Testing LTE and WiMAX OFDM/MIMO-Based Systems

The introduction of new radio technoloiges, like OFDM and MIMO, in LTE and WiMAX systems has created the need for new types of test equipment.

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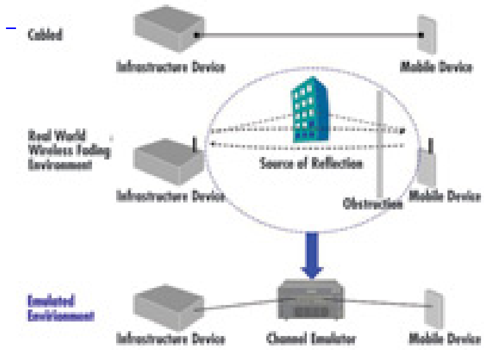

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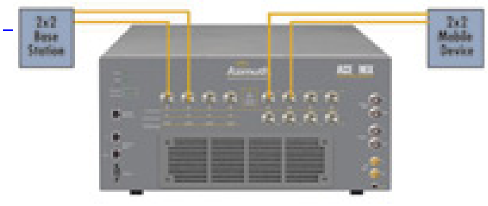
Figure 1. Three methods of testing transmitter and receiver performance: lab-based, direct cable connectivity, over-the-air testing and lab-based, connection through a channel emulator that simulates real world conditions.

Mobile wireless systems have dramatically evolved over the past two decades. Commercial wireless networks in the early 1980s provided low-capacity, voice-only services, whereas, in today's world, a growing number of mobile wireless networks are evolving to support higher capacity throughput for data-hungry applications.

The underlying radio technologies for these networks have undergone extensive changes as well to support the enhancements in capacity. As a result, numerous testing challenges have arisen due to the creation of new, complex, specialized hardware and software. One area that has undergone a radical transformation is test tools, in particular, test tools associated with verifying the performance of the new generation of radio transmitters and radio receivers.

The latest generation of radio technologies for mobile wireless systems is focused on delivering higher levels of throughput in smaller amounts of bandwidth. The standards for these technologies are being defined within several industry consortia. Two leading industry groups — the 3rd Generation Partnership Project (3GPP) and the Institute of Electrical and Electronics Engineers (IEEE) in concert with the WiMAX Forum — have been at the forefront of defining the latest standards to address the challenging goal of squeezing more and more bits of data in less bandwidth. The standards under development by these organizations are commonly known as Long Term Evolution (LTE) and 802.16e-2005 (or Mobile WiMAX), respectively.

Although these standards have evolved from different starting points, they both introduce two new techniques, Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input, Multiple Output (MIMO) radio systems, to enhance the overall performance of radio transmitters and receivers with respect to the effects of air interface. The radio path is subjected to numerous effects, such as signal delay, fading and obstructions, that may combine to improve the conditions or may serve to corrupt the transmitted signal, positively or negatively affecting the overall channel throughput/data rate.



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OFDM is a robust digital modulation scheme that enhances overall spectral efficiency. OFDM uses much lower symbol rates per carrier to reduce multipath interference, but uses multiple carriers to increase the data rate. Instead of transmitting a single symbol at a time, OFDM transmits multiple symbols simultaneously on a number of carriers. The subcarriers are distributed over multiples of frequency such that they are "orthogonal," avoiding any kind of interference caused by adjacent subcarriers.

MIMO systems use multiple transmit and receive data paths to provide significant increases in data throughput and link range without additional bandwidth or transmit power. MIMO systems can be implemented via several different techniques. Some MIMO examples include Spatial Multiplexing, Adaptive Antenna Systems (AAS), Space Time Coding (STC) and Maximal Ratio Combining (MRC). Spatial multiplexing typically provides performance improvements by increasing the capacity of the system. AAS improves the range of the network by steering the signal power to the user or by nulling the effects of interferers. STC, a form of transmitter diversity, and MRC, a form of receiver diversity, are techniques that respectively transmit and receive multiple copies of the same user data in an effort to combat impairments.

