# RF chipset verification for UMTS LTE (FDD) with R&S®SMU200A and R&S®FSQ

## Application Note

**Products:**

- R&S® SMU200A
- R&S® SMU-K55
- R&S® EX-IQ-Box
- R&S® FSQ
- R&S® FSQ-K100
- R&S® FSQ-K101

This application note describes how to verify and validate a LTE (FDD) RF chipset using R&S® SMU200A vector signal generator, R&S® FSQ signal analyzer and R&S® EX-IQ Box. The related signal generation as well as signal analysis is described.

ROHDE&SCHWARZ

Application Note

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# 1 Motivation

In recent years industry alliances have been formed by leading network operators, chipset manufacturers, infrastructure vendors, and wireless device manufacturers in order to push UMTS Long Term Evolution, accomplish an early market entry and to ensure interoperability between networks, network components and wireless devices. One goal for those alliances is to standardize features and requirements for LTE-capable devices, although common availability is not expected before Q4 2009. Such devices are currently under development by all major handset manufacturers, using the proprietary RF and baseband chipsets provided by leading semiconductor companies. In the early stages of development it is essential for the design engineers to prove and verify the design as fulfilling the transmitter and receiver requirements outlined in 3GPP specification Release 8 TS 36.101, version 8.3.0, dated September 2008. Although the specification still has a preliminary status– meaning not all relevant TX and RX measurements are fully described and specified – it is important to verify uplink and downlink for the RF chipset, since customers are relying on the performance keeping the tight limits. Beside new technology, requiring new or modified measurements, the way of testing the chipset changes. The key word is digital IQ data. The use of analog IQ signals between the Baseband IC and RF IC, which is today the standard method, will not be maintained for advanced technologies like LTE or WiMAX. Rohde & Schwarz, as a leading provider of test and measurement solutions, already addresses the needs of verifying LTE-capable RF ICs using a digital IQ interface. This application provides an overview how to test a proprietary LTE-capable RF chipset using Rohde & Schwarz signal generation and signal analysis products, and additional equipment made necessary by the presence of a digital IQ interface.

This document assumes basic knowledge of 3GPP LTE technology as provided in [1].

# 2 Generic principles of UMTS LTE (FDD)

## 2.1 OFDMA – Downlink Transmission Scheme

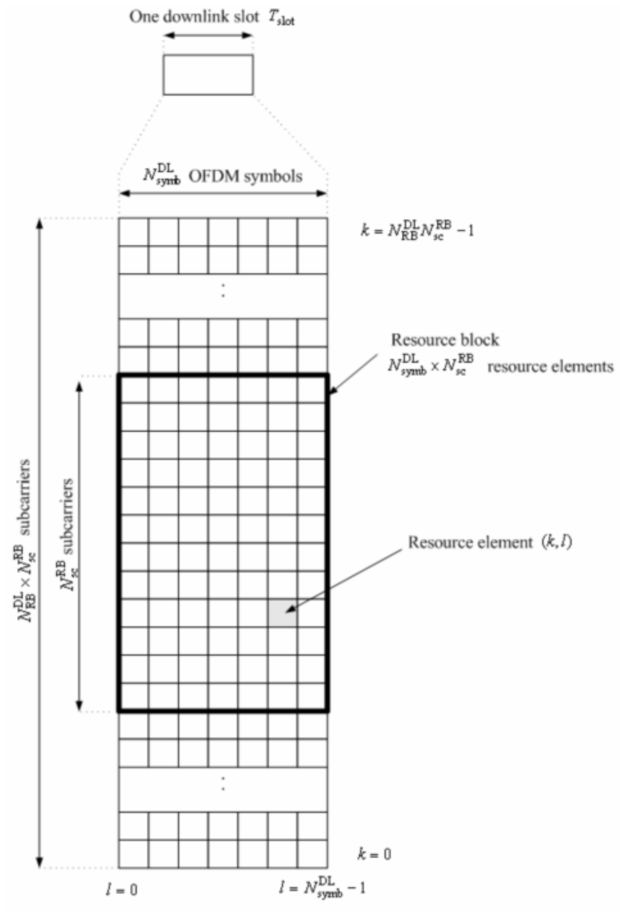
For a more efficient use of the available spectrum OFDMA was selected and introduced as the downlink transmission scheme for 3GPP LTE. The basic principle of OFDM is explained in [1]. Two types of frame structure are defined for LTE, one for FDD and one for TDD mode. The duration of an LTE radio frame is equal for both modes with $T_f = 307200 * T_s = 10$ ms. An FDD radio frame is divided into 10 subframes, where a subframe consists of two time slots ($T_{slot} = 15360 * T_s = 0.5$ ms). The time slots in a radio frame a numbered from 0 to 19. In the frequency domain the number of orthogonal subcarriers, will depend on the available bandwidth. The subcarrier spacing $\Delta f$ is defined as 15 kHz, giving a symbol duration of $T_{symbol} = 1/\Delta f = 66.7$ µs. That implies a number of symbols per time slot, which depends on which of the two defined cyclic prefix is used. As explained in [2] the cyclic prefix is used in OFDM to make the symbol robust against the time-dispersive characteristic of the radio channel. Without the cyclic prefix the subcarriers might lose their orthogonality, at least partly, when they are transmitted. The length of the cyclic prefix is selected so, that it exceeds the maximum duration of time-dispersion expected to be experienced. An increase in the duration of the cyclic prefix reduces the system performance, which results in a trade-off between signal corruption due to time-dispersion and overall system performance. Since time-dispersion increases with cell-size, two cyclic prefixes are defined for LTE. The normal cyclic prefix is used for small-cell environments, whereas the extended cyclic prefix is used where an extreme time-dispersion is expected. For normal cyclic prefix use the number of available OFDM symbols in the downlink is 7, for extended cyclic prefix only 6 OFDM symbols are available.

***Table 1: Parameters for LTE FDD downlink frame structure type 1***

| Configuration | Number of symbols | Cyclic Prefix length in samples | Cyclic Prefix lengths in µs |
|---|---|---|---|
| **Normal Cyclic Prefix**<br>Δf = 15 kHz | 7 | 160 for 1st symbol<br>144 for other symbols | 5.2 µs for 1st symbol<br>4.7 µs for other symbols |
| **Extended Cyclic Prefix**<br>Δf = 15 kHz | 6 | 512 | 16.7 |
| **Extended Cyclic Prefix**<br>Δf = 7.5 kHz | 3 | 1024 | 33.3 |

This variation on cyclic prefix explains the varying the resource allocation for different users in the downlink. Resources for data and control information transmission in LTE are allocated in the form of resource blocks. A resource block is defined as the number of the subcarrier ($N_{sc}^{RB}$) and a number of OFDM symbols ($N_{symb}^{DL}$). 12 subcarriers are forming a resource block, giving an occupied bandwidth of 180 kHz in the frequency domain. As explained above, the number of OFDM symbols varies according to the cyclic prefix used. A subcarrier and an OFDM symbol form a resource element, mapping control information or data. Figure 1 shows the downlink resource grid.

*Figure 1: Downlink resource grid*




Depending on the assigned bandwidth, the number of subcarriers varies and so the number of resource blocks differs. The 3GPP specification defines the possible bandwidths resulting in the number of resource blocks shown in Table 2.

***Table 2: Number of resource blocks for different LTE bandwidths***

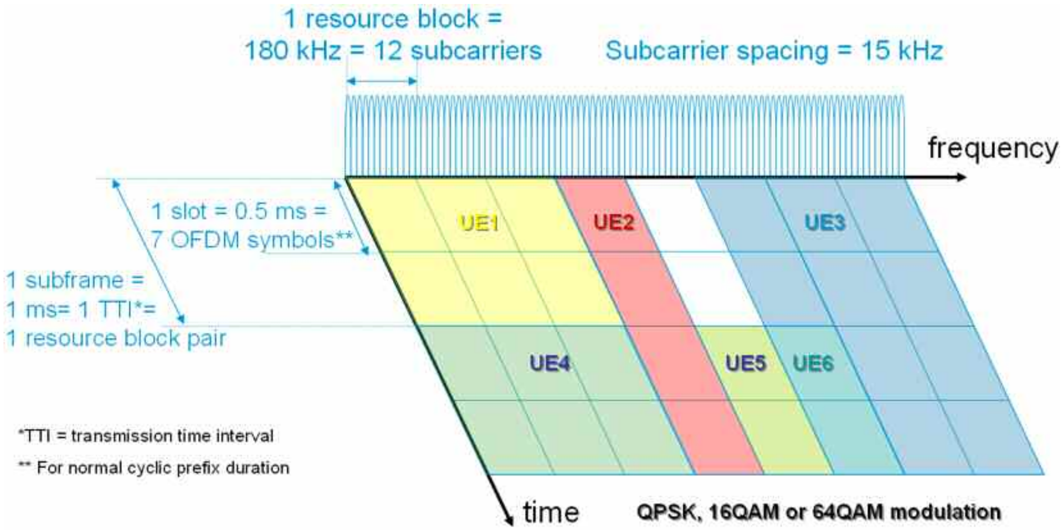
| Channel Bandwidth [MHz] | 1.4[1)] | 1.6[2)] | 3[1)] | 3.2[2)] | 5 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|
| **Bandwidth configuration (Resource Blocks)** | 6 | 7 | 15 | 16 | 25 | 50 | 75 | 100 |

[1)] only used for FDD mode

[2)] only used for TDD mode

With an occupied bandwidth of 180 kHz for one resource block at a given channel bandwidth of 10 MHz equal to 50 resource blocks, a transmission bandwidth of 9 MHz is required. The FFT size to generate the required subcarrier is 1024, where 600 subcarriers containing the 50 resource blocks. The remaining 424 subcarrier are used as 212 guard subcarrier preceding and following the resource blocks. One or more resource blocks are allocated to an UE; the allocation in the frequency domain can be modified every transmission time interval of 1 ms (= 1 sub-frame) in the time domain. The allocations are determined by the base station (enhanced Node B, eNodeB) based on various parameters, such as channel quality and traffic in the cell. Figure 2 shows an example for an allocation to six users.

*Figure 2: OFDMA time-frequency multiplexing for normal cyclic prefix*



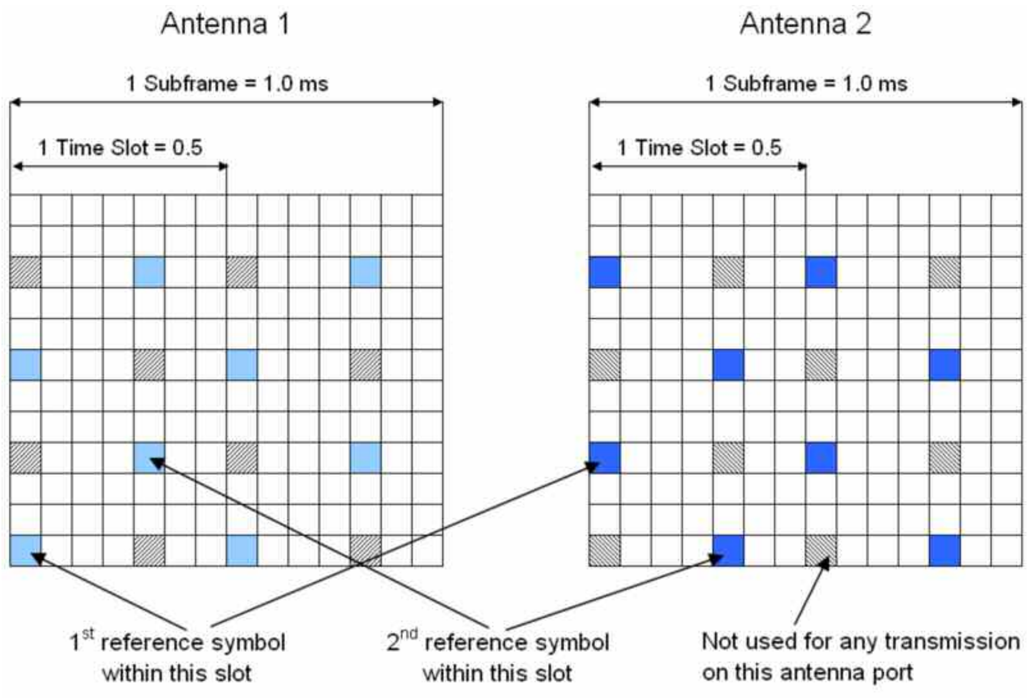

**Transmitting Control Information.** Before transmitting user data the receiver needs to be informed about the resources which have been allocated, and how the data to be sent is configured. This L1/L2 control information is transmitted on the Physical Downlink Control Channel (PDCCH). This QPSK-modulated channel occupies the first OFDM symbols of a subframe, where the number of symbols depends on the amount of information to be transmitted. This number varies between 1 and 4 symbols and depends on the frame structure (duplex mode), support of MBMS[1] and the available bandwidth [5]. The exact number of symbols is indicated by another downlink channel, the Physical Control Format Indicator Channel (PCFICH). This channel is also QPSK-modulated and is carried on specific resource elements groups (see Figure 1) in the first OFDM symbol of the subframe, depending on the assigned bandwidth as well as on the physical-layer cell identity. Four different formats of PDCCH are available, providing different numbers of bits to transmit control information – at maximum 576 bits. The kind of downlink control information is also divided into different formats, depending on which kind of information needs to be transmitted to the UE. Six formats[2] are defined [4], providing the ability to schedule uplink or downlink transmission, in compact, very compact, or with spatial multiplexing mode, as well as power regulation for the uplink physical channels. The Physical HARQ Indicator Channel (PHICH) another downlink physical control channel carries feedback for several UE's, whether a data packet was received by the eNodeB and subsequently decoded successfully. Beside these channels the Packet Broadcast Channel (PBCH) carries broadcast information and the Physical Multicast Channel (PMCH), carries MBMS user data.

[1] MBMS – Multimedia Broadcast Multicast Service;
to be specified with 3GPP Release 9

[2] DCI format 0, 1, 1A, 1C, 2, 3 and 3A

Higher layers provide the information to be transmitted for all these channels. In addition the physical layer itself generates signals, which are used for channel estimation and to demodulate user data (Downlink Reference Signal, DLRS) as well as for synchronization (Primary and Secondary Synchronization Signal, P-Sync und S-Sync). A basic principle of OFDM is that synchronization in both time and frequency is essential for coherent demodulation. Therefore DLRS are inserted in the first and fifth OFDM symbol of a time slot, with a spacing in the frequency domain of six subcarriers. Four reference signals are given per resource block, if only one antenna port is used. However, as the use of more antennas is planned – necessary to achieve the LTE targets for data rate and average user data throughput – more resource elements per resource block are reserved and blocked for DLRS transmission, but only four reference signals per resource block are transmitted identifying the antenna port. The DLRS are generated as a product of a pseudo-random sequence and an orthogonal sequence. In addition, frequency hopping can be applied to the DLRS with a period of one radio frame. Figure 3 shows an example for transmitting reference signals using two antennas.

***Figure 3: Downlink Reference Signals (DLRS) for 2 antenna ports***



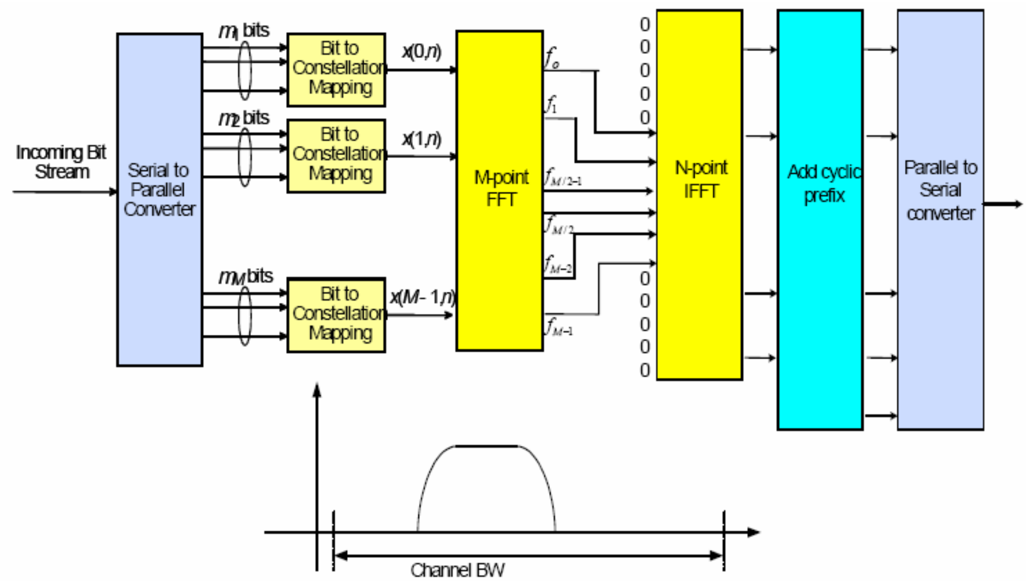

To simplify identification of symbol and radio frame timing, overall transmission bandwidth, antenna configuration and cyclic prefix length – all carried on the PBCH – two synchronization signals are transmitted; LTE uses a hierarchical cell search scheme similar to WCDMA. The primary synchronization signal transports the physical layer cell identity (0, 1 or 2). The secondary synchronization signal carries the physical layer cell identity group (0 …168). Both signals are transmitted twice per radio frame on the $6^{th}$ and the $7^{th}$ OFDM symbol of the first slot in the time domain. The repetition period is 5 ms. In the frequency domain the synchronization signals occupy 62 of the 72 reserved subcarrier equal to 6 resource blocks around the DC subcarrier.

**User data transmission.** The user data in the downlink is transmitted on the Physical Downlink Shared Channel (PDSCH), which one can be QPSK, 16QAM or 64QAM-modulated and is assigned to the remaining resource blocks.

## 2.2 SC-FDMA – Uplink Transmission Scheme

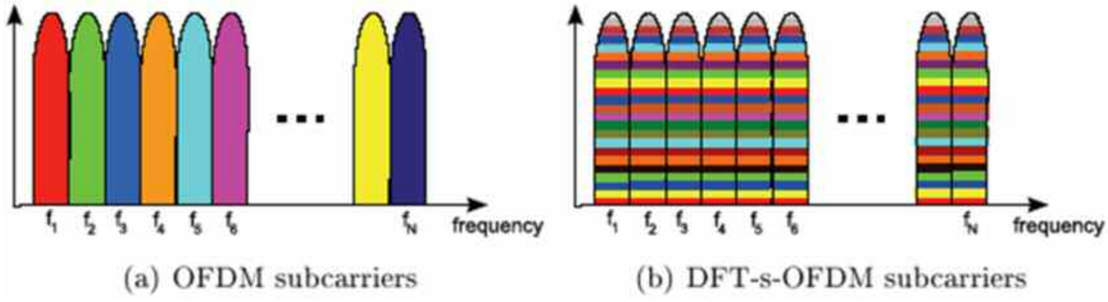
A major disadvantage for any communication system using OFDM as multiple access scheme is the high crest factor or peak-to-average power-ratio (PAPR) of the system. Using OFDM(A) in the uplink would greatly increase the uplink interference. Therefore a low-PAPR transmission scheme with flexible bandwidth assignment and orthogonal multiple access not only in the time domain but also in the frequency domain was a requirement to reduce uplink interference. The transmission scheme, best fulfilling these requirements and subsequently selected for the LTE uplink is Single Carrier FDMA (SC-FDMA). In SC-FDMA the technique used to generate the uplink signal is called Discrete Fourier Transformation-spread-OFDM (DFT-s-OFDM). The basic principle is shown in Figure 4.

***Figure 4: Block Diagram of DFT-s-OFDM (Localized Transmission)***




The major difference between the downlink and uplink transmission scheme is that each subcarrier in the uplink carries information about each transmitted modulation symbol ((b) in Figure 5), whereas in downlink each subcarrier only carries information related to one specific modulation symbol ((a) in Figure 5). The peak-to-average power-ratio is minimized and thus the uplink interference.

*Figure 5: Difference between OFDMA and SC-FDMA*




Resources for uplink transmission are also allocated based on resource blocks, using the same number of subcarriers, same time domain parameterization as in the downlink, but for normal and extended cyclic prefix only.

**User data transmission and control information.** The user data is transmitted on the Physical Uplink Shared Channel (PUSCH), which can be QPSK, 16QAM or 64QAM-modulated. When at the same time data is received on the downlink, the appropriate control information (ACK, NACK also scheduling requests) assigned to that transmission is multiplexed within the data to be sent on the PUSCH. When no data transmission is scheduled for the uplink, the feedback information is transmitted on a separate channel, the Physical Uplink Control Channel (PUCCH). This channel carries than the ACK/NACK and when the UE wants to transmit data the scheduling request. The UE is than informed on the PDCCH, which resources have been reserved for its data transmission. The other physical channel in the uplink is the Physical Random Access Channel (PRACH), which is used by the UE to enter the network first time based on a well-defined procedure.

Like the downlink also the uplink generates its own physical signals for the same purpose, independently from higher layers. The demodulation signals are used to demodulate the transmitted data properly, sounding reference signals are used to estimate the channel. The eNodeB can assign resources quickly at any time, when the UE requests resources for data transmission.

# 3 Equipment requirements

This application note describes the verification and validation of a LTE RF chipset using the R&S® SMU200A vector signal generator and R&S® FSQ signal analyzer. For specific parts of the application other R&S equipment can also be used. The following table shows which alternative R&S products are suitable for Tx and Rx verification.

***Table 3: Products to be used***

| R&S products | | TX Verification | RX Verification | TX and RX Verification |
|---|---|---|---|---|
| Signal Generators | R&S® SMU200A | ✓ | ✓ | ✓ |
| | R&S® SMJ | ✓ | ✓ | ✓ |
| | R&S® AMU200A | ✓ | × | - |
| | R&S® SMBV100A | ✓ | ✓ | ✓ |
| Spectrum Analyzers | R&S® FSQ | ✓ | ✓ | ✓ |
| | R&S® FSG | ✓ | ✓ | ✓ |
| | R&S® FSV | ✓ | ✓ | ✓ |
| | R&S® FMU | × | ✓ | - |

The following abbreviations are used in the following text for R&S® test equipment

- R&S refers to Rohde & Schwarz GmbH & Co KG,
- R&S® SMU200A Vector Signal Generator is referred to as SMU,
- R&S® SMBV100A Vector Signal Generator is referred to as SMBV,
- R&S® FSQ Vector Signal Analyzer is referred to as FSQ,

The following minimum configuration applies to SMU and FSQ.

