

# Critical WiMAX product design and testing demands effective channel emulation

WiMAX is becoming increasingly popular and useful in wide-area wireless network applications. As it does, questions arise on how to best verify—with vendor integrity as well as product and service certainty—that MIMO-enabled applications, such as voice and video, will work to the end-users' satisfaction.

By John Griesing

**M**ultiple-input multiple-output (MIMO) technology is the foundation of the next generation of mobile WiMAX products. By leveraging multiple transmit and receive antennas to employ techniques such as spatial multiplexing, adaptive antenna processing, and beam forming, MIMO-enabled products deliver greater wireless throughput and range, enabling ubiquitous high-speed voice, video and data services. In lab-controlled channel emulation, using a channel emulator is required to accurately characterize the effect of multichannel RF interactions on the conformance, performance and interoperability of MIMO and single-input single-output (SISO) WiMAX systems.

This article explains the critical test requirements of MIMO-enabled WiMAX devices. The understanding of key technical requirements and features that increase user effectiveness will assist engineers and engineering managers in the selection of the channel emulator that best meets their needs.

## Measuring over-the-air conditions

To accurately test real-world, over-the-air conditions in a controlled lab environment, a channel emulator that reproduces these conditions is required. A channel emulator, therefore, must have:

- dynamic emulation to mimic the constantly changing over-the-air channel conditions;
- a real-time path to precisely represent the bidirectional nature of the device and base-station path.

Over-the-air conditions are constantly changing due to many variables, including device movement, the environment, people, cars and buildings. Channel emulation technology uses sophisticated channel models to recreate conditions that occur in real-world wireless transmission. Standards bodies and industry forums define channel models that represent certain classes of channel

Parameters	ITU Pedestrian B	Models ITU, Vehicular A	ITU Vehicular A (long tap)
Max Doppler speed (km/h)	3	60	120
Rms delay spread (ns)	375	595	530
Maximum delay (ns)	3700	2510	10000
Number of taps	6	6	6
Total angular spread (BS)	5°	5°	5°
Total angular spread (MS)	68°	70°	70°
Antenna configurations	BS 4λ, MS λ/2 (high correlation) BS, MS cross-polarized (med. correlation) BS 4λ, MS λ/2 cross-polarized (low correlation)		

Table 1. Parameters of ITU M.1225 Pedestrian B and Vehicular A channel models.

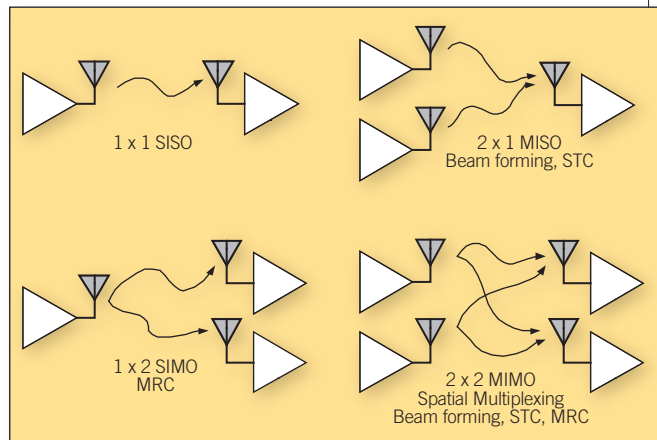


Figure 1. Shown here are SISO, MISO, SIMO and MIMO antenna configurations.

conditions, which serve as statistical characterizations of specific environments. The conditions provided by the channel model are based on random processes that create a specific instance of a channel condition due to fading, multipath and correlations. The models are dynamic in the sense that the conditions (strength and phase of reflections) are constantly changing. Therefore, to accurately represent all the conditions, the emulator must also be dynamic in order to change in time and provide long intervals of statistically non-repeating channel conditions, as the real channel would. This provides the devices under test with a very large number of unique channel instantiations similar to real-world conditions resulting in more test coverage.

