LTE Terminal Tests under Fading Conditions with R&S®CMW500 and R&S®AMU200A

Application Note

Products:

- R&S®CMW500
- R&S®AMU200A

This application note shows how to perform LTE terminal block error rate (BLER) and throughput tests under fading conditions with the R&S®CMW500 Protocol Tester and the R&S®AMU200A Fading Simulator.

Application Note

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25.05.2011 – 1MA177_4e

ROHDE&SCHWARZ

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1 Introduction

The R&S®CMW500 Wideband Radio Communication Tester can be used throughout all phases of LTE device development and provides powerful tools for performing signaling tests. A wide choice of test scenarios is available as product options. Testing under real propagation conditions is important for many of these test scenarios in order to verify the correct operation of the device's protocol stack implementation in detail. For example, correct operation of layer 1 procedures like HARQ (hybrid automatic repeat request) retransmission protocol can be investigated, or throughput performance of the protocol stack can be tested. The HDR High Data Rate test case contained in the LTE example scenarios (option CMW-KF500) supports MIMO and is suited for demonstrating the influence of fading on the downlink BLER (Block Error Rate) and throughput. It is therefore used in this application note as example to explain the test setup for LTE terminal performance tests. Besides the R&S®CMW500 Wideband Radio Communication Tester as base station simulator, the R&S®AMU200 Baseband Signal Generator and Fading Simulator is part of the test setup. It models the propagation conditions including fading for SISO and MIMO scenarios, as well as noise.

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

- The R&S®CMW500 Wideband Radio Communication Tester is referred to as CMW.
- The R&S®AMU200A Baseband Signal Generator and Fading Simulator is referred to as AMU.
- R&S® refers to Rohde & Schwarz GmbH und Co KG.

2 Overview of LTE Technical Concepts

LTE (3GPP Release 8)
UMTS Long Term Evolution (LTE) was introduced in 3GPP Release 8. The objective was to design a high data rate, low latency and packet optimized radio access technology. LTE is also referred to as E-UTRA (Evolved UMTS Terrestrial Radio Access) or E-UTRAN (Evolved UMTS Terrestrial Radio Access Network). LTE defines an FDD (Frequency Division Duplex) and a TDD (Time Division Duplex) mode. The basic concept for LTE in downlink is OFDMA (Orthogonal Frequency Division Multiple Access), while MIMO technologies are an integral part of LTE. The uplink multiple access scheme is SC-FDMA (Single Carrier Frequency Division Multiple Access). See [1] for a detailed introduction into LTE technology.

OFDMA
This downlink transmission scheme for E-UTRA FDD and TDD is based on conventional OFDM (Orthogonal Frequency Division Multiplexing). In an OFDM system the available spectrum is distributed to multiple carriers, called subcarriers. Each of these carriers is independently modulated by a low rate data stream. OFDM has several benefits including its robustness against multipath fading and its efficient receiver architecture. In contrast to an OFDM transmission scheme, OFDMA allows sharing the available bandwidth among multiple users.

A radio frame in LTE lasts 10 ms and consists of 10 subframes lasting 1 ms each. The smallest unit that can be allocated within a subframe is the resource block. It comprises 12 subcarriers with 15 kHz spacing (corresponding to 180 kHz) in the frequency domain and half a subframe (corresponding to 7 OFDM symbols for the normal configuration) in the time domain.

MIMO
Multiple antenna systems are typically known as Multiple Input, Multiple Output systems (MIMO). MIMO can be used to make radio communications more robust, even with varying channels. Towards this end, transmit and/or receive diversity mechanisms are exploited. Multiple antenna technology can also be used to increase the data rate instead of improving robustness: with spatial multiplexing, several data streams can be transmitted simultaneously over the same air interface resource. In practice, spatial multiplexing and diversity methods are used separately or in combination, depending on the channel condition. See [2] for a detailed introduction into MIMO. MIMO is a key technology in LTE to meet the ambitious requirements on peak data rate. Seven MIMO transmission modes, including transmit diversity and spatial multiplexing schemes, are defined in 3GPP release 8.

Single User MIMO (SU-MIMO)
When the data rate is to be increased by spatial diversity for a single UE (user equipment), this is called Single User MIMO (SU-MIMO). The example in this application note uses 2x2 SU-MIMO, which is referred to as 2x2 MIMO in the following. Figure 3 illustrates the 2x2 MIMO scenario, with 2 transmit antennas at the base station, and 2 receive antennas at the UE. The radio channel between each transmit and receive antenna is denoted as h_{ij}, with i being the index of the receive antenna, and j being the index of the transmit antenna. When evaluating the performance of LTE devices, modeling these radio channels realistically is an important task.

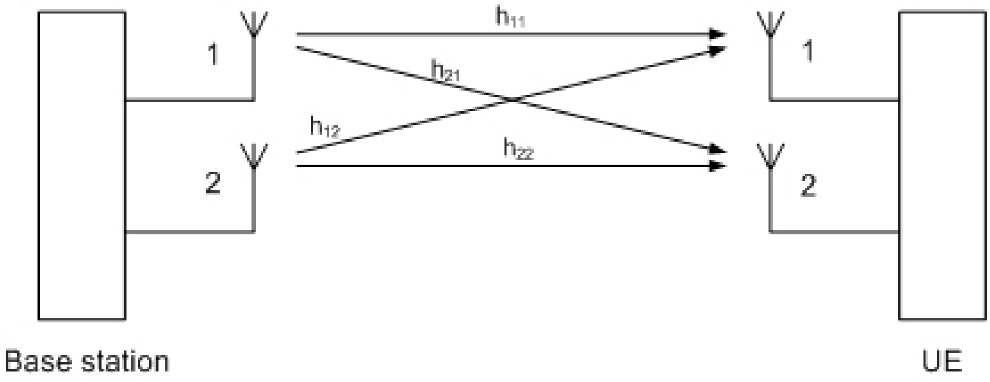

Figure 1: SU-MIMO

MULTIPATH PROPAGATION or **FADING** is an effect which occurs in real world situations. A signal sent from the base station may take different routes (direct line of sight or reflected) and reach the receiving antenna at different times leading to a sum of phase shifted and, if the receiver is moving, frequency shifted signals. For investigating MIMO scenarios, additional aspects have to be considered. The performance of MIMO algorithms largely depends on the correlation between the radio channels (h_{ij} in Figure 3). For example, MIMO spatial multiplexing performance degrades in highly correlated scenarios, because the receiver cannot recover the simultaneously transmitted data streams any more. The AMU fading simulator offers LTE SISO and MIMO fading propagation scenarios covering a wide range of real world situations. Also the channel models defined by 3GPP for LTE are supported, e.g. EPA (Extended Pedestrian A), EVA (Extended Vehicular A) and ETU (Extended Typical Urban) with low, medium and high correlation. See [3] for a detailed description of MIMO test setups with fading.

AWGN (Additional White Gaussian Noise) is typically modeled in receiver tests as well because it may also lead to a decrease of throughput. The quality of the received signal is affected by the ratio of the signal power to the surrounding traffic noise level (Signal/Noise Ratio). The modulated signals from neighbor cells simply appear as noise. This effect is simulated by including AWGN to the signal.

In the following the most important terms and LTE downlink (DL) channel names used in this application note are briefly described.

Downlink Data Transmission

PDSCH – The user data in the LTE downlink is carried on the Physical Downlink Shared Channel.

Downlink Control Channels

PDCCH – Physical Downlink Control Channel serves a variety of purposes. Primarily it is used to convey the scheduling decisions to individual UEs (User Equipment). It carries Downlink Control Information (DCI), e.g. downlink or uplink scheduling assignments, and is located within the first OFDM symbols of a subframe.

PCFICH – Physical Control Format Indicator Channel is carried on specific resource elements in the first OFDM symbol of the subframe. It is used to indicate the number of OFDM symbols for the PDCCH (1, 2, 3, or 4 symbols are possible).

PHICH – Physical Hybrid ARQ Indicator Channel - Carries the ACK/NACKs for uplink data packets.

PBCH – Physical Broadcast Channel - Carries the Master Information Block.

Downlink physical signals

Reference signals – A cell-specific reference signal is transmitted in specified resource elements in downlink. Every sixth subcarrier in the frequency domain is carrying a reference symbol. The reference signal is used for channel estimation in the UE receiver.

Synchronization signals – Primary and Secondary synchronization signals are used by the UE to acquire synchronization to the cell and to identify a cell.

Among other factors, the overall LTE performance will depend on the power settings of the LTE downlink signal. These power settings can be flexibly adjusted in the CMW Protocol Tester, acting as base station simulator in the test setup described in this application note. In LTE, the downlink power control mechanism in the base station determines the energy per resource element (EPRE). A resource element in LTE is defined as the smallest entity in the resource grid of subcarriers (in the frequency domain) and OFDM symbols (in the time domain). Each resource element therefore corresponds to one complex-valued modulation symbol. A commonly used reference value is the energy per resource element for the reference signals:

RS-EPRE – Reference Signal – Energy per Resource Element– Is set by the base station. The levels of the downlink physical channels are typically referenced to RS-EPRE. The downlink reference signal EPRE is derived by the UE from higher layer signaling (system information).

For the PDSCH power setting, it has to be differentiated between PDSCH resource elements in OFDM symbols carrying reference signals and PDSCH resource elements in OFDM symbols without reference signals. The ratio of PDSCH-EPRE to cell-specific RS-EPRE is denoted by either ρ_A or ρ_B. It is denoted by

- ρ_A in case of OFDM symbols without reference signals, and
- ρ_B for OFDM symbols carrying reference signals.

ρ_A is UE-specific and derived from higher layer signaling.

The ratio ρ_B / ρ_A is cell-specific and provided by higher layer signaling.

Figure 4 illustrates a possible scenario with power setting for the reference signals, the PDSCH and the PDCCH (blue).

