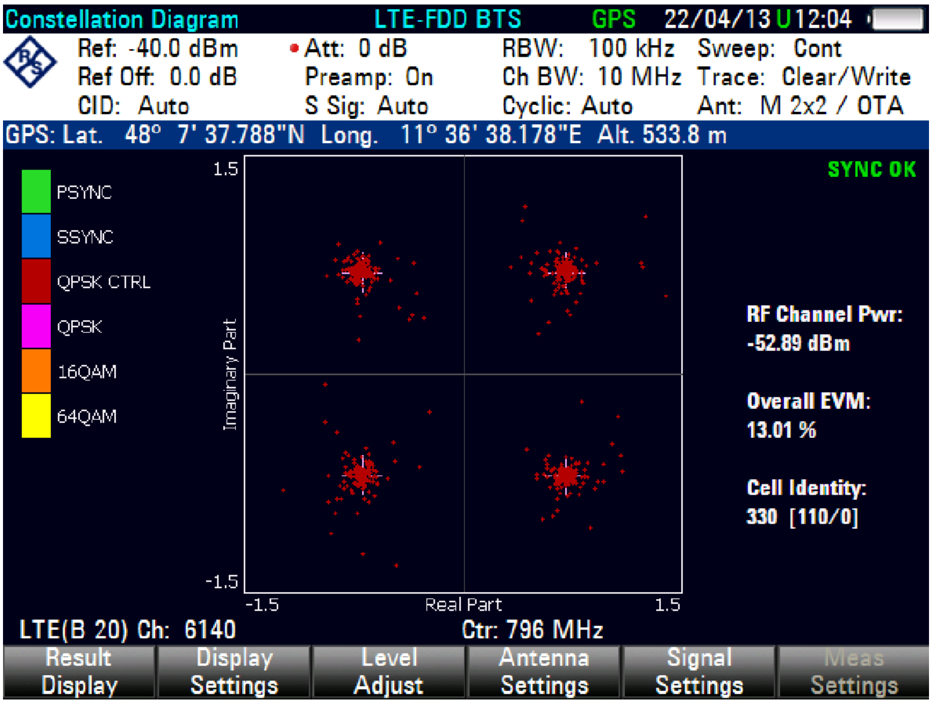

Fig. 10 LTE constellation diagram.

A “blurry” constellation means higher deviation from the ideal (higher EVM). This can be caused either by a high interference level or by signal fading due to poor coverage conditions.

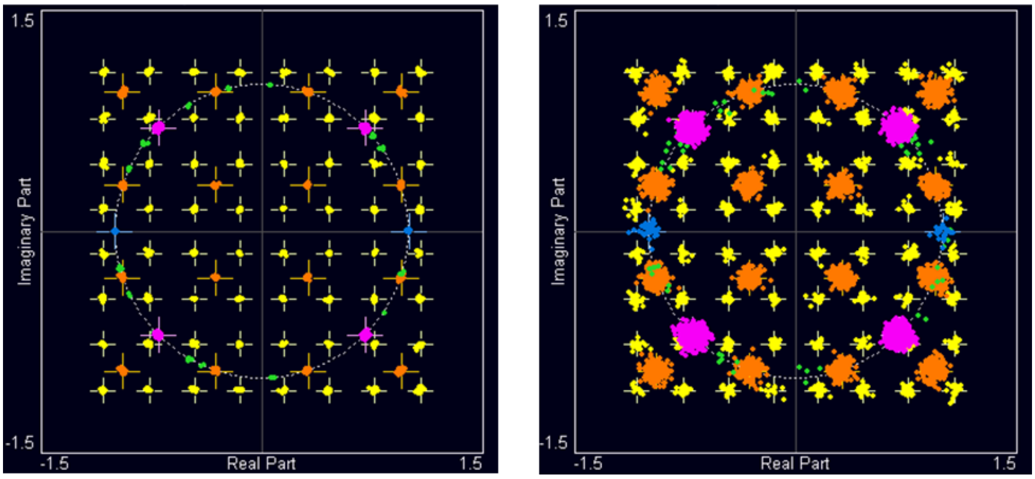

Fig. 11 LTE constellation diagram comparison (ideal signal vs. blurry signal), cable-connected measurement.

The constellation diagram can be customized to show only those channels of interest by using the Display Settings menu.
For example, for a 2x2 OTA signal, the reference signal for antenna 1, antenna 2, or both can be shown in the constellation display. Note that those signals that cannot be extracted from an OTA signal are dimmed.

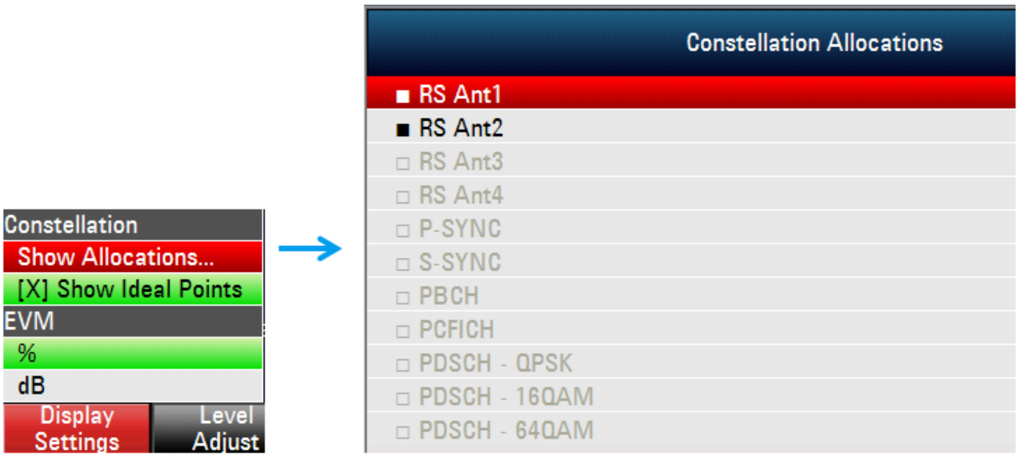

Fig. 12 Constellation allocation selection.