There are often a number of channels that are defined by

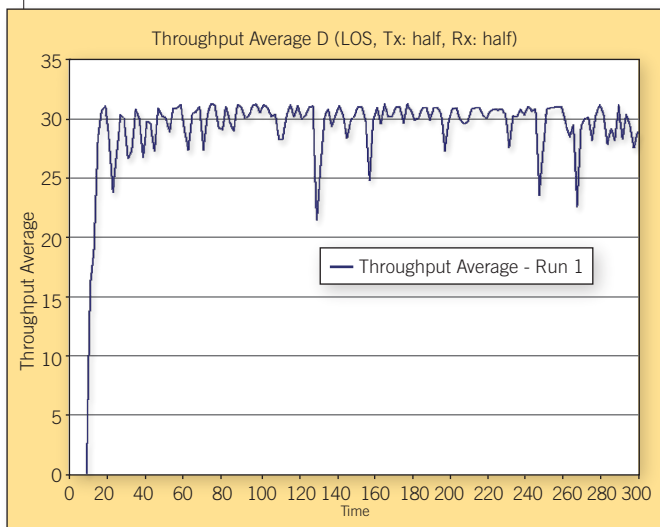


Figure 2. This throughput vs. time plot shows throughput reduction conditions of interest.

standards organizations to create a baseline. For example, ITU M.1225 Pedestrian B and Vehicular A channel models provide a baseline for testing WiMAX devices today. Table 1 provides key parameters of the ITU M.1225 Pedestrian B and Vehicular A channel models.

In addition, test organizations, product development labs and others may have their own models that they feel better represent the conditions in which devices are expected to operate. A channel emulator must have the ability to use standard models as well as custom, user-defined models. In the case of standard models, channel emulators should offer them as a built-in feature. To allow for extensible emulation of channels, a channel emulator must offer the ability to program both spatial and temporal parameters as part of defining custom model parameters.

In real-world device operation, a bidirectional channel exists between the mobile station and the base station. This bidirectional channel is used as part of the normal communication that takes place between these devices. Sometimes, these channels are half duplex in the case of WiMAX time-division duplexing (TDD), but sometimes they are full duplex as is the case with WiMAX frequency-division duplexing (FDD). These channels are often described as downlink and uplink relative to the base station. Both the bidirectional downlink and uplink channels undergo fading and multipath conditions. For a system test that closely represents actual channel conditions, a channel emulator must provide bidirectional channels with full fading and multipath in both the downlink and uplink paths.

The real channel from the base station to mobile station is reciprocal with the real channel from the mobile station to the base station (e.g., the paths traversed by the signal from a base station transmit antenna to a mobile station receive antenna are identical if the signal were to be launched instead at the mobile station and received at the base station). For a channel emulator to accurately reproduce real-world conditions, the emulated downlink

and uplink channels must also adhere to the reciprocity principal. Adaptive antenna system (AAS) technologies such as beam forming rely on this principal to work properly (see the sidebar, "Why is beam forming a critical feature to WiMAX devices?"). This further implies an inherent "balance" between these channels. Without the emulator providing such balance, accurately testing these beam-forming techniques is not possible.

To accurately represent the real-world over-the-air conditions in which WiMAX systems will operate, an effective channel emulator must be dynamic and provide long intervals of non-repeating channel conditions. In addition, the channel emulator must have the ability to use both built-in standard channel models (ITU M.1225 Pedestrian B and Vehicular A) as well as custom, user-defined models. Finally, accurate system testing of current and future MIMO techniques requires a bidirectional (with full fading and multipath in both downlink and uplink paths) and reciprocal channel emulation technology.

### Multiple antenna connection support

Most next-generation data systems make use of multiple antenna technologies to improve range, performance and capacity. There are different techniques used to achieve these enhancements. Some examples include MIMO spatial multiplexing, AAS, space-time coding (STC) and maximal ratio combining (MRC). Such techniques are often described by their multiple antenna configurations, such as SISO, multiple-input single-output (MISO), single-input multiple-output (SIMO), and MIMO. Figure 1 shows SISO, MISO, SIMO and MIMO antenna configurations and indicates the performance-enhancing techniques that each configuration may enable.

Spatial multiplexing (MIMO) typically provides performance improvements by increasing the capacity of the system, defined effectively as bits per second per Hertz (bps/Hz). AAS improves the range of the network by steering the signal power to the user. 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, such as fading. Employing any of these techniques requires multiple antenna connections for proper testing of the system. Furthermore, the correlation between the received signals depends on the transmitter and receiver antenna spacing, hence a system that accurately provides for considerations such as cross correlation, angle of arrival and departure, and angular spread is required.

For WiMAX systems, AAS techniques that use many antennas at the base station are common to extend the range of the system, thereby reducing the number of base stations required. A MISO system with four antennas is not uncommon. At mobile stations, where battery life is a major concern, techniques like STC help improve overall performance without costly multiple receivers (MISO).