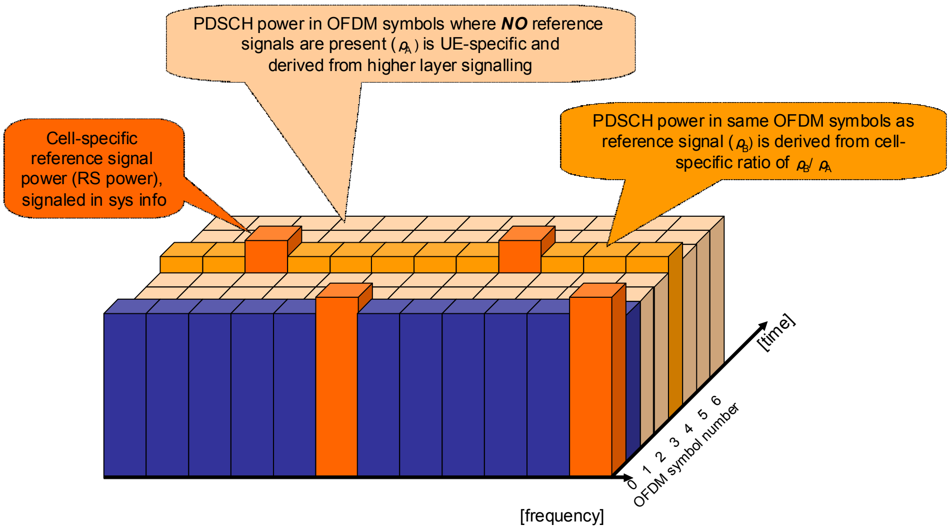

Figure 2: LTE Downlink Power Settings

3 Measurement Setup

3.1 Overview

All the CMW test cases from the LTE example scenarios (option CMW-KF500) use the RF1 COM for SISO and additionally the RF3 OUT connector for the MIMO scenario which is necessary for the HDR High Data Rate test.

Fig. 2 shows the CMW digital baseband connection. SISO tests need input and output A while MIMO requires input and output A and B.

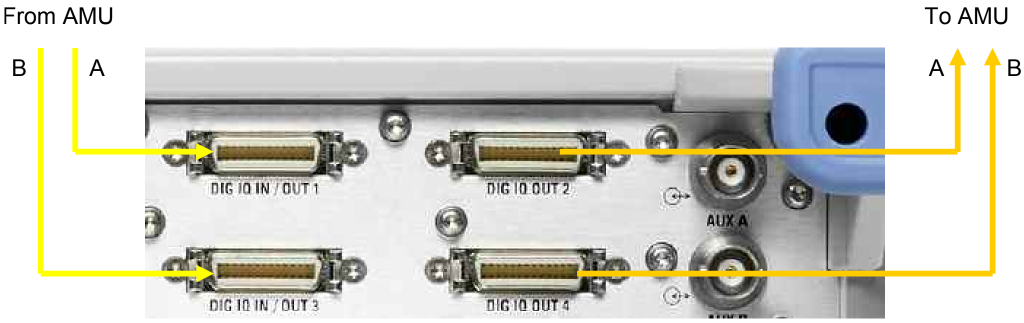

Figure 3: CMW Digital In / Out

3.1.1 SISO Test Setup

The following figure shows the setup for SISO based measurements.

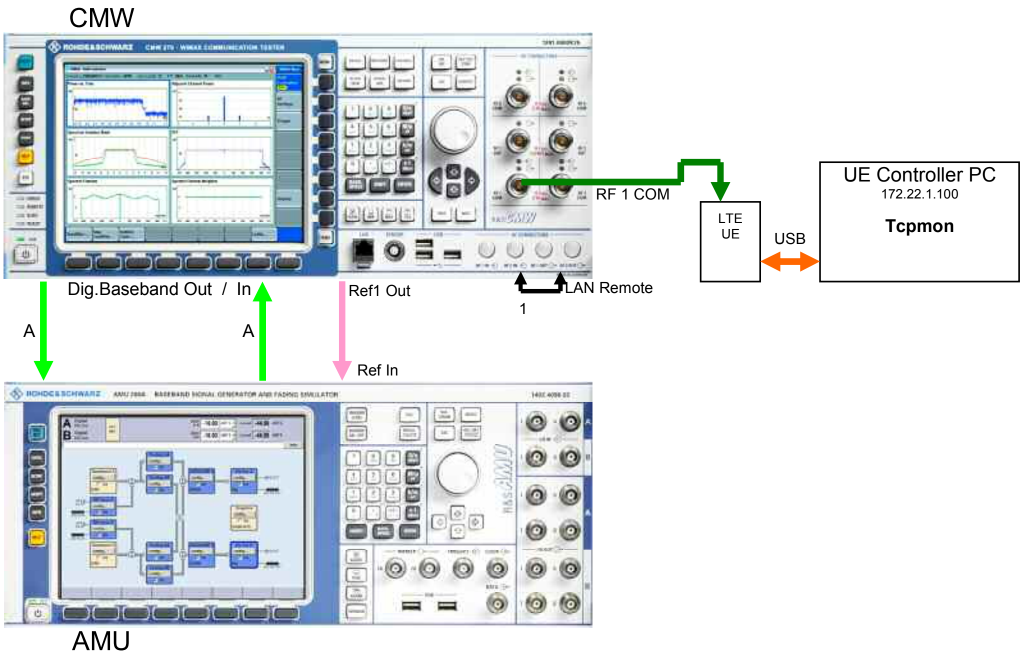

Figure 4: Hardware Configuration for LTE Terminal Test under SISO Fading Conditions

The AMU fading simulator is connected to the CMW via the digital baseband input and output A. Some measurements from the LTE example scenarios are set to SISO by default.

3.1.2 MIMO Test Setup

The following figure shows a MIMO setup which is required for the HDR High Data Rate example scenario.

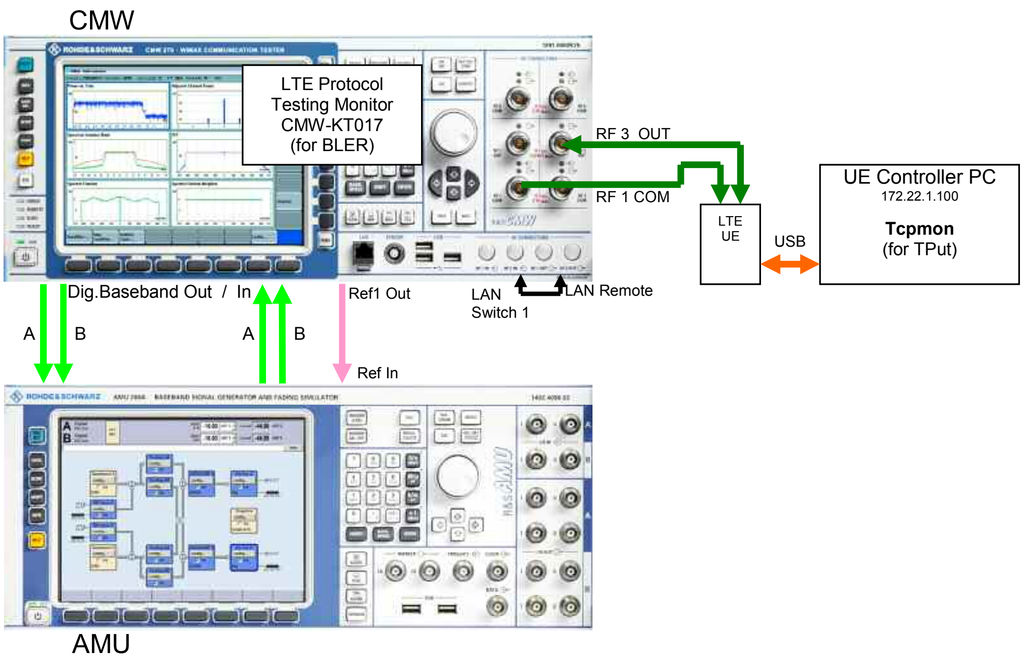

Figure 5: Hardware Configuration for LTE Terminal Test under MIMO Fading Conditions

Detailed configuration information for AMU and CMW can be found at the end of this application note.

The AMU fading simulator is connected to the CMW via two digital baseband inputs and outputs A and B. In this application note the throughput measurement software TCP Monitor Plus (Tcpmon) is used to measure the downlink throughput. It runs on the PC controlling the UE.

3.2 CMW Configuration

Following software tools from the CMW Protocol Tester package R&S MCT are used for configuring the test case ml_HDR High Data Rate. The same principle is also applicable for the other example test cases.

3.2.1 LTE 4 TCT

The LTE 4 TCT (Throughput Configuration Tool) allows easy tweaking LTE test case parameters which affect the throughput. It displays the max. possible throughput for comparison with the actual measurement results.

