

Mobile WiMAX™ MIMO Multipath Performance Measurements Application Note

Products:

- | R&S® CMW270
- | R&S® CMW500
- | R&S® AMU200A

This application note explains the basics of MIMO performance measurements for the mobile WiMAX™ air interface under multipath conditions using R&S® CMW270 or R&S® CMW500 and R&S® AMU200.



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1 Introduction

The mobile WiMAX™ TDD air interface according to IEEE 802.16™-2009 [1] is promising a downlink gross user data rate of up to approx. 31,7 Mbit/s, when operating a 2x2 spatial multiplexing scheme, known as matrix B downlink MIMO according to [1], providing sufficient Signal-to-Noise Ratio [5]. However, in real field operation, the data rate suffers of frequency and time selective propagation conditions, basically caused by multipath propagation and Doppler frequency shift. Therefore, the evaluation of data rates under such conditions is of great interest, in order to verify the device performance under operational conditions and to predict the effective capacity of the mobile WiMAX radio subsystem.

This application note describes a test setup to measure the packet error rate and throughput across the mobile WiMAX air interface including standardized propagation conditions (for customized propagation conditions please refer to [6]).

In the test setup considered, the R&S®CMW270 respectively R&S®CMW500 is representing a mobile WiMAX base station and the R&S®AMU200A simulates the mobile downlink multipath radio channel.

The following acronyms are used in this application note for Rohde & Schwarz test equipment:

- R&S®AMU200A baseband signal generator and fading simulator is referred to as AMU
- R&S®CMW270 wireless connectivity tester, respectively the R&S®CMW500 wideband radio communication tester is referred to as CMW

The WiMAX modem under test, is referred to as device under test (DUT).

2 About the maximum data throughput

Prior to testing the quality of a mobile WiMAX modem implementation or evaluating an end-to-end throughput across the mobile WiMAX interface, it is necessary to determine the theoretical maximum data throughput that can be achieved with WiMAX and to establish the reference values in this way. This requires some insight into the WiMAX transmission scheme. The WiMAX wireless broadband interface transmits data modulated with 2^M -QAM¹ using CP-OFDM² transmission scheme [1] in both directions. This means that the available transmission bandwidth is used by a defined number (N_{data}) of orthogonal data sub carriers. Each of these sub carriers transmits a modulation symbol of the order M , i.e. M bits. Considering the spatial multiplexing MIMO³ scheme, known as matrix B according to [1], the user data rate increases proportional to the number of spatial streams N_{ss} . Therefore, the maximum instantaneous data rate R across the duration of a symbol (T_{symbol}) is as follows:

$$R_{max} = \frac{N_{ss} \cdot M \cdot N_{data}}{T_{symbol}}$$

Equation 1: Calculation of maximum instantaneous data rate

The duration of a symbol depends on the nominal signal bandwidth BW , the corresponding oversampling factor n and FFT length N_{FFT} , and the cyclic prefix factor. Thus, T_{symbol} is given by

$$T_{symbol} = (1 + CP) \frac{N_{FFT}}{n \cdot BW}$$

Equation 2: Calculation of CP-OFDM symbol duration

As an example, let's calculate the maximum instantaneous data rate R for a Matrix B transmission of a nominal bandwidth $BW = 10 \text{ MHz}$ signal, with the corresponding FFT size $N_{FFT} = 1024$, number of data sub carriers $N_{data} = 720$ and the default cyclic prefix factor $CP = 1/8$. According to Equation 2 the CP-OFDM symbol duration is $T_{symbol} = 102.86 \mu\text{s}$ and the maximum instantaneous data rate according to Equation 1 is $R = 84 \text{ Mbit/s}$, providing the modulation scheme 64-QAM ($M = 6$) and 2 spatial streams ($N_{ss} = 2$) due to 2x2 matrix B operation.

However, the raw data rate R is of theoretical interest only! It does not correspond to the maximum possible payload data rate, and thus the maximum payload data throughput. The payload data rate depends on numerous other parameters such as the channel encoding rate. For instance, when a convolution FEC⁴ channel encoding of rate $\frac{1}{2}$ applies, every single payload bit at the input turns into two channel encoded bits at the output. This means that such channel coding simply doubles the required data rate. Thus, for example, a raw data rate of 10 Mbit/s on the mobile WiMAX air interface would correspond to a user payload data rate of 5 Mbit/s only.

¹ Quadratur-Amplitude-Modulation, e.g. 4-QAM (QPSK), 16-QAM or 64-QAM

² Cyclic Prefix – Orthogonal Frequency Division Multiplexing

³ Multiple Input Multiple Output

⁴ Forward Error Correction

In addition, the duplex scheme employed has a significant influence on the data throughput. *Figure 1* shows the typical structure of a mobile WiMAX™ radio frame in time division duplex (TDD). The available resources are first divided between downlink and uplink. When the resources required for the reference signals (e.g. the preamble) and for common signaling (for instance, for broadcasting system information) are subtracted, only a portion of the resources remains available per radio frame for transmitting payload data in both directions. The WiMAX Forum® defines the exact distribution of resources for the different bandwidths in the profile document [2].

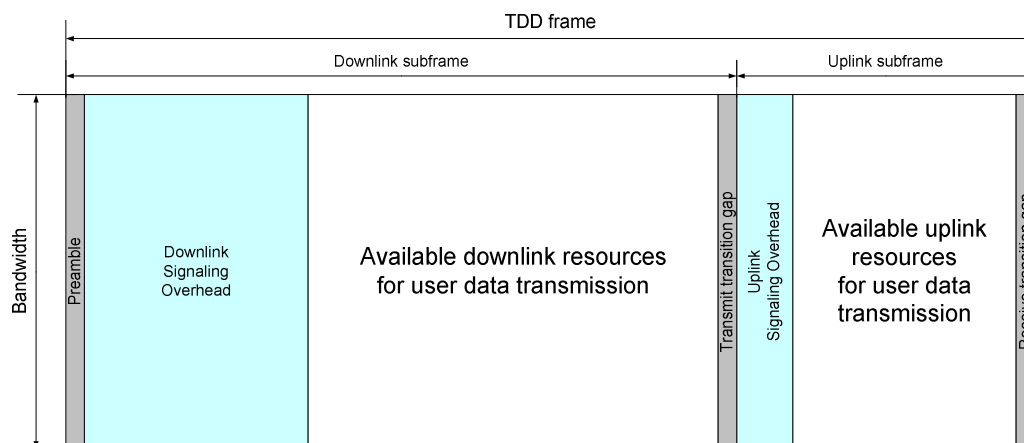


Figure 1: Typical mobile WiMAX TDD radio frame composition

Basically the resources of a mobile WiMAX TDD radio frame are divided into slots. Each and every slot conveys 48 data modulation symbols, since it covers 24 data sub carriers for the duration of two CP-OFDM symbols. Consequently, the maximum payload throughput depends on the number of slots available for data payload, which simply depends on the configuration of the TDD radio frame according to the profile document [2].

For example, let's calculate the available downlink resources for user data transmission according to *Figure 2*. The 5 ms radio frame according to [2] is divided into 47 CP-OFDM symbols, in case of 10 MHz nominal signal bandwidth. 35 CP-OFDM symbols are available to the downlink sub frame, 12 CP-OFDM symbols are allocated to the uplink sub frame. Since the downlink sub frame requires one CP-OFDM symbol for the preamble, and another 12 CP-OFDM symbols for broadcasting common system information, there are 22 CP-OFDM symbols left for downlink user data transmission. Considering the 10 MHz nominal signal bandwidth case, there are 30 sub channels available, and thus there are 330 downlink data slots, which all can hold a maximum of 48 data modulation symbols. Thus, in case of 64-QAM modulation we are talking about 288 bits/slot, respectively 95 kbits/frame. With the default frame duration of 5 ms we end up at 19 Mbit/s for a single spatial stream, i.e. 38 Mbit/s for 2x2 matrix B operation. This is the maximum physical, encoded data rate that can be achieved for such a profile. With the lowest FEC rate for 64-QAM of 5/6, the maximum physical payload rate is approx. 31.7 Mbit/s. This is the maximum physical downlink payload data rate that can be offered by the specified WiMAX profile to higher layer applications, such as UDP⁵ or TCP⁶, for instance.