*Table 4: Options and minimum firmware versions required for R&S instruments*

| R&S® FSQ, R&S® FSG | |
|---|---|
| **Firmware Version** | 4.45 (required for ACLR, SEM), 4.35 (FSQ), 4.39 (FSG) |
| **Hardware Options** | FSQ-B17 (Digital Baseband Interface) |
| **Software Options** | FS-K100 (LTE DL Analysis), FS-K101 (LTE UL Analysis), EUTRA/LTE Analysis Software 2.2 Beta 7 |
| **R&S® SMU200A** | |
| **Firmware Version** | 2.05.222.24 |
| **Hardware Options** | SMU-B17 (Analog/Digital Baseband Inputs), SMU-B18 (Digital Baseband Output) |
| **R&S® EX-IQ Box** | |
| **Firmware Version** | 00.00.13-143 |

# 4 RF chipset verification

## 4.1 Basics

For transmission the RF chipset determines a part of the layer 1 functionality in a wireless device, and consequently the IQ modulation/demodulation process, as well as the mapping onto the carrier frequency for the selected frequency band. Nowadays advanced RF chipsets from leading chipset manufacturers support almost all frequency bands for the appropriate standard. For LTE these are the same frequency bands as for 3G: band I - XIV for LTE FDD and the currently unused TDD bands for LTE TDD. Verification tests are executed for each of the supported bands, in early development stage very often multiple frequencies per band are tested, later in development this is reduced to three frequencies per band: low, mid and high, in order to save test time.

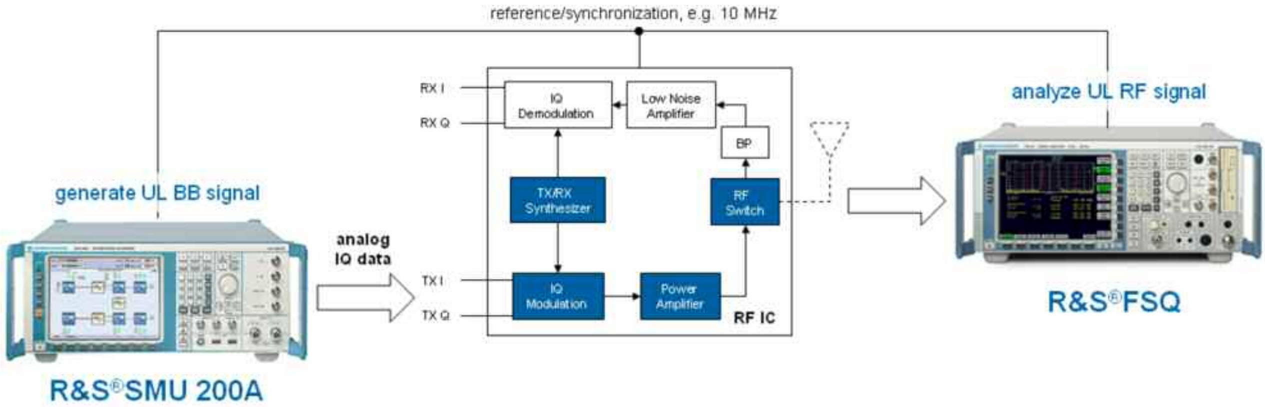
Additionally the tests for TX and RX are executed for three different temperature ranges, for example at -30°C, 25°C and 85°C, where either a temperature chamber is used or the RF chipset is cooled down directly. These tests at different temperatures are done to ensure the operability of the device within different climatic conditions.

In general the chipset itself is assembled on an adaptor board, which provides the necessary interfaces for feeding in the specific test signals (baseband or RF) and data ports for controlling the chipset. Controlling the chipset often requires a vendor-specific software tool or solution.

## 4.2 Tx verification

Figure 6 shows the general measurement setup for transmitter verification for a common RF chipset with the SMU and the FSQ.

***Figure 6: Uplink verification (Tx), simplified diagram***

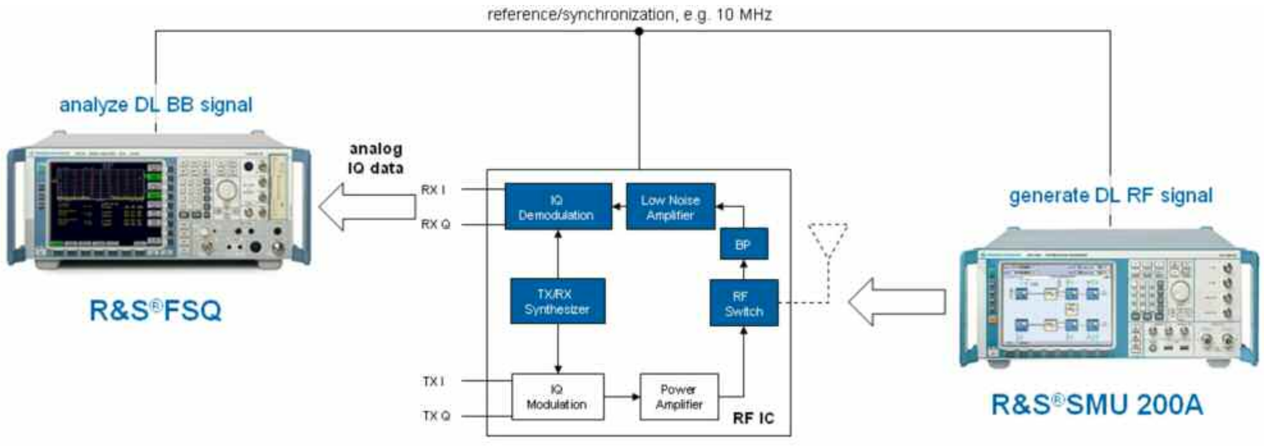



The SMU is used to generate an uplink baseband signal, which is then fed to the analog I and Q input for the RF IC normally located on an adaptor board. The remote controlled chipset provides the IQ modulation and amplification; meaning an up-conversion of the signal to an RF frequency so that it can be transmitted over the antenna. The signal from the antenna is directly connected to the RF port of the FSQ, where the uplink RF signal is measured and verified against the specified limits within the 3GPP specification. For the measurements, performed in general see chapter 6. This setup validates the complete transmitter chain. For specific transmitter component measurements such as on the synthesizer  the measurement setup changes.

## 4.3 Rx verification

On the RX side the SMU is used to generate an RF DL signal at a low output power fed into the antenna port of the adaptor board, which interfaces with the chipset. The chipset performs the amplification using a Low Noise Amplifier (LNA), demodulates the signal and splits the signal into an I- and Q-portion. The separated I- and Q-signal is then fed into the analog I and Q input of the FSQ, where the signal is analyzed. Figure 7 shows the required measurement setup.

*Figure 7: Downlink verification (Rx), simplified diagram*




This setup analyzes the complete receiver chain. For measurements on specific components, such as the LNA, the setup changes. The signals are than fed into the LNA, taken from the LNA and analyzed. Accessing specific components depends on the design and is very often customer specific.

## 4.4 About digital IQ

The method described above, using analog IQ data between the base band integrated circuit (BB IC) and the radio frequency integrated circuit (RF IC), is today's standard method for verifying both ICs. In the recent years several attempts have taken place to define a common digital interface between the BB and the RF IC. DigRF is such an attempt to define a digital serial interface standard for wireless devices.. Today there are two variants of the DigRF standard available DigRFv1.12 and DigRFv3.09, which one is not backward compatible[3]. The standardization for DigRF, which is driven by an industry alliance called MIPI, focuses on the physical interface and the protocol running on this interface. The protocol configures the interface itself and arranges the transport of the digital data between both circuits. For the physical layer parameters, depending on the supported air interface standard, like data rate, system clock speed, as well as pin usage are defined.

The benefits of a digital instead of an analog interface between the chipsets are:

- Less susceptibility to interference,
- Providing higher bandwidths/data rates,
- “Plug & Play” configurability,
- Interoperability between BB and RF ICs of different vendors,
- Easier and cheaper implementation (further cost reduction),

[3] DigRFv1.12 supports 2.5G standards (GSM, EGPRS); DigRFv3.09 supports 2.5G as well as 3G/3.5G standards (WCDMA/HSPA)

- Lower power consumption,

LTE specifies requirements such as higher data rates and a higher average user data throughput, high spectrum efficiency, using scalable bandwidths and MIMO principles. The DigRFv3.09 standard is not capable of supporting these challenging parameters, so for advanced technologies like LTE and WiMAX one more standard is currently under preparation: DigRFv4. Today[4] the specification of this standard is, like LTE, not completely finished. The protocol running on the physical interface is at the moment still a working item in the standardization process. A harmonization is expected for first half of 2009, although a first draft of the specification is available since November 2008. Due to the delays several companies, developing chipsets for LTE are going to use their own digital IQ format for now.

## 4.5 Changes on RF chipset validation with digital IQ

The emerging use of digital IQ data between the BB and RF IC for LTE has made a big impact on the overall measurement setup. Up to now the digital baseband signal has been converted by the signal generator into an analog base band signal, often differential, and were fed using standard BNC connectors into the analog I and Q inputs of the adaptor board carrying the RF chipset. On the reverse direction the output of the RF chipset was analog I and Q signals, which have been fed into the analog base band input of a signal analyzer. In a device the baseband chipset handles the analog-digital and digital-analog conversion. With digital IQ, this conversion will be done at the RF IC, so that the signals between BB IC and RF IC become digital.

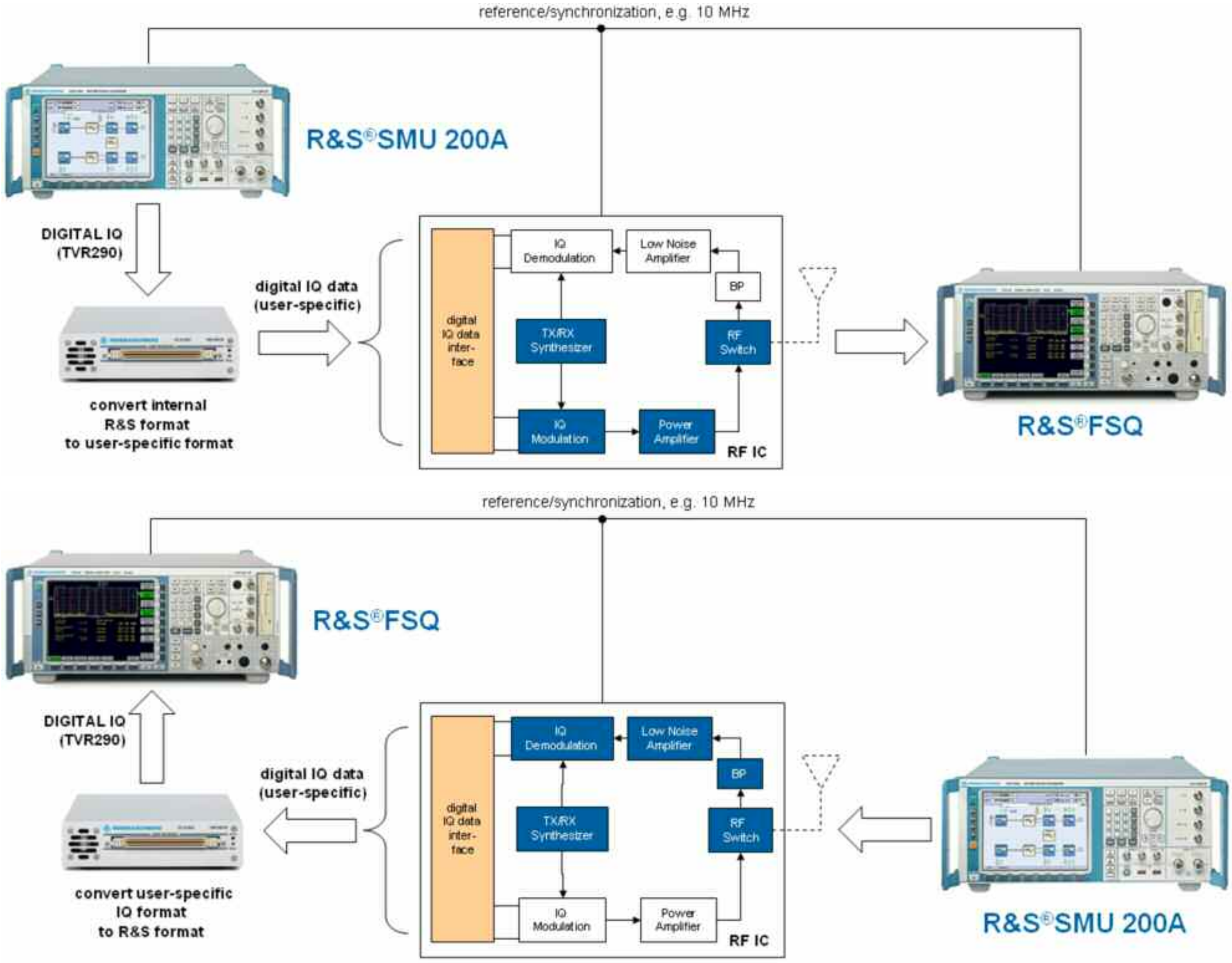
As there is currently no common digital interface standard that covers all applications, R&S uses its own, internal format to provide digital I/Q signals. This standard is referred to as DIGITAL IQ (TVR290). Via this interface standard R&S instruments, like the SMU and FSQ, can be connected directly to each other. However TVR290 can only be used between R&S equipment. To connect to equipment from other manufacturers using different digital IQ standards the R&S EX-IQ Box has been developed. With the EX-IQ Box the R&S internal format can be converted to digital I/Q formats as they are used today in the market for handsets as well as for base stations. The adaptation to customer-specific physical connectors is provided by break-out boards (see Figure 8). R&S provides support to design break-out boards suitable for other manufacturers equipment.

[4] as of October 2008

***Figure 8: R&S® EX-IQ-Box shown with AMU convert R&S internal IQ data to different digital formats***


With the help of the EX-IQ Box the radio frequency and baseband components of the device can be tested using a digital interface, not the interface itself. For TX validation of a LTE-capable RF chipset using a digital IQ format, the EX-IQ-Box is connected to the digital baseband output of the SMU (HW option SMU-B18). The output of the EX-IQ-Box is connected directly to the interface of the RF IC, feeding in the digital I- and Q-Signal. The RF IC does the digital-analog-conversion, IQ modulation with up-mixing to the RF frequency. The RF portion of the uplink signal can now be analyzed with an FSQ or FSG. Similarly the down-converted, digitized RF downlink signal is converted by the EX-IQ Box from the user-specific digital IQ format to the R&S format. This is fed into the digital baseband input of the spectrum analyzer (FSQ-B17), where the signal analysis is than executed. An appropriate measurement setup for both applications is shown in Figure 9.

*Figure 9: Tx and Rx verification with EX-IQ Box*



# 5 Reference Measurement Channels for 3GPP LTE

WCDMA (3GPP Release 99 and 4) successfully introduced reference measurement channels (RMC) for downlink and uplink to fix the variable parameter and ensure reliable and repeatable measurements. This proven strategy has continued with HSDPA and HSUPA. Fixed Reference Channel Handsets (FRC H-Set) for the specific UE categories have been defined for the downlink. For the uplink specific combinations of several parameters[5], which the majority of transmitter measurements based on, have been specified. Only for specific test cases, mainly at the receiver side, other signal configurations need to be applied to the device under test. This will continue now also with LTE. Flexible parameters for the downlink and uplink, such as bandwidth, number of allocated resource blocks, used modulation schemes and number of transmitting and receiving antennas will be fixed for test purposes. This applies to both link directions, uplink and downlink as well as for both modes: FDD and TDD. For FDD the downlink reference measurement channel for the UE is specified. For the uplink, so far no proposal has been supplied to 3GPP. Nevertheless it is expected, that the basic parameters as proposed for the downlink will also be considered for the uplink. The following table shows today's status.

For the LTE TDD reference measurement channel no proposal has been made for downlink or uplink.

[5] Gain factors $ß_c$ and $ß_d$ for HSDPA and HSUPA; Cubic Metric (CM), Maximum Power Reduction (MPR) for HSDPA and HSUPA and Absolute Grant Value and E-TFCI for HSUPA

*Table 5: LTE Reference Measurement Channels for Downlink and Uplink (FDD 10 MHz*

| Parameter | Unit | Downlink | Uplink |
|---|---|---|---|
| **Channel bandwidth** | MHz | 10 | 10 |
| **Allocated Resource Blocks (RB)** | Blocks | 50 | tbd |
| **Subcarrier per RB** | | 12 | 12 |
| **Allocated subframes per Radio Frame** | | 10 | 10 |
| **Modulation** | | QPSK | QPSK |
| **Coding Rate** | | 1/3 | 1/3 |
| **Number of HARQ processes** | | 8 | tbd |
| **Maximal number of HARQ transmissions** | | 1 | tbd |
| **Information bit payload** | | | |
| **Sub-frames 1,2,3,4,6,7,8,9** | Bit | 4392 | tbd |
| **Sub-frames 0** | Bit | 4392 | tbd |
| **Sub-frames 5** | Bit | 4392 | tbd |
| **Transport block CRC** | Bit | 24 | tbd |
| **Number of code blocks per subframe** | | 1 | tbd |
| **Code block CRC size** | Bit | 0 | tbd |
| **Binary channel bits per subframe** | | | |
| **Sub-frames 1,2,3,4,6,7,8,9** | Bit | 13800 | tbd |
| **Sub-frames 0** | Bit | 12960 | tbd |
| **Sub-frames 5** | Bit | 13512 | tbd |
| **Max. throughput averaged over 1 frame** | kbps | 4392 | tbd |

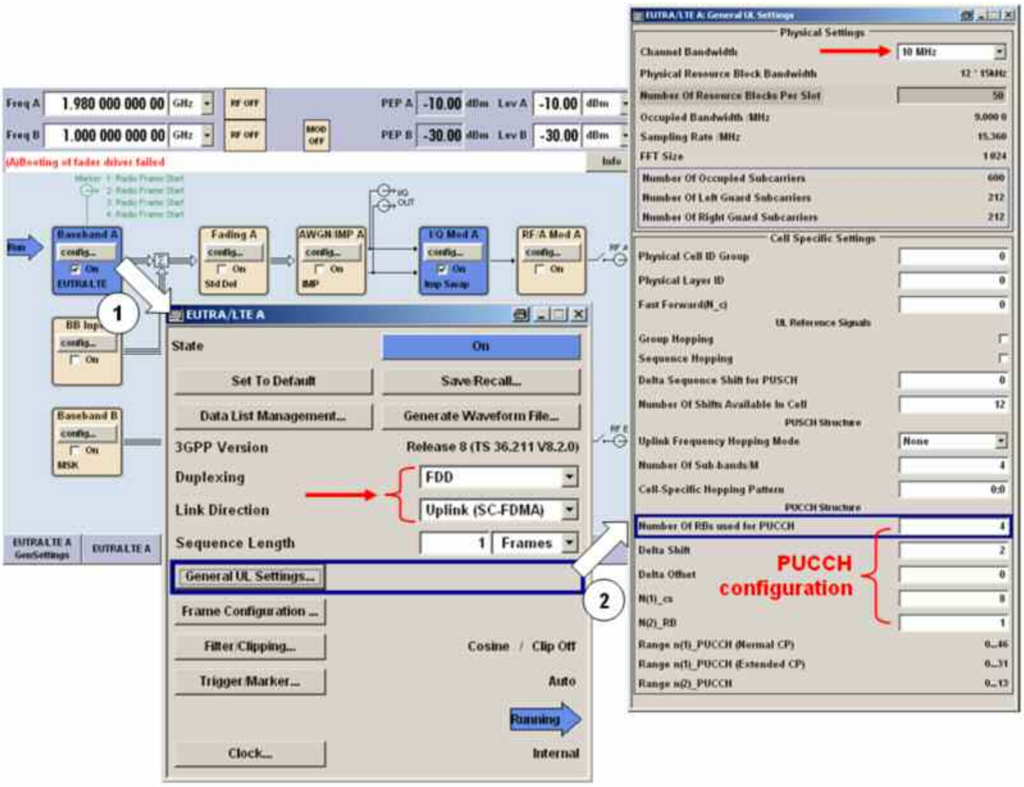
The SMU can already generate appropriate uplink and downlink reference measurement channels based on the table above and the current specification. Configuring the SMU to generate and preparing the FSQ to analyze these kind of signals is described in the next sections.

# 6 Transmitter verification; settings and measurements

## 6.1 LTE uplink signal generation with SMU

Before the bandwidth, resource blocks and number of subcarriers according to Table 5 can be selected the duplex mode and link direction needs to be set.

***Figure 10: Basic configuration for a LTE uplink signal as a reference measurement channel***

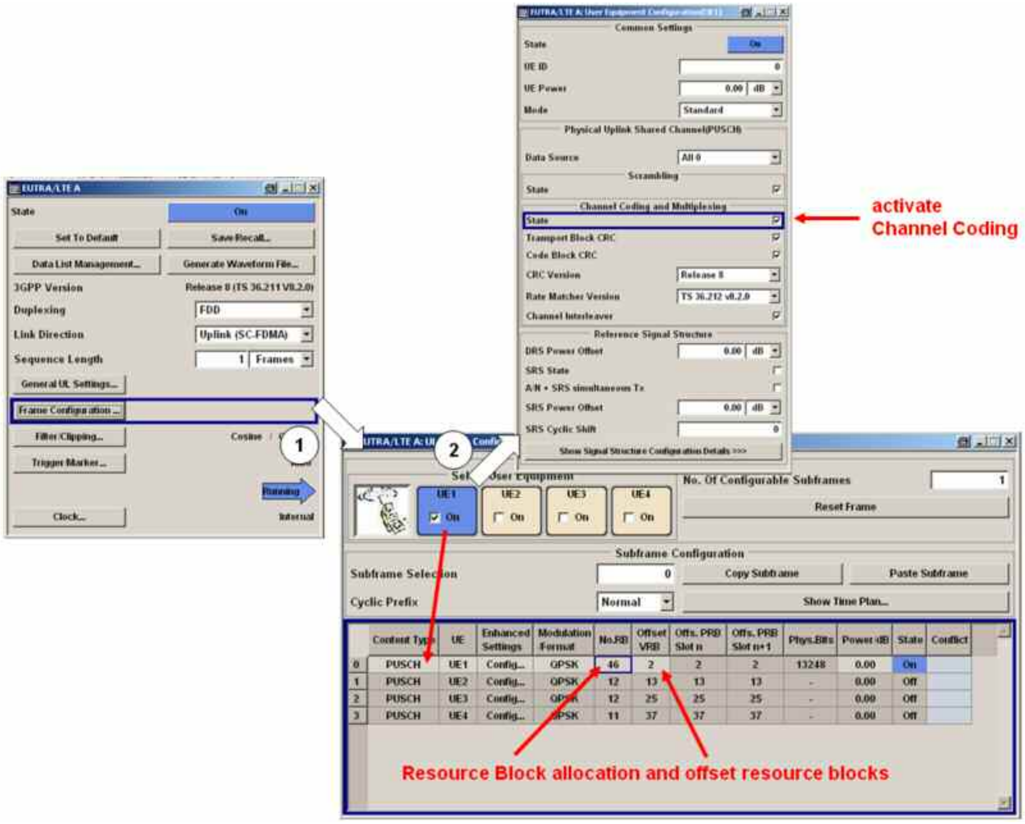



At the moment no proposal has been presented to 3GPP for an uplink reference measurement channel for LTE FDD. Nevertheless the principle used for WCDMA can be adopted for LTE, by mirroring the downlink parameters. For WCDMA a 12.2 kbps reference measurement channel was defined for downlink and uplink. Thus the general parameters for the LTE downlink, such as bandwidth, modulation scheme and antenna can be adopted to the uplink for LTE as well, as covered in Table 5. To provide a practical scenario with this measurement channel the following standard and technology-related things need to be considered. User data in the uplink is carried by the Physical Uplink Shared Channel (PUSCH). If there is a parallel downlink transmission the feedback information from the HARQ process, the channel quality (CQI) as well as scheduling requests, are multiplexed with the user data onto this physical channel. When there is no uplink transmission granted to the user, control information is transmitted on a separate channel; the Physical Uplink Control Channel (PUCCH). This channel will be also used by other UEs for transmitting control information. In practice, this physical channel is most probably present at any time and will block resources, which can not be allocated to the device under test. A look at the mapping of the PUCCH to the available resources is therefore essential to understand the setup of the SMU and the configuration of FSQ.