- Execute **START** → **PROGRAMS** → **R&S MCT** → **LTE TCT**

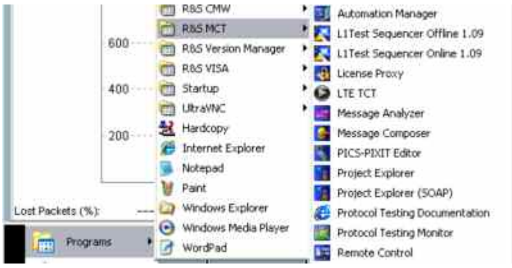

Figure 6: Execute LTE TCT

- Press **MOUNT** and select the directory of the desired test case, e.g. c:\Rohde-Schwarz\Scenarios\27.25.0\APPL old\MLAPI\TCT4LTE\1\ml_tct4lte\msg\

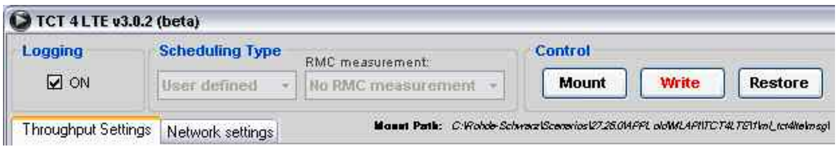

Figure 7: Mount Path

- Edit the desired parameters, e.g. E-UTRA Band (e.g. Band 20) and the ones affecting the uplink and downlink data rate, **ANTENNA CONFIG**uration (SISO, TxDiv or MIMO), **SYSTEM BANDWIDTH** (1.4, 3, 5, 10, 15, 20 MHz) and the **PERFORMANCE ASSIGNMENT** parameters **MODULATION** scheme (QPSK, 16 QAM and 64 QAM), **NPRB** (Number of Physical Resource Blocks) and **TBS** (Transport Block Size). The max. possible data rates (**MAC TBS**, **RLC** and **MAX. IP**) are updated whenever one of the parameters above is changed. The **EST. UL POWER LEVELS** displays the evaluated power levels for PRACH and PUSCH transmissions. Set the **DL** power to e.g. -500 cBm = -50 dBm and check **AUTO UL POWER** in this example. In automatic mode, the setting of the Uplink reference level will be chosen +3 dB on top of the calculated PUSCH power level (max: +21 dBm). If the **MSG #5** and **PUSCH** levels are displayed red, the **NOMINAL PUSCH** slider needs to be changed until they turn green. A **TBS**/**NPRB** combination evaluating into a code rate higher than “1” is displayed in a red color and a tooltip informs that it can be resolved in either changing the number of **PDCCH** symbols (by moving the **CFI** slider) or in adapting the **MCS** index.

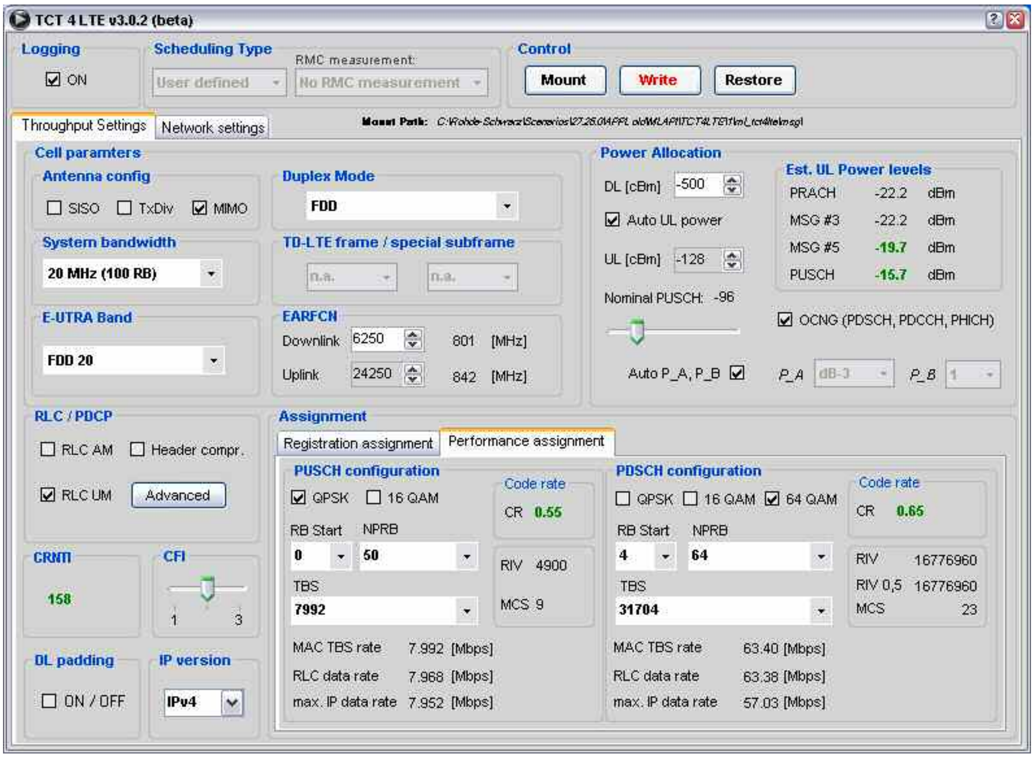

Figure 8: TCT 4 LTE GUI

- **REGISTRATION ASSIGNMENT** – It is convenient not to use the highest possible but rather medium values for NPRB and TBS for uplink and downlink to ensure successful registration even under non-ideal transmission conditions (fading and AWGN turned ON in AMU).

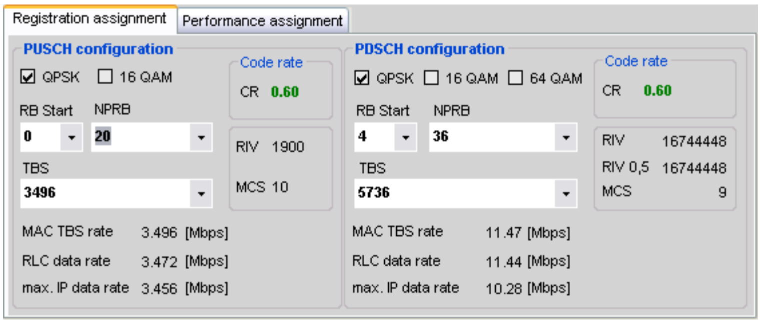

Figure 9: Registration Assignment

- **PERFORMANCE ASSIGNMENT** – The maximum theoretical DL data rate is 142.2 Mbps with System Bandwidth = 20 MHz, Modulation Type = 64 QAM, NPRB = 96 and TBS = 71112. The **MAX. IP DATA RATE** in this example is 57.03 Mbps with the parameters as shown in Figure 8. The data rate sent by the DAU must be ≤ max. IP data rate (e.g. 56 Mbps, see 4.1).

- After editing the parameters press the **WRITE** button which updates all necessary *.xml files in the mounted directory.

For detailed information see the TCT 4 LTE manual.

3.2.2 Project Explorer (Option CMW-KT010)

3.2.2.1 TestProjectLTE

Open the test project description file e.g. c:\Rohde-Schwarz\Scenarios\27.25.0\APPL old\MLAPI\TCT4LTE\1\ TCT4LTE_TestProjectDescription.tpd and check the **ML_TCT4LTE** test case.

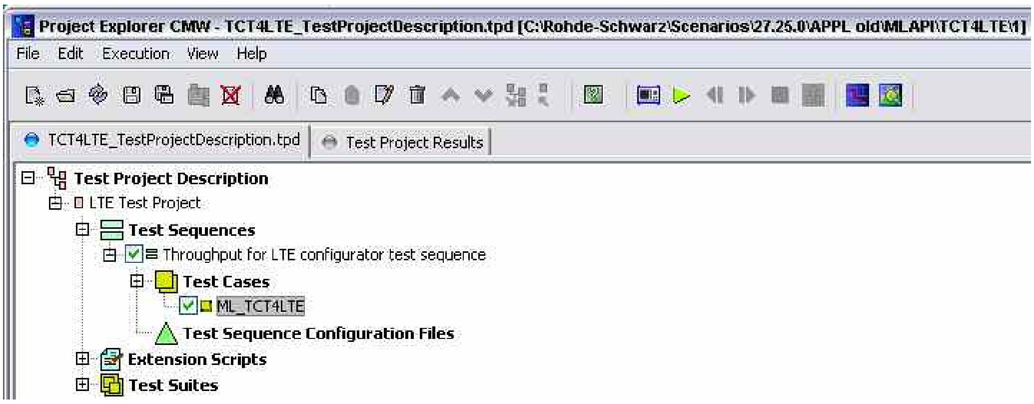

Figure 10: Select Test Case

Click the System Configuration Button.

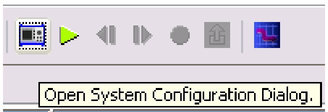

Figure 11: Open System Configuration Dialog

In the System Configuration Dialog set UE Connected To RF (Fading). Close the Dialog and click yes to save the configuration.

Figure 12: UE Connected to RF

3.2.2.2 TestSuiteLTE

Open the test suite description file e.g. c:\Rohde-Schwarz\Scenarios\27.25.0\APPL old\MLAPI\TCT4LTE\1\ TCT4LTE_TestSuiteDescription.tpd and check the **ML_TCT4LTE** test case. Turn **RF WITH EXT. DIGIQ FADER** ON in order to use the external fading simulator AMU.

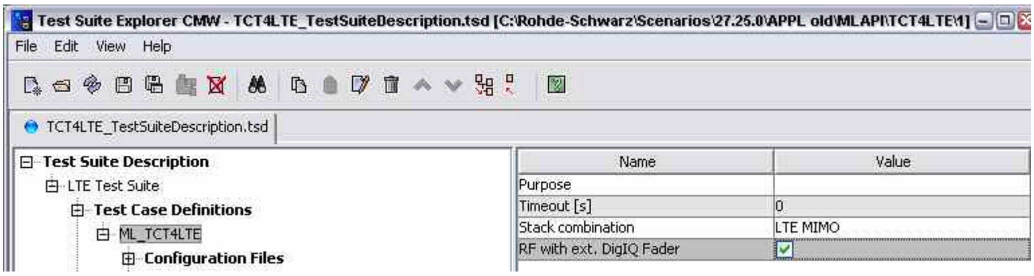

Figure 13: Turn external fading simulator ON

3.3 AMU Configuration

Changing input level, fading profile or AWGN settings on the AMU affect the insertion loss and must be compensated on the CMW as shown in 3.3.7 ***before*** a throughput or other measurement is performed!

3.3.1 External Reference

The AMU needs to be synchronized by connecting the CMW Ref1 Out to the AMU Ref In. The AMU must be set to external reference in the following menu.