Note: You may find calculations for all possible configurations in [5].

⁵ User Datagram Protocol

⁶ Transport Control Protocol

These calculations, of course, are based on the assumption, that the channel conditions are perfect and not affected by any kind of disturbance like additive white Gaussian noise (AWGN), for instance. However, under real-world conditions, the transmission of a RF signal is affected by many factors like path loss and shadowing (*Figure 2*), which could lead to serious degradation of the received signal. Multipath propagation in conjunction with the movement of the receiver and/or the transmitter leads to drastic and random fluctuations of the received signal. Fades of 30 to 40 dB and more below the mean value of the received signal level can occur several times per second, depending on the speed of the mobile unit and the carrier frequency.

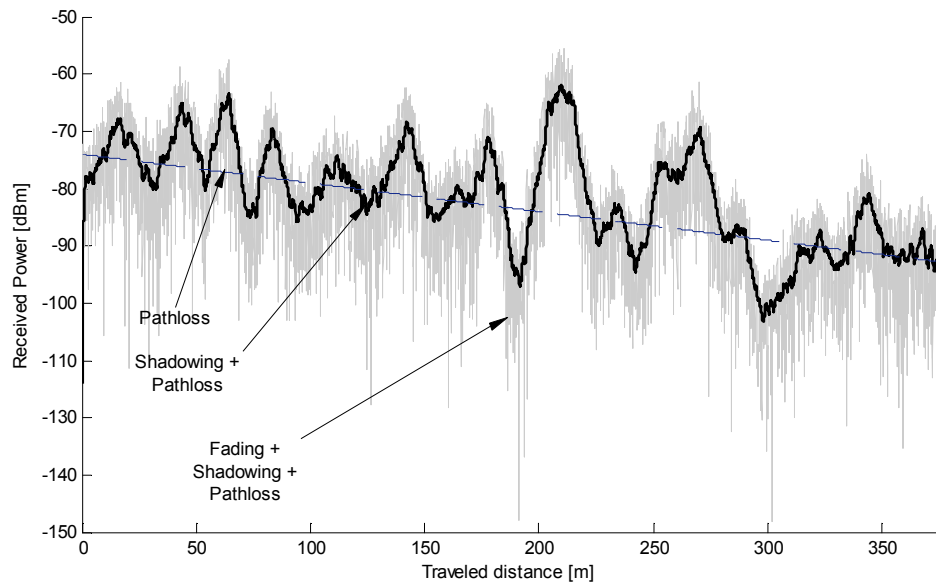


Figure 2: Real signal propagation

Such conditions strongly reduce the amount of the transmitted data and the achievable throughput because of the increased rate of erroneous packets [8]:

$$R = \frac{N_{ss} \cdot M \cdot N_{data}}{T_{symbol}} \times (1 - PER)$$

Equation 3: Calculation of the actual instantaneous data rate

The Packet Error Rate (PER) is defined as a ratio between the amount of transmitted data packets and the number of the received packets with errors within one measurement time interval. It is mainly dependent of the actual Signal-to-Noise Ratio (SNR) and can be used to evaluate the channel conditions. For example, *Figure 3* shows the PER behavior of a QPSK data sequence in a static AWGN and in a flat fading channel under variation of the SNR values. It is obviously that the PER with fading is significantly worse than without fading.

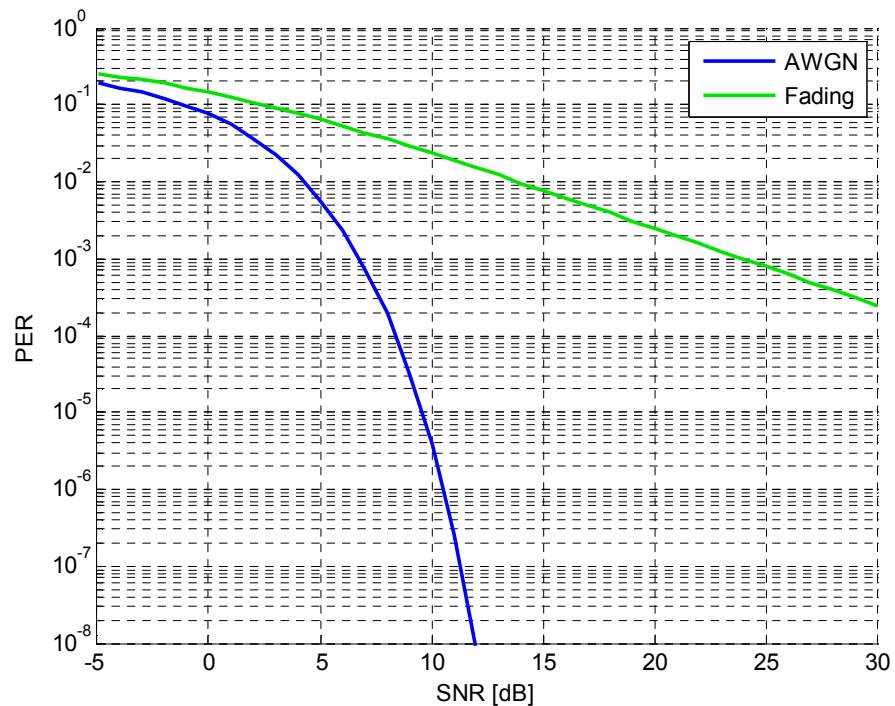


Figure 3: QPSK Packet error rate for AWGN and flat fading

[1] specifies some advanced techniques such as Adaptive Modulation and Coding (AMC) and multiple input, multiple output (MIMO) in combination with OFDMA in order to mitigate the fading impact and to assure greater throughput and robust data transmission. The overall performance gain for a network that uses such techniques is strongly dependent by the receiver characteristics of subscriber devices within that network.

2.1 Ping mechanism and PER

In order to evaluate the receiver capabilities of DUT under bad link conditions the WiMAX Forum™ defines in [3] few test cases for AWGN and fading channels. The measurement is based on the Ping mechanism, which could be extremely useful for analyzing both the link condition and the receiver behavior. The main goal is to evaluate the Packet Error Rate (PER) behavior at the receiver end and its capability to deal with fading phenomena.

In order to calculate the PER, a Ping message including an ICMP⁷ control message header and some random payload bits is sent to the DUT at an interval of 5 ms (one frame). If the test device decodes the packet errorless, it echoes back the sent payload. Otherwise the frame is accounted as erroneous or lost. The measurement must be evaluated over a large number of frames, e.g., 10000 or even 30000 frames, in order to obtain significant statistical information about the channel condition.

⁷ Internet Control Message Protocol

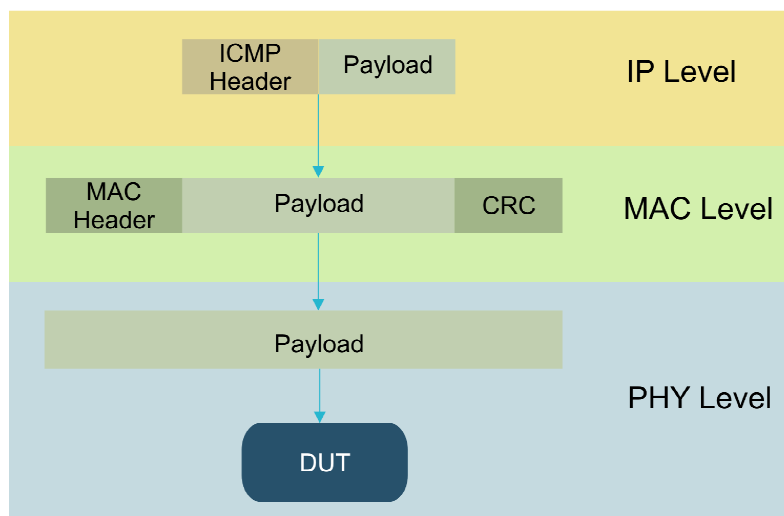


Figure 4: Generation of the Ping message

Figure 4 depicts the process flow for generating the test data sequence based on ISO/OSI⁸ reference model for WiMAX. The payload size for fading test, including all headers and CRC, is chosen to be a single FEC block with a maximum data size allowed by the Convolution Turbo Code (CTC) sub channel concatenation rule, i.e., 60/54/48 bytes depending on the particular Modulation and Coding Scheme (MCS) level (Table 1). So the PER is equal to the Block Error Rate (BLER).