4.4 Resource Allocations

The Resource Allocations screen shows the number of subframes and resource blocks used for data transmission by the base station for the selected frequency channel.

LTE divides capacity into resource blocks, and each resource block can be transmitted with its own power level. Therefore, by looking at the resource allocations display, you can evaluate how much traffic is currently on the carrier based on the power levels of each resource block. You can also see narrowband interferers in this display.

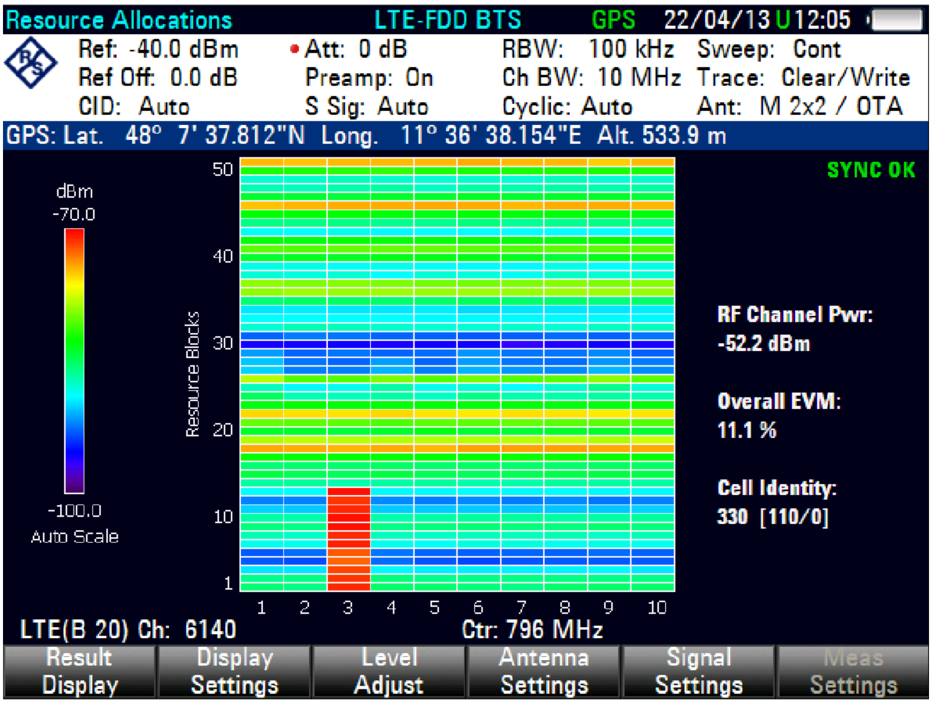

Fig. 13 LTE resource allocation display.

The maximum number of available resource blocks is based on the channel bandwidth, as listed in Table 2 below:

Channel bandwidth (MHz)	Number of available resource blocks (RB)
1.4	6
3	15
5	25
10	50
15	75
20	100

Table 2 Number of available resource blocks vs. LTE channel bandwidth.

4.5 BTS Scanner

The BTS Scanner screen displays all receivable base stations (i.e. eNodeBs) in the surrounding area. It can show up to eight cells with their cell IDs, group IDs and signal strengths.
This way, the FSH can be used to determine whether interference from adjacent base stations may be an issue.

The max hold trace makes it possible capture cells that are present only intermittently, thus helping users to also detect possible interferers close to detection threshold and to optimize their frequency/code plan.