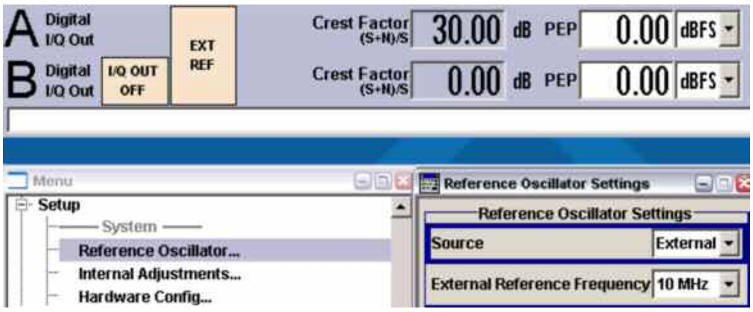

Figure 14: External Reference

3.3.2 Digital Input

Two important criteria of the baseband signal are the Crest Factor and the PEP (Peak Envelope Power). The PEP of the digital LTE basband signal coming from the CMW is defined as **0 dBFS** (= dB Full Scale, the level ratio of the signal to the maximum possible voltage of I or Q, e.g. 0.5Vp = 1Vpp [peak to peak]). The Crest Factor is the ratio between PEP and (RMS) **LEVEL**.

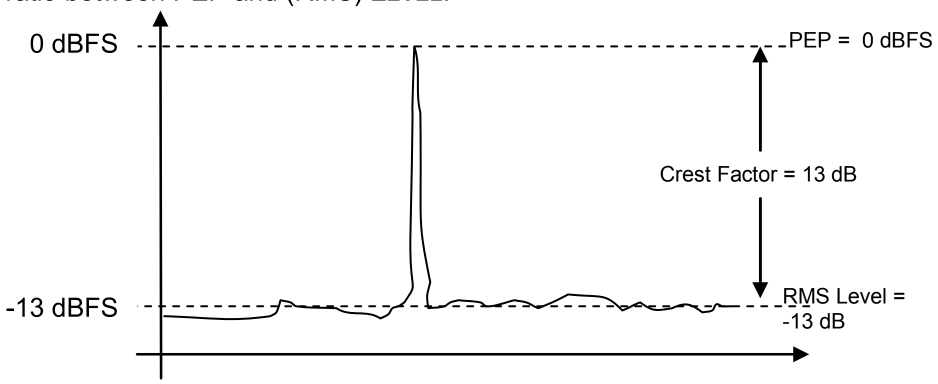

Figure 15: PEP, RMS Level and Crest Factor

The LTE signal at the CMW digital baseband output is defined as follows:

Crest Factor = 15 dB – (DL RS Power Offset wrt maximum EPRE)
= 15 dB – (-5 dB) = **20** dB

wrt means “with reference to”.

DL RS Power Offset wrt maximum EPRE is found in the configuration file **Lte_CrrcCellPowerAssignementConfigReq.xml** which can be viewed and edited with the **Message Composer** (option CMW-KT012) or a text editor. In the example of Figure 16, DL RS Power wrt maximum EPRE is -5 dB, thus
Crest Factor = 15 dB – (-5 dB) = 20 dB.

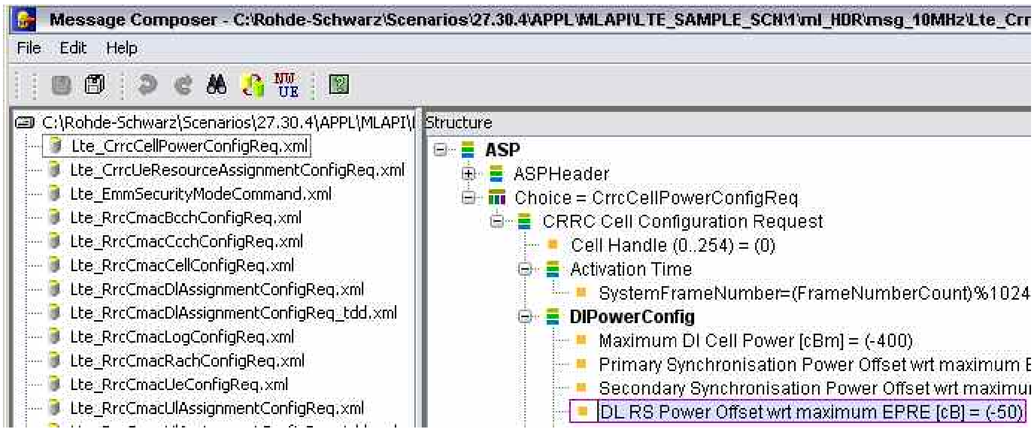

Figure 16: DL RS Power Offset

It must be taken into account when adjusting the digital input to the AMU. The AMU BB Input A (and B for MIMO) must be set to 0dBFS PEP and the Crest Factor as determined above (20 dB in this example).

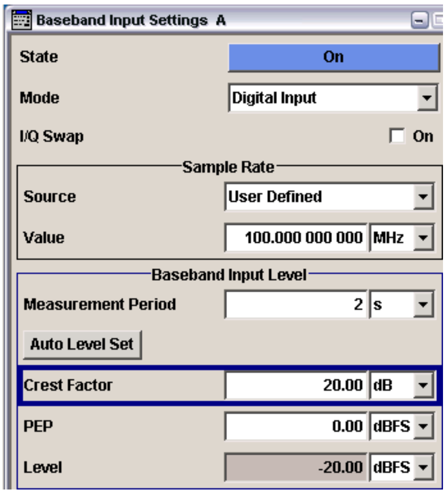

Figure 17: AMU Baseband Input Settings

<u>Remote Commands:</u>

```
SOURce1|2:BBIN:STATe ON              // Turn Baseband A|B Inp. ON
SOURce1|2:BBIN:MODE DIGital          // Select Digital Input Mode
SOURce1|2:BBIN:SRATe:SOURce USER     // Select Digital Input Mode
SOURce1|2:BBIN:SRAT 100MHz           // 100 MHz sample rate
```

```
SOURce1|2:BBIN:CFACtor 20.00        // Set 20 dB Crest Factor
SOURce1|2:BBIN:POWer:PEAK 0.00      // Set 0 dBFS PEP
```

3.3.3 Digital Output

The digital I/Q output A (and B for MIMO) must be turned ON and the PEP set to the same value as at the input (0.00 dBFS). Set the output sample rate to 100 MHz.

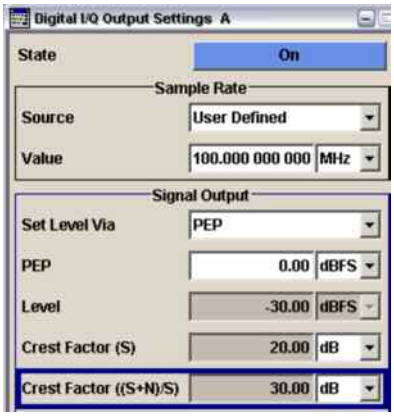

Figure 18: Digital I/Q Output Settings

<u>Remote Commands:</u>

```
SOURce1|2:IQ:OUTPut:DIGital:SRATe:SOURce USER
SOURce1|2:IQ:OUTPut:POWer:VIA PEP
SOURce1|2:IQ:OUTPut:DIGital:POWer:PEP 0    // Set PEP = 0 dBFS
SOURce1|2:IQ:OUTPut:DIGital:STATe ON       // BB A|B dig. outp ON
```

3.3.4 Display Settings

In the **I/Q OUT SETTINGS** menu select **LEVEL DISPLAY SETTINGS…** for the easy readout of output level and insertion loss.

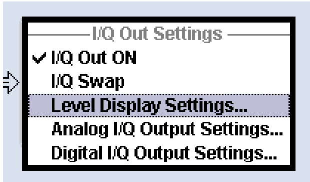

Figure 19: Level Display Settings

Set the **AUXILIARY INFORMATION** parameter in the **LEVEL DISPLAY SETTINGS A** (and **B** for MIMO) menu to **CREST FACTOR ((S+N)/S)**. This crest factor indicates the ratio of the peak value of the signal plus noise, to the RMS level of the signal without noise.

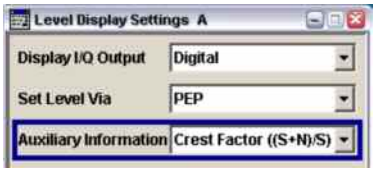

Figure 20: Level Display Settings

<u>Remote Commands:</u>

```
SOURce1|2:IQ:OUTPut:DISPlay DIGItal
SOURce1|2:IQ:OUTPut:POWer:VIA PEP
SOURce1|2:IQ:OUTPut:DISPlay:AINFormation CFSN
```

3.3.5 Fading Settings

The example HDR High Data Rate test case runs with 2x2 MIMO, but some of the other LLAPI/MLAPI example test cases use a SISO scenario. Both scenarios are described below.

3.3.5.1 2x2 MIMO Scenario

Select **2x2 MIMO** in the Fading A (or B) config… menu.

