# Testing of WiMAX MIMO Devices in a Realistic Manner by Using MIMO Over-the-Air Testing

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To overcome the ever increasing end-user performance requirements of mobile devices, new multi antenna devices are being developed utilizing the recent advances in Multiple-Input Multiple-Output (MIMO) techniques, such as transmit diversity and spatial multiplexing introduced e.g. in IEEE802.16 standard. However, MIMO technique not only presents new opportunities, but also poses completely new testing challenges. Since MIMO terminal performance is greatly defined by antenna design, the conventionally conducted testing methods do not give realistic results. The latest solution to solve this problem is MIMO Over-the-Air (OTA) testing, which can be used to verify the performance of the wholly integrated product – including the antennas.

#### Challenging WiMAX Applications

The use of MIMO technology improves reception and allows better coverage and spectral efficiency. Inthe IEEE802.16 standard, defined MIMO configuration is negotiated dynamically between each individual base station and mobile station. This implementation gives the ability to support a dynamic mix of mobile stations with different MIMO capabilities. This helps to maximize the sector throughput but also sets requirements for terminal design; in practice, optimizing the antenna to support SIMO, MISO and MIMO configurations.

#### Space Time Coding

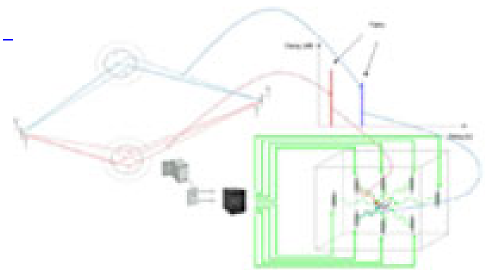
The IEEE802.16 specification supports transmit Diversity, which is known as Space Time Coding (STC). With this method, two or more antennas are employed at the transmitter and one antenna at the receiver. The use of multiple receive antennas (thus MIMO) can further improve the reception of STC transmitted signals. With a Transmit Diversity rate = 1 ("Matrix A"), different data bit constellations are transferred on two different antennas during the same symbol. The conjugate and/or inverse of the same two constellations are transferred again on the same antennas during the next symbol. The data transfer rate with STC remains the same as the baseline case, i.e. spectral efficiency is not increased in terms of data throughput. The received signal is more robust to fading notches of propagation media. This configuration offers comparable performance to the case of two receive antennas and one transmitter antenna.

#### Spatial Multiplexing

The IEEE802.16 specification also supports the MIMO technique of Spatial

Multiplexing. (Transmit Diversity rate = 2 or "Matrix B"). Instead of transmitting the same bit over two antennas, this method transmits one data bit from the first antenna, and another bit from the second antenna simultaneously, per symbol. As long as the receiver has more than one antenna and the signal is of sufficient quality, the receiver can separate the signals. This method involves added complexity at both the transmitter and receiver. However, with two transmit antennas and two receive antennas, data can be transmitted twice as fast as compared to systems using Space Time Codes with only one receive antenna. Matrix B however requires uncorrelated propagation paths for each antenna in order to separate data streams in TRX. Getting these low correlations to the receiver requires special antenna design. MIMO efficiency is defined by correlation, correlation is defined by spatial domain and propagation and both of these are antenna dependent. Mutual coupling or leakage from the antenna branches greatly affects the correlation properties. This means that the antenna effects, in addition to spatial domain propagation, need to be taken into account in the testing.

**MIMO Over-the-Air Testing**



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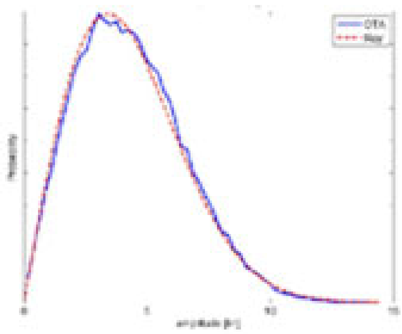
click to enlarge
Figure 1. The geometrical models mapped to the MIMO OTA test system.

MIMO OTA testing enables the use of fully-integrated products as the device-under-test (DUT), even commercial off-the-shelf products. This gives full understanding of the performance of the DUT and enables comparison of DUTs in equal conditions.

The main components of a MIMO OTA test system (Figure 1) are 1) test transmitter (e.g. communication tester or base station emulator), 2) radio channel emulator with MIMO OTA channel modeling tool, 3) anechoic chamber, 4) OTA antennas and 5) device under test (DUT). The DUT is typically a relatively small device.

The spatial domain propagation is generated by the radio channel emulator and radiated by the antennas into the anechoic chamber. The MIMO OTA test system is able to generate almost any kind of spatial propagation behavior into the chamber. This is achieved by intelligent weighting of the signals in the radio channel emulator. Consequence of this angular propagation behavior and antenna design is the correlation. Since the model has to be realistic, it has to be based on the observations, thus physical measurements. Therefore, only Geometry Based Stochastic Models, such as SCM, SCME, WINNER or IMT-A models are applicable.