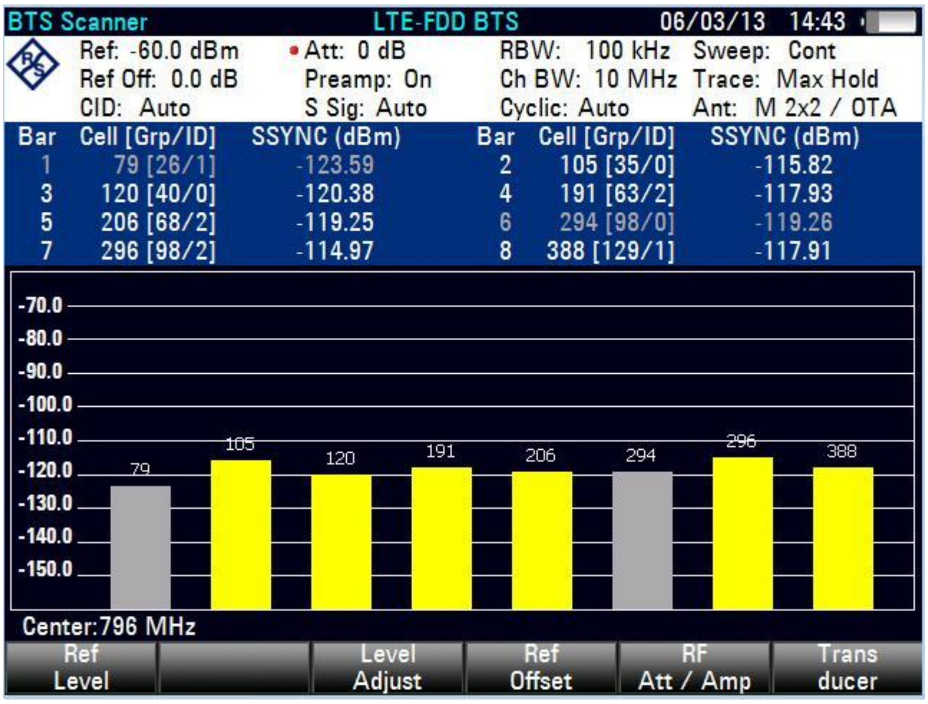

Fig. 14 Max hold trace mode for BTS scanner function.

4.6 Limits

For users who only need to measure a few RF parameters, the result summary display explained in section 4.2 may appear too crowded.

The Limits display gives you a quick pass/fail indication for the key LTE signal parameters.

Failed limits appear in red; if any of the tested limits fail, the result "LIMITS FAILED" is displayed.

The FSH is preloaded with limits set in accordance with the relevant LTE standard. These limits can be modified using the R&S®FSH4View software. Please refer to section 5.2 to see how to configure and change the limits.

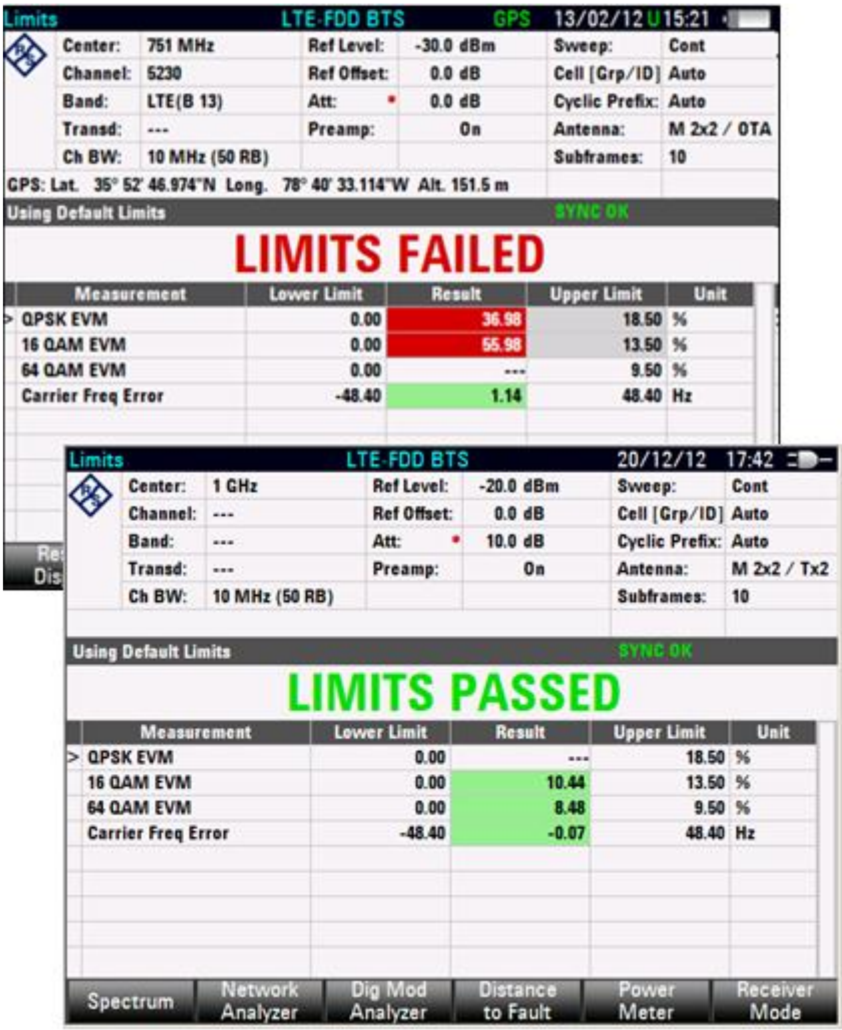

Fig. 15 Limits function.

4.7 Isotropic Antenna

The Isotropic Antenna function allows you to perform LTE field strength measurements with a suitable isotropic antenna such as the R&S TS-EMF.
When attached to the isotropic antenna, the FSH can make individual measurements in the X, Y and Z planes and RMS measurements of the SSYNC and RF channel power. This is especially useful for analyzing polarization and multipath related coverage issues.

Fig. 16 below shows the isotropic antenna display. The spectrum graph shows the isotropic spectrum, taking into account the composite power of the X, Y and Z planes.