The introduction of LTE and WiMAX technologies, and particularly their OFDM and MIMO aspects, requires advanced testing capabilities and tools to ensure product designs meet or exceed 3GPP / 802.16e performance expectations.

Advanced Laboratory Testing is Achieved through the use of Channel Emulation

There are several methodologies for testing the performance of transmitters and receivers. The first logical step in testing radio circuitry, in general, is to directly connect the radio transmitter to the radio receiver using RF cable(s) and connectors. Although this type of test configuration enables a controlled and repeatable mechanism to test transmitter and receiver performance, it is an ideal and non-realistic scenario. Cable testing fails to provide the more sophisticated testing required to imitate the real world dynamic conditions that are introduced when signals are transmitted over-the-air (OTA).

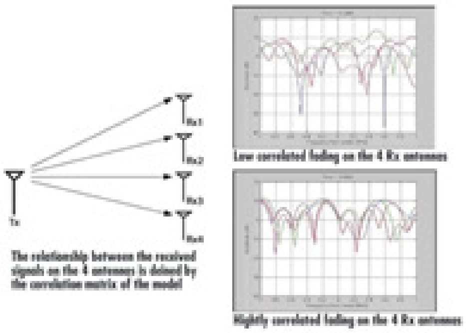

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Figure 3. Illustration of correlation variations in received signals of multi-antenna systems.

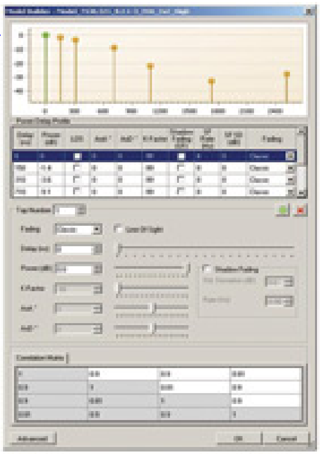
The second methodology, over-the-air testing — where the radio signal is transmitted through the air to a physically remote receiver — provides a level of performance measurement, but fails to provide consistent accuracy and repeatability. The lack of consistency, accuracy and repeatability is due to variations in the radio path caused by motion of the mobile receiver, obstructions, etc. Due to these radio path variations, OTA testing tends to be extremely time-consuming and expensive.

A third methodology for testing radio transmitter/receiver performance combines the repeatability aspects of the laboratory-based direct connection testing with signal-affecting conditions experienced in over-the-air testing. This lab-based testing methodology introduces a device called a channel emulator, a system that emulates real-world channel propagation conditions in a controllable and repeatable fashion, in the cabled path between the radio transmitter and receiver. Sophisticated channel emulators offer bi-directional operation with independent programmability of channel characteristics in both directions. By using channel emulators, radio designs and performance can be verified, test coverage can be improved, test cycles decreased and higher quality products can be introduced to the market sooner. Figure 1 illustrates the three methods of testing.

High RF Performance and Fidelity Requirements for Channel Emulation

Simple, single input, single output (SISO) channel emulators or fading simulators have been available for a number of years; however, the introduction of OFDM and MIMO as well as higher order modulation schemes, such as 64 QAM, have imposed new, very rigid RF performance and fidelity requirements on test equipment overall and, specifically, for channel emulators. These specifications must be met or exceeded by channel emulators; otherwise, the test equipment itself will introduce errors into the measurement process. These requirements come in the form of broad dynamic range, minimal noise considerations, multi-antenna support and diverse channel modeling capabilities.

LTE/WiMAX devices can have a very wide dynamic power range. Mobile devices implement more than 30 dB of transmit power control, typically varying their output power to compensate for their distance from the base station. In addition, although the average power may have some maximum value, when OFDM is employed, the peak-to-average power ratio (PAPR) may be 13 dB. Furthermore, when the device is transmitting a higher order modulation, like 64 Quadrature Amplitude Modulation (QAM), an adequate signal to noise ratio (SNR) must be maintained. Thus, a channel emulator must allow for direct connection of devices that transmit a wide dynamic range and still allow for sufficient PAPR and SNR margin to provide a robust and efficient test configuration.