The structure of the PUCCH can also be set in the configuration window. Per definition the PUCCH has multiple formats, six in all [4]. The use of these formats depends on the type of uplink control information to be sent. The cyclic prefix used (normal or extended cyclic prefix) has an impact on the format too. Given a channel bandwidth of 10 MHz, 50 resource blocks, equal to 600 subcarriers are available for control information and data transmission. In the time domain two resource blocks per time slot are for example assigned to carry the PUCCH, which means two resource blocks per subframe. To transmit this resource blocks a frequency region is reserved, which is located at the edge of the available bandwidth. The first resource block uses the lower edge of the spectrum, the second one uses the upper edge of the spectrum. This minimizes the effects of a possible frequency-selective fading affecting the transmission channel. Depending on the format used, this principle might be reversed, so that the first resource block uses the upper edge of the spectrum, and the second one uses the lower part. As a consequence not all 50 resource blocks of a 10-MHz channel can be assigned to an UE for data transmission. Instead just 46 are allocated in this example to the UE, giving an offset of two resource blocks (see Figure 11) at each side of the available bandwidth.

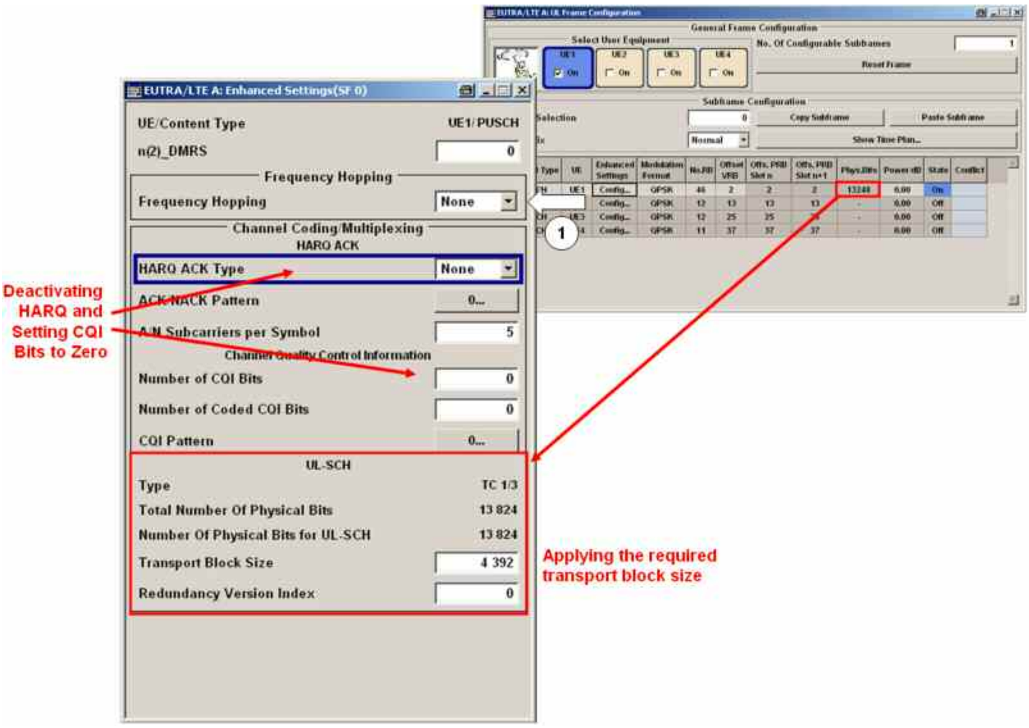
By selecting the appropriate button another window will appear, enabling the user to configure up to 4 UE’s. For this scenario the configuration of just one UE is necessary, as the signal generator is used to simulate the BB IC.

***Figure 11: Allocating resources for PUSCH transmission, activating channel coding***




Selecting QPSK modulation for PUSCH and assigning 46 resource blocks with an offset of 2 resource blocks gives 13.248 physical bits per subframe for transmission (see Figure 12). Not all bits can be used for data transmission, as channel coding needs to be applied to the data. Via enhanced settings the transport block size can be defined. Taking into account that the UL reference measurement channel is not yet specified, the transport block size is set to 4392 bits as for the DL reference measurement channel (see Table 5).

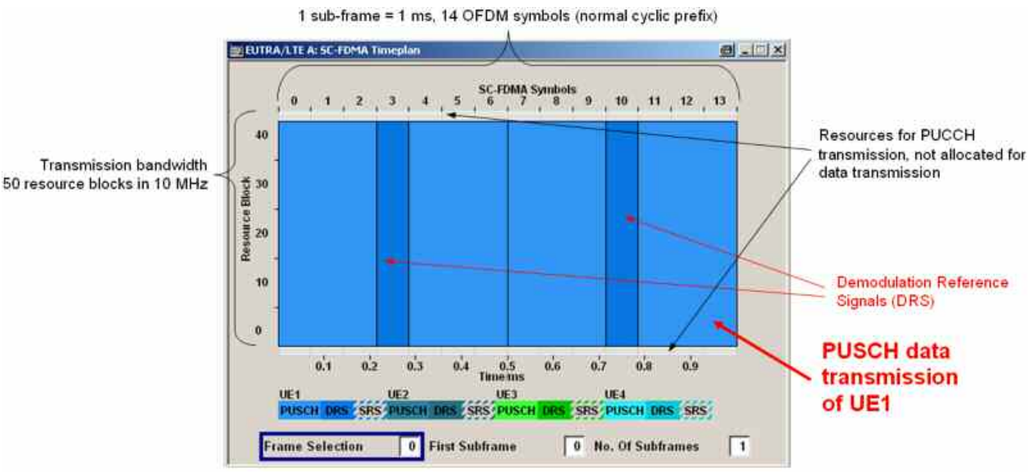
*Figure 12: Define the Transport Block Size (TBS)*




In addition – so that all available bits are used for data transmission – the HARQ ACK(knowledge) Type must be set to 'None' as well as the Number of CQI Bits needed is set to zero.

The configuration of the uplink reference measurement channel is now finished, a final look at the SC-FDMA time plan shows the allocated resources and required physical signals.

*Figure 13: SC-FDMA time plan for the uplink*



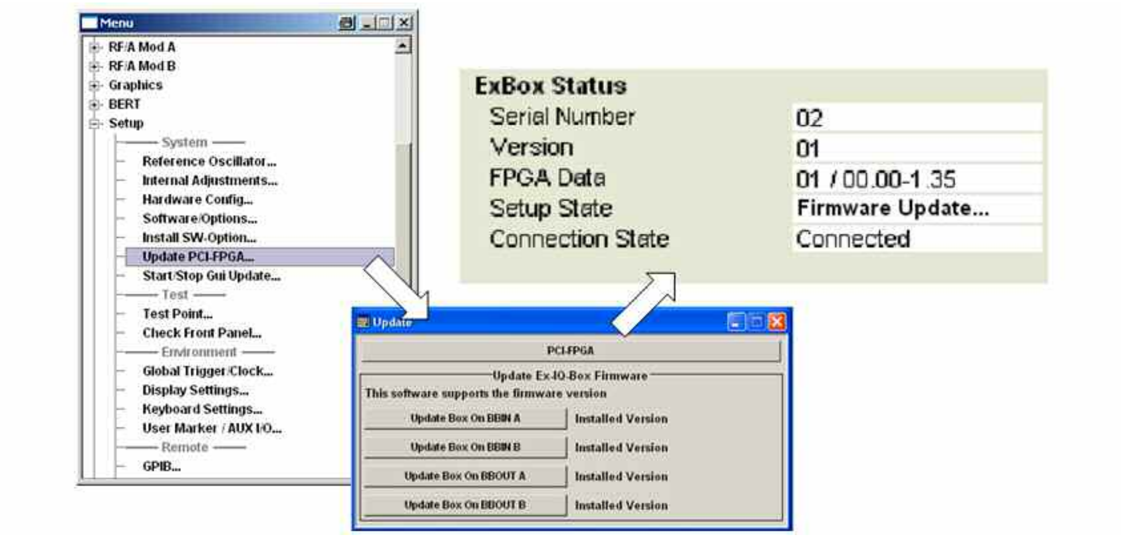

Before switching on the generator, the output as digital IQ data via the Ex-IQ-Box needs to be configured.

## 6.2 Configuring the EX-IQ-Box in conjunction with the SMU

It is expected that the majority of LTE-capable RF IC will use DigRFv4 interfacing the BB IC, when the standard becomes available in 2009. Currently several companies use their own, manufacturer-specific digital IQ formats. Mostly there are differences in data word size and length. This section describes how to configure the EX-IQ-Box in a general way.

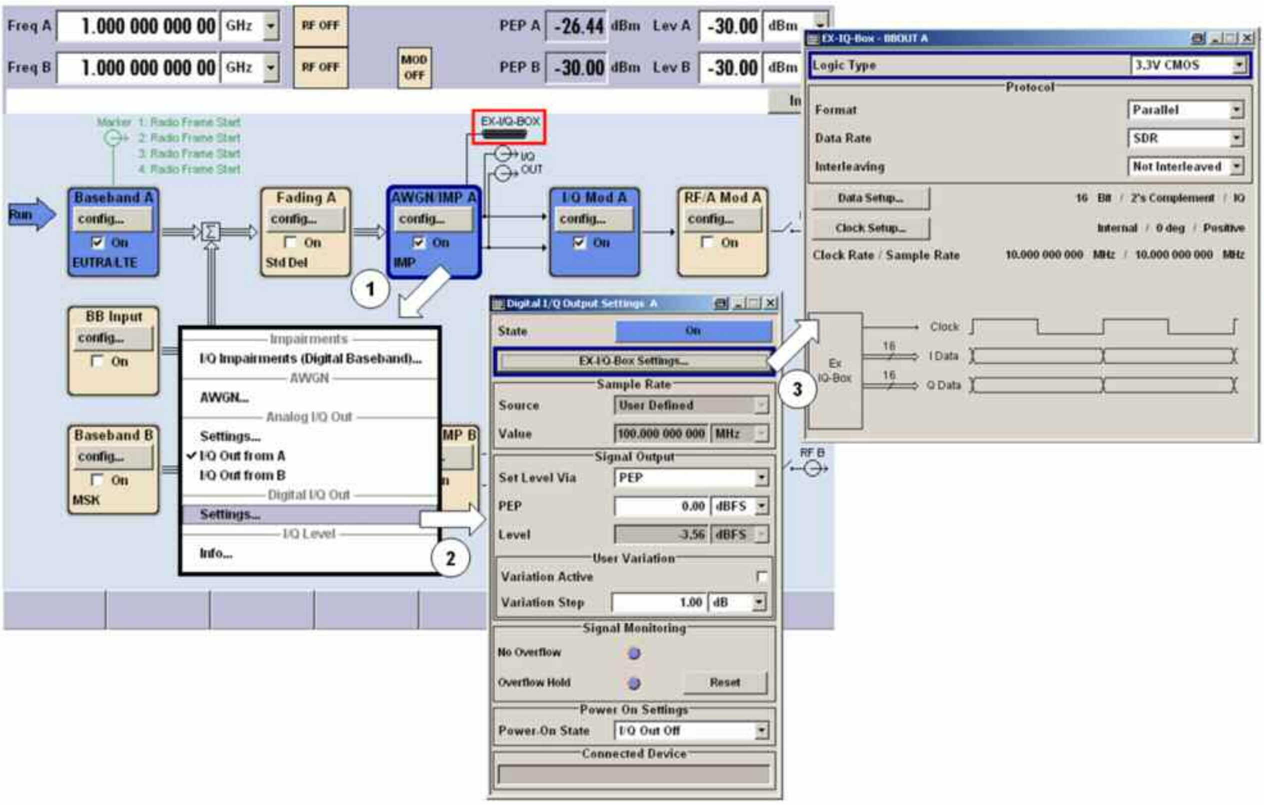
The EX-IQ-Box is automatically recognized by the SMU. The generator will display an appropriate icon on the screen, depending on the interface, the box is connected too. The EX-IQ Box needs to be configured as digital IQ output. Before configuring the EX-IQ-Box, check and if necessary update the firmware. The update is performed by the connected R&S instrument in this case the SMU. Choose Menu → Update PCI-FPGA and select the EX-IQ-Box to be updated.

*Figure 14: Updating the EX-IQ-Box might be required*




After the firmware check, the digital IQ output can be configured by selecting the appropriate functional block “AWGN/IMP A”, going to section “Digital I/Q Output” and selecting “Settings…” (see Figure 15). By choosing the appropriate button the EX-IQ-Box output can be configured for the desired digital IQ.

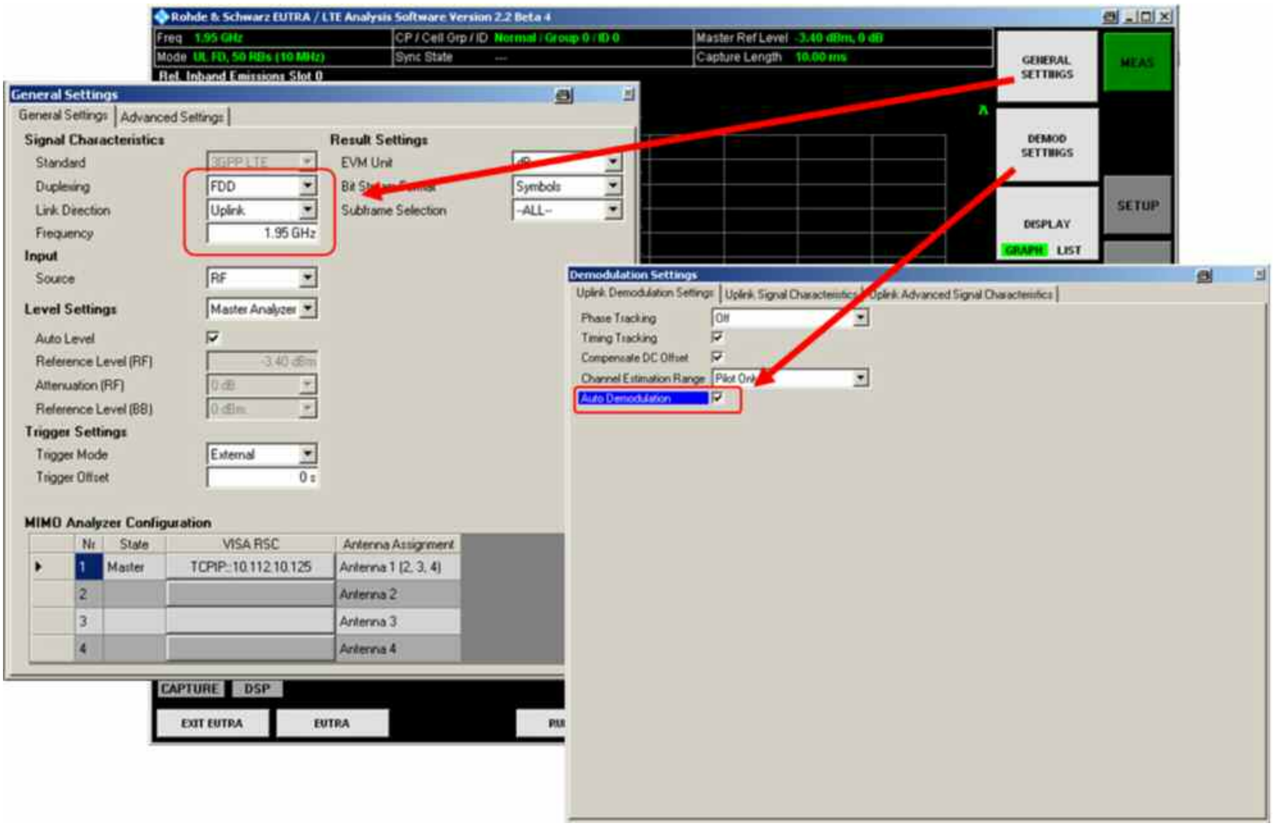
*Figure 15: Automatic recognition and manual configuration of the EX-IQ-Box*




## 6.3 FSQ settings for Tx verification

All measurements, described in more detail in the following paragraphs, are executed for an uplink signal generated by the SMU. The FSQ must also be set up. The FSQ provides in the “Uplink Demodulation Settings” a check box, where “Auto Demodulation” can be selected. The information to demodulate the signal are extracted from the signal itself. With help of the general setting tab, shown in Figure 16, the LTE duplex mode, link direction, and frequency needs to be defined.

***Figure 16: General and demodulation settings for the FSQ (UL, 10 MHz FDD)***



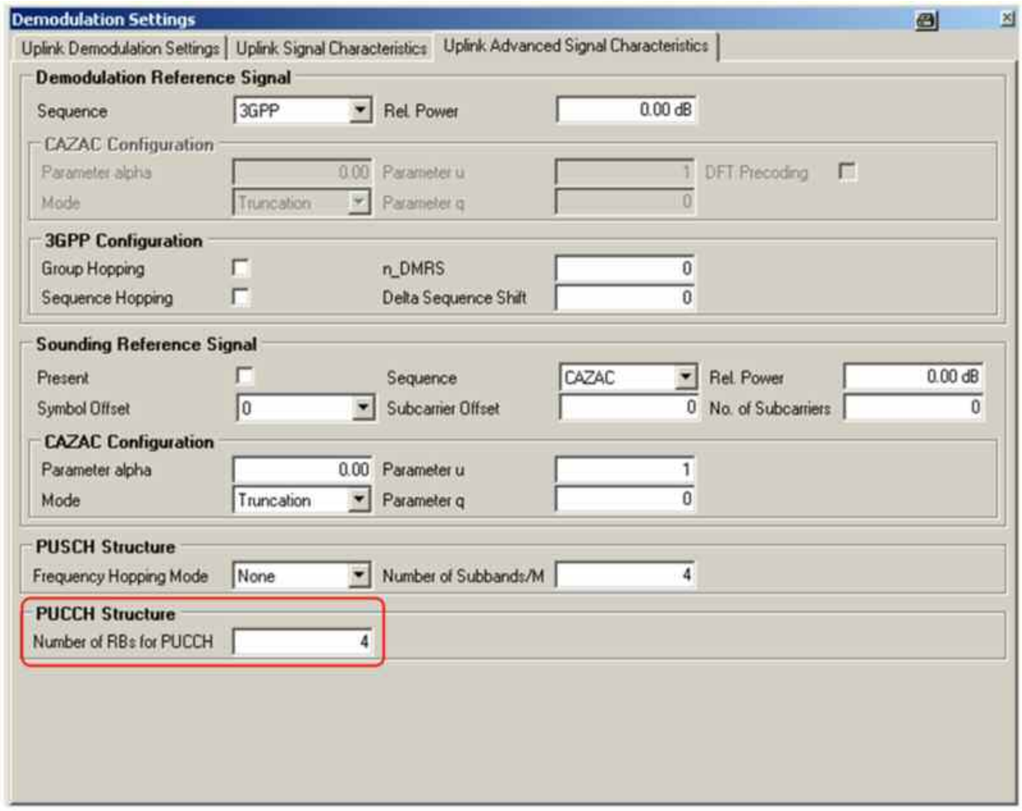

In [6] the frequency bands supported by LTE are defined; the same as used for WCDMA/HSPA transmission. [7] defines for each frequency band the frequencies to be tested, based on the selected bandwidth. Assuming the RF IC under test supports frequency band I, the channels to be tested can be extracted from the following table.

***Table 6: Test frequencies for E-UTRA channel bandwidth for operating band I [7]***

| Test range | BW [MHz] | $N_{UL}$ | Frequency UL [MHz] | $N_{DL}$ | Frequency DL [MHz] |
|---|---|---|---|---|---|
| Low | 5 | 13025 | 1922.5 | 25 | 2112.5 |
| | 10 | 13050 | 1925 | 50 | 2115 |
| | 15 | 13075 | 1927.5 | 75 | 2117.5 |
| | 20 | 13100 | 1930 | 100 | 2120 |
| Mid | 5/10/15/20 | 13300 | 1950 | 300 | 2140 |
| High | 5 | 13575 | 1977.5 | 575 | 2167.5 |
| | 10 | 13550 | 1975 | 550 | 2165 |
| | 15 | 13525 | 1972.5 | 525 | 2162.5 |
| | 20 | 13500 | 1970 | 500 | 2160 |

The advanced uplink signal characteristic (see Figure 17), which includes defining the resource for the PUCCH has a big impact on the subframe configuration.

***Figure 17: Uplink Advanced Signal Characteristics***



In the example for the uplink reference measurement channel 4 resource blocks are allocated for PUCCH transmission. This allocation will be reflected by the subframe configuration, where for a 10 MHz bandwidth with 50 resource blocks only 46 resource blocks are allocated for PUSCH transmission with an offset of two resource blocks on both ends of the spectrum.