Critical Requirements for Effective Channel Emulation	Key Channel Emulator System Feature(s)
Comprehensive WiMAX system testing requires accurate representation of over-the-air conditions	Dynamic with very long intervals of statistically non-repeating data  Use standard channel models (ITU M.1225 Pedestrian B and Vehicular A for WiMAX) as well as custom, user-defined models  Bidirectional and reciprocal channel emulation
Test WiMAX devices with many antennas	4 x 4 MIMO channel emulation
True assessment of multi-antenna WiMAX device performance	EVM better than the device under test, high dynamic range and low noise floor
Simplify troubleshooting WiMAX device behavior	Sophisticated channel model play/forward/rewind/pause control
Obtaining accurate and repeatable channel emulation test results	Integration with a controlled RF test environment
Regression and interoperability certification testing completed without human intervention	Integration with system-level test automation and results database

Table 2. Critical engineering and management requirements for channel emulation of WiMAX devices.

Both of these techniques result in the need for channel emulation with a large number of antenna connections.

Effective channel emulation requires at least 4 x 4 capabilities to handle the many modes that are being deployed today, as well as to be ready for the technologies defined by the IEEE 802.16e standard upon which mobile WiMAX technology is based.

### WiMAX channel emulation highs and lows

Data communications technologies, as employed in WiMAX, present demanding requirements on system dynamic range and fidelity. Most modern radio systems employ advanced digital modulation technologies to increase capacity, as defined by bits per symbol. An example is the WiMAX 64 quadrature amplitude modulation (QAM) that offers a capacity of six bits per symbol. But such high-order modulations also demand high dynamic range and linearity. To operate properly, an OFDM 64 QAM signal is capable of a peak to average power ratio (PAPR) of 13 dB and a high signal-to-noise ratio (SNR) of greater than 26 dB.

As is the case with products that employ advanced modulation, most will have some rate adaptation that allows the device to change to less aggressive modulation when the conditions do not support a more aggressive modulation. The implementation of rate adaptation combined with transmit power control results in a signal power that can change over a significant range (e.g., greater than 10 dB) during normal radio operation.

The summation of all these factors requires a test device that has a wide dynamic range of operation. For OFDM 64 QAM, 13 dB (PAPR) + 26 dB (to maintain adequate SNR) + 20 dB (rate adaptation and power control) = a dynamic of at least 59 dB for the expected input signal.

As the device signal for the device is then “processed” by the channel emulator, the high dynamic range of the signal requires even greater fidelity on the channel emula-

tor to avoid introducing any unwanted distortions. IEEE 802.16, the technical standards body that defines the technical requirements for WiMAX, specifies that a WiMAX transmitter should have an output fidelity, as described by error vector magnitude (EVM) of -31 dB. It can be shown mathematically that if a channel emulator offers the same fidelity as the device under test, -31 dB, the fidelity of the signal out of the channel emulator will be 3 dB less, or -28 dB. Ideally, test equipment should introduce as little distortion as possible when passing the signal. A channel emulator with an EVM of -41 dB, 10 dB better than the signal being evaluated, will contribute little

noise so that the resultant signal has an EVM of -30.6 dB. This is close to the originally transmitted signal.

With the burst nature of WiMAX transmissions, devices go from offering full-power output to no power on a transmission-by-transmission basis. This requires a relatively high dynamic range and low noise floor for proper receiver evaluations. The channel emulator should faithfully reproduce this range. The inherent thermal/noise in a 20 MHz-wide channel (20 MHz is the maximum defined WiMAX channel bandwidth) is given by  $-174 \text{ dBm/Hz} * 20 \text{ MHz} = 101 \text{ dBm}$  in 20 MHz, at room temperature. A receiver with a real noise figure of 10 dB would then have a noise threshold or noise floor of -91 dBm at 20 MHz. The test equipment should not be the limitation in receiving low-power signals.