MCS	DL PDU size [bytes]	Slots per PDU
QPSK 1/2	60	10
QPSK 3/4	54	6
16QAM 1/2	60	5
16QAM 3/4	54	3
64QAM 1/2	54	3
64QAM 2/3	48	2
64QAM 3/4	54	2
64QAM 5/6 ⁹	60	2

Table 1: MCS dependent parameters for PER measurement under fading [3]

Of course, the payload can incorporate multiple frames, leading to increased instantaneous data rate, but also suffering of higher PER. It should be mentioned, that the payload is bounded by the capacity of the uplink connection. E.g. the WiMAX TDD uplink sub frame according to Figure 1 offers for a 10 MHz nominal bandwidth signal and a downlink : uplink symbol ratio of 35 : 12 according to [2] – which is by the way the default setting of the CMW – a maximum payload size that is related to the modulation and coding scheme. Knowing that according to [1] 16QAM3/4 is the highest order uplink MCS that is mandatory for any DUT, the maximum payload size per frame in that case is 150 slots x 48 modulation symbols x 4 bits x ¾ coding rate = 2700 Bytes.

⁸ International Standardisation Organisation / Open System Interconnection

⁹ 64QAM 5/6 is defined just for channels with slow mobility, e.g. ITU PedB@3kmph

As mentioned in the previous section, the PER is strongly related with the SNR associated to the data subcarriers. In order to describe statistically the variation of received power at the receiver, [1] defines two indicators for channel quality measurements (CQI): the Received Signal Strength Indicator (RSSI) and the CINR (Carrier-to-Interference-plus-Noise) indicator.

For PER measurements is beneficial to use the RSSI as a controlled variable, because of two main reasons:

- The RSSI measurements do not require necessarily receiver demodulation lock and for this reason offer reasonably reliable channel strength assessments even at low signal levels.
- The RSSI is directly related to the preamble power¹⁰, which in turn is based on used transmitting power for the data subcarriers and the amount of allocated sub channels. If the power of one data zone within a radio frame is needed, a power level offset to the measured RSSI must be considered. For example, the preamble power of one fully allocated burst is 3,8 dB higher than the subsequent data zone, including the pilot and data subcarriers (*Figure 5*). This is important, since the PER measurement takes into account the data zone only.

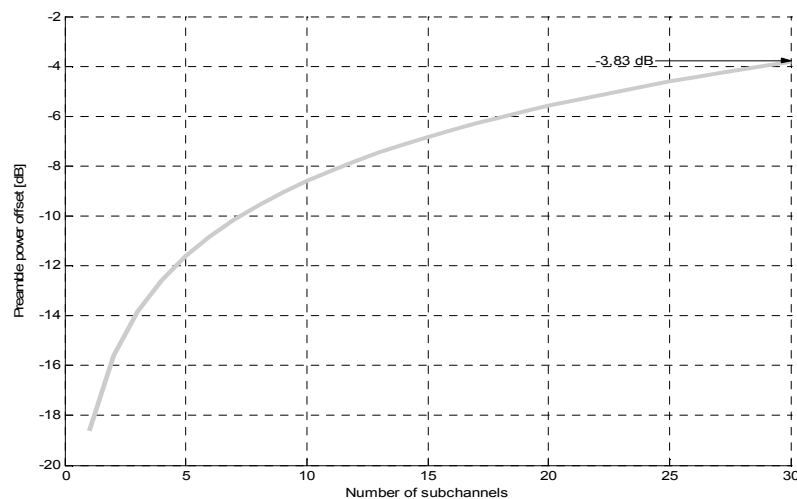


Figure 5: Data zone power offset with respect to the preamble power

¹⁰ The spectral preamble power is 33,5 dB higher than the single data carrier power, due to a boosting factor of 9 dB is applied to the 284 preamble pilots in case of a FFT-1024 preamble.

For example, *Figure 6* shows a snapshot taken from one PER measurement¹¹. The used MCS is 16QAM $\frac{3}{4}$ and the size of the ICMP message is 540 Bytes long. For this constellation, the user data sequence occupies 30 sub channels and the resulting power difference between the preamble and the data zone is approx. 3,8 dB, as expected.

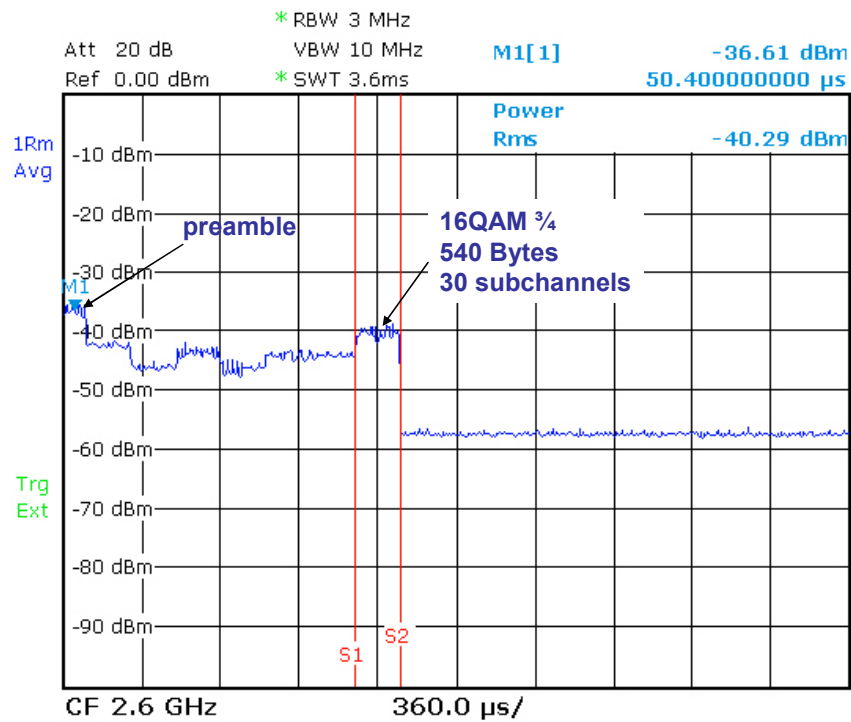


Figure 6: Occupied data zone for 540 bytes and 16QAM3/4 MCS

¹¹ Measurement done with R&S©FSL signal analyser

3 MIMO

The MIMO technology is one of the key benefits of the Mobile WiMAX systems. It is based generally on multiple-antennas configuration both at the transmitter and at the receiver end. It can be used to [8]:

- Increase the system reliability (decrease the bit and packet error rate)
- Increase the achievable data rate and hence the overall system capacity
- Increase the coverage area
- Decrease the required transmit power

3.1 MIMO and Fading

Under time-varying radio environment the performance of a SISO system could be strongly degraded due to fading and multipath. For a single link connection there is an unavoidable probability for a deep fade in the path that may cause errors in the communication link [12]. By utilizing a MIMO system a diversity gain and/or multiplexing gain can be achieved, leading to higher data rates and robust transmission. The MIMO technique works best in multi-path environment with multiple uncorrelated fading channels [6]. In this case the receiver has the opportunity to distinguish the data streams coming from the different antennas. Unfortunately uncorrelated fading channels are only best-case scenario. Under real operating conditions, the different fading channels are not fully independent of each other, due to the geometric arrangement of the antennas. Thus, the achievable performance of a MIMO system is strongly correlated with the statistical independence of the fading channels.

3.2 MIMO and WiMAX

[1] specifies two types of open-loop¹² multi-antenna techniques for downlink transmission referred as Matrix A and Matrix B.

Matrix A MIMO is basically the WiMAX version of the spatial diversity technique for 1 receiving and 2 transmitting antenna as depicted in *Figure 7*. It is based on 2x2 space-time coding scheme [1], which is orthogonal in nature and amenable to a linear optimum maximum-likelihood detector:

$$A = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}.$$

¹² Open-loop systems do not require knowledge of the channel at the transmitter.

The diversity gain is achieved by sending two conjugated copies of the input data stream, so that the receiver has a higher probability of successfully encoding of the desired signal.