## 6.4 General measurement aspects

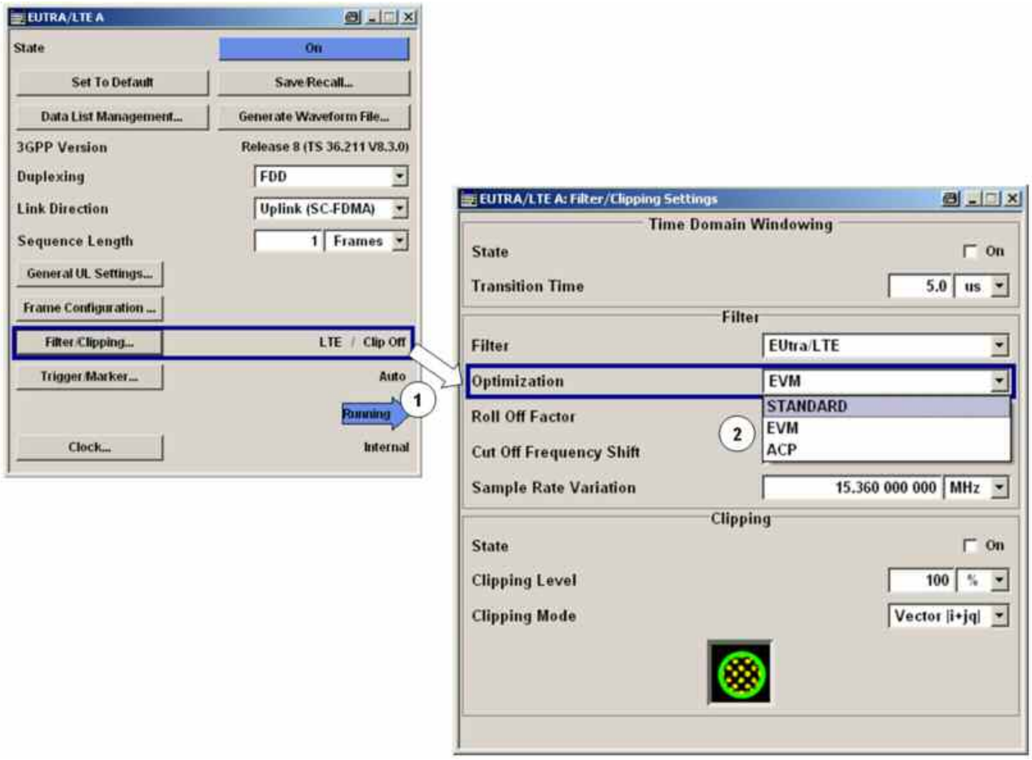
One of the major differences between CDMA-based 3G/3.5G technologies and OFDM-based LTE is the lack of a definition for a transmission filter. In WCDMA/HSPA a Root-Raised-Cosine (RRC) filter with a roll-off factor of α = 0.22 is specified by the standardization body 3GPP. The use of this filter increases the signal bandwidth of 3.84 MHz to a transmission bandwidth of 4.68 MHz. It also explains, why a channel bandwidth of 5 MHz is necessary to achieve the required out-of-channel performance for not disturbing adjacent channels.

For LTE no filter is specified. This has the advantage that the filter can be optimized for in-channel performance or out-of-channel performance. Improving the in-channel performance, meaning the modulation quality, results in an improved Error Vector Magnitude (EVM). Out-of-channel performance is evaluated by measuring Adjacent Channel Power (ACP) and Spectrum Emission Mask (SEM). Rohde & Schwarz is addressing the open filter definition by offering three different filter types especially designed for EUTRA/LTE. As indicated by the name, two of these filters are designed to improve the in-channel (EVM) or the out-of-channel performance (ACP). The third filter is a trade-off between in-channel and out-of-channel performance with good ACP and acceptable modulation quality (STANDARD[6]).

As shown in Figure 18 the filter, which is applied to the signal, can be selected via the filter/clipping button.

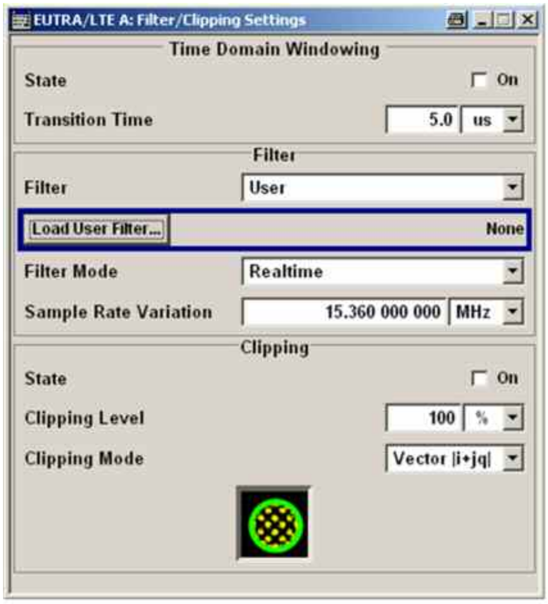
[6] The notation 'STANDARD' does have no relationship with the 3GPP specification

*Figure 18: Selecting a specific filter type for LTE*




Beside these supplied filters all R&S signal generators support user-specific filtering to the signal (see Figure 19).

*Figure 19: User-specific filtering*



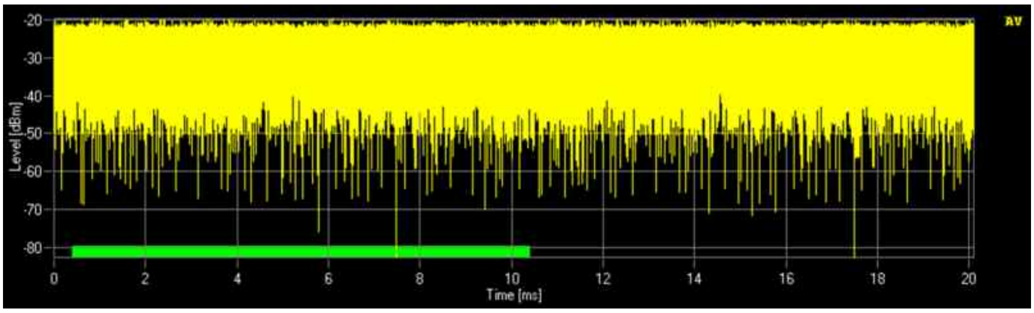
**Note:** In the remainder of section 6 use the STANDARD filter unless another filter is shown.

## 6.5 TX measurements

### 6.5.1 RF output power

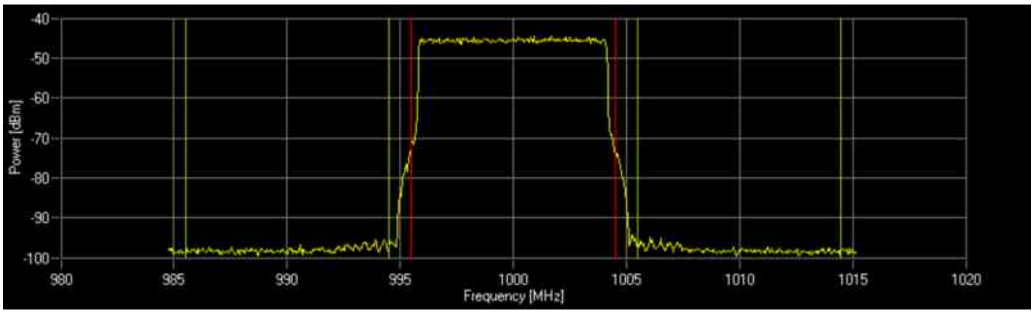
A first step in verification is to measure the exact output power of the RF IC. The output power is measured and recorded for different gain factors for the power amplifier in the transmitter chain. Another method to measure the power is to use the result summary, where the frame power for the physical channel, demodulation reference and sounding signals are displayed (see Figure 26).

***Figure 20: Power versus time (UL FDD, 10MHz), filter: STANDARD***



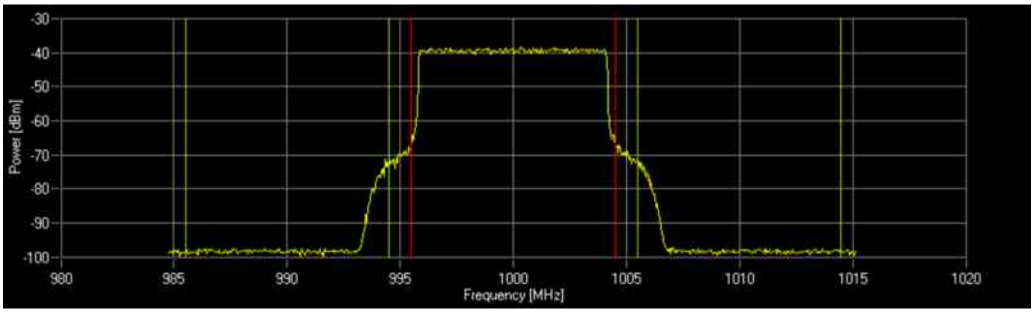

Different signal shapes can be seen, depending on the filter used. The following three example screenshots (Figure 21 to Figure 23) showing the impact of the three different filter types used in the SMU, on the shape of the uplink signal. Figure 21 shows the impact of the filter STANDARD.

***Figure 21: Power versus frequency (UL FDD, 10MHz), filter: STANDARD***



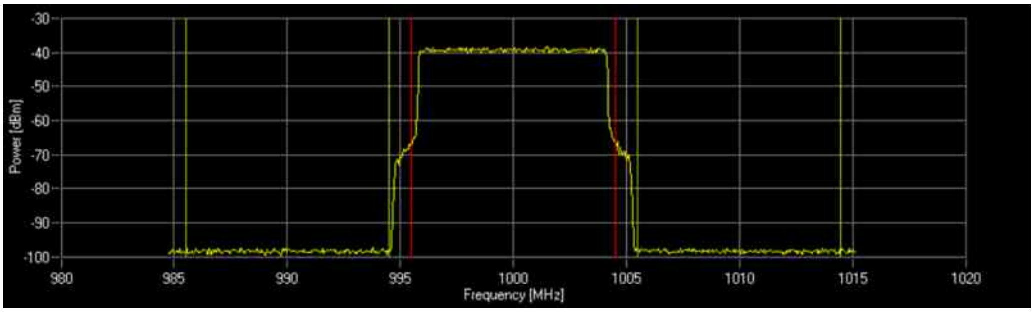

The default values for the EVM-optimized filter are a roll-off factor of α = 0.10 and a cut-off frequency shift of -0.20.

*Figure 22: Power versus frequency (UL FDD, 10MHz), filter: EVM*




The filter optimized for ACP uses a cut-off frequency shift of 0.34.

*Figure 23: Power versus frequency (UL FDD, 10MHz), filter: ACP*




As show in Figure 22 compared to Figure 23 the signal is falling off more smoothly, which is resulting in much better EVM performance. The strong filtering applied to the signal by using the ACP filter (Figure 23) will decrease modulation quality, but improves the ACP and minimizes therefore the impact to other channels or signals.

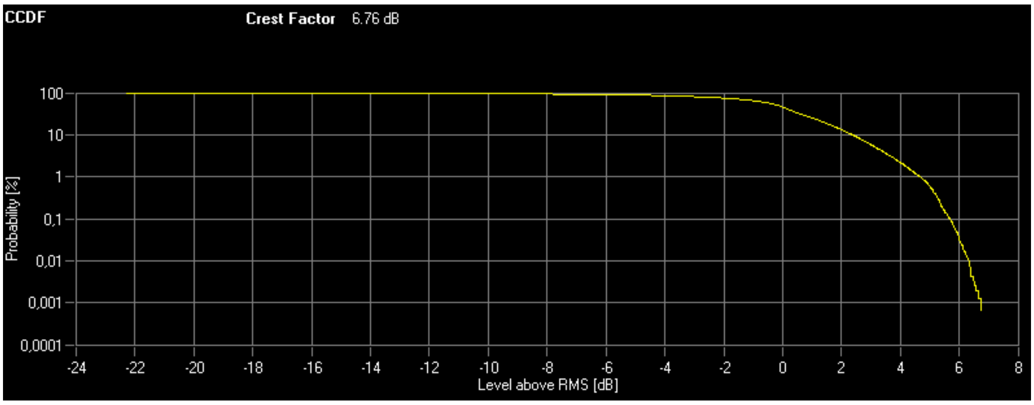
### 6.5.2 Peak-average-power ratio, using CCDF[7]

SC-FDMA is used in the uplink to overcome one of the disadvantages of OFDM: the high peak-to-power average ratio (PAPR). With SC-FDMA a Discrete Fourier Transform (DFT) is performed, before the Inverse Fast Fourier Transform (IFFT. The modulation symbols are spread, so that each subcarrier is carrying a part of each modulation symbol. In OFDM(A) each subcarrier is carrying a specific symbol per subcarrier (see Figure 5).

The PAPR is estimated by calculating the Conditional Cumulative Distribution Function (CCDF), which describes the probability distribution of the signal power.

[7] CCDF – Conditional Cumulative Distribution Function

*Figure 24: Peak-to-average power ratio, estimated with CCDF (UL, 10 MHz FDD), filter: STANDARD*




The PAPR depends on the filter used as well as on the modulation format, in contrast to the downlink, where OFDM(A) is used as transmission scheme.

### 6.5.3 Frequency Error & Transmit Modulation

**Frequency Error.** The frequency error should be in the range of ±0.1 ppm[8] depending on the carrier frequency. For the LTE frequency range the frequency error can differ between ±77.7 and ±198 Hz, depending on the frequency band used. Compared to UTRA FDD, using the same frequency bands, these are tighter tolerances, meaning a higher demand on accuracy. The frequency error is displayed in the numeric overview of the measurement results (see Figure 26) and can be displayed for each subframe separately.

**Error Vector Magnitude vs. subcarrier.** There is a major dependency between the Error Vector Magnitude (EVM) and the phase noise of the voltage controlled oscillator (VCO) used in the IQ modulator of the device. Exceeding the limits for EVM, depending on the selected modulation scheme is an indication for a high phase noise, generated by the VCO and the Phase Locked Loop (PLL) controlling the VCO. Nonlinearities of components used in the device can also negatively affect the EVM. Evaluating the spectrum emission mask (SEM) will prove, whether the phase noise (only EVM fails) or nonlinearities (EVM and SEM – both are failing) are causing the problem. The estimation of EVM is an essential feature for proving the modulation quality for any single carrier transmission schemes using a digital modulation scheme. EVM measurements have been performed on devices since the introduction of 8PSK as modulation format with the upgrade of the 2G networks to Enhanced GPRS (EGPRS), later termed Enhanced Data Rates for Global Evolution (EDGE). In an EVM measurement the received signal is compared to a well-defined reference signal; the difference results in an error vector. The magnitude of the error vector should not exceed predefined limits to avoid errors in demodulating the signal.

So far all cellular standards are use single carrier transmission schemes, with only one signal analyzed to estimate the modulation quality. With LTE multi-carrier transmission schemes are used in downlink and uplink, with the number of orthogonal subcarriers dependent on the allocated resource blocks or transmission bandwidth, rather the

[8] ppm – parts per million

available channel bandwidth. For each of these subcarriers the EVM is estimated, depending on the modulation scheme used (QPSK, 16QAM or 64QAM). The measured values are compared against defined limits, which are 17.5% for QPSK and 12.5% for 16QAM. For 64QAM a tolerance of 8%, as for the downlink is under consideration. While 8% is portable the definition is open and awaiting a future version of the specification.. The support of 64QAM in the uplink is furthermore an optional feature for an LTE-capable UE, depending on the UE category. Figure 25 shows the graphical result for the EVM versus subcarrier measurement for a 10 MHz FDD uplink signal as peak, average and minimum value (blue, yellow, green curves). The x-axis shows the frequency, from where the occupied bandwidth can easily be estimated. The allocated 46 resource blocks are equal to 552 subcarriers, which gives a transmission bandwidth of 8.28 MHz (±4.14 MHz). The maximum and minimum EVM, based on the average curve, are highlighted as a numeric value for the affected subcarriers.

***Figure 25: EVM versus subcarrier (UL FDD, 10 MHz), filter: STANDARD***

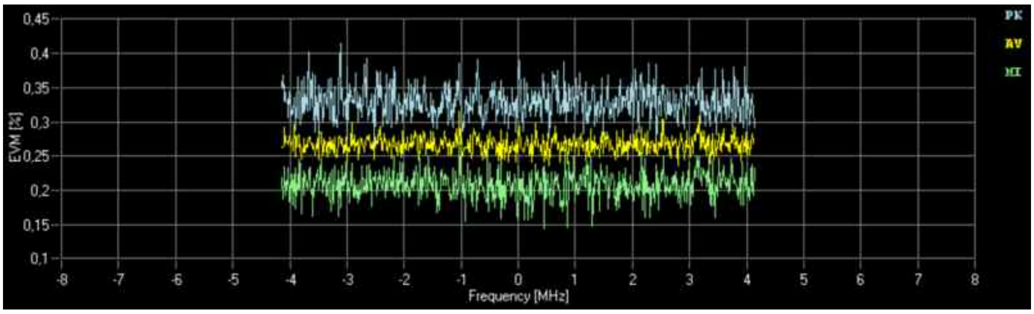



Figure 26 shows the numeric overview of the measurement results for transmit modulation, showing beside the EVM various other parameters, which will be discussed later on. More than one EVM value is shown, one for physical channels, one for physical signals and an overall EVM. What does this signify?

***Figure 26: Numeric Transmit Modulation Parameters (UL, 10 MHz FDD)***


As explained in section 2.2 LTE uses different types of signals in both directions for various purposes. Physical signals, directly generated in the layer 1, are used for synchronization, channel estimation (uplink as well as downlink) and cell identification (downlink only). The other types of signals are the physical channels, carrying user data, control and scheduling information. Physical signals are divided into two parts for the uplink. The demodulation reference signals (DRS) are associated with PUSCH and/or PUCCH. These signals are used by the base station for a correct, coherent demodulation of the uplink. The PUCCH, carrying scheduling requests, ACK/NACKs, CQI, PMI[9] or RI[10], depending on the format used, is only present when no data is transmitted. When a data transmission is proceeding the control information is multiplexed with these data, so that no PUCCH is required. Neither the PUSCH nor the PUCCH are present, for example, when no data is transmitted and no feedback on a parallel downlink data transmission needs to be reported back to the base station.

Sounding reference signals (SRS) are issued by the UE to estimate the radio channel in frequency areas, other than the allocated one. The information collected by the base station based on the SRS is used for scheduling and helps to decide and assign resources for data transmission in the uplink.

Uplink reference measurement channel resources are allocated to the UE according to the application and desired resources, and data is transmitted on the PUSCH. The physical signal, generated by the UE and on which EVM is measured is therefore a DRS. The DRS and SRS are special CAZAC sequences, Zhadoff-Chu sequences. CAZAC stands for Constant Amplitude Zero Auto Correlation. The signals amplitude is

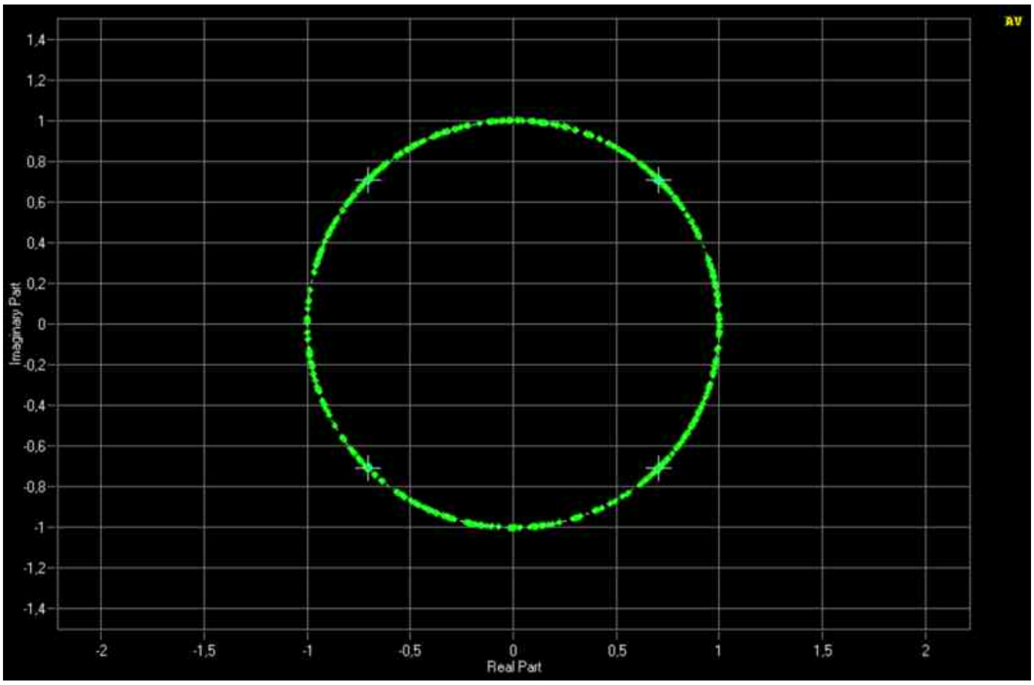
[9] PMI – Pre-coding Matrix Indicator (for MIMO)

[10] RI – Rank Indication (for MIMO)

constant and “zero auto correlation” indicates, that the signals do not correlate (much) with each other.

Figure 27 shows the constellation display for the uplink signal.

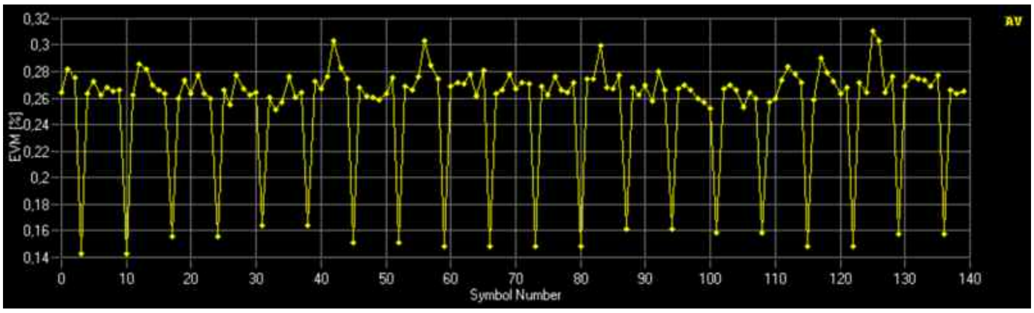
***Figure 27: Constellation Display for complete UL signal (UL FDD, 10 MHz)***




Using the evaluation filter the DRS can be found in SC-FDMA symbols #3 and #10, transmitted over the entire bandwidth, meaning all 552 subcarriers (±276 subcarriers).

**Error Vector Magnitude vs. symbol.** EVM can be estimated for consecutive SC-FDMA symbols; the measurement is called “EVM versus symbol”. In the time domain there are seven SC-FDMA symbols per time slot when normal cyclic prefix is used, and six when extended cyclic prefix is used. The measurement is carried out for a complete radio frame, meaning for 140 SC-FDMA symbols.