### Channel control aids troubleshooting

As previously discussed, effective WiMAX testing requires running channel models for long periods of time, often several hours or even days. As the channel evolves over time, events may occur long into a run of the channel model that cause a significant loss in signal throughput. Investigating the conditions that created this loss in throughput requires advanced control of the emulator. If an engineer’s control of the emulator is limited to the simple act of starting it, the engineer would have to possibly wait several hours or days until the specific channel condition is recreated. A channel emulator that provides the user with channel control commands such as fast forward, rewind, pause, and play, enable the engineer to start the emulator and immediately fast forward to the time period of interest that may have occurred hours or even days earlier in the test run. Similarly, if a test is in progress and an anomaly is observed as having occurred in the past, pause and rewind controls allow the engineer to pause the emulator and rewind to the time period of interest. Once the channel conditions under investigation are being run, the engineer may

## Why is beam forming a critical feature to WiMAX devices?

Beam forming is believed to be a critical enabler of cost-effective WiMAX network installations. Without taking advantage of the range extension capabilities of beam forming, typical WiMAX installations will require a large number of WiMAX base stations to provide adequate network coverage for a given area. This will increase the capital and operating costs of a WiMAX network.

need to debug the radio. Advanced channel controls such as looping on a point in time, single stepping the channel and observing the actual channel parameters during those steps, significantly aid the engineer in debugging of the issue and provides data that can be used in system simulations.

Figure 2 shows the results of a throughput vs. time performance test conducted on a SISO device. The test plot identifies significant throughput reductions throughout the test. Using the advanced channel emulator controls the user “plays” the specific time period of interest to help understand the cause or causes of the throughput reductions.

### Accurate and repeatable emulation

The value of wireless device design and quality assurance testing increases when test results are both accurate and repeatable. Accurate and repeatable testing of wireless equipment is achieved in a controlled RF environment that is not subjected to external RF interference.

To obtain accurate and repeatable results when using a channel emulator that has high dynamic range, the channel emulator must be integrated with a controlled RF environment. Cost-effective channel emulation in a controlled RF testing environment can be done with an engineering bench top setup that uses RF-isolated enclosures for the devices under test coupled with a well-designed channel emulator. Such setups can replace the need for costly screen rooms or standard test house environments that lack repeatability across multiple locations.

### Automated channel emulation test systems

The need to run time-consuming, statistically significant tests with a channel emulator, coupled with the need to run several models as well as to adjust parameters like range (e.g., of the client device from the base station) and motion, results in many hours or days of testing effort. Without a completely automated test environment, engineers either need to be physically present or at least log in frequently to the test setup to make all the necessary changes.

By using a channel emulator that is completely coupled to a test automation environment, which not only controls the emulator, but can also command and control the base station and clients, many tests can be batched up and run without human intervention. Test automation systems that automatically store the results in a database, with appropriate timestamps and product information, provide a complete record of the testing performed. They also

provide a basis for comparing test results as system hardware/software is changed, or alternate devices are tested. Such automated testing improves time to market, test coverage, repeatability and the collection and archival of the results.

### Summary

Table 2 provides an “at-a-glance” look at the critical engineering and management requirements for channel emulation of WiMAX devices and the corresponding channel emulator or test system feature that addresses each requirement.

The complexity of WiMAX technologies, particularly those employing MIMO, as well as the performance and interoperability demands of the data, voice and video applications that will run over WiMAX networks, is driving the need for extensive testing of WiMAX devices. Channel emulation enables vendors and service providers to test WiMAX devices using re-created real-world channel conditions, thus avoiding the time and expense of testing in the “actual” real world. Technical specifications are a critical consideration in choosing a channel emulator. To accurately re-create the over-the-air conditions of the real world, a channel emulator must be dynamic and bidirectional with reciprocal channel calibration. The performance of an emulator must be better than the device under test, and the noise floor must be low. In addition, a 4 x 4 MIMO-capable channel emulator is required.

Channel emulators also vary in the efficiency with which they can be used. Features such as sophisticated channel model control as well as seamless integration with a controlled RF test environment, system-level test automation and a results management database, all help to optimize the effectiveness of a channel emulator as an engineering tool. In selecting a channel emulator, engineers should look for the combination of technical specifications and end-user features that meet the demanding requirements of their new WiMAX product designs. **EWT**

*John Griesing is the vice president of R&D at Azimuth Systems. Prior to joining Azimuth, he was a senior director at 3Com, where he led engineering operations for the company's cable data business and grew the group to a staff of 120. He also served as general manager of engineering for Chipcom's David Systems division and led development of 10/100 Mb Ethernet products. His contributions are reflected in IEEE standards and four U.S. patents. Griesing has an M.S. in electrical engineering/data communications from Northeastern University and a B.S. in electrical engineering from the University of Connecticut.*