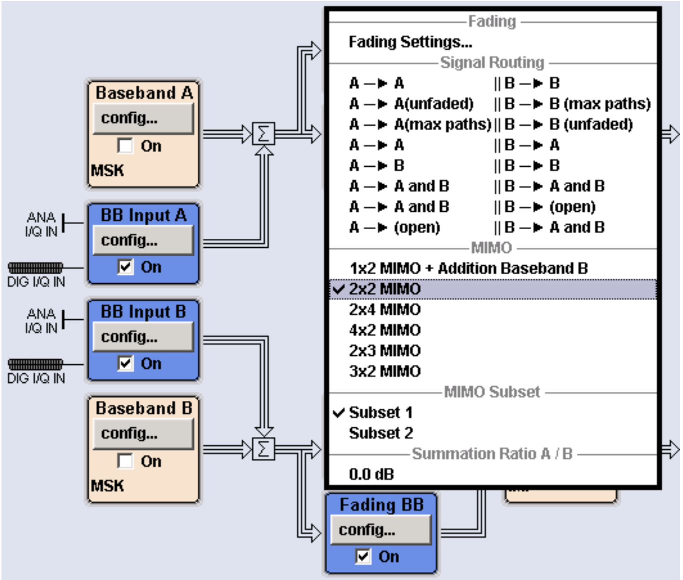

Figure 21: 2x2 MIMO Scenario

Remote Command:

```
SOUR:FSIM:ROUT FA1A2BFB1A2BM24
```

Select the desired fading standards in the LTE MIMO menu, e.g. EPA 5Hz Low (Enhanced Pedestrian A, low correlation).

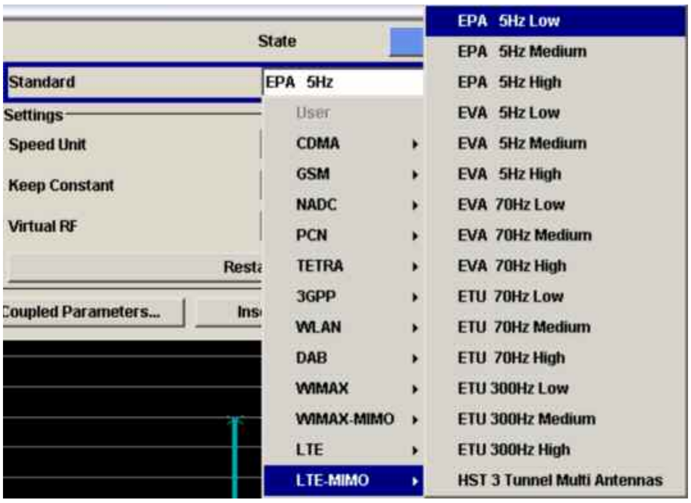

Figure 22: LTE-MIMO Fading Standards

Remote Command:

```
SOURce1|2:FSIMulator:STANdard LMEPA5L
```

The AMU needs to know the CMW RF frequency in order to calculate Doppler based fading standards correctly. This frequency, e.g. 2.646 GHz, must be entered in the **VIRTUAL RF** control.

Figure 23: Virtual RF

<u>Remote Command:</u>

```
SOURce1|2:FSIMulator:FREQuency 2646MHz
```

Turn fading ON.

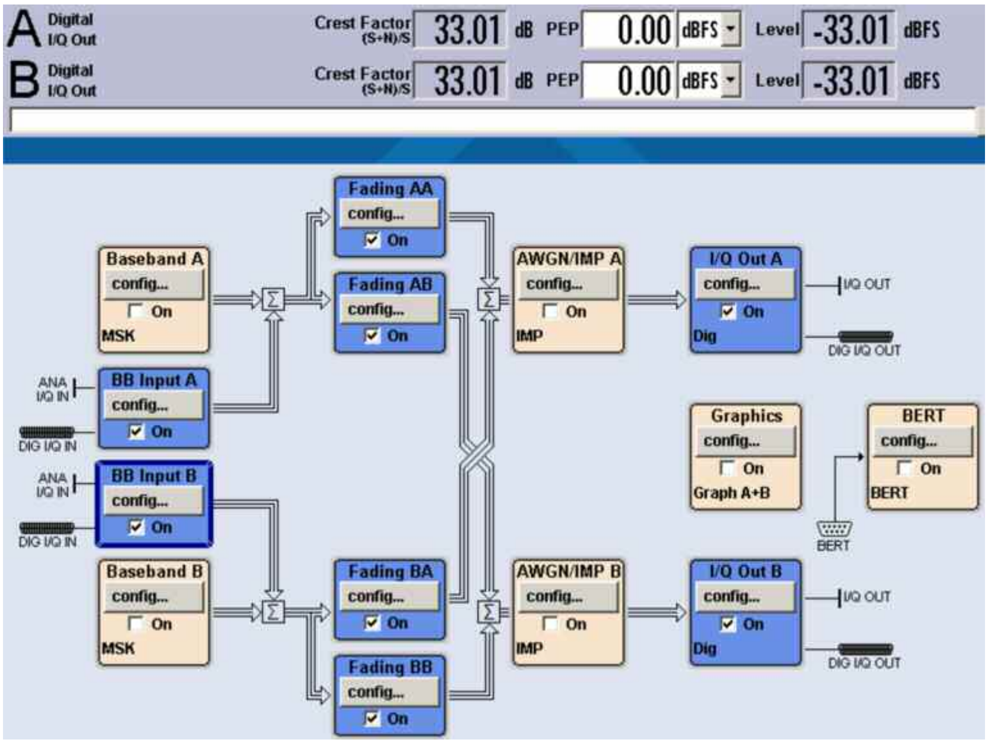

Figure 24: 2x2 MIMO Fading Scenario

<u>*Note:*</u> *When changing a setting in one of the fading blocks Fading AA, AB, BA or BB, it also always applies to all other blocks.*

There are three correlation modes for EPA, EVA and ETU LTE fading settings according to 3GPP specification TS36.101.

- Low = No correlation between path A and B faders. This results in best throughput and BLER results.
- Medium = A and B are correlated to a certain degree, throughput decreases and BLER increases.
- High = Full correlation between A and B faders which annuls the improvement by MIMO.

3.3.6 AWGN Settings

Press Config… in AWGN/IMP A/B control and select AWGN…

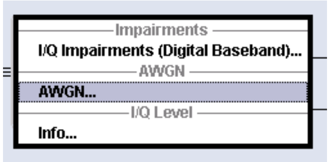

Figure 25: Select AWGN menu

In the AWGN menu set the System Bandwidth (e.g. 10 MHz), the desired Signal/Noise Ratio (e.g. 0.00 dB) and turn State ON.

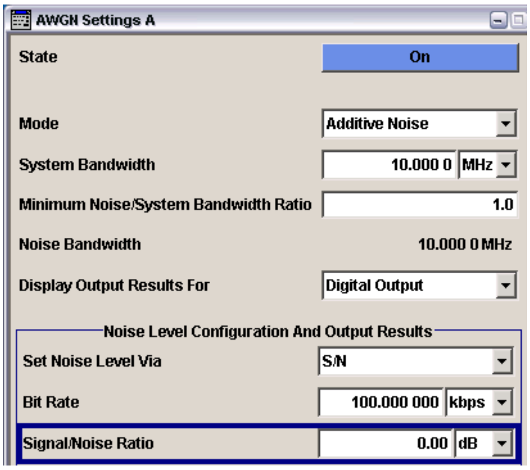

Figure 26: AWGN Parameters

<u>Remote Commands:</u>

```
SOURce1|2:AWGN:MODE ADD
SOURce1|2:AWGN:BWID 20 MHz
SOURce1|2:AWGN:BWID:RAT 1.0
SOURce1|2:AWGN:DISP:ORES DIG
SOURce1|2:AWGN:POWer:MODE SN
SOURce1|2:AWGN:BRATE 100 kbps
SOURce1|2:AWGN ON
```

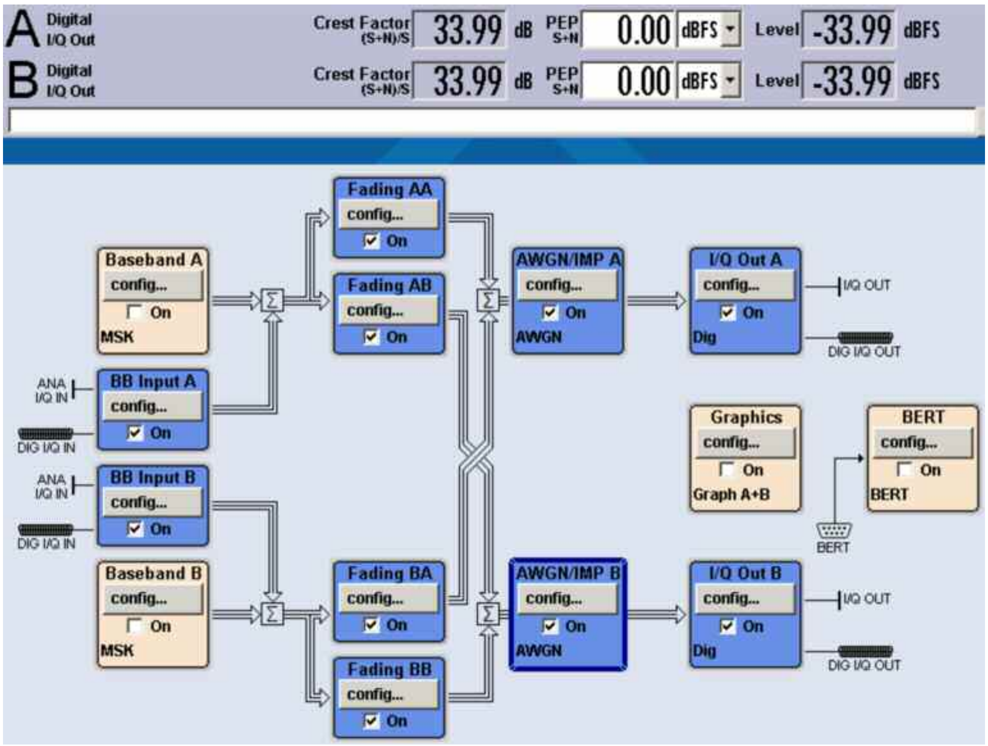

Figure 27: MIMO Fading + AWGN

3.3.7 Insertion Loss Compensation

A faded signal has a higher Crest Factor as an unfaded one. In order to avoid distortion the signal must be attenuated before entering the fading unit. The necessary attenuation aka insertion loss depends on the fading standard and AWGN level.