***Figure 28: EVM versus symbol (UL FDD, 10 MHz)***




This type of measurement is more important than an alternative due to lack of a specification for a transmit filter. Aggressive filtering will add time distortion to the signal, which will reduce the effects of the cyclic prefix, which can cause unwanted intersymbol interference. For this reason it is essential to estimate the EVM over time, meaning for symbol duration.

### 6.5.4 Spectrum Emission Mask (SEM)

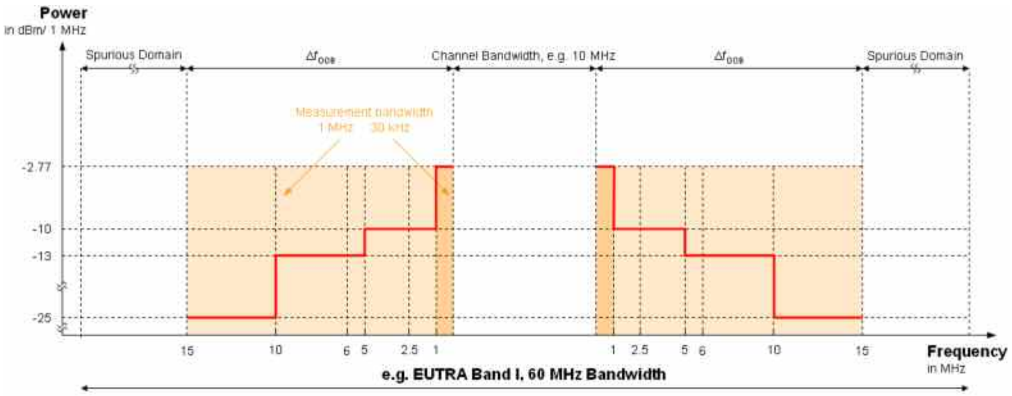
By analyzing the spectrum emission mask (SEM) it is possible to conclude whether the failure of the EVM measurement is related to the VCO, or comes from non-linearities generated by components used in the device under test. The 3GPP specification defines – as for WCDMA and HSPA – exact limits, which shall not be exceeded by the device. For a given bandwidth of 10 MHz the following limits are defined for an out-of-band transmission.

***Table 7: Measurement limits for SEM (UL, 10 MHz FDD)***

| $\Delta f_{OOB}$ in MHz | ±0...1 | ±1...2.5 | ±2.5...5 | ±5...6 | ±6...10 | ±10...15 | ±15...20 | ±20...25 |
|---|---|---|---|---|---|---|---|---|
| Power in dBm per BW | -18 | -10 | | -13 | | -25 | - | - |
| Measurement Bandwidth | 30 kHz | 1 MHz | | | | | | |

It is important to notice, that the power values (in dBm) for out-of-band emissions vary, depending on the resolution bandwidth (30 kHz and 1 MHz). This is a method already used for WCDMA and HSPA Spectrum Emission Mask measurements. Transferring the results of Table 7 into a graphical format is shown Figure 29.

***Figure 29: Spectrum Emission Mask (SEM) normalized to 1MHz***




The y-axis shows the measured power value related to the 1 MHz resolution bandwidth. Although for ±1.0 MHz adjacent to the occupied channel, the resolution bandwidth is specified with 30 kHz. Converting the specified tolerance of -18 dBm/30 kHz to a resolution bandwidth of 1 MHz results in a limit of -2.77 dBm/1 MHz. This new harmonized value is taken as the limit instead of dividing the diagram into two separate areas, where one is related to a resolution of 30 kHz and the other to 1 MHz, as it is used for the spectrum emission mask measurement for WCDMA and HSPA. An increase in channel bandwidth also increases the limit requirements for the 30 kHz resolution bandwidth versa decrease in bandwidth decreases the limit requirements. In addition enhanced requirements can be signaled by the network to the device. The network signaling values (NS_0x) re-define not just the tolerances for spectrum emission mask, but also the limits for maximum output power, adjacent channel power depending on the EUTRA frequency band used, channel bandwidth and allocated resource blocks. The details can be found in [3], Table 6.2.4-1. The present application note assumes, that the RF IC is supporting EUTRA frequency band I, uplink 1920 to 1980 MHz, where for SEM measurement no additional requirement is specified.

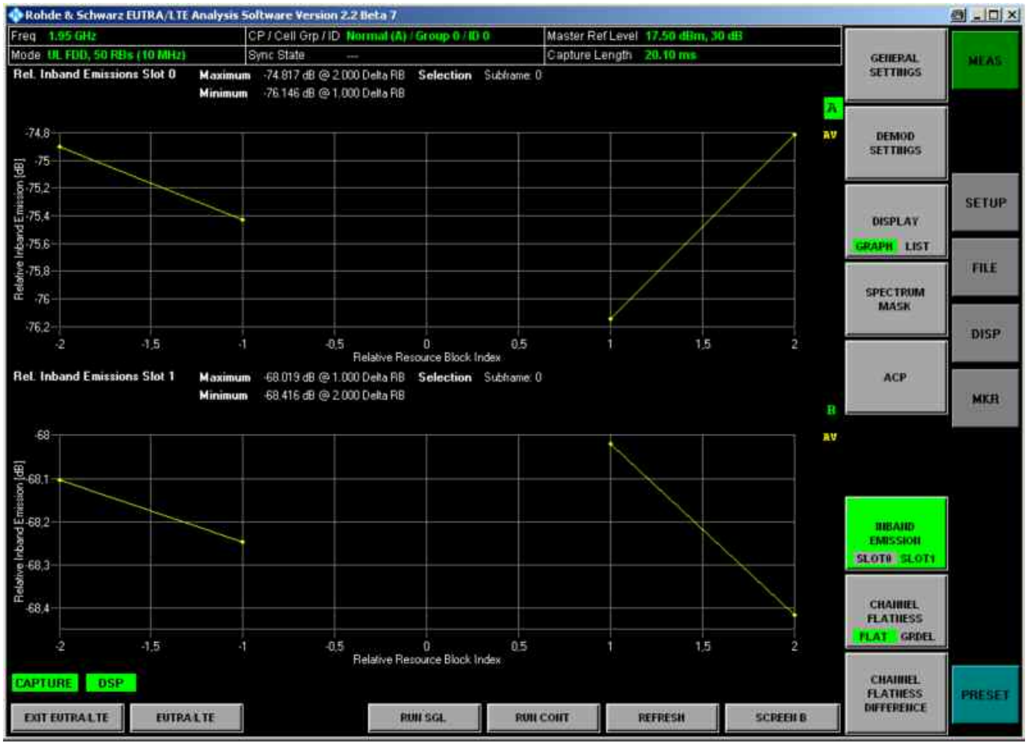
Figure 30 shows now the SEM measurement according to the 3GPP specification with a resolution bandwidth of 30 kHz and 1 MHz, which is the reason for the shape of the signal.

***Figure 30: Spectrum Emission Mask measurement with FSQ (UL, 10 MHz FDD), filter: STANDARD***


## 6.5.5 In-band emission

EVM measurements are only performed on resource blocks, allocated to the user. Not all 50 resource blocks either in the uplink or in the downlink can be assigned to one user due to the need for control channels, such as PUCCH or PDCCH. In this example 46 resource blocks are assigned at maximum to a single user for a given bandwidth of 10 MHz. In real network operation fewer than 46 resource blocks are allocated to one user, in fact they are of course allocated to more than one. Therefore the impact of a user to non-allocated resources must be estimated. That ensures, that the transmission of own user data in the uplink via the PUSCH does not interfere with the data transmission of other users as well as with transmitting control information on a control channel. The measurement for estimating the interference – given as power – affecting non-allocated resource blocks, is called in-band emission measurement. An absolute and relative in-band emission are measured, where the relative in-band emission is derived from the absolute in-band emission. Both results are expressed in dB. With an FSQ the measurement can be performed for each subframe individually for time slot 0 and time slot 1 versus the resource block indices.

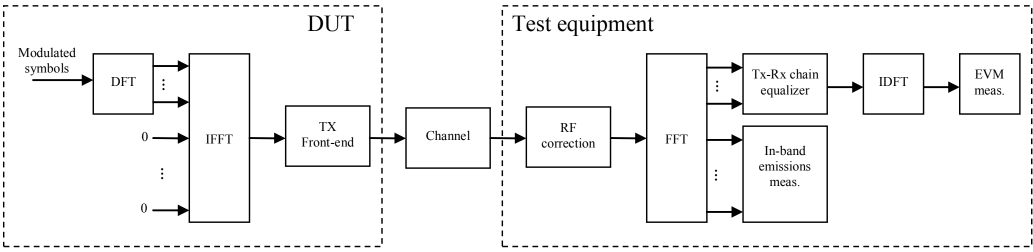
***Figure 31: In-band emissions subframe #0, time slot #0 and #1 (UL, 10 MHz FDD), filter: STANDARD***




## 6.5.6 Spectrum flatness, flatness difference and channel group delay

The definition of the Error Vector Magnitude foresees, that the measurement takes place after the IDFT. The EVM is measured by estimating and removing the sampling timing offset and the RF frequency offset.

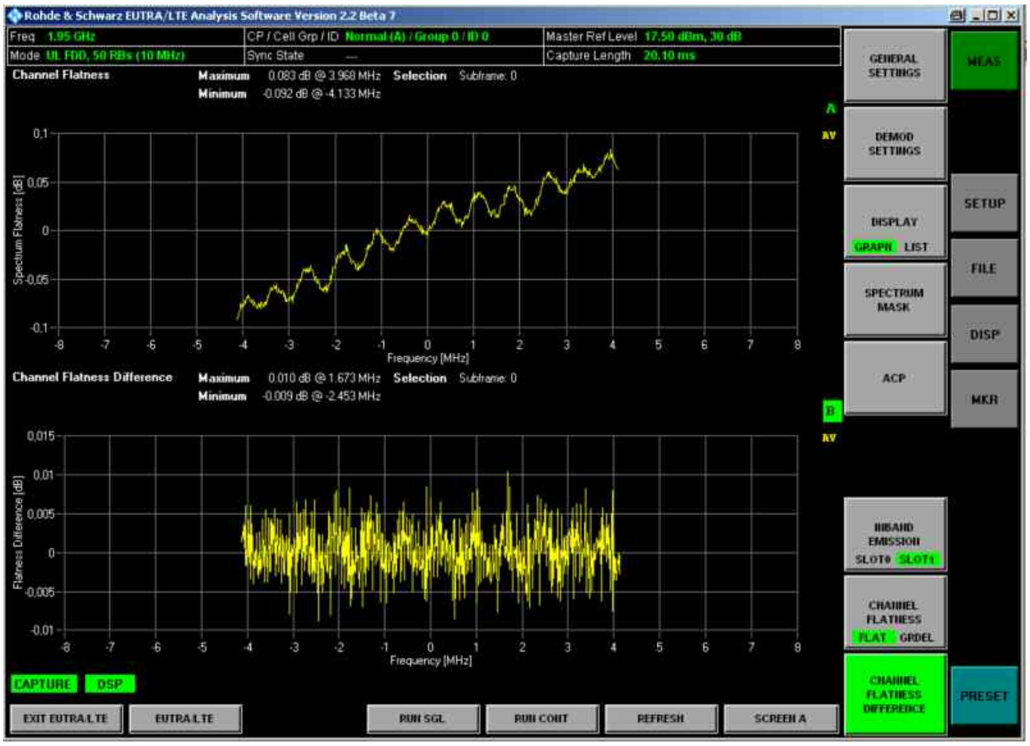
***Figure 32: EVM measurement point [3]***




This will however hide possible problems in the transmitter at the power amplifier and IQ modulator. Therefore additional EVM testing or further measurements are necessary, to check for problems. The two additional requirements, defined to ensure excellent transmitter performance are spectrum flatness and flatness difference. With the spectrum flatness measurement, the power variations of a subcarrier are compared to the average power of all subcarriers, in dB.

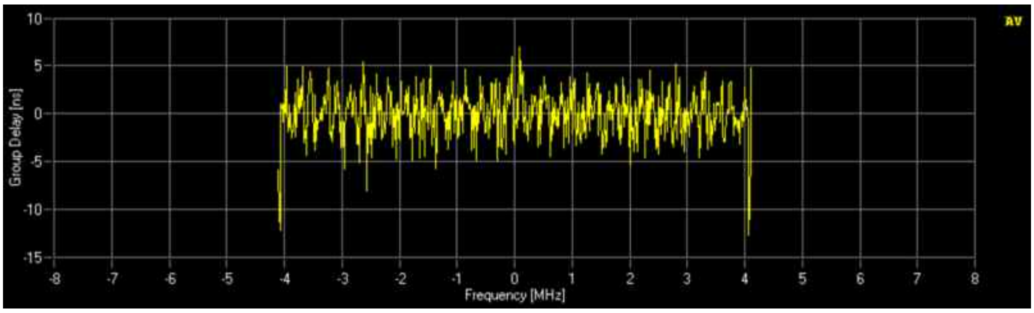
On the other hand it is an estimation of the frequency response H(f) of the transmission channel, where the flatness difference shows the deviation to this estimation. This variance is measured in dB.

***Figure 33: Spectrum Flatness and flatness difference (UL, 10 MHz FDD), filter: STANDARD***




Also of interest is the channel group delay measurement. As group delay is the derivative of the phase of the signal, the group delay can only be constant when the phase of the signal is linear. Since the phase is never straight linear, the group delay can not be constant. Group delay always exists, but only reduces signal, if it exceeds the guard interval, the cyclic prefix. If the group delay exceeds cyclic prefix it cause intersymbol interference to the digital modulated signal.

***Figure 34: Group delay measurement (UL, 10 MHz FDD), filter: STANDARD***



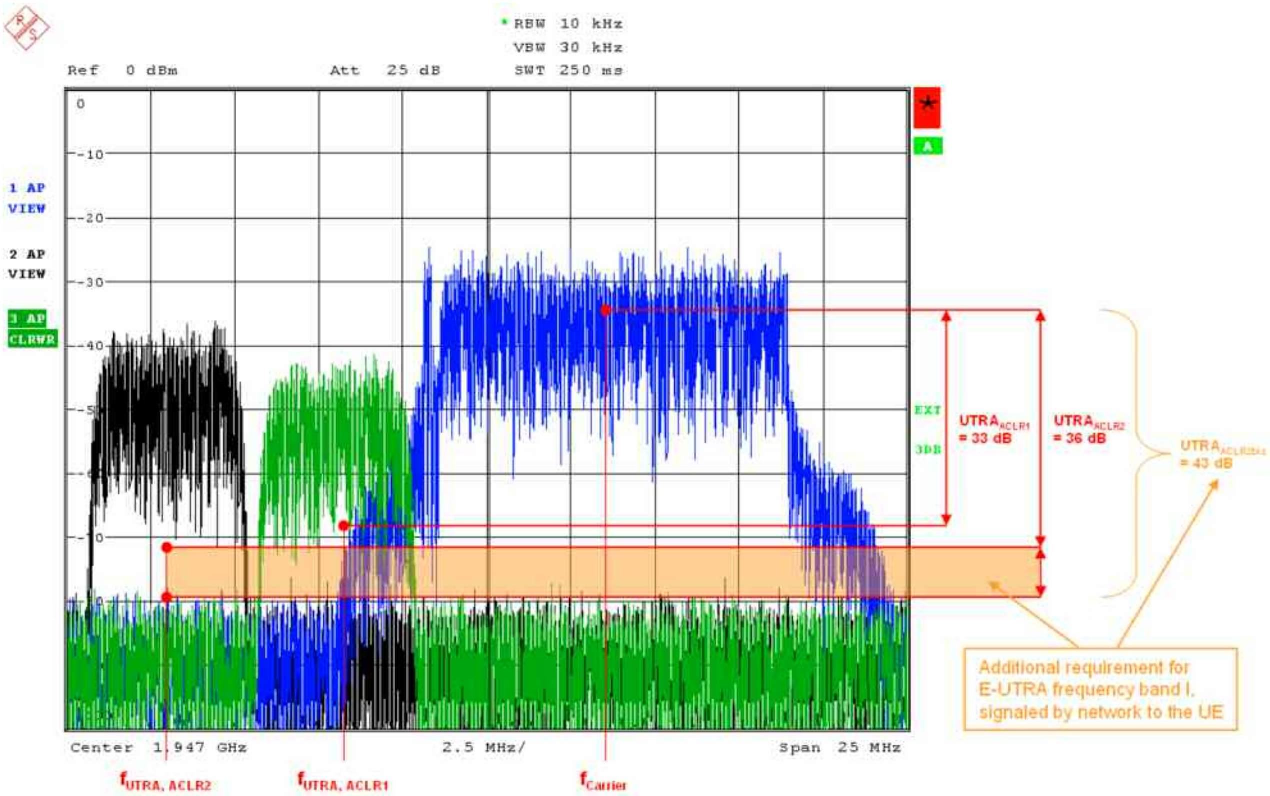
The group delay varies, depending on the filter used. The filter optimized for EVM will decrease the group delay, whereas the ACP-optimized filter will increase the group delay.

### 6.5.7 Adjacent Channel Leakage Power Ratio (ACLR)

LTE will use the same frequency bands, used by WCDMA/HSPA. As a consequence LTE will coexists with WCDMA/HSPA. Different frequencies of the same frequency band might be used, for downlink as well as uplink. Therefore it is important to verify the impact of an LTE signal on a WCDMA/HSPA signal, using the Adjacent Channel Leakage Power Ratio (ACLR) measurement. This measurement characterizes the distortions of the power output from the transmitter, which can cause interference to adjacent channels – whether they are WCDMA/HSPA or LTE. For the impact on WCDMA/HSPA, the power of the LTE signal is measured using a root-raised cosine filter with a resolution bandwidth of 3.84 MHz and a roll-off factor of α = 0.22 in an offset of 5 and 10 MHz ($UTRA_{ACLR1}$ and $UTRA_{ACLR2}$) from the edge of the allocated bandwidth. The filter is moved to the desired frequency and the power of the signal is integrated for the resolution bandwidth. The resulting power value is than displayed for the desired frequency offset in this case 5 and 10 MHz.

Figure 35 shows an LTE signal (blue graph) configured as uplink reference measurement channel, with 10 MHz bandwidth at a carrier frequency of $f_c$ = 1950 MHz and a power level of -35 dBm. The spectrum shows also a WCDMA uplink signal (black graph, $f_{UTRA,\ ACLR2}$ = 1937.5 MHz) as well as an HSDPA uplink signal (green graph, $f_{UTRA,\ ACLR1}$ = 1942 MHz).

*Figure 35: Spectrum showing LTE, WCDMA and  HSDPA uplink signals*




The limits for ACLR measurement are 33 dB respectively 36 dB for $UTRA_{ACLR1/2}$ as shown in Table 8.

*Table 8:General requirements for ACLR measurement in LTE*

| BW in MHz | 1.4 | 3 | 5 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|
| **$UTRA_{ACLR1}$** | 33 dB | 33 dB | 33 dB | 33 dB | 33 dB | 33 dB |
| **$UTRA_{ACLR2}$** | - | - | 36 dB | 36 dB | 36 dB | 36 dB |
| **$E\text{-}UTRA_{ACLR1}$** | 30 dB | 30 dB | 30 dB | 30 dB | 30 dB | 30 dB |

As for SEM measurement, the network can send additional requirements to the UE for specific deployment scenarios. Assuming an RF IC supporting frequency band I the limits of the ACLR measurement for $UTRA_{ACLR2}$ changes to 43 dB. In an offset of 10 MHz from the occupied bandwidth, the transmission power must have dropped by 43 dB. In the following two figures a ACLR measurement is performed to verify the tolerances defined for the presence of a WCDMA signal. Figure 36 shows now the ACLR measurement using the filter optimized for EVM. As highlighted the ACP is acceptable and is not exceeding the specified limits.

*Figure 36: ACLR measurement in presence of a WCDMA signal (UL, 10 MHz FDD), filter: EVM*


A much better performance is achieved, when an ACP-optimized filter is used. The ACLR improves by approximately 20 dB.

*Figure 37: ACLR measurement in presence of a WCDMA signal (UL, 10 MHz FDD), filter: ACP*

As well as interfering with a WCDMA/HSPA signal interference with an LTE signal from another network operator is possible. For this situation the impact on the neighbouring LTE signal is analyzed with the second part of the ACLR measurement. A rectangular filter with a variable resolution bandwidth, depending on the allocated bandwidth, is used to estimate the impact on this LTE signal. For a reference measurement channel with a channel bandwidth of 10 MHz, the resolution bandwidth for the rectangular filter is defined as 9 MHz. The limit for ACLR in presence of another LTE signal is 30 dB (see Table 8).

***Figure 38: ACLR in presence of another LTE signal, same BW (UL, 10 MHz FDD), filter: STANDARD***


## 6.5.8 Spurious Emissions

To measure spurious emissions the RF IC is connected to a spectrum analyzer with a frequency range of at least 12.75 GHz. The signal is analysed for defined frequency ranges using a measurement filter with a specified resolution bandwidth. The clearly defined limits may not be exceeded. The tolerances are summarized in the following table.

***Table 9: Spurious Emission Limits for LTE***

| Frequency range | Maximum Level | Measurement BW |
|---|---|---|
| **9 kHz ≤ f < 150 kHz** | -36 dBm | 1 kHz |
| **150 kHz < f < 30 MHz** | | 10 kHz |

| | | |
|---|---|---|
| **30 MHz < f < 1 GHz** | | 100 kHz |
| **1 GHz < f ≤ 12.75 GHz** | -30 dBm | 1 MHz |

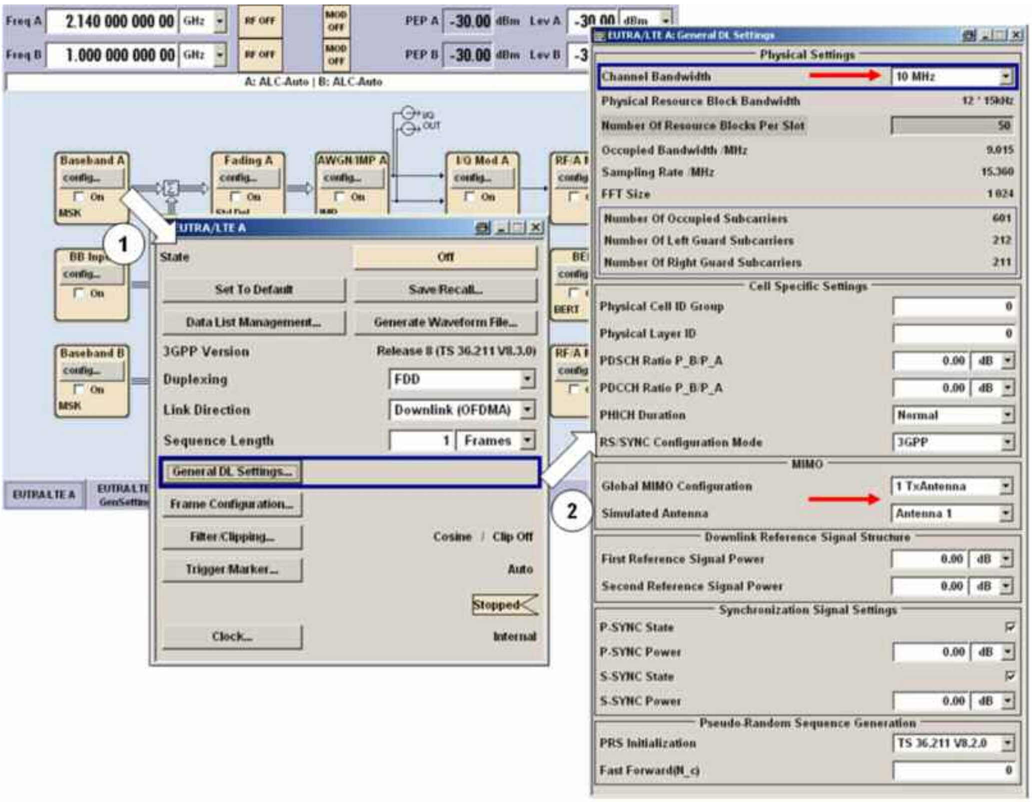
# 7 Receiver verification; settings and measurements

## 7.1 LTE downlink signal generation with SMU

Table 1 in section 5 shows the settings for the downlink reference measurement channel for LTE FDD. The signal can be configured very easily using a SMU, since the majority of the parameters are based on each other. A few things to be taken into account, as described below.