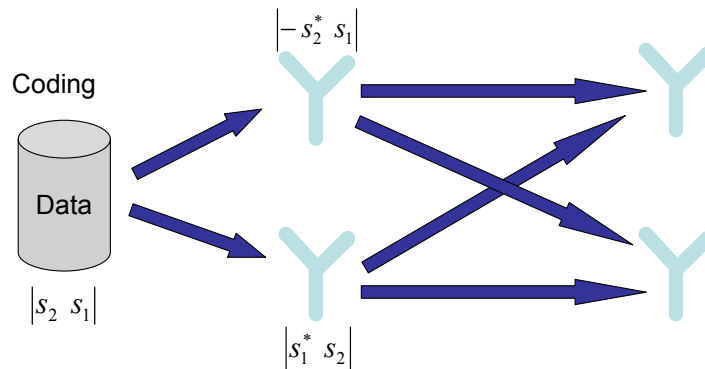


Figure 7: Matrix A transmission scheme

As depicted in *Figure 7* the data stream is mapped into symbols s_1 and s_2 . These symbols are processed by the Space-Time Encoder which sends s_1 followed by $-s_2^*$ to the first transmitter and s_2 followed by s_1^* to the second transmitter. Because the two antennas are sending two symbols in two time periods, there is no increasing of the transmitted overall data throughput. Actually, this particular constellation of the transmitted signals improves the error rate performance of the system, which in turn allows the using of higher order modulation schemes. Thus, the capacity of the system is indirectly improved.

Matrix B MIMO implements the spatial multiplexing technique for WiMAX systems (*Figure 8*). It does not provide any diversity, and thus does not affect the robustness of the system, but offers a doubling of the achieved data rate when the system bandwidth is limited. Like the Matrix A transmitting scheme there is an initial mapping of the sent symbols according to the matrix:

$$B = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}.$$

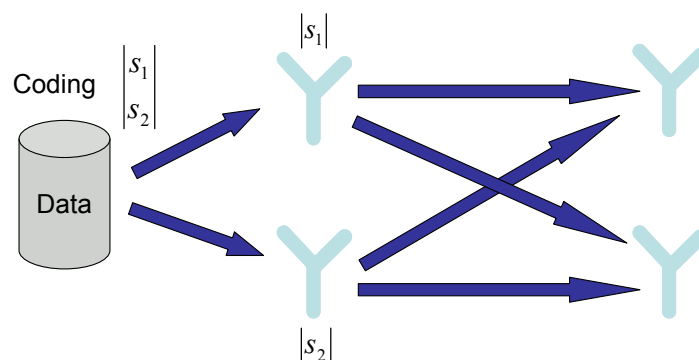


Figure 8: Matrix B transmission scheme

The data stream to be transmitted is split into two independent data streams, which are sent simultaneously on the same frequency via the different transmit antennas.

An interesting feature of the WiMAX open-loop multiple-antenna systems is the adaptive mode selection between matrix A and matrix B. The scheme allows optimization of the transmission based on predefined criteria, e.g. PER or throughput, in order to achieve the desired performance. For example, in case of optimization of the spectral efficiency under variation of received SNR (owing to fading fluctuations), a switching point between the both schemes could be defined (*Figure 9*).

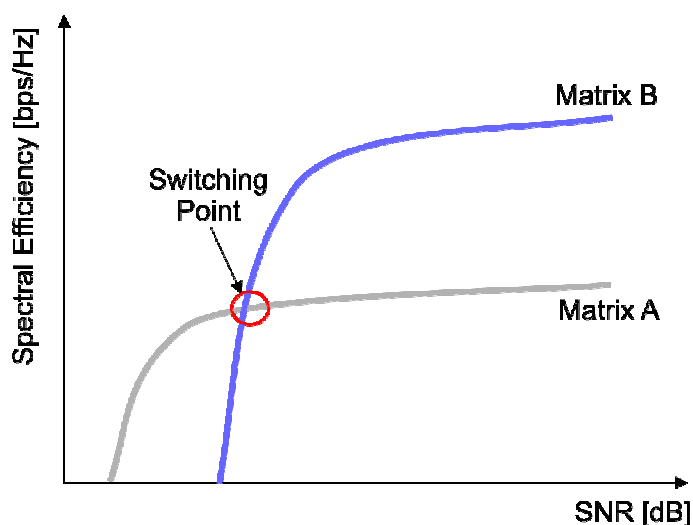


Figure 9: AMC transmitting scheme

4 Mobile Radio Channel Emulation

To test the "real life" performance of a mobile WiMAX device, it is required to emulate the downlink mobile radio channel. The test setup for WiMAX downlink matrix B corresponds to the mobile radio channel model according to Figure 10. The two transmit antennas at the WiMAX base station are represented by $s_A(t)$ resp. $s_B(t)$, the two receive antennas at the DUT are represented by $r_A(t)$ and $r_B(t)$. The 2x2 downlink MIMO radio channel in between is modeled by the transfer functions $h(t,\tau)$ from each transmit antenna to each receive antenna. The transfer functions $h(t,\tau)$ are representing downlink multi-path transmissions including typical statistical variations of parameters like path delay, attenuation and Doppler shift.

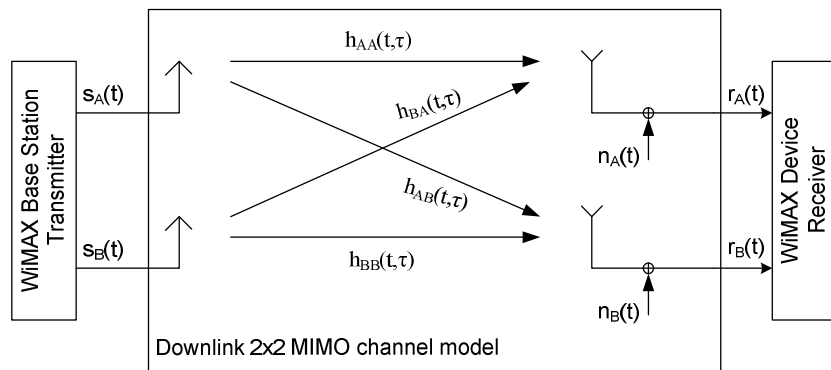


Figure 10: Mobile Radio Channel Model

The AMU offers a 2X2 MIMO channel emulation according to Figure 10 within a single box, as depicted in Figure 11.

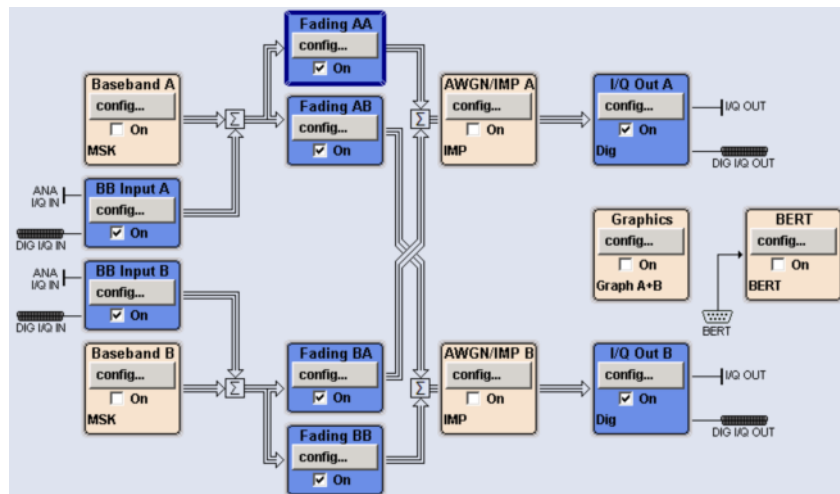


Figure 11: AMU 2X2 MIMO channel emulation

The Fading blocks AA, AB, BA and BB simulate the transfer functions $h_{AA}(t,\tau)$, $h_{AB}(t,\tau)$, $h_{BA}(t,\tau)$ and $h_{BB}(t,\tau)$. The BB input A and BB input B blocks represent the MIMO channel input signals $s_A(t)$ resp. $s_B(t)$, which are provided by the AMU digital BB inputs A and B, which will be fed by the CMW digital I/Q outputs. The MIMO channel output signals $r_A(t)$ and $r_B(t)$ are provided by the AMU I/Q Out A and B blocks towards the RF frontend of the CMW, where they will be up-converted to the operational frequency band. Additive noise $n_A(t)$ resp. $n_B(t)$ according to the 2X2 MIMO channel model (Figure 10) is supported by the AMU AWGN/IMP blocks.