It can be calculated by subtracting the input Crest Factor from

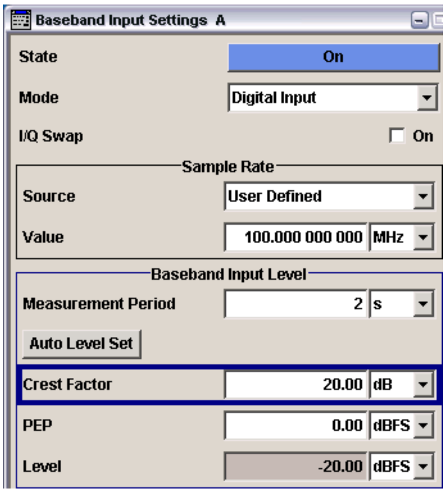

Figure 28: Baseband Input Crest Factor

the output Crest Factor (see Level Display Screen).

Figure 29: AMU Level Display Screen

$$InsertionLoss = OutpCrestFactor - InpCrestFactor = 33.99dB - 20dB = 13.99dB$$

The insertion loss in the baseband must be compensated on the CMW RF level either by

1. using the RF1COM and RF3OUT output attenuation. With 2.0 dB cable loss Ext. Out Attenuation = 2.0 dB + 13.99 dB = **15.99 dB**

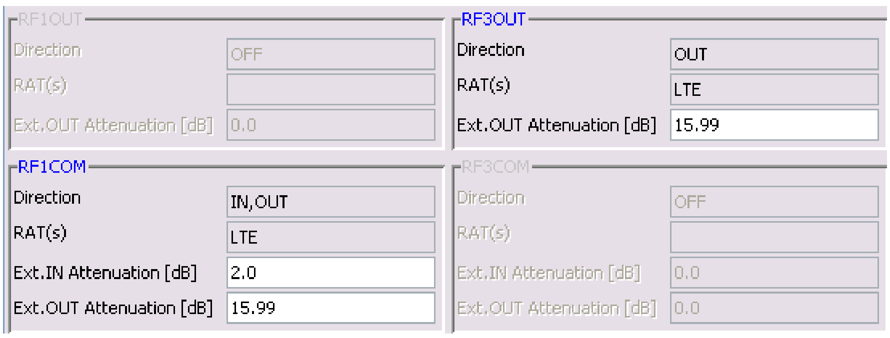

Figure 30: External Input and Output RF Attenuation

The measurement examples in chapter 4 use this method of compensation since it allows to store setups for different fading standards.

2. adding the insertion loss to the **DL** power (see chapter 3.2.1). Max. Dl Cell Power = nom. Value + insertion loss = -50 dBm + 13.99 dB = **-36.01 dBm**.

Figure 31: Compensate Insertion Loss with Dl Power

Note: The fading profile and AWGN settings should not be changed during an active LTE connection, since it affects the DL power which may lead to a call drop. Always set the fading profile and AWGN before establishing the connection.

4 LTE Performance Measurements

This section describes the necessary steps to perform an LTE BLER or throughput measurement under condition of 2x2 MIMO fading with various standards. The numbered steps below apply for both BLER and throughput measurements.

1. Configure the AMU first as shown in chapter 3. Memorize the Insertion Loss in the Level Display field.
2. Configure the CMW as shown in chapter 3 and compensate the Insertion Loss as shown in chapter 3.3.7.
3. Run the TCT4LTE test case on the CMW by clicking the green arrow or pressing F5 in the Project Explorer.

Figure 32: Start Test Case

A message box tells you to switch the UE OFF.

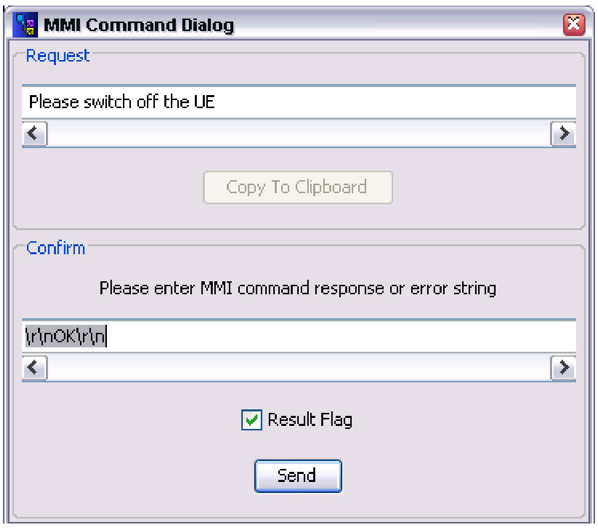

Figure 33: Switch UE OFF

After pressing **SEND** a message box tells you to turn the UE ON.

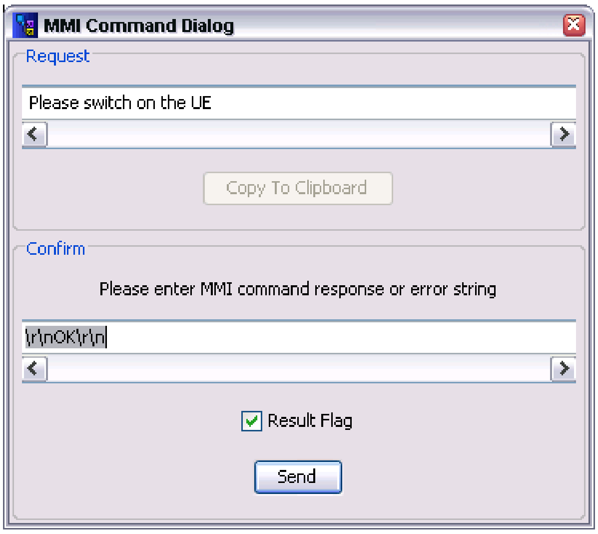

Figure 34: Switch UE ON

Press **SEND** when the UE control program notifies that an internet connection has been established. A message box informs you that the UE is ready to receive data.

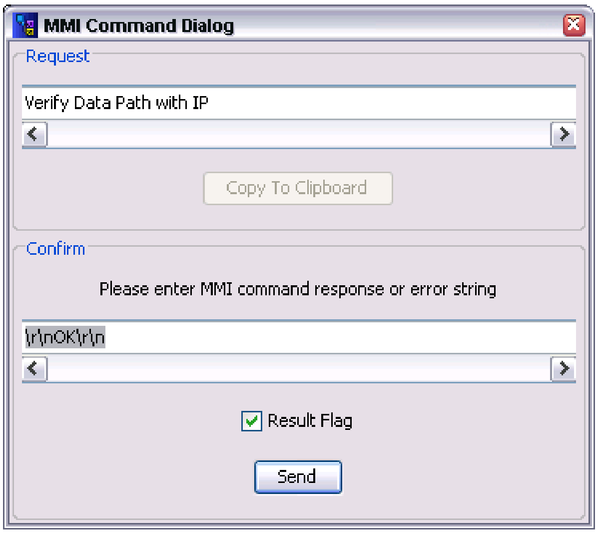

Figure 35: Data Path ready

4.1 DAU (Option CMW-B450A) iperf

The DAU application **IPERF** sends data packages with a defined data rate to the UE. It is used for the following BLER and Throughput measurement.

- Press the MEASURE button on the CMW and check Data Appl. → Measurements 1.

Figure 36: Select DAU menu

- Press the **DATA 1 MEAS** software tab to enter the DAU Menu.
- Select the iPerf menu tab
- Press **CONFIGURE SERVICES** software key.
- In the **DATA APPLICATION CONTROL** window select the **IP CONFIG** tab and use following settings. Close the window.

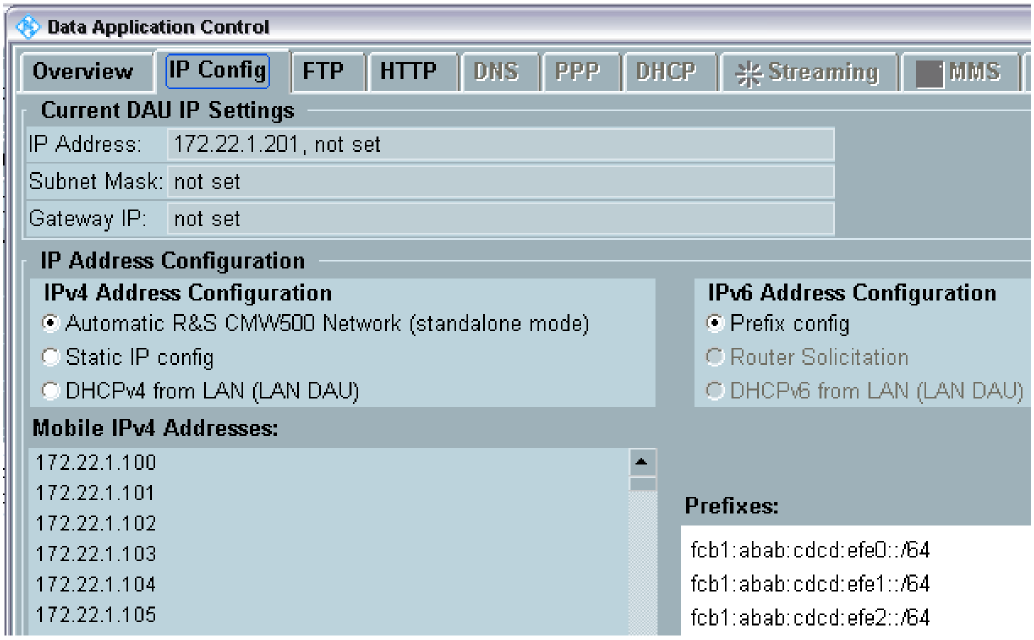

Figure 37: IP Config menu

- In the **DATA APPLICATION MEASUREMENTS 1** window press the **CONFIG…** software key.
- In the **IPERF CONFIG** window select **CLIENT #1**, **UDP** and **BIT RATE** = e.g. 56 MBit/s (must be ≤ DL IP data rate, see 3.2.1). Press Ok to return to the **DATA APPLICATION MEASUREMENTS 1** window.