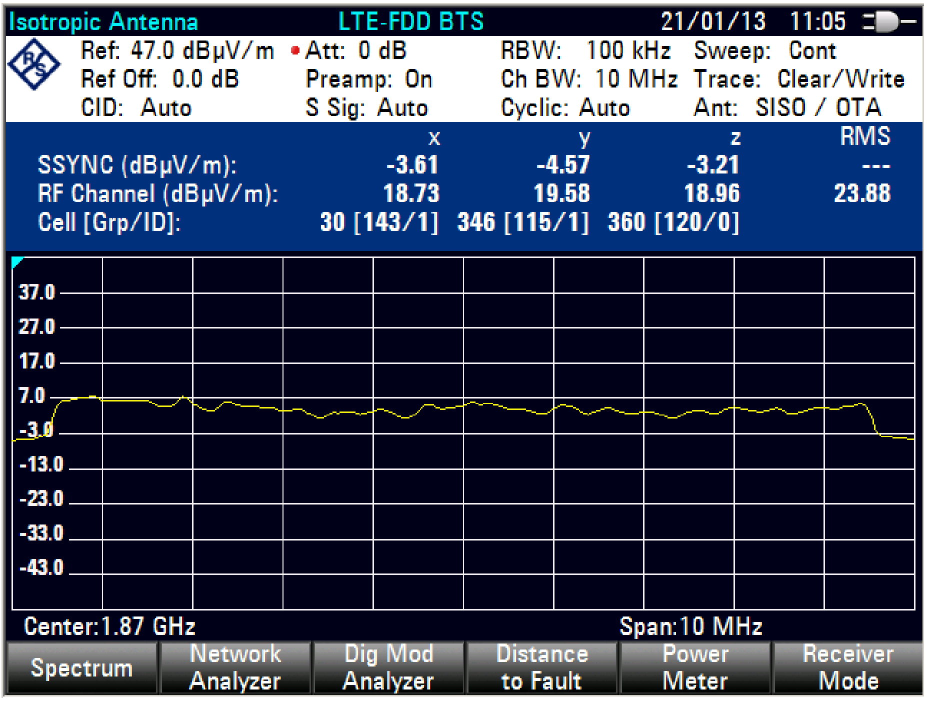

Fig. 16 LTE FDD isotropic antenna display.

5 R&S®FSH4View Software

5.1 General

R&S®FSH4View is delivered with the FSH as standard.
The R&S®FSH4View software allows you to set up a LAN or a USB connection to control the FSH remotely. You can control the FSH from any windows PC using the remote desktop application within R&S®FSH4View. The R&S®FSH4View software also makes it possible to make measurements, edit measurement results, generate reports, set up templates for limit lines, channel tables, cable models, etc., as well as to transfer files between the instrument and the PC.

R&S®FSH4View is available for download on the Rohde & Schwarz website:
http://www.rohde-schwarz.com/en/software/fsh4/8/

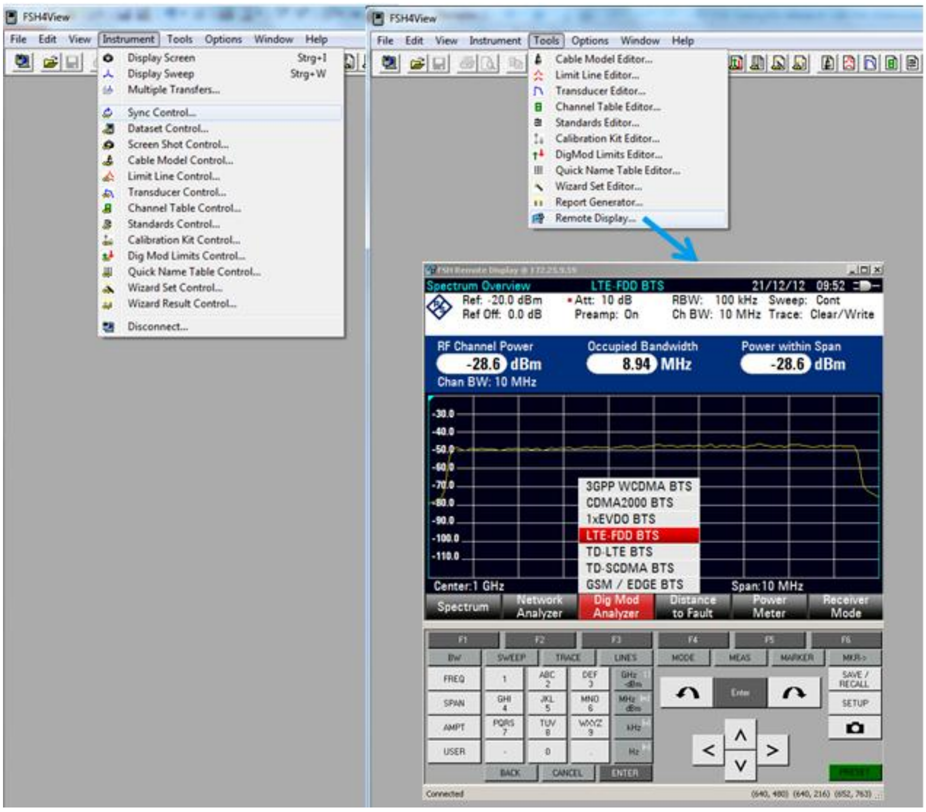

Fig. 17 R&S®FSH4View.

5.2 How to Set a New Limit Lines Configuration File

The FSH is preloaded with limits set in accordance with the relevant LTE standard. These limits can be changed to adapt to each customer's measurement requirements.