The baseline to simulate real-world multipath radio propagation conditions is a selection of standardized propagation models [4]. For WiMAX there is a set of propagation models for SISO and MIMO operation provided by [3]. All those propagation models are supported by the AMU fader.

The ITU channel models are considered as a good representation of the urban and sub-urban macro-cellular environment and are useful for comparative analysis with other wireless technologies. In general, multipath propagation models are given by a characteristic tapped power delay profile along with a set of statistical parameters for each tap. Table 2 gives some examples of WiMAX propagation profiles, as they are specified in [3] and [4].

Path (tap)	ITU Pedestrian B, 3 kmph		ITU Vehicular A, 60 kmph	
	Relative delay	Relative power	Relative delay	Relative power
1	0 ns	0 dB	0 ns	0 dB
2	200 ns	- 0.9 dB	310 ns	- 1.0 dB
3	800 ns	- 4.9 dB	710 ns	- 9.0 dB
4	1200 ns	- 8.0 dB	1090 ns	- 10.0 dB
5	2300 ns	- 7.8 dB	1730 ns	- 15.0 dB
6	3700 ns	- 23.9 dB	2510 ns	- 20.0 dB

Table 2: Basic WiMAX power delay profile parameters

The AMU fader implementation provides graphical representations of the power delay profiles. For instance, Figure 12 depicts the ITU Vehicular A profile @ 60 kmph according to Table 2.

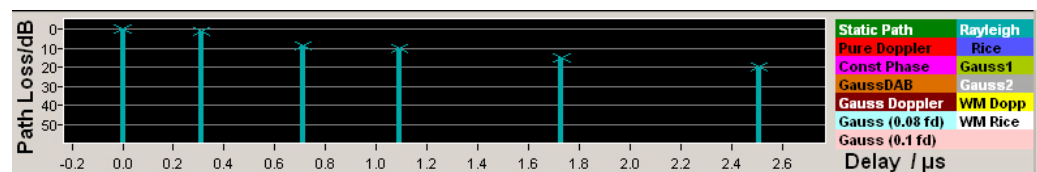


Figure 12: AMU Display of ITU Veh A @ 60 kmph power delay profile

5 Measurement setup

The basic measurement instrument setup (*Figure 13*) allows SISO and 2x2 MIMO performance measurements for faded downlink signals. Required instruments and options are listed in sub clause 11 in detail

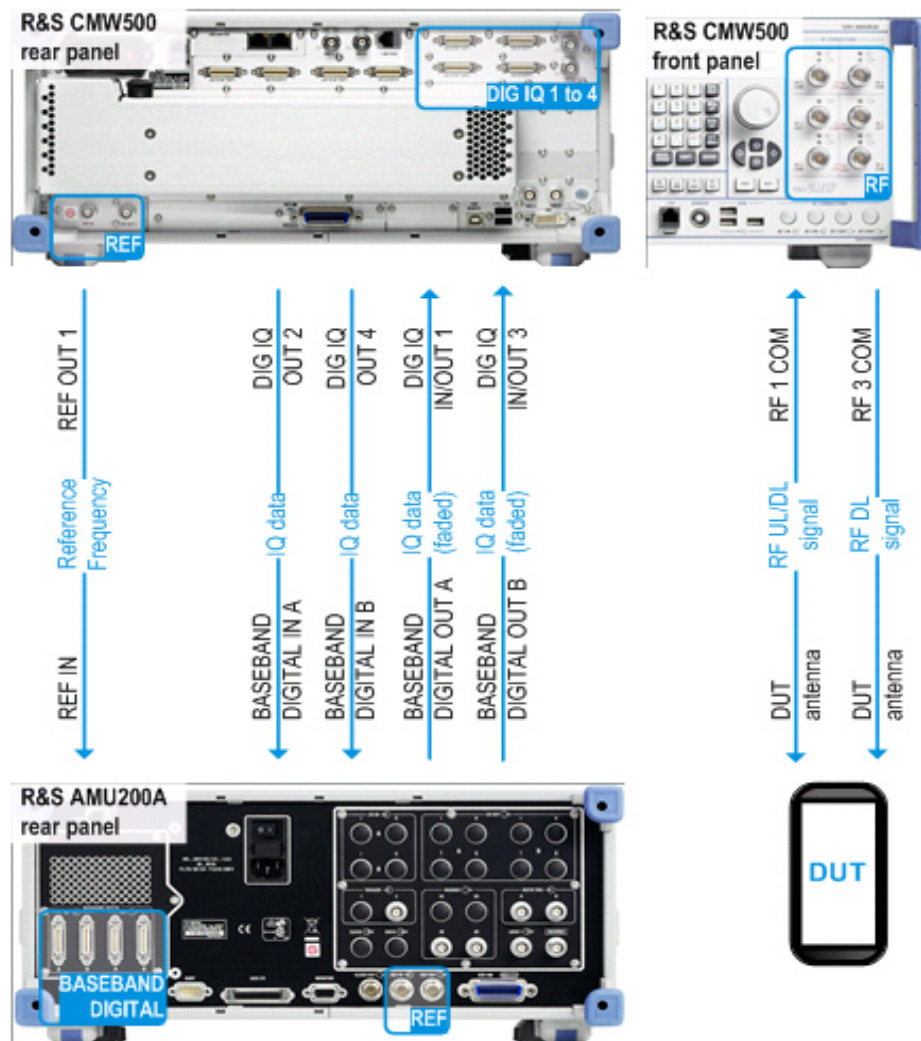


Figure 13: Basic measurement instrument setup

5.1 Basic settings of instruments

After cabling of the instruments is completed according to *Figure 13* both instruments need to be configured for the emulation of a WiMAX base station under fading conditions.

Note:

This chapter will explain explicit settings for both instrument based on their RESET state, i.e. after pressing the blue (P)RESET button on both instruments (for further information please refer to the instruments manuals [14] and [15].

The default bi-directional CMW RF connectors are **RF1COM** for antenna 1 and **RF3COM** for antenna 2 (in case of MIMO operation).

The default DUT IP address is set to 100.100.100.10. and DHCP¹³ is activated, i.e. this address will be assigned to the DUT during call setup procedure by DHCP.

5.1.1 Basic CMW settings

After powering up the instrument and selection of the WiMAX signaling option according to [14] it is required to check the TX Digital fading path check box in the CMW WiMAX menu common settings. This will route the CMW downlink baseband signal towards the AMU.

Furthermore, it is required to select common settings as Frequency, which corresponds to the required carrier frequency, Bandwidth and downlink power for both antennas (TX1 power and TX2 power). The preamble power will be automatically indicated according to the TX1 power data carrier set (Figure 14a).

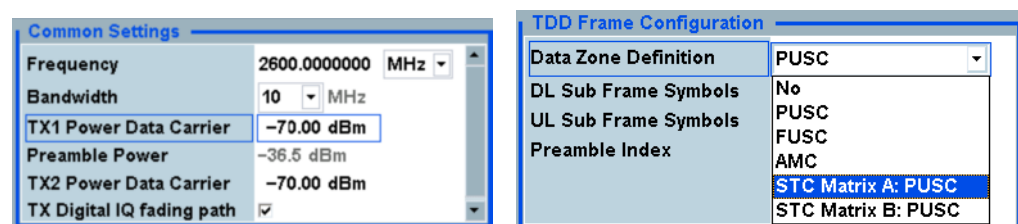


Figure 14: Basic CMW common settings (a) and TDD configuration (b)

Now it is required to select the TDD frame configuration. The data zone definition allows the selection of either SISO or MIMO operation. For SISO operation select **PUSC**, for matrix A operation select **STC Matrix A:PUSC** and for matrix B operation select **STC Matrix B:PUSC** (Figure 14b).

¹³ DHCP = Dynamic Host Configuration Protocol

In case of MIMO operation, it is required to reduce the data carrier power for both antennas by 3 dB, in order to maintain a constant total power. This is done via the CONFIG menu of the CMW WiMAX signaling menu (Figure 15).