**System Validation**

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The key issue within MIMO OTA is how to validate the radio channel characteristics inside the anechoic chamber. The MIMO OTA is discussed in various technical forums such as CTIA, WiMAX Forum and 3GPP; also COST2100 is doing technical work for 3GPP. There are several technical papers available describing the system performance. The following pictures depict some essential radio channel parameters and their validation results.

Figure 2a) shows that the fading statistics from measured SCME Urban Macro model matches to the theoretical Rayleigh fading.

Figure 2b) shows that the power delay profile (PDP) measured from the MIMO OTA test system matches to the used channel model.

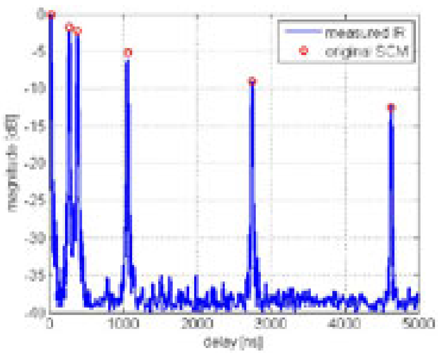


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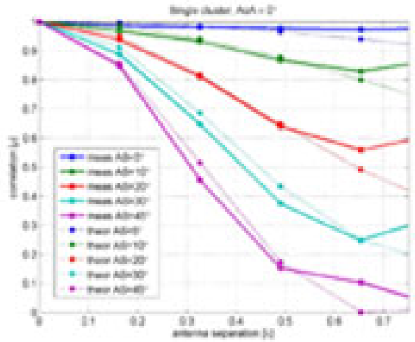
Figure 2c) plots the spatial correlation characteristics, meaning that both angular and angular spread characteristics are mapped with good accuracy. Thus the spatial channel model, essential for MIMO testing, can be modeled and generated with MIMO OTA.



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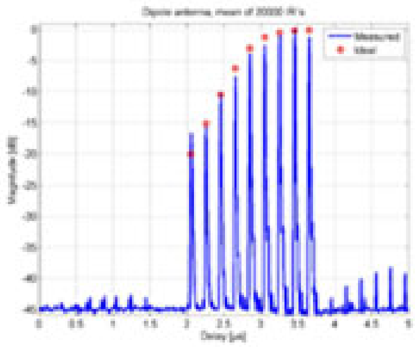
Finally, the polarization characteristics are shown in figure 2d)



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**Practical Example**

A test scenario was created by using the RACE platform (R&D MIMO platform manufactured by EB) to demonstrate the performance of different MIMO antenna designs and effects of radio channel. The test results show that the achievable spectral efficiency clearly depends on the used antennas and also on the propagation environment.

Figure 3 presents throughput results with different antenna designs and spatial propagation characteristics using diversity and spatial multiplexing. Used antenna designs: Reference antenna (REF), Compact MIMO Antenna (CMA) with vertical and horizontal orientations:

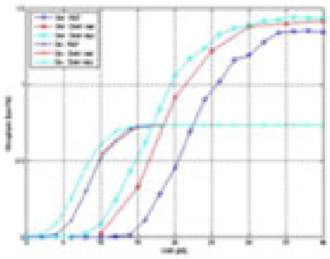

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Figure 3 a) results with WINNER indoor-to-outdoor

Figure 3 b) single cluster with 0dB XPR

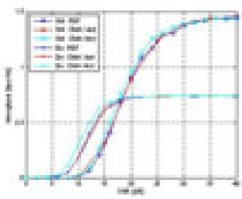

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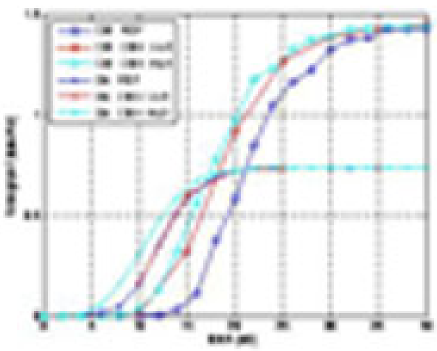
Figure 3 c) single cluster with 10dB XPR



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**Conclusions**

Wireless applications, such as WiMAX, utilizing MIMO and especially spatial multiplexing are challenging from the terminal design perspective. The MIMO performance is dependent on antenna orientation and angular information plays an extremely important role. The key to this angular behavior is Geometry Based Stochastic Models mapped correctly to the anechoic chamber.

Based on the above presented practical example and numerous measurement results contributed to standardization forums, the MIMO OTA test system benefits are clear. It is capable of repeating spatial propagation effects in the laboratory conditions; therefore it reduces the number of required field tests and shortens the development time.

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