To configure a new limits file, simply follow the steps below using the R&S®FSH4View software:

1. Select *DigMod Limits Editor* under the *Tools* pulldown menu.

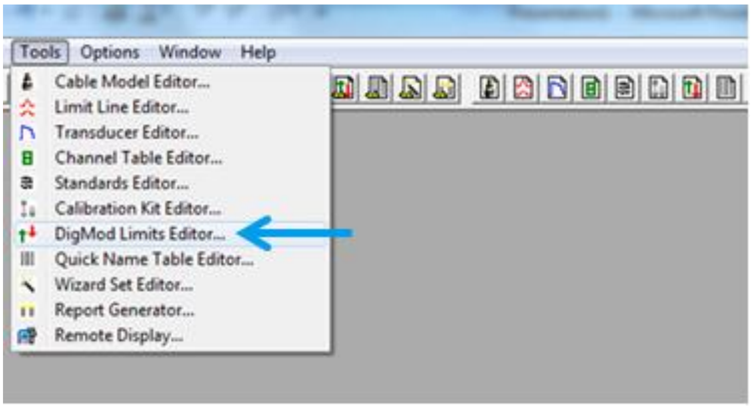

Fig. 18 Digital modulation limits editor.

2. Open the current limit lines file using R&S®FSH4View.

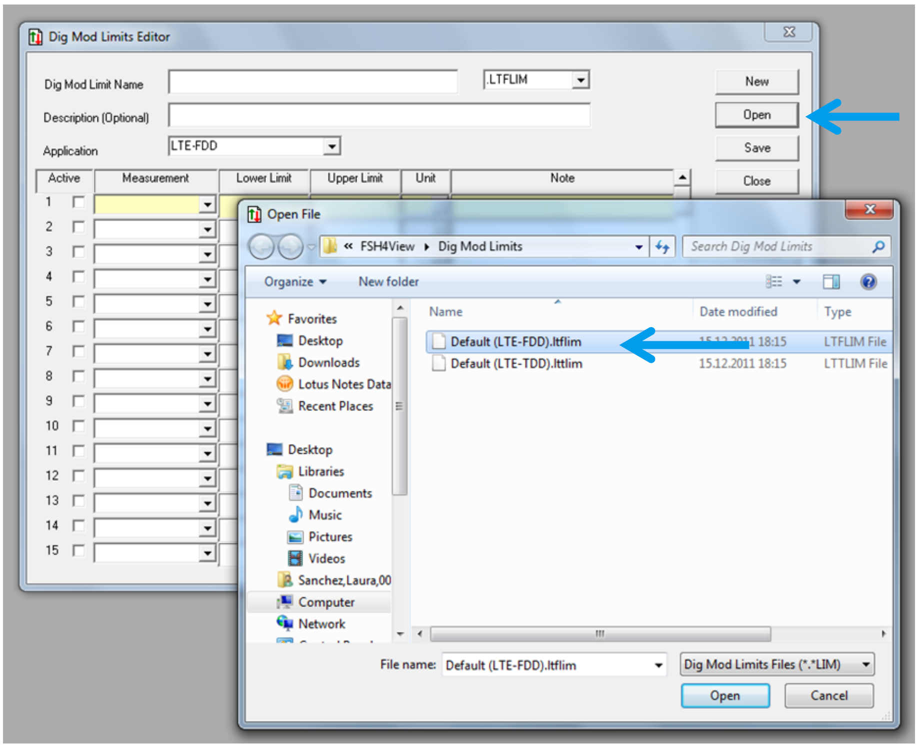

Fig. 19 Opening the existing limits file.

3. Modify the limits file settings according to test requirements and save the new limits file.
4. Transfer the new limits file back to the FSH using the *Dig Mod Limits Control* function.

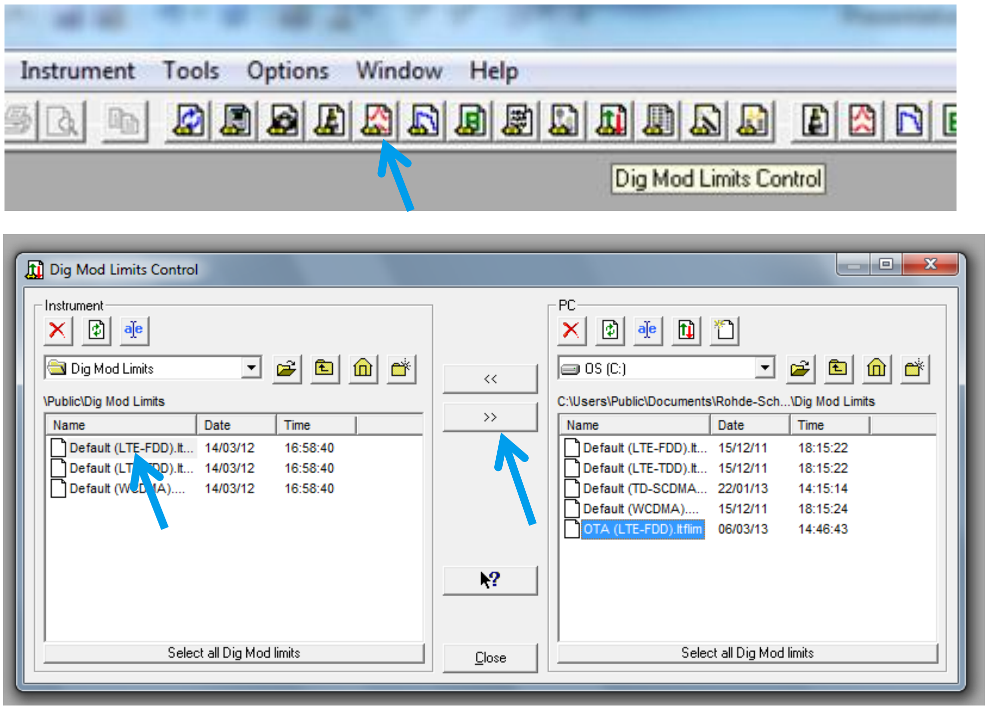

Fig. 20 Transferring the limit lines file from the PC to the FSH.