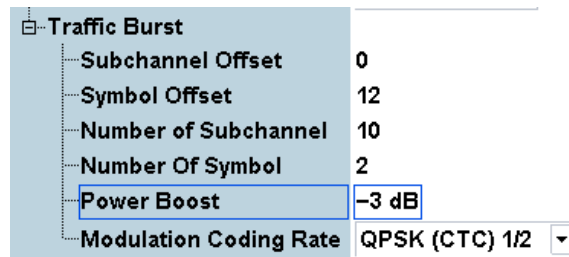


Figure 15: 3 dB reduction of data carriers for MIMO operation

5.1.2 Basic AMU settings

To ensure synchronization of both instruments, the AMU shall lock its reference to the CMW. This is done by appropriate selection in the AMUs SETUP menu.

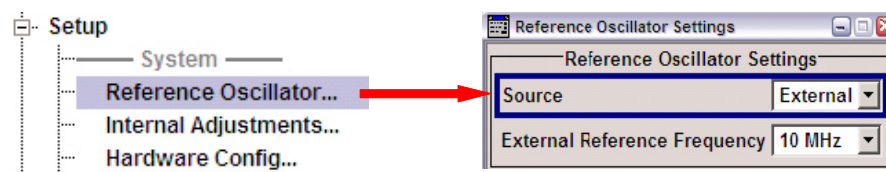


Figure 16: AMU REF frequency setting

Now, the AMUs digital inputs and outputs have to be set to digital IQ. Select the **BB Input A config...** button (and the **BB Input B config...** in case of MIMO) and set the parameters as follows:

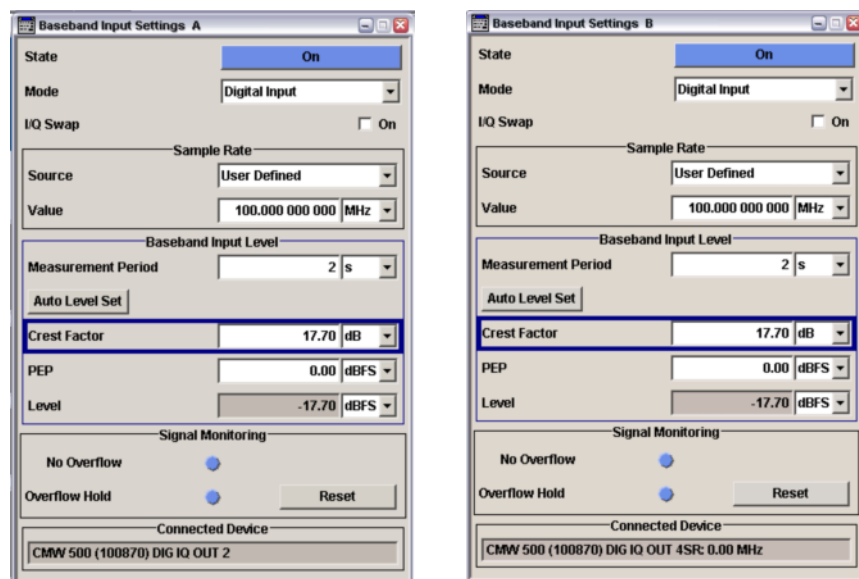


Figure 17: AMU digital baseband input settings

To ensure a proper leveling inside the AMU, the reference RMS level of the digital I/Q signal input into the AMU has to be known. The reference level of a WiMAX signal is related to the preamble power. The static CMW digital baseband IQ output power for the preamble is specified as **- 17.7 dBFS** for FFT-1024 signals, and **- 20.7 dBFS** for FFT-512 signals, respectively. Thus, it is required to enter 17.7 dB resp. 20.7 dB as virtual crest factor for AMU BB input A (and B in case of MIMO operation) according to Figure 17, which creates the known input level of - 17.7 dBFS. By the way, the bottom of the Baseband Input Setting menu shows the connected CMW device. This information can be used to check the correct cabling!

Finally, the **I/Q Out A config...** block (and **I/Q Out B config...** block in case of MIMO operation) shall be set according to Figure 18. The signal output level shall be set via Level and the same values as for the input. Thus, w/o fading, the digital input signals at the **AMU BB Input A** (and **B**) will exit the AMU unchanged at the **AMU I/Q Out A** (and **B**).



Figure 18: AMU digital baseband output settings

Now the setup is ready to connect a WiMAX DUT at the CMW RF connectors **RF1COM** for antenna 1 and **RF3COM** for antenna 2 (in case of MIMO operation). After activation of the base station (pressing the On/Off button for the WiMAX signaling), the DUT should establish a connection with the CMW, and the downlink signal is routed via the AMU. All test features, e.g. CMW WiMAX PER measurements, or throughput measurements according [5] are now available, and can be extended by downlink fading scenarios.

5.2 Instrument settings for testing with fading

5.2.1 AMU fader settings

The AMU Fading A (and Fading B) block can now be configured and activated for downlink fading profile simulation according to the AMU operation manual [15]. However, in case of active fading, the AMU causes an insertion loss to avoid output signal clipping, which shall be compensated by the CMW RF output stage.

In case of SISO fading, the AMU causes an insertion loss of 10 dB. This value may change for different fader configurations. Thus, it should be read out of the AMU via the **Fading block config...** menu and the **Insertion Loss Configuration...** according to Figure 19.

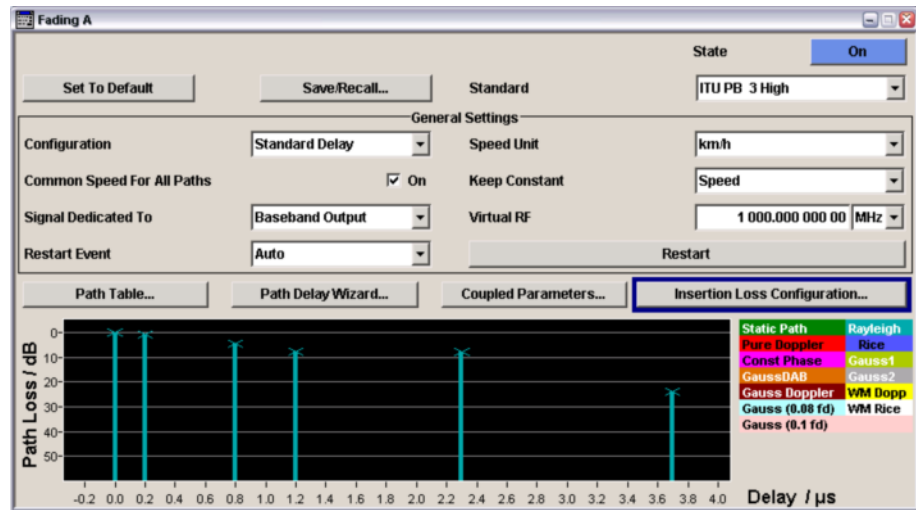


Figure 19: Fading block configuration

The example in Figure 19 configures a fading profile ITU PB High, with the power delay profile as depicted in the graph. By pressing the **Insertion Loss Configuration...** button, the AMU insertion loss caused by this setting is available according to Figure 20. The left snapshot shows the typical SISO fading insertion loss of 10 dB, the right one the typical MIMO insertion loss of 16 dB.

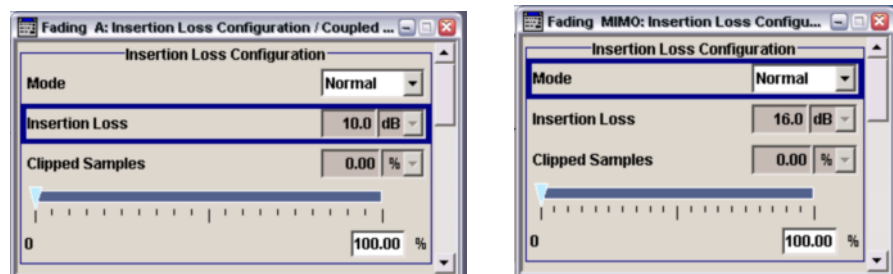


Figure 20: Reading out the AMU insertion loss

Please make sure, that the rate of clipped samples is 0 %. Otherwise, the BB output level must be adapted!