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Signal quality for advanced modulation signals, such as 64 QAM, are often described by a single parameter, Error Vector Magnitude (EVM). EVM is used as the single specification to account for many types of degradations on the signal by defining the error between the signal's decoded constellation and the ideal. Any device that transfers the signal contributes to the overall degradation of the signal, and this holds true with channel emulator test equipment. When the signal passes through the channel emulator, the residual noise of the channel emulator must be added to the original signal noise level to understand the total EVM that will be presented to the receiver under test. Ideally, the channel emulator will contribute little or no noise to the transmitted signal.

A channel emulator is employed to provide realistic fast fading conditions, as found in the real world. These conditions result in frequency selective fading across the channel bandwidth. With an OFDM signal, as used in LTE/WiMAX systems, certain subcarriers may be faded or momentarily reduced in amplitude by 20 dB or more due to the frequency selective fading. As each subcarrier is a modulated signal, with modulation up to 64 QAM, this momentary drop in signal amplitude must be considered relative to the noise floor of the channel emulator equipment. If the noise floor of the channel emulator is too high, it is possible that, as the channel emulator fades the channel, it is introducing a noise level that will cause errors in the receiver as a direct result of the channel emulator noise floor. A well-designed channel emulator will have a sufficient noise floor so it will not corrupt the results of the device under test when using a fading channel.

Multiple Antenna Connection Support is Critical for Advanced Radio Technologies

Examples of MIMO systems, such as spatial multiplexing and adaptive antenna systems, were previously described. Employing any of those techniques requires multiple antennas and, hence, multiple antenna connections on the base station and mobile device are required. To enable proper interfacing with MIMO-based base stations and mobile device, a channel emulator must therefore support several connectors and antenna configurations. For MIMO systems, these configurations commonly include connections for two antennas from the base station and two antennas from the mobile device and can easily extend to four or more antennas for each device. Figure 2 illustrates a MIMO configuration with two transmitters at the base station and two receivers at the mobile device ? a 2x2 configuration commonly required for today's channel emulators.

To usefully recreate the real-world over-the-air conditions in which OFDM/MIMO systems will operate, dynamic and long representations of OTA conditions are provided by channel models. The dynamic or constantly changing conditions provided by these statistical channel models are based on random processes that create a specific instance of a channel condition due to fading, multipath and correlations. The fading represents the time varying signal levels, whereas the multipath represents the variation over frequency due to the multiple reflections on the path between the transmit and receive antenna. Complex-valued correlation matrices describe the correlation of the fading between different MIMO paths, which are impacted by the antenna correlation properties defined by items like angle of arrival, angle of departure and power angular spread. Channel emulators must support these OTA aspects as well as numerous other radio channel effects. Figure 3 illustrates correlation variations in received signals, and Figure 4 provides an example of a parametric channel emulator implementation of a 3GPP Channel Model.

Conclusion

The introduction of new radio technologies, such as OFDM and MIMO, in LTE and WiMAX systems has created the need for new types of test equipment. Channel emulators are now required to meet very rigid and demanding RF performance and fidelity specifications to support these OFDM/MIMO and higher-order modulation systems.

These new channel emulators must also provide the necessary connectivity for systems like 4x4 MIMO and offer a rich set of channel modeling capabilities that includes traditional fast fading channel models, shadow fading and multiple other features for stressing certain aspects of OFDM/MIMO radio technology designs. By utilizing channel emulators specifically built to support OFDM/MIMO radios, test time and costs can be reduced due to testing accuracy and repeatability. As a result, high-quality products and systems can quickly and efficiently be delivered to the market to meet the ever-increasing data requirements of the latest generation of radio technologies.

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