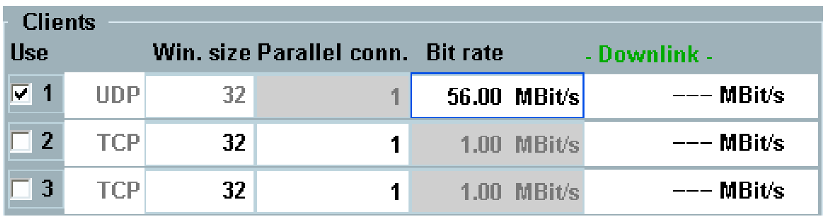

Figure 38: IPerf Config window

- Press the Iperf software key and press the ON/OFF button. The yellow RUN status message indicates that the data generator is running.

Figure 39: Iperf is running

<u>Remote Commands:</u>

Configuration:

TEST DURATION – Time the test should last (in seconds).
`CONFigure:DATA:MEAS1:IPERf:TDURation 1000`
PORT NUMBER – Data Application Unit (LAN DAU) port number for the connection.
`CONFigure:DATA:MEAS1:IPERf:CLIent1:PORT 5001`
WINDOW SIZE – Size of the Negative Acknowledgement (NACK) window (in kByte).
`CONFigure:DATA:MEAS1:IPERf:CLIent1:WSIZe 32`
LISTEN PORT – UE's listen port number for the connection.
`CONFigure:DATA:MEAS1:IPERf:CLIent1:LPORt`
BITRATE – Maximum bit rate to be transferred (in kBit/s).
`CONFigure:DATA:MEAS1:IPERf:CLIent1:BITRate 56M`
PROTOCOL – Specifies the protocol used for data transfer for the client connection.
`CONFigure:DATA:MEAS1:IPERf:CLIent1:PROTocol UDP`
IPADDRESS – Specifies the IP address of an IPerf client.
`CONFigure:DATA:MEAS1:IPERf:CLIent1:IPADdress 172.22.1.100`
ENABLE – Activates an IPerf client instance.
`CONFigure:DATA:MEAS1:IPERf:CLIENT1:ENABLE ON`

Start/Stop generating data:

```
INIT:DATA:MEAS1:IPERf
STOP:DATA:MEAS1:IPERf
ABORt:DATA:MEAS1:IPERf
```

4.2 BLER

The BLER (Block Error Rate) can be determined by counting the ACK/NACKs (ACKnowledged / Not ACKnowledged) returned by the UE. A BLER measurement can be performed with the **CMW-KT017 LTE PROTOCOL TESTING MONITOR** (PTM) option.

1. Turn 2x2 MIMO Fading ON and select fading profile e.g. **EPA 5HZ LOW** on the AMU.

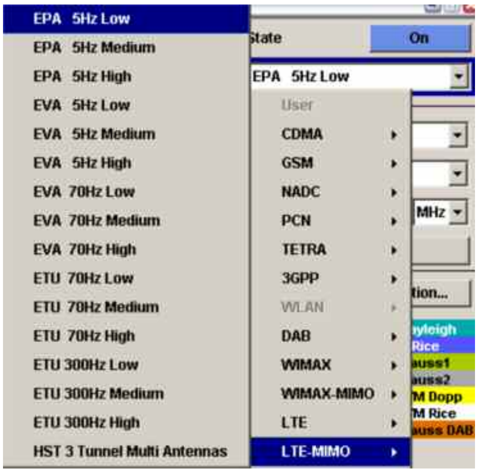

Figure 40: Select LTE-MIMO Fading Profile

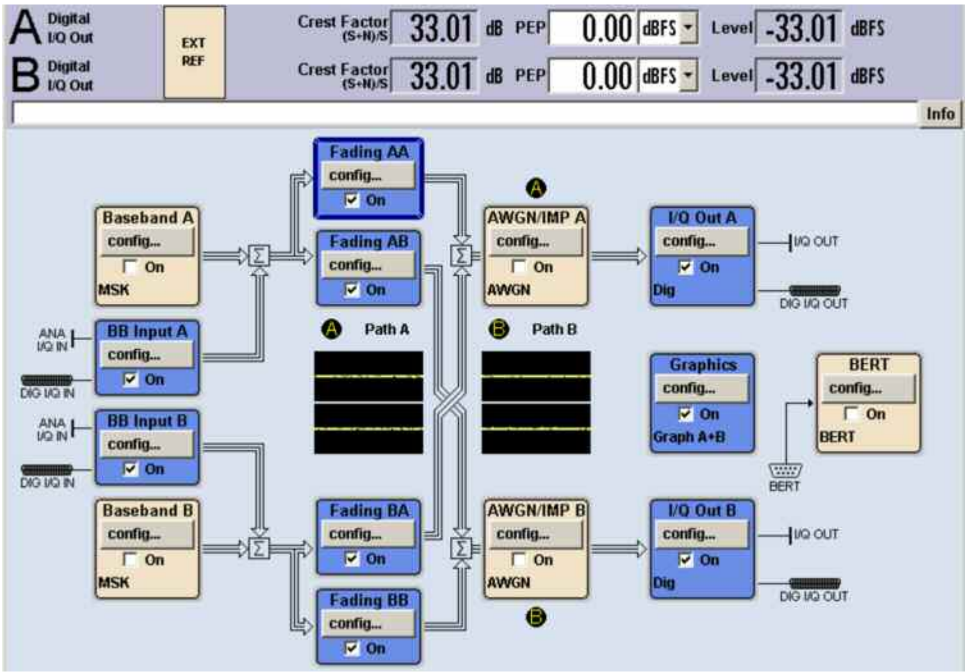

Figure 41: 2x2 MIMO Fading

2. The baseband insertion loss is BB Output Crest Factor – BB Input Crest Factor = 33.01 dB -20.00 dB = 13.01 dB
3. Set the insertion and cable losses in the System Configuration menu of the CMW Project Explorer. DL cable loss = 2 dB + 13.01 dB = 15.01 dB

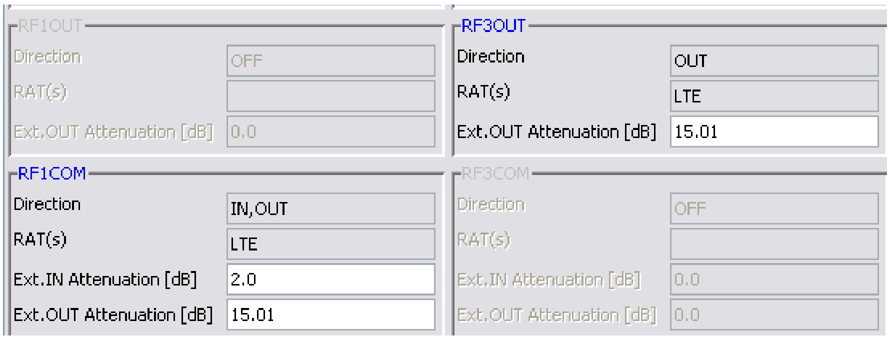

Figure 42: Cable and Insertion Loss

4. Establish an LTE connection and turn IPerf ON (56 Mbps).
5. Start the PTM on the CMW with Start → Programs → R&S MCT → Protocol Testing Monitor.
6. In PTM select Window → LTE → BLER Chart

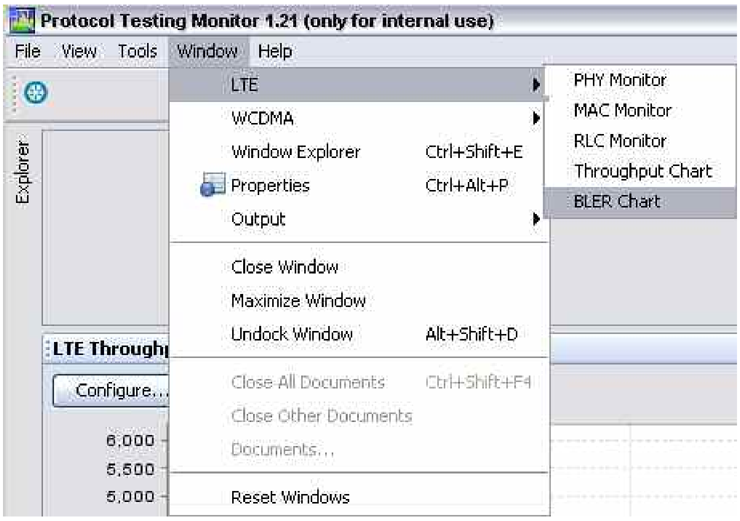

Figure 43: Select BLER Chart

7. Perform BLER measurements with e.g. EPA 5Hz Low, Medium and High fader correlations.

Figure 44: BLER Measurement

Fig. 37 shows increasing BLER with increasing fader correlation. The green and red points indicate measured BLER values for the two different data streams, respectively.

4.3 Throughput

The throughput can be determined by sending data blocks with the DAU (Data Application Unit, option CMW-B450A) as shown in 4.1 and performing a measurement with TCP monitoring program on the UE PC. This example shows the difference between data rates with 2x2 MIMO fading with varying correlation. The cable loss is assumed as 2 dB.

1. Turn 2x2 MIMO Fading ON and select fading profile e.g. **EPA 5Hz Low** on the AMU.
2. The baseband insertion loss is BB Output CF – BB Input CF = 33.01 dB -20 dB = 13.01 dB
3. Set the insertion and cable losses in the System Configuration menu of the CMW Project Explorer. DL cable loss = 2 dB + 13.01 dB = 15.01 dB
4. Establish an LTE connection and turn IPerf ON (56 Mbps).
5. Measure the DL throughput (IP data rate) on the UE controller PC for instance with the freeware program TCP Monitor Plus. The **Rcv AVE** (Received Average) value shows the average throughput over the capture time. Repeat this step with differently correlated fading profiles (e.g. EPA 5Hz Medium and High).