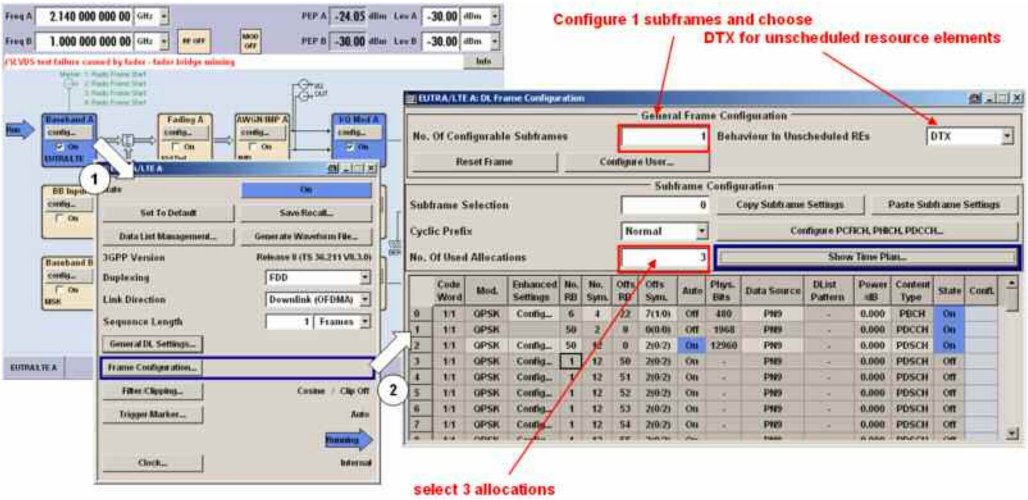
First of all, the general settings need to be applied to the signal, like setting the right frequency depending on [7] as well as selecting duplex method, link direction, channel bandwidth and the antennas used.

*Figure 39: Applying the general setting for the LTE downlink signal 10 MHz, FDD*




Next step is the frame configuration. By pushing the frame configuration tab the appropriate window will appear. As for uplink, no tall resources can be allocated to the UE for user data transmission. Selecting three allocations for the first subframe is necessary for the transmitting of control and broadcast information. As explained in section 2.1 the physical layer generates valid demodulation, synchronization and reference signals.

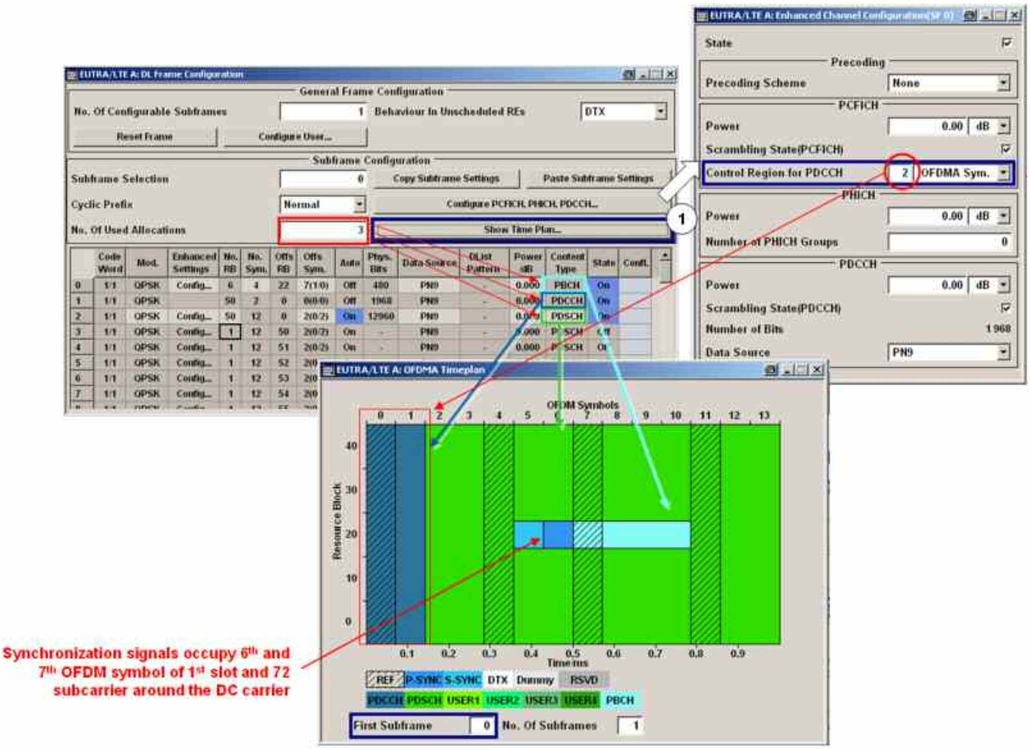
*Figure 40: Configuration of the first subframe (DL, 10 MHz FDD), part I*




The primary and secondary synchronization signals occupy 62 of the 72 reserved subcarriers[11] around the DC carrier and are transmitted on the second last and last OFDM symbols of the first time slot of the first subframe. The PBCH follows the synchronization signals, using the next four OFDM symbols in time domain and all 72 subcarriers in frequency domain. The channel responsible for carrying the control information can be configured by hitting the appropriate tab in the frame configuration screen. The PCFICH, and therefore the number of OFDM symbols used for the PDCCH, can be configured as well as power levels to be used for this type of control channel. The configuration and all settings described above are shown in Figure 41.

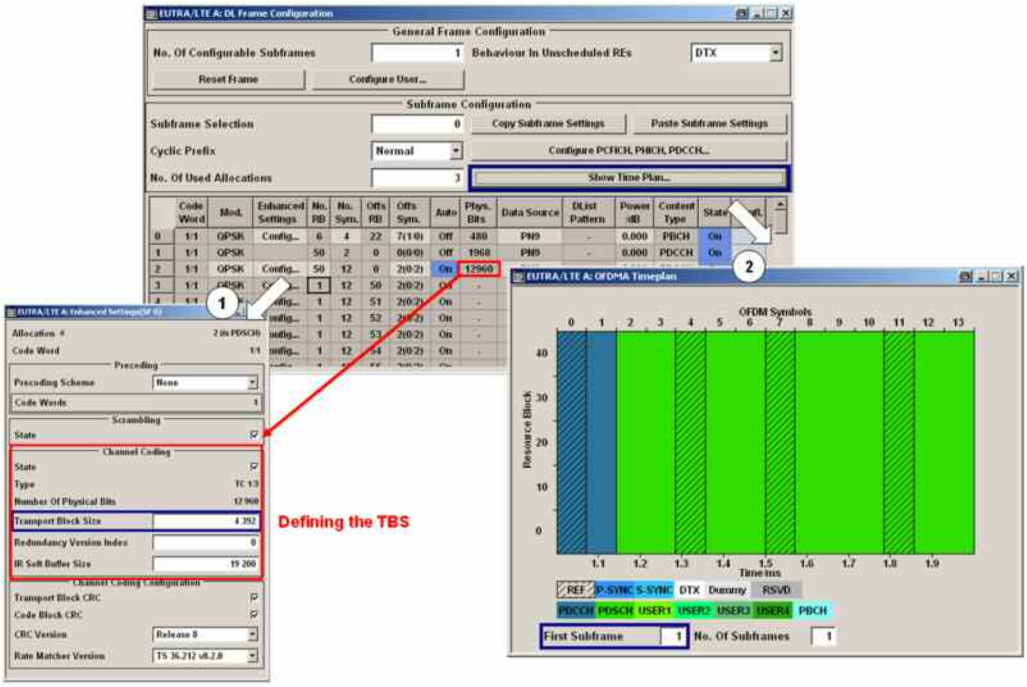
[11] 6 resource blocks = 72 subcarrier are reserved for transmission of synchronization signals and broadcast information

***Figure 41: Configuring the first subframe (DL, 10 MHz FDD), part II***




Due to synchronization signals in the first time slot of subframe #0 as well as reference signals in every resource block a number of resource elements are not available for data transmission. This is also valid for the downlink physical channels, carrying control and broadcast information. The PDCCH is present in every subframe, therefore the first two symbols in each subframe, depending on the settings, are always occupied by this control channel. Deducting reference signals, synchronization signals, and control channels at maximum 12960 Bit can be used for data transmission using QPSK modulation for PDSCH. By following the definition for the reference measurement channel, the transport block size (TBS) needs to be set to 4392 Bit for all 10 subframes (see Table 5, see Figure 42).

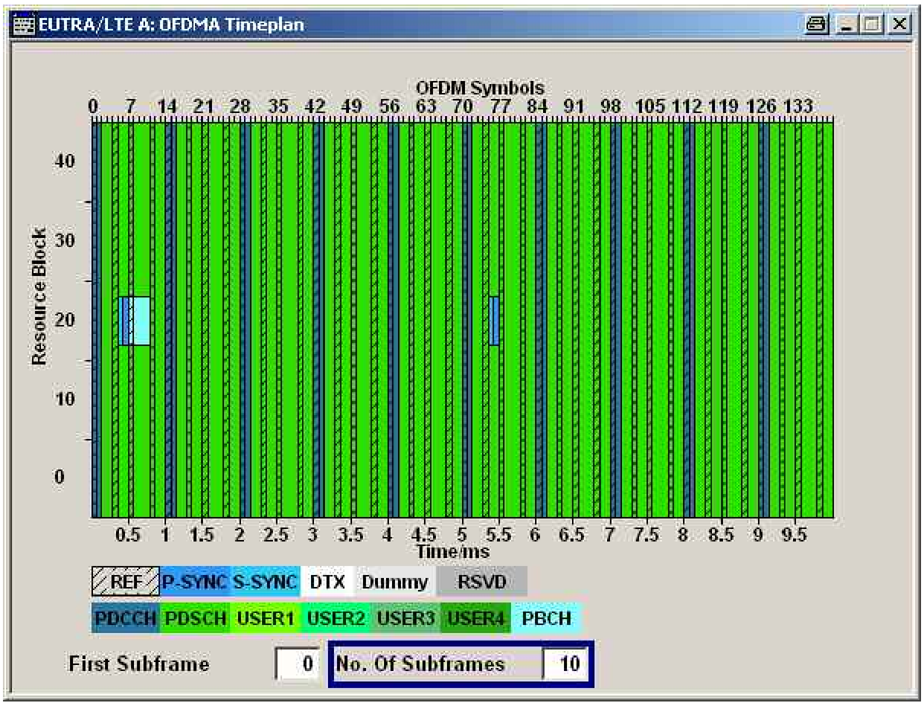
***Figure 42:Setting the Transport Block Size (TBS) for the first subframe (DL, 10 MHz FDD), part III***




Since the TBS is equal for every subframe, the setting is applied automatically to each subframe by just configuring one frame is described above. This is the reason, why the number of configurable subframes is selected as 1 (see Figure 40). In the case, that a different TBS needs to be set for the individual subframes, the number of configurable subframes needs to be increased. Each subframes needs then to be configured individually.

The configuration of the SMU is now complete and the generator can be switched on. The overall time plan is shown in Figure 43.

*Figure 43: Overall time plan for 1 radio frame (DL, 10 MHz FDD)*

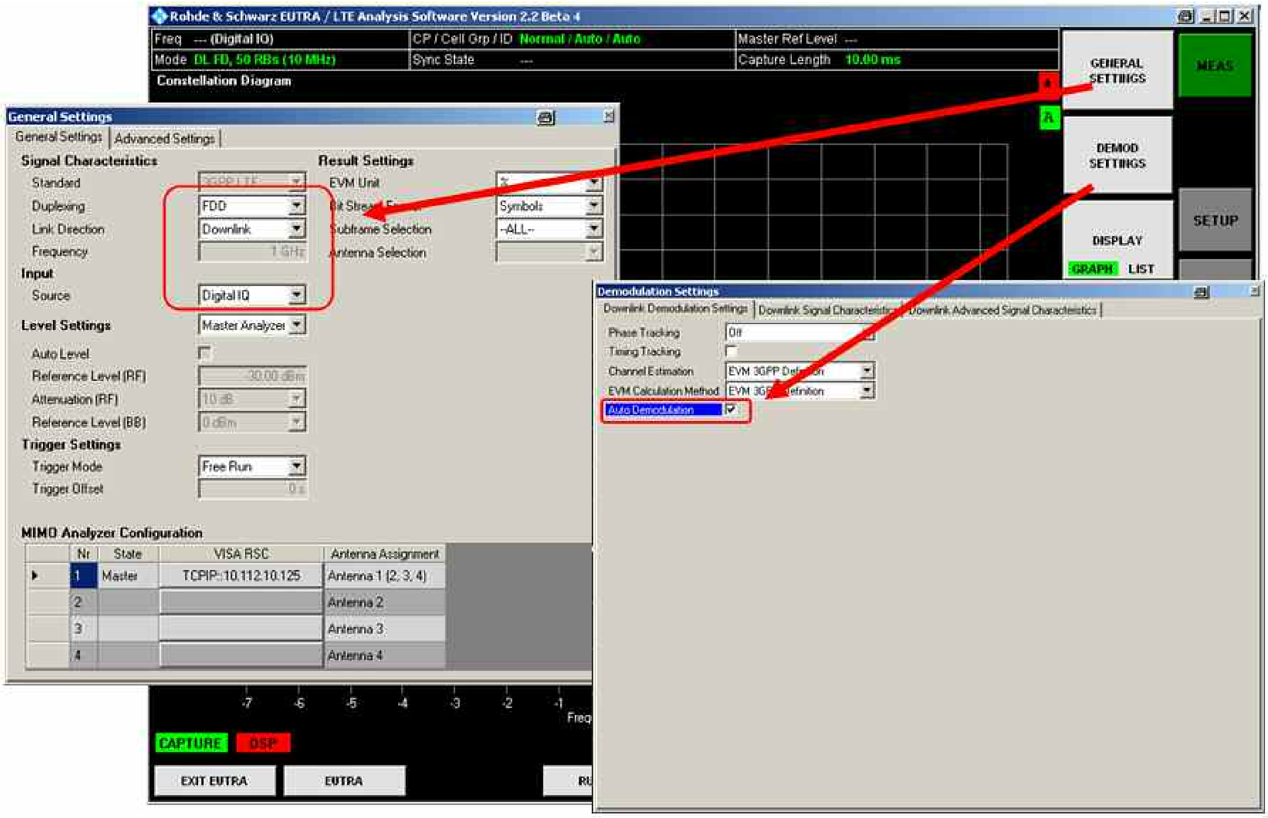



## 7.2 FSQ settings for Rx verification

Since a digital IQ standard is used on the RF IC, as described for TX verification, the output of the device under test needs to be converted into the R&S used DIGITAL IQ format (TVR290) using the EX-IQ Box. To prepare the FSQ:

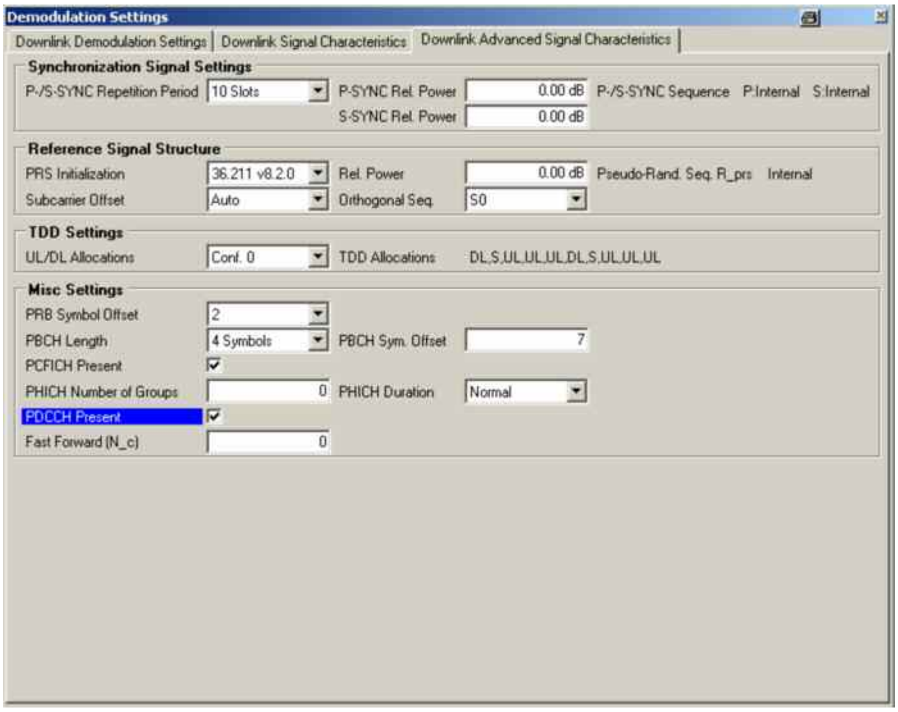
- From the “General Settings” tab select
  - Digital IQ as input source,
  - FDD as duplexing method,
  - Downlink as link direction
- From the “Demodulation Settings” select Auto-demodulation as downlink demodulation settings.

*Figure 44: General and demodulation settings for the FSQ (DL, 10 MHz FDD)*




It is also possible to set this manually be selecting in ‘Signal Characteristic’ tab the right parameters like the used modulation scheme as well as the number of resource blocks, which are assigned for user data transmission in downlink. These are 50 resource blocks, based on the definition of the downlink reference measurement channel for 10 MHz. In the advanced signal characteristics tab for the downlink, the presence of the PDCCH and furthermore PCFICH as set on the signal generator side, needs to be indicated by activating the appropriate check boxes.

*Figure 45: Downlink Advanced Signal Characteristics (DL, 10 MHz FDD)*

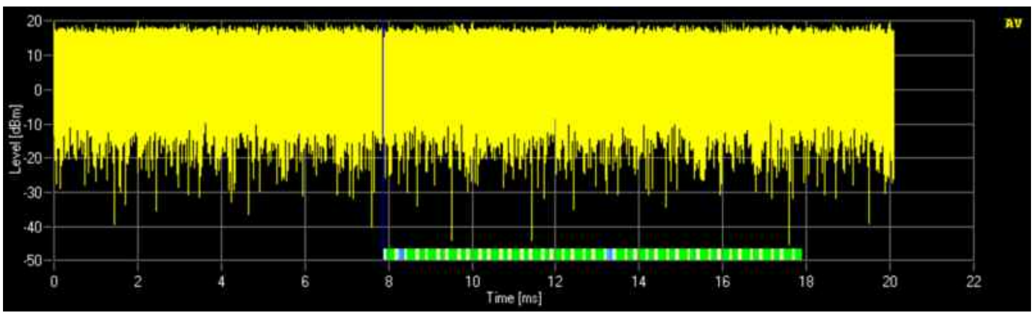



## 7.3 Rx measurements

### 7.3.1 Power measurements

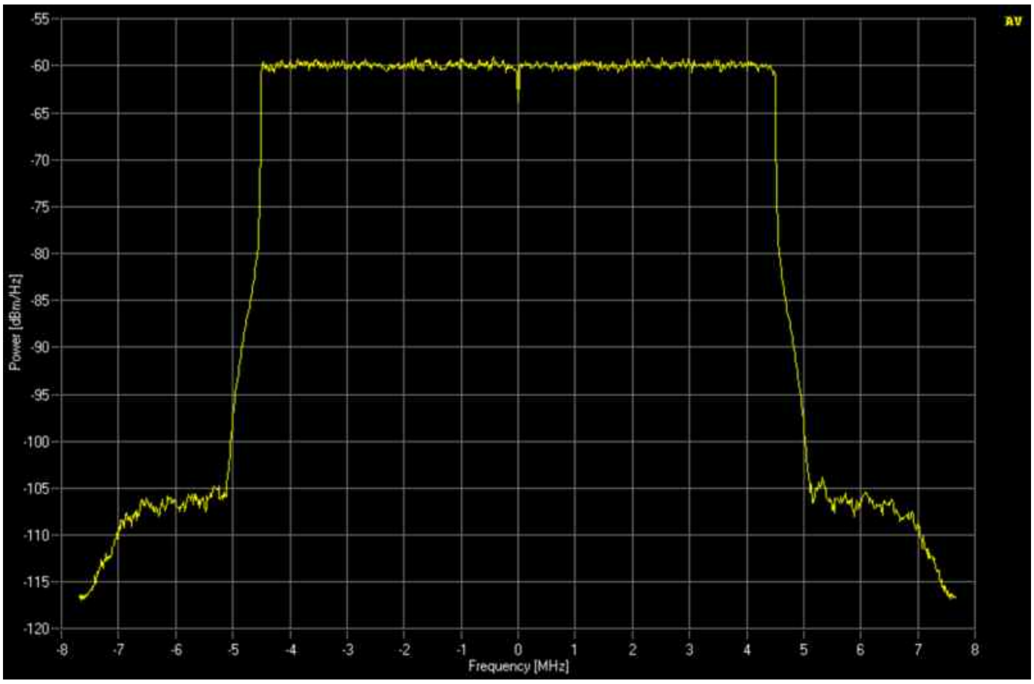
Output and standard power vs. frequency is measured. The output power is analyzed in the time domain displaying power versus time as shown in Figure 46. Two complete radio frames (= 20 ms) are displayed. The primary and secondary synchronization signals are highlighted (light and dark blue bars). From the graph the repetition rate for the synchronization signals, can be detected, as it is a half radio frame, or in this case 5 ms.