5. In the FSH LTE Limits display, click “Select” and choose the new LTE OTA limits file.

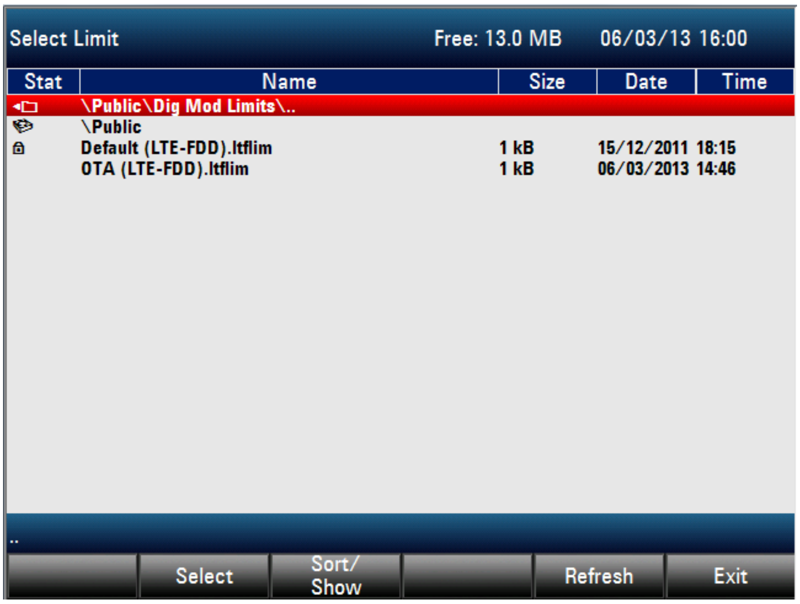

Fig. 21 Selecting LTE limits file.

6 Appendix 1: LTE Measurements in Spectrum Analyzer Mode

Basic spectrum measurements are available with the FSH as standard, i.e. at no additional cost for the customer. These measurements are recommended for customers who do not need to demodulate LTE signals.

The following measurements are available in spectrum analyzer mode. The measurement can be performed both connected to the BTS RF port and over the air:

RF channel power

This measurement is the summation of the power of all subcarriers contained in the downlink signal. To prevent base stations from interfering with one another, it is important that the total power is measured to be that value specified by the RF engineer.

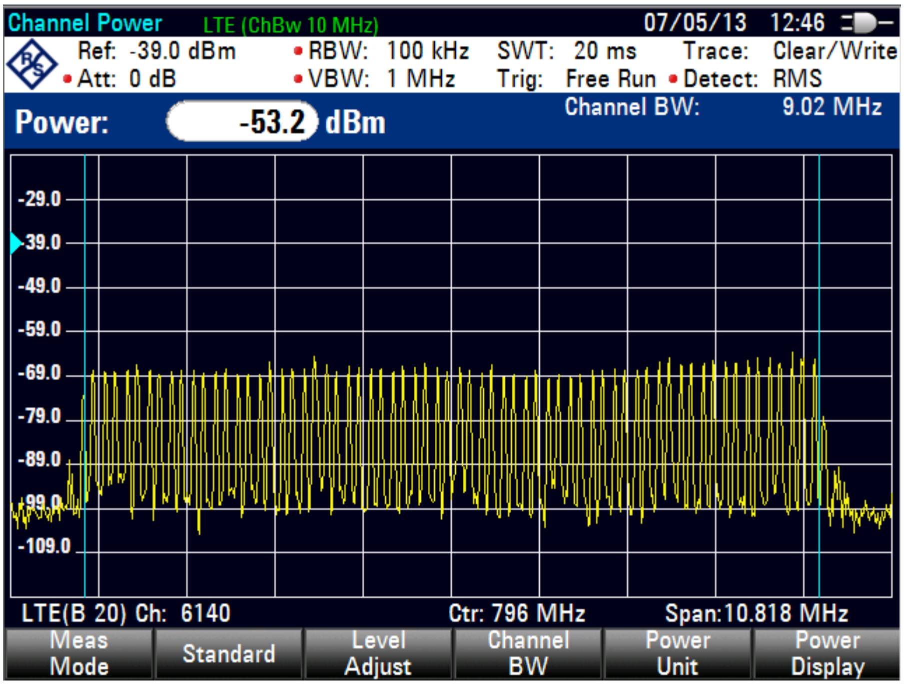

Fig. 22 RF OTA channel power of a 10 MHz FDD LTE signal.

Occupied bandwidth (OBW)

This measurement helps to verify that the emission of the base station does not occupy an excessive bandwidth. The occupied bandwidth needs to be less than the nominal channel bandwidth.