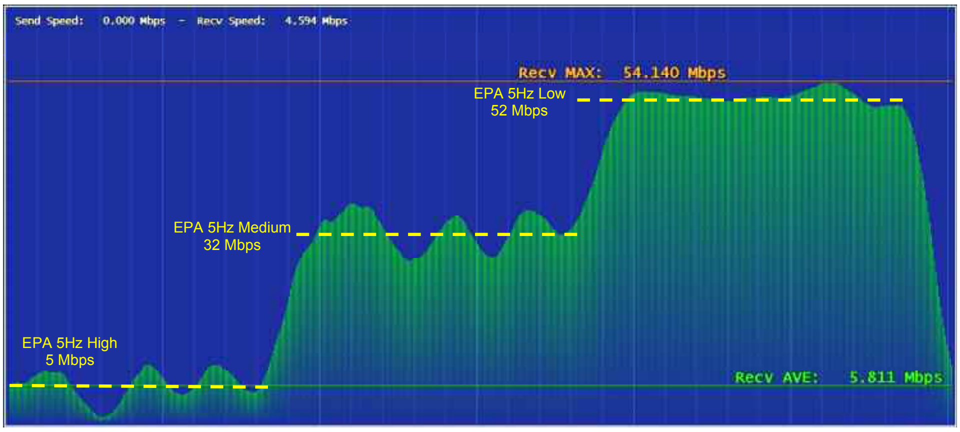

Figure 45: Throughput with varying correlation

Figure 46 shows increasing throughput with decreasing correlation.

5 Advanced Solutions for RRM (Radio Resource Management) and Performance Testing

5.1 RRMLib (Option CMW-KP542)

The RRM library (RRMLib) is a CMW add-on software option for protocol testing. RRMLib extends the MLAPI (Medium Level Application Programming Interface) of the CMW by RRM related functionality. The product contains the Windows library and related C++ source files containing the C++ interface classes. The RRMLib is targeting R&D purposes, benchmarking of user equipment and regression testing. In addition to the RRMLib, Rohde & Schwarz provides several packages of RRM MLAPI sample scenarios using the RRM API functions.

MLAPI Structural Overview
The RRM API framework extends the MLAPI framework by RF and RRM related features. The framework libraries are part of the here described product package CMW-KP542.The RRM sample scenario packages will use the RRM API to implement RRM specific scenarios.

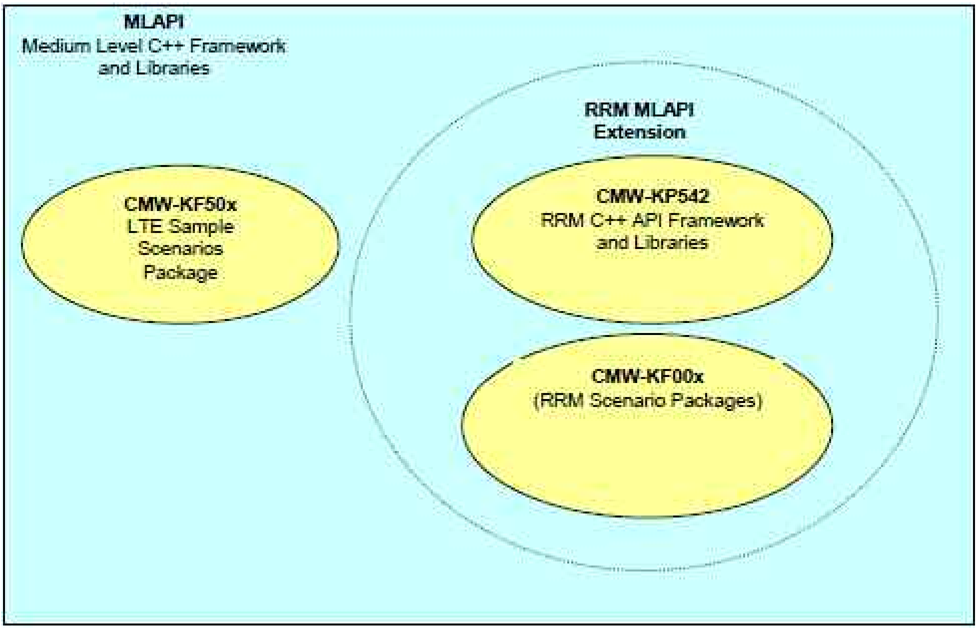

Figure 46: Required Software Options

5.2 R&S® Contest-PQA Performance Quality Analysis

The CONTEST-PQA is a user-plane throughput testing solution based on CONTEST software and CMW protocol tester hardware platform. CONTEST-PQA allows configuration of various propagation path parameters and features throughput measurements through all layers of the protocol stack. It is possible to switch the technology with a single mouse click. As such you can run tests under identical propagation conditions with various technologies and compare the results. The whole test procedure is fully automatable. That means that the UE control and even the generation of custom IP data can be fully automated in order to run unattended regressions. Finally, for pre-compliance environments, CONTEST-PQA allows setting up a test sequence (called “Test Plan”) which runs several measurements with different settings in a sequence including a final comparison with pre-defined limits for the expected throughput. This way the test will end with a simple PASS or a FAIL verdict. The CONTEST-PQA allows configuration of various radio channel properties (fading, noise) as well as cell properties including cell and channel powers. In addition there are several configurations for generating custom data.

6 Literature

[1] Application Note 1MA111, "UMTS Long Term Evolution (LTE) Technology Introduction"

[2] Application Note 1MA142, "Introduction to MIMO"

[3] Application Note 1GP51 "Guidelines for MIMO Test Setups – Part 2 "

[4] Application Note 1SP11 "WiMAX MIMO Multipath Performance Measurements"

7 Additional Information

Please send your comments and suggestions regarding this application note to

TM-Applications@rohde-schwarz.com

8 Ordering Information

Ordering Information		
CMW500 Wideband Radio Communication Tester		
CMW500 Protocol Tester Hardware configuration		
CMW500	**Base Unit**	**1201.0002K50**
CMW-PS502	CMW500 Mainframe 02	1202.5408.02
CMW-S600B	CMW500 FP with MMI H600B	1201.0102.03
CMW-S550B	BB Flexible Link H550B	1202.4801.03
CMW-S590A	RF Frontend (Basic) H590A	1202.5108.02
CMW-B590A	RF Frontend (Basic) H590A	1202.8707.02
CMW-B620A	DVI Interface	1202.5808.02
CMW.B660A	Option Carrier H660A	1202.7000.02
CMW-B661A	Ethernet Switch H661A	1202.7100.02
CMW-B690B	OCXO (Highly Stable) H690B	1202.6004.02
CMW-B100A	BB Generator H110A	1202.5508.02
CMW-B300A	Signaling Unit Wideband H300A	1202.8759.02
CMW-B300A	Signaling Unit Wideband H300A	1202.8759.02
CMW-B570B	RF TRX H570A	1202.8659.03
CMW-B450A	Data Application Unit	1202.8759.02
CMW-B510A	Digital IQ 1 to 4 H510A	1202.8007.02
Software LTE Protocol Tester		
CMW-KP080	Protocol Tester Framework, Network Emulation	1203.2254.02
CMW-KP505	LTE Stack Extension: FDD Mode	1207.2459.02
CMW-KP510	LTE (R8) MIMO 2x2 API Ext.	1203.5853.02
CMW-KP500	LTE (R8) MLAPI Interface for Network Emulation	
CMW-KF500	LTE FDD and TDD LLAPI/MLAPI Example Scenarios	1203.7556.02
CMW-KT010	Project Explorer	1203.2302.02
CMW-KT011	Message Analyzer	1203.2354.02
CMW-KT012	Message Composer	1203.2402.02
CMW-KT017	LTE Protocol Testing Monitor	1203.5801.02
CMW-XT015	PC R&D Framework	1203.3309.03

IP Test Extension		
CMW-KA100	Enabling of IP-Data Interface for IPV4	1207.2607.02
CMW-KA150	Extension of IP-Data Interface to IPv6	1207.2659.02
CMW-KM050	IP Based Measurements	1203.5901.02
Optional		
CMW-Z03	Mini USIM LTE R8	1202.9503.02
CMW-KP550	LTE Stack Extension: TDD Mode	1204.8756.02
CMW-KP511	LTE (R8) MIMO 4x2 API Ext.	1203.5901.02
Service Contracts		
CMW-PU-010	Software Maintenance Contract Protocol Test PQA and Tools	1202.9503.02
CMW-PU510	Software Maintenance Contract Protocol Test LTE Stack	1204.9400.82
CMW-PU520	Software Maintenance Contract Protocol Test LTE LLAPI and MLAPI R&D Test Scenarios	1207.4651.82
AMU200A Baseband Signal Generator		
AMU200A	**Base Unit**	**1402.4090K02**
AMU-B13	Baseband Main Module	1402.5500.02
AMU-B13	Baseband Main Module	1402.5500.02
AMU-B17	Analog/Digital Baseband Inputs	1402.5900.02
AMU-B17	Analog/Digital Baseband Inputs	1402.5900.02
AMU-B14	Fading Simulator	1402.5600.02
AMU-B15	Fading Simulator extension	1402.5700.02
AMU-B18	Digital I/Q Output	1402.6006.02
AMU-B18	Digital I/Q Output	1402.6006.02
AMU-K62	Additional White Gaussian Noise	1402.7202.02
AMU-K62	Additional White Gaussian Noise	1402.7202.02
AMU-K74	MIMO Fading	1402.9857.02

About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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