*Figure 46: Power versus time (DL FDD, 10 MHz), filter: STANDARD*



A standard power versus frequency measurement is shown in Figure 47.

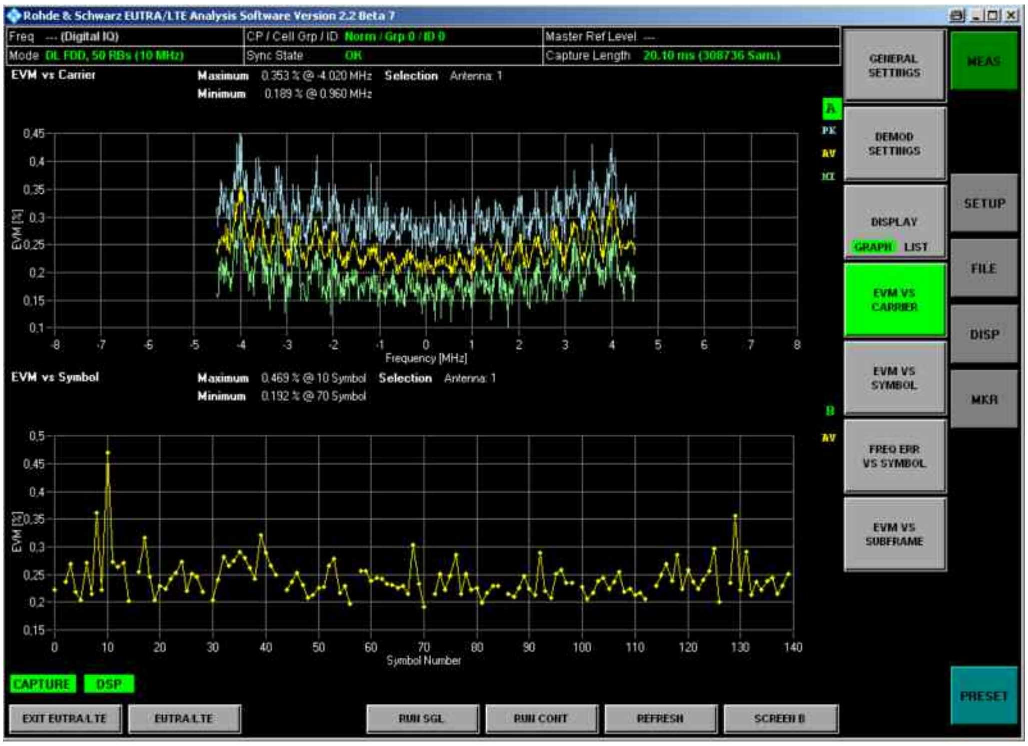
***Figure 47: Power Spectrum (DL FDD, 10 MHz), filter: STANDARD***




## 7.3.2 EVM vs. subcarrier, vs. symbol and vs. subframe

As for the uplink, the Error Vector Magnitude versus carrier rather than symbol can be measured for the downlink. As for uplink, the filter has an impact to the results. The results shown in following figures are achieved using the EMV-optimized filter.

*Figure 48: EVM vs. subcarrier and vs. symbol (DL, 10 MHz FDD), filter: EVM*




By changing the filter type to ACP the results change completely as shown in Figure 49. The strong filtering acts a like a delay and is impacting the signal quality at the edge of the transmission bandwidth. The EVM is increased so much, that under real conditions the performance is not good enough to use a higher order modulation scheme.

*Figure 49: EVM vs. subcarrier (DL, 10 MHz FDD), filter: ACP*

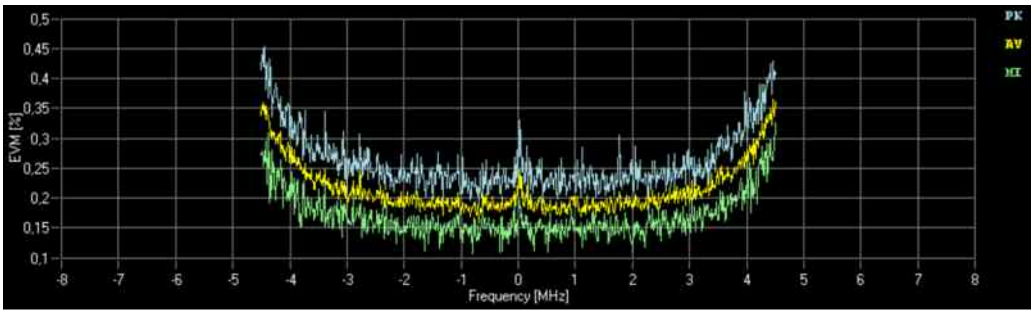
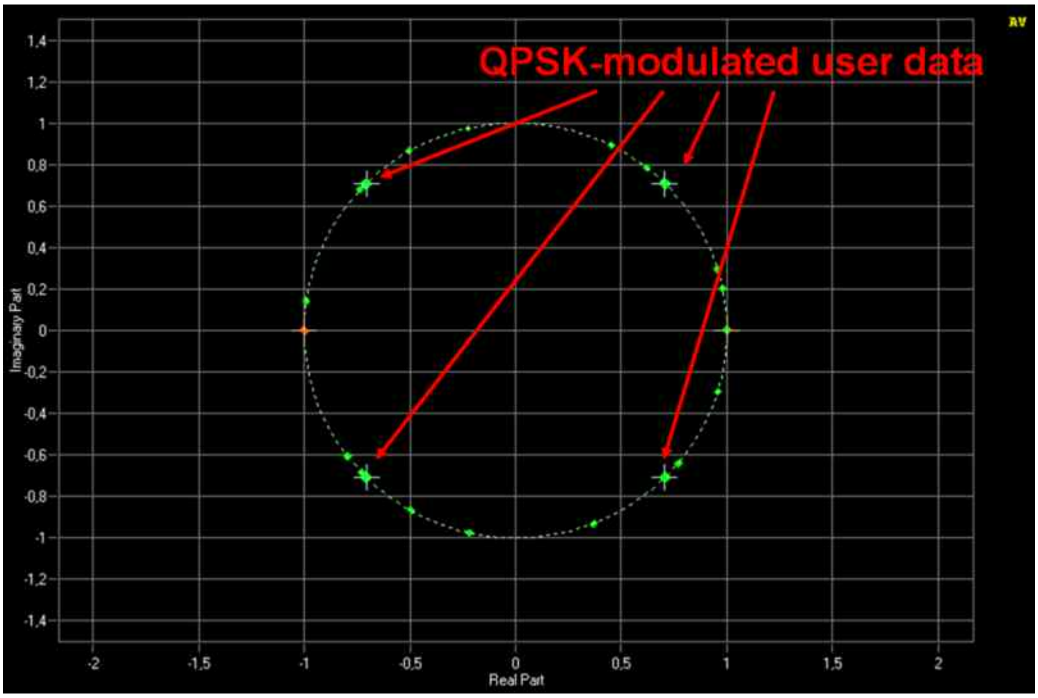


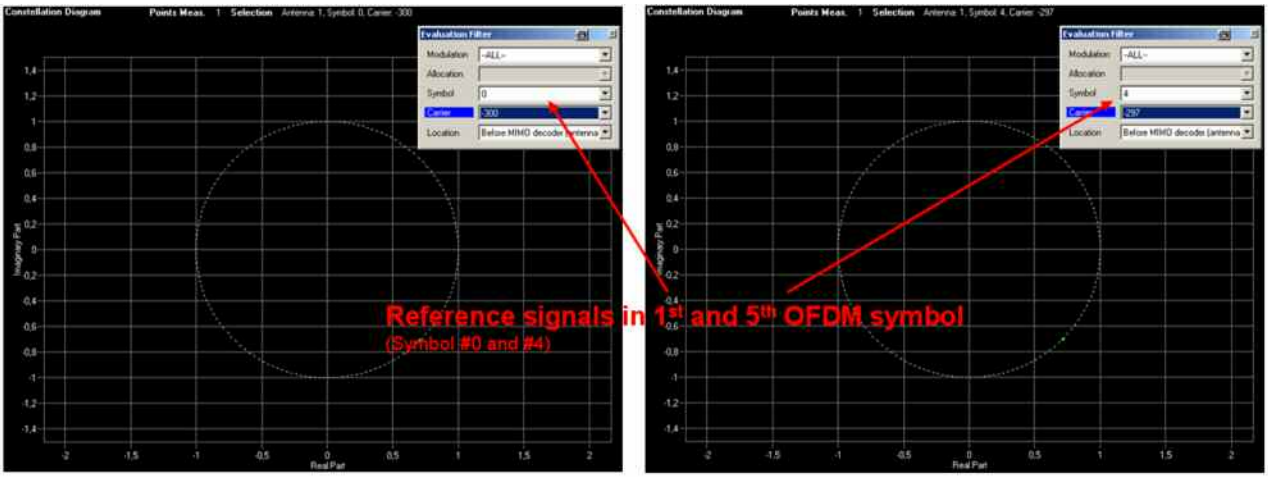

Figure 50 shows the constellation display for the complete downlink signal, featuring the QPSK-modulated user data, the reference and the synchronization signals.

*Figure 50: Constellation Display for complete DL signal*



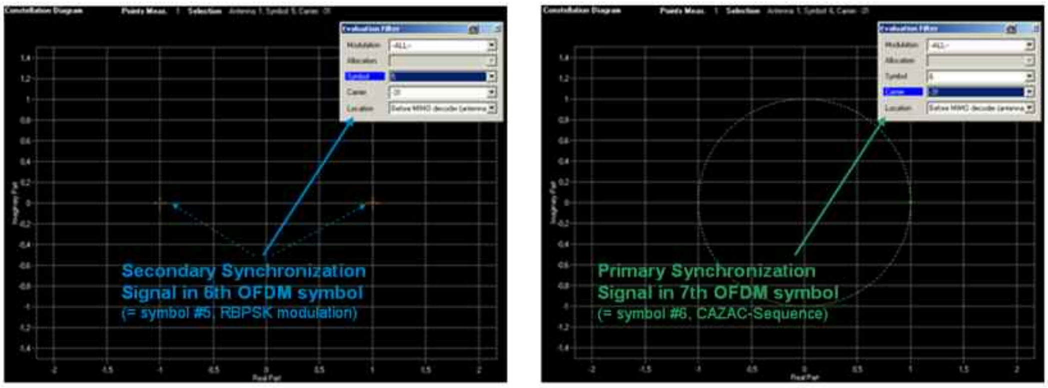

The constellation display in Figure 51 shows the reference signals as part of the downlink signal. Reference signals are always transmitted time-wise in the 1st (symbol #0) and 5th OFDM symbol (symbol #4) for SISO operation. The frequency spacing between the reference signals is six subcarriers. Based on this the first reference signal for 10 MHz LTE downlink signal is expected in OFDM symbol 0 at subcarrier -300. This is shown in the left constellation display. The right constellation display shows the reference signal carried in symbol #4 on subcarrier -297.

*Figure 51: Constellation Display showing the DL reference signals*




Besides user data and the reference signals, synchronization signals are part of the first subframe. These are shown in Figure 52.

*Figure 52: Constellation Display showing synchronization signal (P- and S-Sync)*



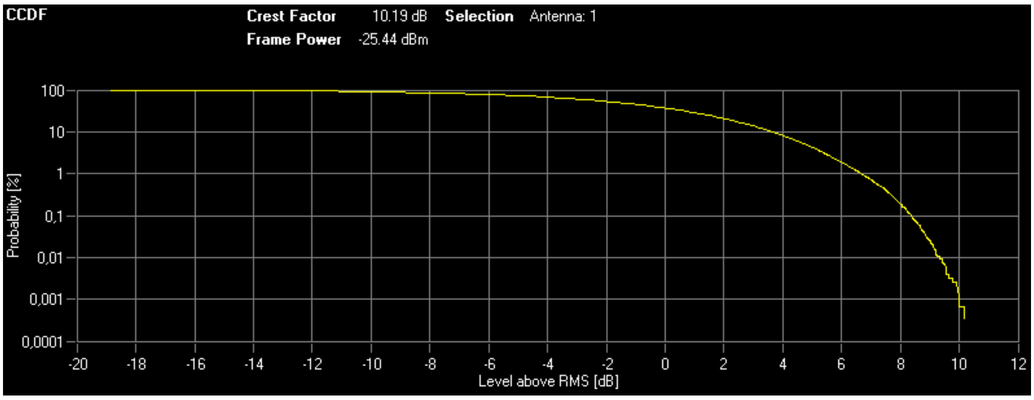

## 7.3.3 Crest Factor CCDF

A numeric overview of all measurement parameters can be displayed by the FSQ.

*Figure 53: Numeric overview of DL measurement parameters*


The last parameter listed in the table is the crest factor, also known as peak-to-average power ratio (PAPR). The maximum PAPR for LTE is approximately 12 dB, the same as it is for WiMAX, a competing technology for broadband wireless.

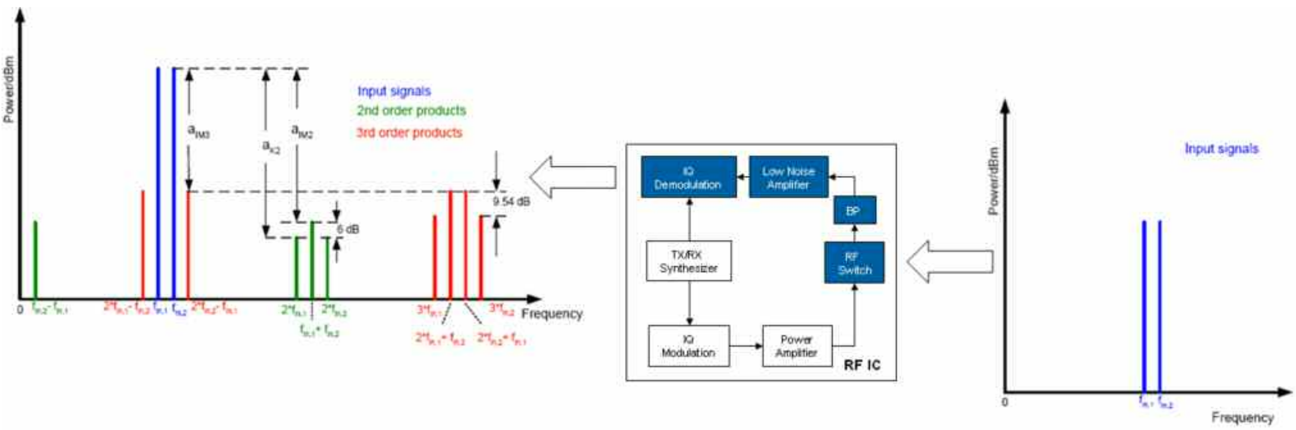
*Figure 54: CCDF (DL, 10 MHz FDD), filter: STANDARD*




## 7.3.4 Intermodulation characteristics, IIP3 and IIP2

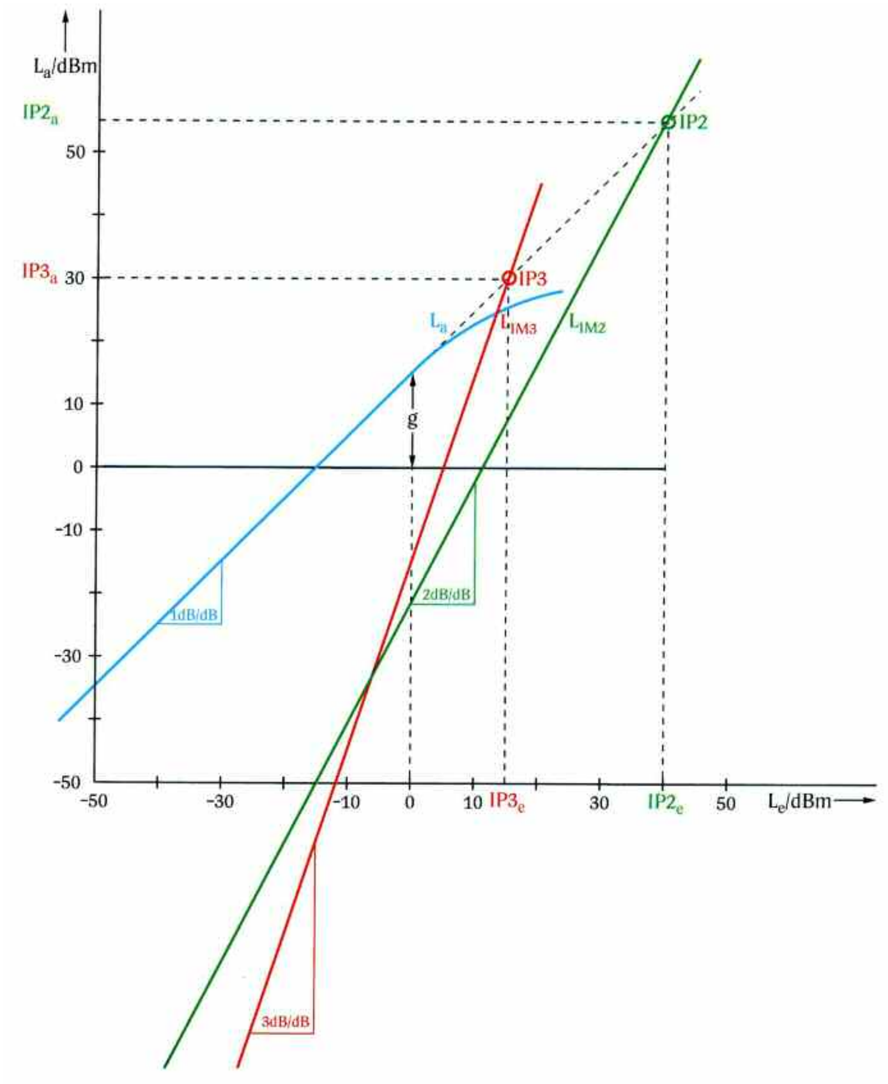
Intermodulation refers to unwanted spectral components generated by the non-linear behaviour of semiconductor components in signal processing, such as the power amplifier or IQ modulator. Mathematically, non-linear behaviour is approximated, using the Taylor series, where the detailed derivation can be found in [10]. With just a single-tone signal, such as a sinus, as input to the receiver chain, harmonics will be created in the output. These harmonics are created by non-linearities and are at multiples of the input frequency. Using two signals at frequencies $f_{in,1}$ and $f_{in,2}$ as input to the receiver (also called two-tone driving) will result in intermodulation products.

*Figure 55: Intermodulation products up to 3rd order for two-tone driving*



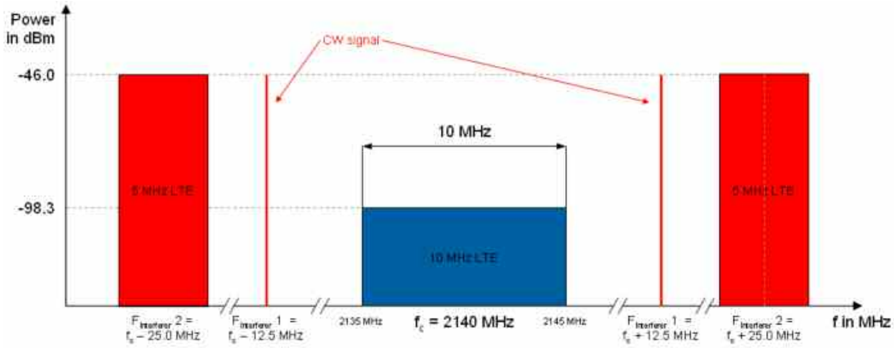

With help of the Taylor series it can be shown, that beside the harmonics of each input frequency ($2f_{in,1}$, $3f_{in,1}$ and $2f_{in,2}$, $3f_{in,2}$) 2nd order intermodulation products occur at the sum and the difference of the input frequencies ($f_{in,1}+f_{in,2}$, $f_{in,2}-f_{in,1}$) and 3rd order intermodulation products occur at $2f_{in,1}-f_{in,2}$, $2f_{in,1}-f_{in,2}$ as well as at $2f_{in,1}+f_{in,2}$ and $2f_{in,2}+f_{in1}$. The outcome spectrum is shown in Figure 55. In general the even numbered intermodulation products are far away from the two input signals, when the offset between the two tones is very small and can be suppressed by filtering. The odd-numbered intermodulation products are close to the input signals and can therefore not suppressed by filtering. In addition there is a relationship between the power level of the 2nd order harmonic and 2nd order intermodulation products, which is 6 dB, 9.54 dB for the 3rd order. To determine the interference caused by intermodulation products the n-th order intercept points are estimated. The input intercept point is the point at which the intermodulation product would reach the same power level as the interfering, stimulating signal, which is fed into the receiver's input. The intercept points with the most practical relevance are the 2nd and 3rd order input intercept points (IIP2 and IIP3). IIP3 describes the superficial intermodulation behaviour, IIP2 describes the demodulation characteristics in the baseband.

*Figure 56: Estimation of Input Intercept Point 3 and 2 [9]*




**3rd order input intercept point (IIP3).** To assess the LTE receiver for resistance from interference from internally generated intermodulation products, the receiver is tested according to 3GPP specification for its average throughput ($R_{av}$ in kbps) in presence of third-order intermodulation products, by using two signals with equal power level as interferer. The first interferer is a CW signal, the second is another LTE signal, where the bandwidth is dependent on the bandwidth of the user LTE signal. According to 3GPP TR 36.101 V8.2.0, chapter 7.8, the two interferers are using a fixed power level ($P_{test}$) of -46 dBm. The wanted signal mean power is calculated by taking the reference sensitivity value for the QPSK-modulated LTE reference measurement channel (REFSENS = -97 dBm) and adding a bandwidth dependent value of 6 dB giving -91 dBm. Depending on the bandwidth, the offset of the interferer to the carrier frequency $f_c$ is calculated. For 10 MHz bandwidth the first interferer, the CW signal is placed ±12.5 MHz from the carrier. The second interferer, the modulated LTE signal, is placed at twice the offset of the first.