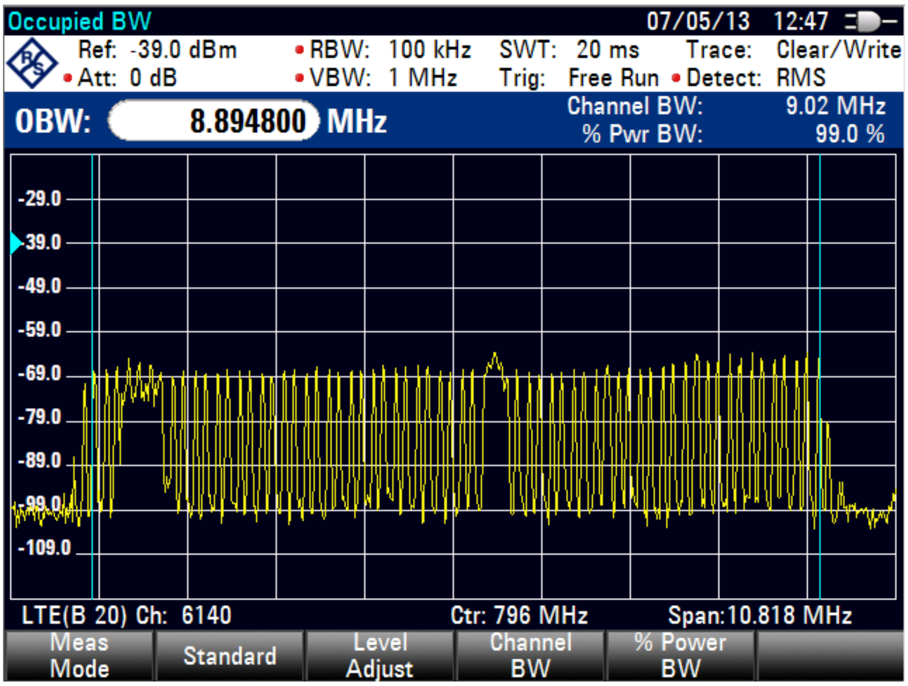

Fig. 23 OTA occupied bandwidth measurement of a 10 MHz FDD LTE signal.

Adjacent channel leakage ratio (ACLR)

ACLR is the ratio of the filtered mean power centered on the assigned channel frequency to the filtered mean power centered on an adjacent channel frequency.

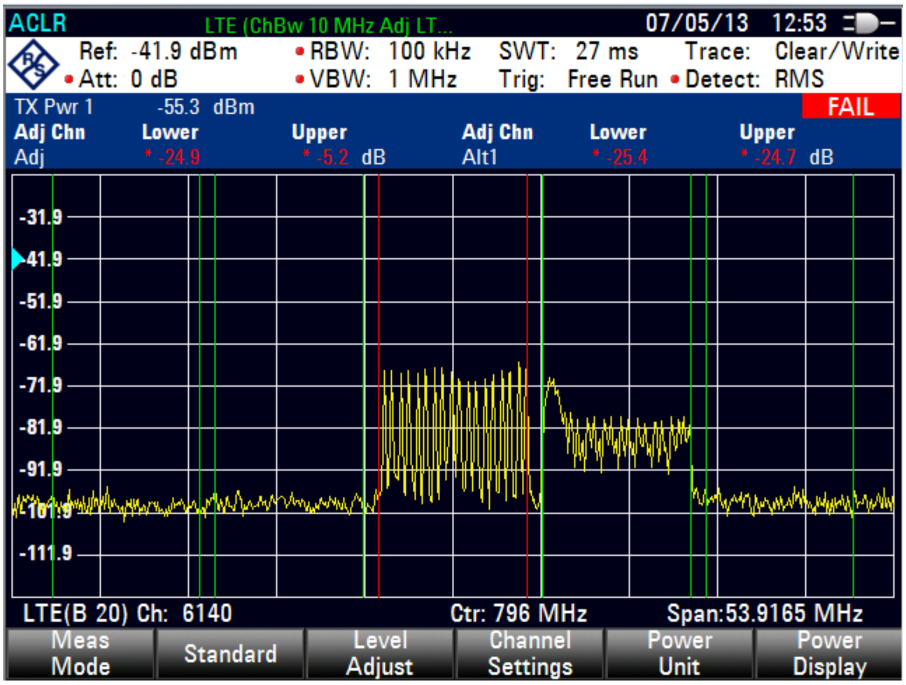

Fig. 24 ACLR OTA measurement of a 10 MHz FDD LTE signal.

Spectrum emission mask (SEM)

SEM is commonly used for spurious tests in neighboring frequency bands. The 3rd Generation Partnership Project (3GPP), the standardization body for LTE, has defined conformance specifications that define a mask for out-of-channel emissions.

Fig. 25 SEM OTA measurement of a 10 MHz FDD LTE signal.

3GPP BTS spurious emission

This measurement is performed at the base station RF port to exclude out-of-band emissions. The frequency range for spurious emission measurement is specified from 9 kHz and 12.75 GHz, excluding the frequency range from 10 MHz below the lowest frequency of the downlink operating band up to 10 MHz above the highest frequency of the downlink operating band. In some countries, spurious emissions are measured while the base station is being put into operation.