5.2.2 CMW settings related to the fading profiles

Now, this insertion loss can simply be compensated by the CMW RF output stage, by adding this AMU insertion loss as external attenuation. Therefore, press the **Config...** button at the CMW WiMAX signaling menu, and change the **RF Output settings** accordingly. Set the **External Attenuation** for **FrontEnd 1** (and FrontEnd 2 in case of MIMO operation) according to the AMU insertion loss value, or add those values to any other external attenuation values required at the CMW (e.g. DUT cable loss values). In the example of Figure 21 both front ends are set to 16 dB as the AMU MIMO insertion loss value.

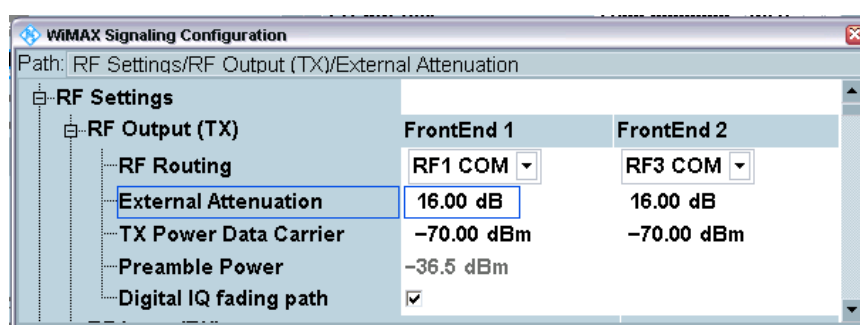


Figure 21: AMU insertion loss compensation by the CMW RF output

6 Measurements

Figure 22 shows the maximum achievable throughput for Matrix B mode under variation of the received power. The measurement is based on [5], assuming a thermal noise disturbance. As one can see, the throughput for a certain MCS is upper-bounded by the offered physical resources. Under sufficient good channel conditions (very high SNR, higher preamble power), the DUT reaches around 31 Mbit/s for UDP traffic. The used CTC encoding causes precipitous behavior at the receiver sensitivity limits, which leads to fast decreasing of the data rate. It's interesting to note, that between a perfect transmission without loss and a transmission where no data can be transmitted due to errors, the signal quality only needs to vary little. For example, in case of 64QAM 5/6, a decreasing of the received power by 0,1 dB could lead to more than 2 Mbit/s loss of the achievable data rate. The variation step between the lower modulation levels (QPSK 1/2 to 64QAM 1/2) is around 2÷3 dB. On the other hand, the high rate MCSs are showing smaller difference (approx. 1 dB). According to [1,3] there should be a 17 dB difference between QPSK 1/2 and 64QAM 5/6.

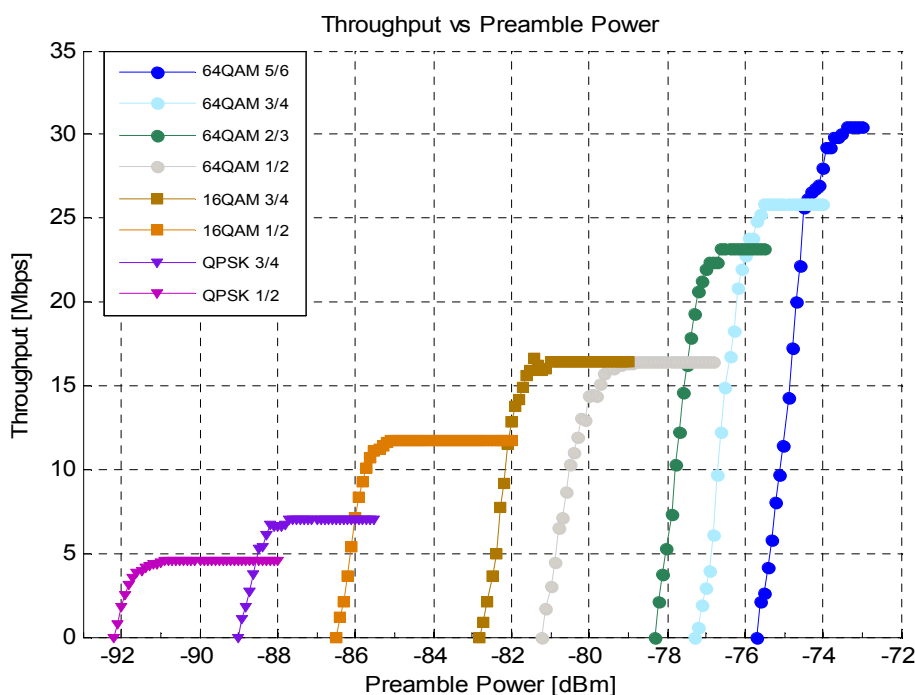


Figure 22: Achievable throughput for matrix B

Figure 23 depicts the PER behavior at the limits of the receiver sensitivity. The MCS curves are showing similar behavior as the throughput measurement curves. According to [3] maximum 0,43% can be tolerated. The intersection of the defined PER limit with the measured curves can be used to identify the so called “break-off” points for each MCS. If the AMC technique is applied to the WiMAX system, a threshold value for each MCS can be determined, giving an optimum power-data rate performance.

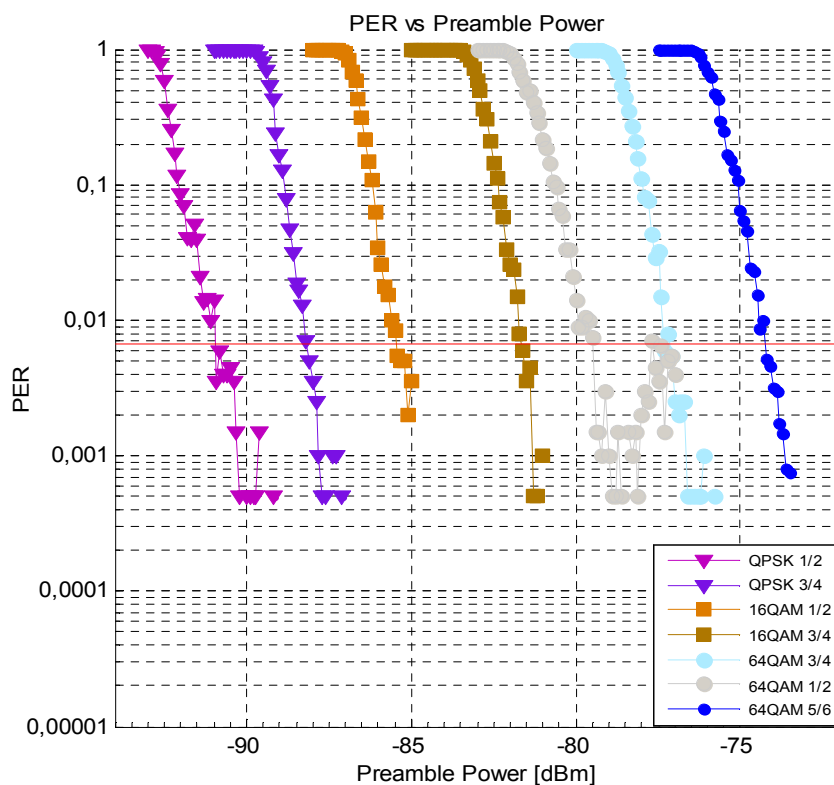


Figure 23: MCS related receiver sensitivity

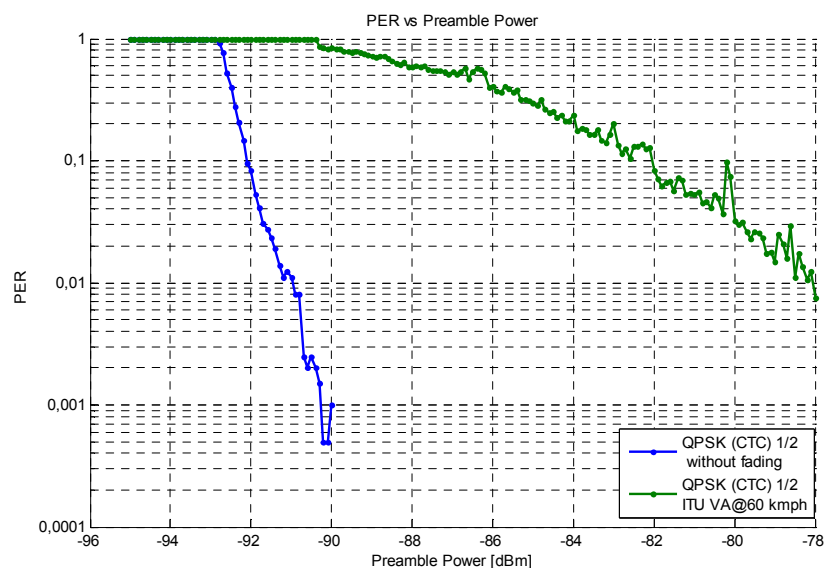


Figure 24: PER degradation in fading environment

Figure 24 shows the PER degradation for SISO QPSK $\frac{1}{2}$ using an ITU Vehicular 60@kmph fading profile. As expected the PER curve under fading disturbance is showing significantly worse performance. In order to maintain the PER level of about 1%, the required SNR is over 12 dB higher in fading. [3] specifies maximum tolerable PER level of 10% for testing under fading conditions.