*Figure 57: Intermodulation characteristics for LTE (DL,10 MHz FDD)*




$F_{Interferer}$ 1 = $f_C$ - 12.5 MHz = 2127,5 MHz = $f_1$
$F_{Interferer}$ 1 = $f_C$ + 12.5 MHz = 2152,5 MHz = $f_2$

| Intermodualtion products (non-harmonic) | | | | |
|---|---|---|---|---|
| 1st order | $f_1$ | $f_2$ | 2127,5 | 2152,5 |
| 2nd order | f1 +f2 | f2-f1 | 4280 | 25 |
| 3rd order | 2*f1-f2 | 2*f2-f1 | 2102,5 | 2177,5 |
| | 2*f1+f2 | 2*f2+f1 | 6407,5 | 6432,5 |
| 4th order | 2*f2+2f1 | 2*f2-2*f1 | 8560 | 50 |
| 5th order | 3*f1-2*f2 | 3*f2-2*f1 | 2077,5 | 2202,5 |
| | 3*f1+2*f2 | 3*f2+2*f1 | 10687,5 | 10712,5 |

$F_{Interferer}$ 2 = $f_C$ - 25 MHz = 2115 MHz = $f_1$
$F_{Interferer}$ 2 = $f_C$ + 25 MHz = 2165 MHz = $f_2$

| Intermodualtion products (non-harmonic) | | | | |
|---|---|---|---|---|
| 1st order | $f_1$ | $f_2$ | 2115 | 2165 |
| 2nd order | f1 +f2 | f2-f1 | 4280 | 50 |
| 3rd order | 2*f1-f2 | 2*f2-f1 | 2065 | 2215 |
| | 2*f1+f2 | 2*f2+f1 | 6395 | 6445 |
| 4th order | 2*f2+2f1 | 2*f2-2*f1 | 8560 | 100 |
| 5th order | 3*f1-2*f2 | 3*f2-2*f1 | 2015 | 2265 |
| | 3*f1+2*f2 | 3*f2+2*f1 | 10675 | 10725 |

Calculating the intermodulation products for the first interferer scenario with an offset of ±12.5 MHz from the carrier frequency $f_c$ – respectively ±25 MHz for the second scenario – shows, that the odd intermodulation products, especially the $3^{rd}$ and $5^{th}$ order, are close to the downlink carrier frequency and would interfere with the user signal and so impact the data throughput. A possible throughput measurement as required by 3GPP in the related specification [3] is only in signalling mode possible, when the UE sends the required information for calculating the throughput on the uplink channel. The data throughput $R_{av}$ is calculated as for HSPA, by counting the *ACK*nowledged and *N*on-*ACK*nowledged data blocks and transferring this into a Block Error Rate (BLER). Average throughput and BLER are linked to each other by the Nominal Average Information Bit Rate, which depends on the signal configuration and therefore on the selecting reference measurement channel. The Nominal Average Information Bit Rate is defined according to 3GPP and is, as given in Table 5, 4392 kbps.

***Formula 1: Calculating the BLER and average user data throughput $R_{av}$***

$$BLER = \frac{NACK + DTX}{ACK + NACK + DTX} \leq 0.1$$
$$R_{av} = (1 - BLER) * Nom.\_Avg.\_Inf.\_Bit\_Rate$$

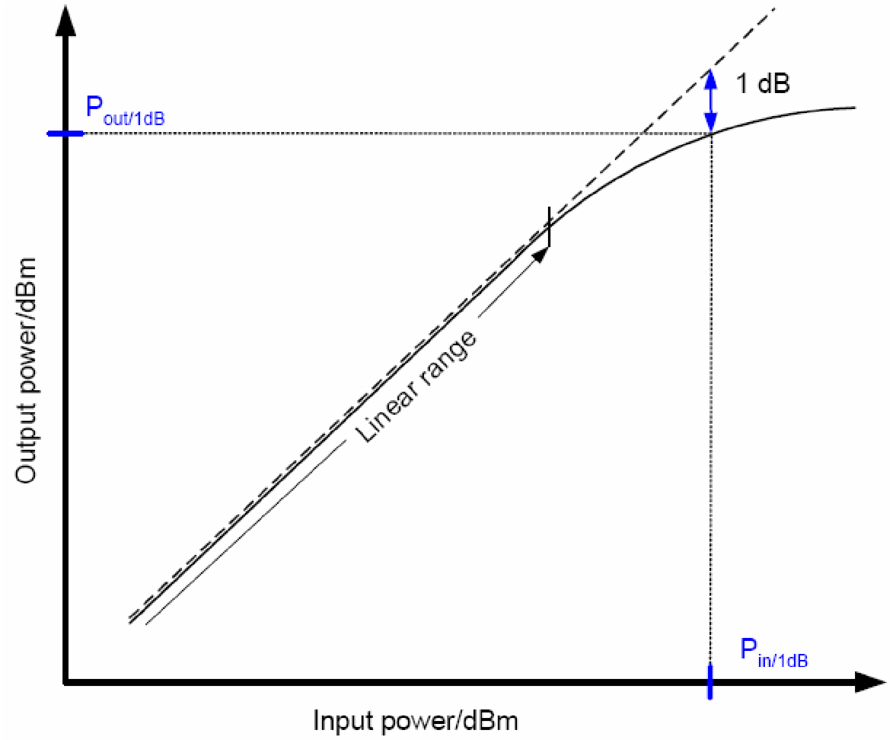
For RF IC level testing this method is simply not practical, due to the lack of baseband chipset and protocol stack functionality. The method only makes sense at a later stage of the development, this method would make sense. At chipset level another, indirect measurement of the IIP3 is a sufficient method to verify the receivers behaviour for 3rd intermodulation products. The method differs in that way, that two CW signals are used as interferer. To test the linearity of the receiver itself, these two interferers are placed very close to the carrier frequency, with just an offset, for example 1 MHz. Additionally half-duplex-tests are made, where the offset frequencies are chosen so that a 3rd order modulation product occurs exactly on the carrier frequency $f_c$. The first offset frequency is set to be the same as the uplink frequency, e.g. for E-UTRA Band I as $f_{in,1} = f_{TX}$ = 1950 MHz. The second interferer is either set at $f_{in,2} = 2f_{in,1} - f_{RX}$ or $f_{in,2} = (f_{in,1}+f_{RX})/2$. The receiver is tuned to one of the 3rd order intermodulation product frequencies and the IIP3 is measured.

**2nd order input intercept point (IIP2).** The biggest contribution to the 2nd order intermodulation product and therefore to the 2nd order input intercept point (IIP2) is caused by cross modulation by the mixer in the receiver. The IIP2 is a virtual point, which can not be directly measured, since the receiver would already be in compression at that power level (see Figure 56). The IIP2 can be determined under various conditions, for different interferers at various frequencies. One way to measure the IIP2 is to use two CW signals generated at an offset from the carrier frequency $f_c$ and a small offset from each other, e.g. 1 MHz. The offset to the carrier frequency for FDD validation relates to the duplex distance, meaning the distance between downlink and uplink, which depends on the testing frequency band. For the RF IC assumed in this application note supporting frequency band I, the duplex distance is 190 MHz. The first interferer will be generated at a frequency offset of $f_c$+190 MHz, the second one at $f_c$+191 MHz. Both interferers are the only signals fed into the RF IC. The RF IC will mix the two interferers down to the baseband, where the IP2 analysis is performed and the IIP2 is estimated. Using a conventional signal generator two signal generators would be needed to generate two CW signals, as also high-end signal generators are not free of intermodulation. With a two-path SMU just one signal generator is required.

### 7.3.5 1 dB compression point

The intermodulation products are examined to analyze the non-linear behavior of the RF IC. Linearity is estimated by measuring the 1 dB compression point at a selected input frequency, which gives a good indication of the performance of the low noise amplifiers used in the RF IC. By focusing on the amplifier it can be shown, that the output power typically exhibits a linear correspondence to the input power as it changes. The ratio output power to input power, the amplifiers gain, stays constant, up to a critical point beyond which the gain decreases, as the maximum power of the amplifier is reached. The amplifier compresses. This behavior is shown in Figure 58.

*Figure 58: Definition of the 1 dB compression point [10]*




The 1 dB compression point specifies the output power of the receiver at which the signal lags behind the ideal output by 1 dB. There are two preferred ways to measure the 1dB compression point with a signal generator and spectrum analyzer approach as shown in the setup in Figure 7. Before measuring the compression, the setup needs to be calibrated by taking the DUT of the setup and estimating the reference level offset. The details are explained in [10]. For the standard method a CW signal is used, generated at a frequency, e.g. 2140 MHz, with a power level of for example $P_{in}$ = -60 dBm. Stepwise the power of the signal generator is increased by 1 dB and the output power of the receiver is measured with the analyzer. The 1 dB compression point is reached, when the change of the output power do not correspond anymore to 1 dB (± measurement tolerance).

For any kind of wideband receiver, such as LTE or WCDMA, another method of measuring the 1dB compression point is also used. This method is referred to as desensitization test. For the method two CW signals are input to the receivers input, with the second interferer at a particular frequency offset from the first. Both signals use initially the same power level. The level of the second interferer is increased by 1 dB steps until the output power of the receiver no longer corresponds to a change of 1 dB.

### 7.3.6 Noise Figure

The components in the RF IC receiver will all contribute noise to the received signal. This receiver noise will effect the receivers sensitivity as well as the signal-to-noise ratio (SNR) at the output of the receiver. A way to estimate the impact of the receiver noise on the received signal is to measure of the noise figure (NF). The easiest method to measure the NF is to compare the SNR at the receivers input ($SNR_{input}$) to the SNR at the output of the receiver ($SNR_{output}$).

*Formula 2: Calculation of the receiver's Noise Figure*

$$NF\big|_{dB} = SNR_{input} - SNR_{output} = \frac{S_{in}}{N_{in}}\bigg|_{dB} - \frac{S_{out}}{N_{out}}\bigg|_{dB}$$

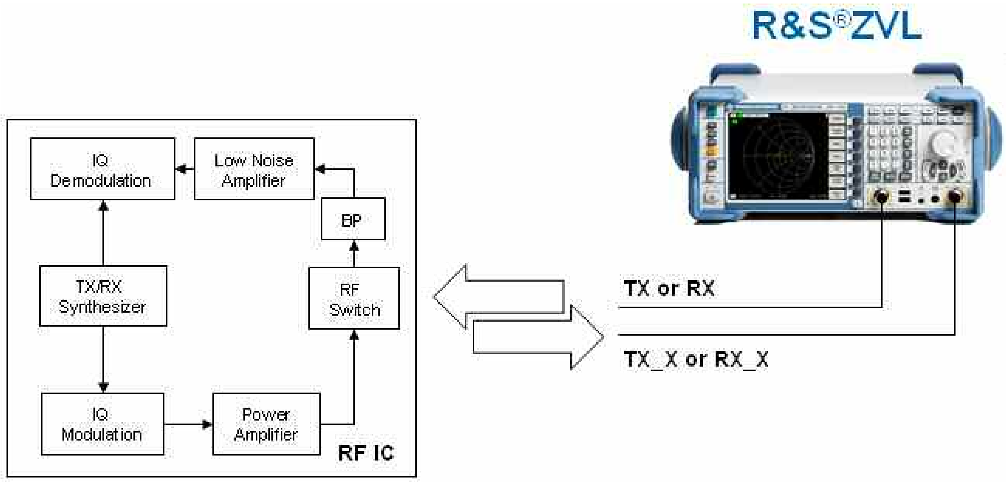
The input SNR is calculated by setting the power of the incoming signal $S_{input}$ in relation to the noise $N_{input}$, which is the basic noise as a product of Boltzmann's constant k and an appropriate temperature T, normally room temperature[12]. The output SNR is calculated by taking the output power $S_{out}$, which is the input power of the signal plus the gain of the low noise amplifier in the receiver chain relative to the noise, $N_{out}$, measured at the receivers output, when no signal is present at the input.

## 7.3.7 Other measurements

Beside the concrete RF measurements other parameters are measured at chip level to ensure the operability of the RF IC.

**S-Parameter and VSWR measurements.** One such measurement is the receiver's input impedance. This measurement requires a network analyzer, for example R&S® ZVA, R&S® ZVB or R&S® ZVL.

*Figure 59: VSWR, S-Parameter measurement with R&S ZVL*




For transmitting as well as receiving it is important that the output and input impedance differ from the expected matching of 50 Ohm. Otherwise a poorer value for noise in the

[12] k = 1,3806504(24)*10$^{-23}$ J/K, T = 293.15 K (20°C)

receiving direction results due to an increase in the insertion loss. In the transmitting direction a high mismatch than 50 Ohms would result in higher reflection back to the transmitter, causing also an increase in the insertion loss.

# 8 Abbreviations

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| ACK | Acknowledgement |
| ARQ | Automatic Repeat Request |
| BCCH | Broadcast Control Channel |
| CCDF | Complementary Cumulative Density Function |
| CP | Cyclic Prefix |
| CQI | Channel Quality Indicator |
| CRC | Cyclic Redundancy Check |
| DCI | Downlink Control Information |
| DL | Downlink |
| DL-SCH | Downlink Shared Channel |
| DRS | Demodulation Reference Signal |
| eNB | E-UTRAN NodeB, enhanced Node B |
| E-UTRA | Evolved UMTS Terrestrial Radio Access |
| E-UTRAN | Evolved UMTS Terrestrial Radio Access Network |
| FDD | Frequency Division Duplex |
| HSDPA | High Speed Downlink Packet Access |
| HSPA | High Speed Packet Access |
| HSUPA | High Speed Uplink Packet Access |
| LTE | Long Term Evolution |
| NACK | Negative Acknowledgement |
| OFDM | Orthogonal Frequency Division Multiplexing |
| OFDMA | Orthogonal Frequency Division Multiple Access |
| PAPR | Peak-to-Average Power Ratio |
| PBCH | Physical Broadcast Channel |
| PDCCH | Physical Downlink Control Channel |
| PDSCH | Physical Downlink Shared Channel |
| PHY | Physical Layer |
| PMI | Precoding Matrix Indicator |
| PUCCH | Physical Uplink Control Channel |
| PUSCH | Physical Uplink Shared Channel |
| QAM | Quadrature Amplitude Modulation |
| QPSK | Quadrature Phase Shift Keying |
| RF | Radio Frequency |

| | |
|---|---|
| RI | Rank Indicator |
| SC-FDMA | Single Carrier – Frequency Division Multiple Access |
| SISO | Single Input Single Output |
| SRS | Sounding Reference Signal |
| TDD | Time Division Duplex |
| UCI | Uplink Control Information |
| UE | User Equipment |
| UL | Uplink |
| UL-SCH | Uplink Shared Channel |

# 9 Literature

[1] Application Note 1MA111_2E; UMTS Long Term Evolution (LTE) Technology Introduction, Rohde & Schwarz,

[2] E. Dahlmann, S. Parkvall, J. Sköld, P. Beming; 3G Evolution – HSPA and LTE for Mobile Broadband; Academic Press,

[3] 3GPP TS 36.101 V8.3.0; User Equipment (UE) radio transmission and reception (Release 8),

[4] 3GPP TS 36.211 V8.4.0; Physical Channels and Modulation (Release 8),

[5] 3GPP TS 36.212 V8.4.0; Multiplexing and channel Coding (Release 8),

[6] 3GPP TS 36.521-1 V2.0.0; User Equipment (UE) conformance specification, radio transmission and reception Part 1: conformance testing (Release 8),

[7] 3GPP TS 36.508 V0.1.0; Common test environments for User Equipment (UE); Conformance testing (Release 8),

[8] 3GPP TR 36.803 V2.0.0; User Equipment (UE) radio transmission and reception (Release 8),

[9] C. Rauscher; Fundamentals of Spectrum Analysis, Rohde & Schwarz GmbH & Co. KG,

[10] Application Note 1MA71_0E; Measuring the Non-linearities of RF Amplifiers using Signal Generator and Spectrum Analyzer, Rohde & Schwarz,

[11] 3GPP TR 25.913 V7.3.0; Requirements for Evolved UTRA (E-UTRA) and Evolved UTRAN (E-UTRAN) (Release 7)

# 10 Additional Information

This application note is updated from time to time. Please visit the website 1MA138 to download the latest version.
Please send any comments or suggestions about this application note to [TM-Applications@rsd.rohde-schwarz.com](mailto:TM-Applications@rsd.rohde-schwarz.com).

# 11 Ordering Information

**Vector Signal Generator**

| | | |
|---|---|---|
| R&S® SMU200A | | 1141.2005.02 |
| R&S® SMU-B102 | Frequency range 100 KHz to 2.2GHz for 1st RF Path | 1141.8503.02 |
| R&S® SMU-B103 | Frequency range 100 KHz to 3GHz for 1st RF Path | 1141.8603.02 |
| R&S® SMU-B104 | Frequency range 100 KHz to 4GHz for 1st RF Path | 1141.8703.02 |
| R&S® SMU-B106 | Frequency range 100 KHz to 6 GHz for 1st RF Path | 1141.8803.02 |
| R&S® SMU-B202 | Frequency range 100 KHz to 2.2 GHz for 2nd RF Path | 1141.9400.02 |
| R&S® SMU-B203 | Frequency range 100 KHz to 3 GHz for 2nd RF Path | 1141.9500.02 |
| R&S® SMU-B9 | Baseband Generator with digital modulation (realtime) and ARB (128 M Samples) | 1161.0766.02 |
| R&S® SMU-B10 | Baseband Generator with digital modulation (realtime) and ARB (64MSamples) | 1141.7007.02 |
| R&S® SMU-B11 | Baseband Generator with digital modulation (realtime) and ARB (16MSamples) | 1159.8411.02 |
| R&S® SMU-B13 | Baseband Main Module | 1141.8003.02 |
| R&S® SMU-K55 | Digital Standard 3GPP LTE/EUTRA | 1408.7310.02 |
| R&S® SMU-K255 | Digital Standard 3GPP LTE/EUTRA for WinIQSIM2 | 1408.7362.02 |
| R&S® SMU-B14 | Fading simulator | 1160.1800.02 |
| R&S® SMU-B15 | Fading simulator extension | 1160.2288.02 |
| R&S® SMU-K74 | 2x2 MIMO Fading | 1408.7762.02 |
| R&S® SMU-K62 | AWGN | xxxx.xxxx.xx |
| R&S® SMJ100A | | 1403.4507.02 |
| R&S® SMJ-B103 | Frequency range 100 kHz - 3 GHz | 1403.8502.02 |
| R&S® SMJ-B106 | Frequency range 100 kHz - 6 GHz | 1403.8702.02 |
| R&S® SMJ-B9 | Baseband generator with digital modulation (realtime) and ARB (128 M Samples) | 1404.1501.02 |
| R&S® SMJ-B10 | Baseband Generator with digital modulation (realtime) and ARB (64MSamples) | 1403.8902.02 |
| R&S® SMJ-B11 | Baseband Generator with digital modulation (realtime) and ARB (16MSamples) | 1403.9009.02 |
| R&S® SMJ-B13 | Baseband Main Module | 1403.9109.02 |
| R&S® SMJ-K55 | Digital Standard 3GPP LTE/EUTRA | 1409.2206.02 |
| R&S® SMJ-K255 | Digital standard 3GPP LTE/EUTRA for WinIQSIM2 | 1409.2258.02 |
| R&S® SMATE200A | | 1400.7005.02 |
| R&S® SMATE-B103 | Frequency range 100 KHz to 3 GHz for 1st RF Path | 1401.1000.02 |
| R&S® SMATE-B106 | Frequency range 100 KHz to 6 GHz for 1st RF Path | 1401.1200.02 |
| R&S® SMATE-B203 | Frequency range 100 KHz to 3 GHz for 2nd RF Path | 1401.1400.02 |
| R&S® SMATE-B206 | Frequency range 100 kHz - 6 GHz for 2nd RF path | 1401.1600.02 |
| R&S® SMATE-B9 | Baseband Generator with digital modulation | 1404.7500.02 |

| | | |
|---|---|---|
| | (real time) and ARB (128 M samples) | |
| R&S® SMATE-B10 | Baseband Generator with digital modulation (realtime) and ARB (64MSamples) | 1401.2707.02 |
| R&S® SMATE-B11 | Baseband Generator with digital modulation (realtime) and ARB (16MSamples) | 1401.2807.02 |
| R&S® SMATE-B13 | Baseband Main Module | 1401.2907.02 |
| R&S® SMATE-K55 | Digital Standard 3GPP LTE/EUTRA | 1404.7851.02 |
| | | |
| R&S® AMU200A | Baseband signal generator, base unit | 1402.4090.02 |
| R&S® AMU-B9 | Baseband generator with digital modulation (realtime) and ARB (128 MSamples) | 1402.8809.02 |
| R&S® AMU-B10 | Baseband generator with dig. modulation (realtime) and ARB (64 MSamples) | 1402.5300.02 |
| R&S® AMU-B11 | Baseband generator with dig. modulation (realtime) and ARB (16 MSamples) | 1402.5400.02 |
| R&S® AMU-B13 | Baseband main module | 1402.5500.02 |
| R&S® AMU-K55 | Digital Standard LTE/EUTRA | 1402.9405.02 |
| R&S® AMU-K255 | Digital Standard LTE/EUTRA for WInIQSIM2 | 1402.9457.02 |
| R&S® AMU-B14 | Fading Simulator | 1402.5600.02 |
| R&S® AMU-B15 | Fading Simulator extension | 1402.5700.02 |
| R&S® AMU-K74 | 2x2 MIMO Fading | 1402.9857.02 |
| | | |
| R&S® AFQ100A | IQ modulation generator base unit | 1401.3003.02 |
| R&S® AFQ-B10 | Waveform memory 256 Msamples | 1401.5106.02 |
| R&S® AFQ-B11 | Waveform memory 1Gsamples | 1401.5206.02 |
| R&S® AFQ-K255 | Digital Standard LTE/EUTRA, WinIQSIM 2 required | 1401.5906.02 |

**Signal Analyzer**

| | | |
|---|---|---|
| R&S® FSQ3 | 20 Hz to 3.6 GHz | 1155.5001.03 |
| R&S® FSQ8 | 20 Hz to 8 GHz | 1155.5001.08 |
| R&S® FSQ26 | 20 Hz to 26.5 GHz | 1155.5001.26 |
| R&S® FSQ40 | 20 Hz to 40 GHz | 1155.5001.40 |
| | | |
| R&S® FSG8 | 9 kHz to 8 GHz | 1309.0002.08 |
| R&S® FSG13 | 9 kHz to 13.6 GHz | 1309.0002.13 |
| | | |
| R&S® FSV3 | 9 kHz to 3.6 GHz | 1307.9002.03 |
| R&S® FSV7 | 9 kHz to 7 GHz | 1307.9002.07 |
| | | |
| R&S® FSQ-K100 | EUTRA/LTE Downlink / BS Analysis | 1308.9006.02 |
| R&S® FSV-K100 | EUTRA/LTE Downlink / BS Analysis | 1310.9051.02 |
| R&S® FSQ-K101 | EUTRA/LTE Uplink / UE Analysis | 1308.9058.02 |
| R&S® FSV-K101 | EUTRA/LTE Uplink / UE Analysis | 1310.9100.02 |
| R&S® FSQ-K102 | EUTRA/LTE Downlink, MIMO | 1309.9000.02 |

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