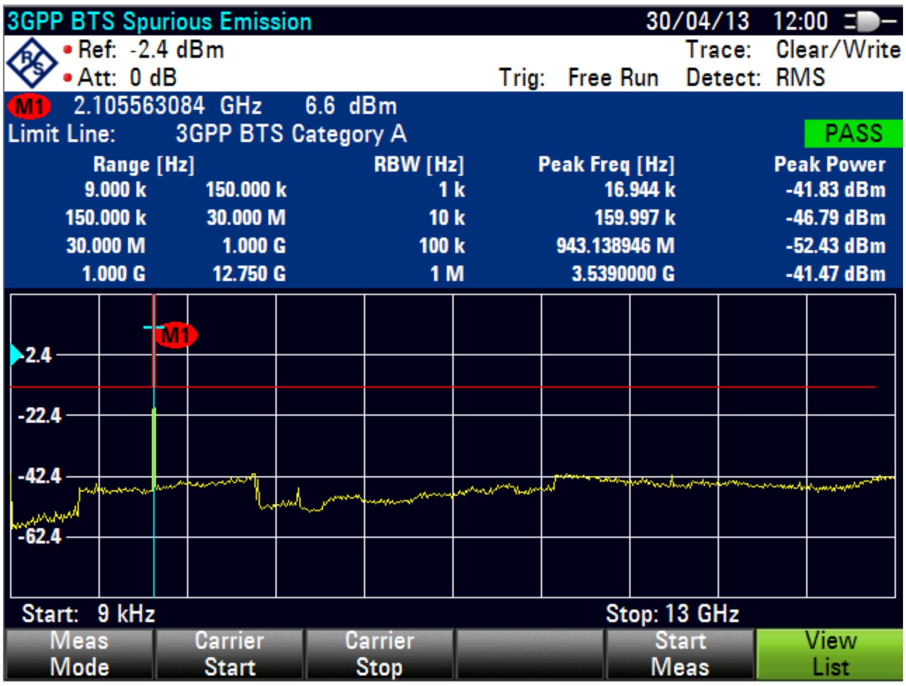

Fig. 26 3GPP BTS spurious measurement of a 10 MHz FDD LTE signal (cable connected).

7 Appendix 2: LTE Frequency Bands

The table below shows the operating frequency bands for an LTE-FDD base station (extracted from 3GPP TS36.141):

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit			Downlink (DL) operating band BS transmit UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
5	824 MHz	–	849 MHz	869 MHz	–	894MHz	FDD
6[1]	830 MHz	–	840 MHz	875 MHz	–	885 MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
9	1749.9 MHz	–	1784.9 MHz	1844.9 MHz	–	1879.9 MHz	FDD
10	1710 MHz	–	1770 MHz	2110 MHz	–	2170 MHz	FDD
11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	FDD
12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	FDD
13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	FDD
14	788 MHz	–	798 MHz	758 MHz	–	768 MHz	FDD
15	Reserved			Reserved			FDD
16	Reserved			Reserved			FDD
17	704 MHz		716 MHz	734 MHz		746 MHz	FDD
18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	FDD
19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	FDD
22	3410 MHz	–	3490 MHz	3510 MHz	–	3590 MHz	FDD
23	2000 MHz	–	2020 MHz	2180 MHz	–	2200 MHz	FDD
24	1626.5 MHz	–	1660.5 MHz	1525 MHz	–	1559 MHz	FDD
25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	FDD
26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	FDD
27	807 MHz	–	824 MHz	852 MHz	–	869 MHz	FDD
28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
Note 1: Band 6 is not applicable.							

The table below shows the operating frequency bands for a TD-LTE base station (extracted from 3GPP TS36.141):

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit			Downlink (DL) operating band BS transmit UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	
33	1900 MHz	–	1920 MHz	1900 MHz	–	1920 MHz	TDD
34	2010 MHz	–	2025 MHz	2010 MHz	–	2025 MHz	TDD
35	1850 MHz	–	1910 MHz	1850 MHz	–	1910 MHz	TDD
36	1930 MHz	–	1990 MHz	1930 MHz	–	1990 MHz	TDD
37	1910 MHz	–	1930 MHz	1910 MHz	–	1930 MHz	TDD
38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
41	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
43	3600 MHz	–	3800 MHz	3600 MHz	–	3800 MHz	TDD
44	703 MHz	–	803 MHz	703 MHz	–	803 MHz	TDD

8 References

[1] 3GPP TS 36.141: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) conformance testing"

[2] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception"

[3] R&S®FSH4/8/13/20 Operating Manual (available at www.rohde-schwarz.com)

[4] 1MA154 Rohde & Schwarz application note: LTE Base Station Tests (November 2009)

9 Ordering Information

Designation	Type	Order No.
Handheld Spectrum Analyzer, 9 kHz to 3.6 GHz, with preamplifier	R&S®FSH4	1309.6000.04
Handheld Spectrum Analyzer , 9 kHz to 8 GHz, with preamplifier	R&S®FSH8	1309.6000.08
Handheld Spectrum Analyzer, 9 kHz to 13.6 GHz, with preamplifier	R&S®FSH13	1314.2000.13
Handheld Spectrum Analyzer, 9 kHz to 20 GHz, with preamplifier	R&S®FSH20	1314.2000.20
LTE FDD Downlink Pilot Channel and EVM Measurement Application[1] (software license)	R&S®FSH-K50	1304.5735.02
LTE FDD Downlink Extended Channel and Modulation Measurement Application, R&S®FSH-K50 required[1] (software license)	R&S®FSH-K50E	1304.5793.02
LTE TDD Downlink Pilot Channel and EVM Measurement Application[1] (software license)	R&S®FSH-K51	1304.5812.02
LTE TDD Downlink Extended Channel and Modulation Measurement Application, R&S®FSH-K51 required[1] (software license)	R&S®FSH-K51E	1304.5829.02
Geotagging Measurement Application (software license)	R&S®FSH-K16	1309.7494.02
GPS Receiver	R&S®HA-Z240	1309.6700.03

[1] for FSH serial numbers ≥ 105000)

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ISO 9001

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