Figure 25 depicts the achievable throughput for QPSK-CTC $\frac{1}{2}$ Matrix A and Matrix B transmission modes under fading conditions. The Matrix A scheme demonstrates diversity gain by improving the receiver sensitivity with about 4 dB compared to MIMO mode, without increasing the data rate. According to [5], the SISO QPSK-CTC $\frac{1}{2}$ modulation and coding scheme should reach data rate of about 3,07 Mbps under optimal transmission conditions. As the measurements shows, the achievable maximum throughput for Matrix A is around 2,35 Mbps. This can be explained with the fact, that ITU VA@60 kmph fading scenario doesn't allow fully utilization of the available capacity due to irreducible errors at the receiver. Data rate loss can be observed also for Matrix B mode. However, even under such sever conditions, it is possible to double the data throughput.

In order to optimize the transmission, a switching point between the both multiple-antenna modes can be determined. In this practically case, a switching point of around -86,5 dBm applies.

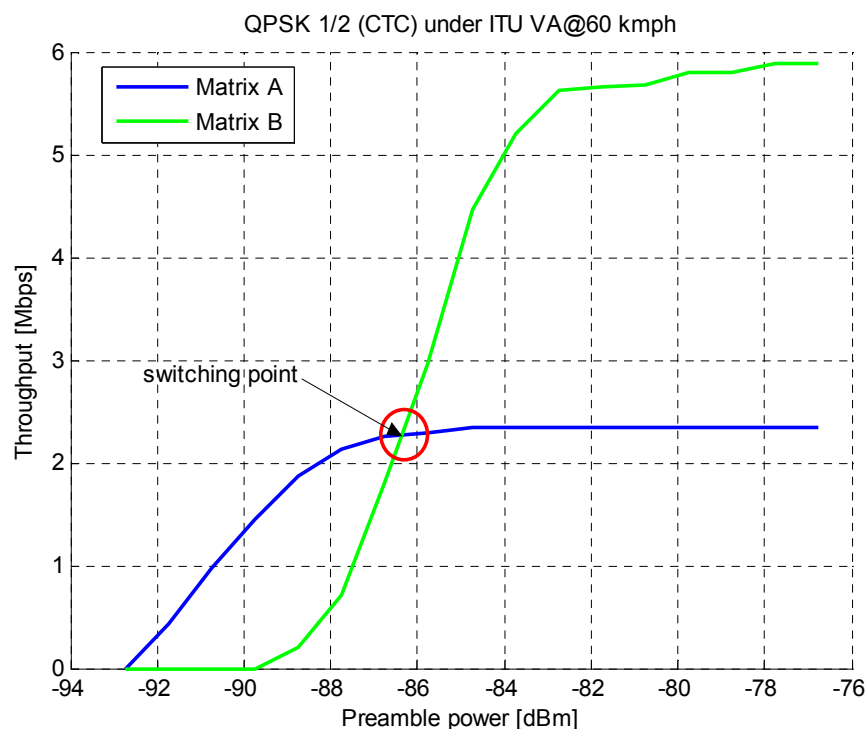


Figure 25: Matrix A and B throughput

7 Conclusion

The goal of this application note is to describe the usage of a simple two-box solution for mobile WiMAX performance testing under real multipath conditions. In addition, the test setup, consisting of a WiMAX base station emulator and a baseband fading simulator, allows an analysis of the standardized multiple antenna technologies like Matrix A and Matrix B. Some measurement examples are provided to show how this easy to use setup can be used to characterize the performance of a MIMO capable receiver.

8 Abbreviations

AMC	Adaptive Modulation and Coding
AWGN	Additive White Gaussian Noise
BLER	Block Error Rate
BS	Base Station
BSE	BS Emulator
CQI	Channel Quality Indicator
CINR	Carrier-to-Interference plus Noise Indicator
CP	Cyclic Prefix
CTC	Convolution Turbo Coding
DHCP	Dynamic Host Configuration Protocol
DL	Downlink
DUT	Device Under Test
FDD	Frequency Division Duplex
FEC	Forward Error Coding
ICMP	Internet Control Message Protocol
IFFT	Inverse FFT
IP	Internet Protocol
ISO/OSI	International Standardizations Organization/Open System Interconnection
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
PDU	Protocol Data Unit
PER	Packet Error Rate
PUSC	Partical usage of sub channelisation
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RMS	Root Mean Square
SISO	Single Input Single Output
STBC	Space Time Block Code
TCP	Transport Control Protocol
TDD	Time Division Duplex
UDP	User Datagram Protocol
UL	Uplink
WiMAX	Worldwide Interoperability for Microwave Access

9 Literature

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10 Additional Information

This application note is likely to be extended for future data throughput applications. Please visit our web site www.rohde-schwarz.com in order to download updated or related application notes. Please send any comments or suggestions about this application note to tm-applications@rohde-schwarz.com.

Further information on CMW270 can be obtained at www.cmw270.rohde-schwarz.com and www.wimax.rohde-schwarz.com.

11 Ordering Information

Baseband Channel Emulator		
Designation	Type	Order No.
Baseband Signal Generator and Fading Simulator	R&S@AMU200A	1402.4090.02
2 x Baseband main module	R&S@AMU-B13	1402.5500.02
2 x Baseband Generator with ARB (16 Msamples)	R&S@AMU-B11	1402.5400.02
2 x Baseband IQ input (digital / analog)	R&S@AMU-B17	1402.5900.02
2 x Baseband digital IQ output	R&S@AMU-B18	1402.6006.02
Fading Simulator	R&S@AMU-B14	1402.5600.02
Fading Simulator Extension	R&S@AMU-B15	1402.5700.02
MIMO Fading	R&S@AMU-K74	1402.9857.02
2 x Cable set for connecting R&S digital IQ interfaces	R&S@SMU-Z6	1415.0201.02
Wireless Connectivity Tester		
Designation	Type	Order No.
Wireless Connectivity Tester	R&S@CMW270	1201.0002K75
CMW270 Basic Assembly (mainframe), 70 MHz to 3.3 GHz	R&S@CMW-PS272	1202.9303.02
Baseband Interconnection, flexible link	R&S@CMW-S550B	1202.4801.03
RF Frontend, basic functionality	R&S@CMW-S590A	1202.5108.02
CMW270 Frontpanel With Display/Keypad	R&S@CMW-S600D	1201.0102.05
Signaling Unit Universal (SUU),	R&S@CMW-B200A	1202.6104.02
WiMAX™ Signaling Module	R&S@CMW-B270A	1202.6504.02
4 Digital IQ Interfaces, connectors 1 to 4	R&S@CMW-B510A	1202.8007.02
Option Carrier	R&S@CMW-B660A	1202.7000.02
Ethernet Switch	R&S@CMW-B661A	1202.7100.02
WiMAX IEEE 802.16e, enabling IPv4 data interface	R&S@CMW-KA700	1202.6904.02
WiMAX™ IEEE 802.16e, basic signaling	R&S@CMW-KS700	1202.6704.02
WiMAX™ IEEE 802.16e, adv. signaling	R&S@CMW-KS701	1202.6710.02
WiMAX™ IEEE 802.16e MIMO 2x2, generic signaling	R&S@CMW-KS702	1202.6640.02
Extra RF Converter (TRX)	R&S@CMW-B570B	1202.8659.03
Extra RF Frontend, basic functionality	R&S@CMW-B590A	1202.8707.02
2 x Extended frequency range, 3.3 GHz to 6 GHz	R&S@CMW-KB036	1203.0851.02

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