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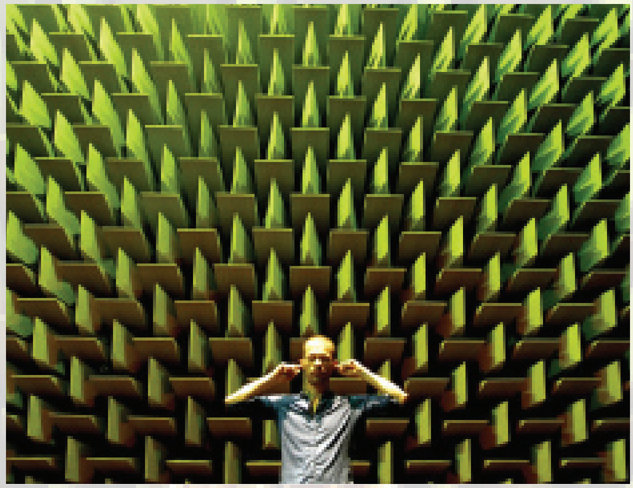


Evaluating WiMAX signal quality

By Daljeet Singh

WiMAX testing is important to ensure that units provide reliable operation. Setting up an effective WiMAX test requires an understanding of the critical parameters and application of advanced strategies and test equipment. The author provides an overview of the technology involved in testing WiMAX systems.

Given the complicated nature of WiMAX signals, thorough testing requires specialized equipment. Equally important is that the testing needs to be done on many levels. At one end of the testing spectrum are operational profiles and at the other physical-layer signal impairments.

The WiMAX Forum has developed certain certification profiles to ensure interoperability between devices. Different system profiles exist for fixed and mobile operations. Additionally, IEEE has established system profiles that serve as guidelines rather than hard specifications.

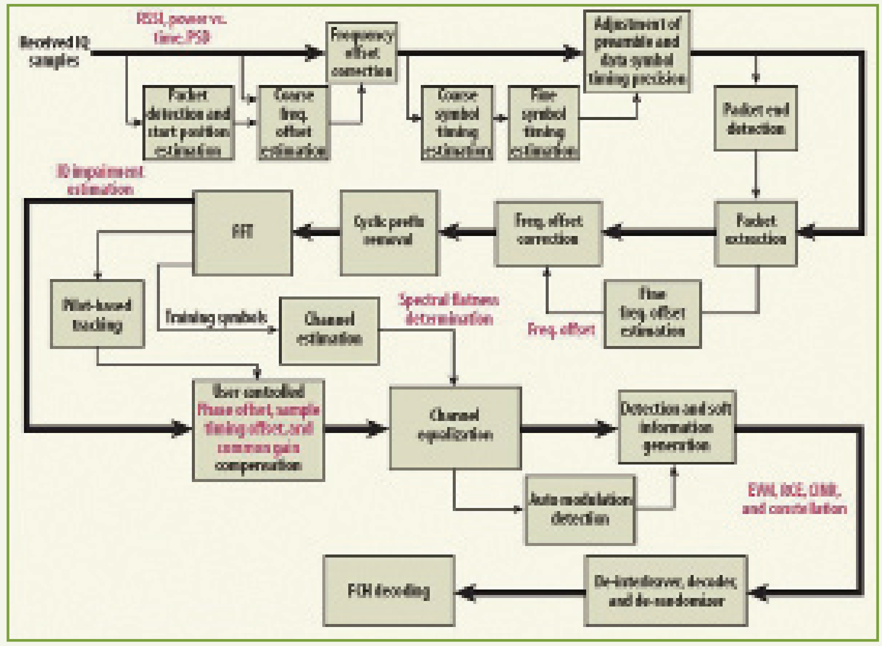
IEEE 802.16, the base specification of WiMAX, operates with a 10-66 GHz carrier and up to 28 MHz bandwidth in direct Line-Of-Sight (LOS) applications. 802.16-2004 was an amendment made by IEEE to cover Non-LOS (NLOS) use from 2-11 GHz. IEEE 802.16e introduced support for terminal mobility. IEEE 802.16 can be viewed as a toolbox that offers a number of air interface techniques as well as data mapping techniques to create an interoperable family of wireless communication products.

Test receivers

To improve WiMAX signal reliability, the WiMAX Forum selected the Orthogonal Frequency Division Multiplexing (OFDM)-based physical layers from the IEEE 802.16 standard. While OFDM is an effective modulation method, it has certain deficiencies. Several impairments can degrade the performance of OFDM if the system and its transceivers are not properly designed. Practical integration of RF and baseband circuitry in these systems requires realistic testing and verification procedures and equipment. This involves incorporating test and measurement capabilities for the standards-based WiMAX signals into the measurement receivers.

Representative test signals, including standards-based In-phase (I) and Quadrature (Q) baseband samples, must be generated for use with test instruments. Developing a baseband test receiver that can work in conjunction with a Vector Signal Analyzer (VSA) and a Vector Signal Generator (VSG) (or simulator) allows engineers to determine signal quality per IEEE 802.16 and WiMAX specifications.

The WiMAX test receiver can be a digital baseband receiver that processes I/Q data provided by the front end of any receiver or VSA. The transmitted signal can be passed through a channel emulator to add the desired impairments for test purposes. The received signal represents I/Q samples that include possible impairments due to the actual hardware at the transmitter and receiver front ends, as well as the intentional impairments that are included in the channel emulator. Figure 1 below shows a block diagram of a typical test receiver for this application.



This diagram shows the essential function blocks of the proposed receiver for WiMAX testing.

Figure 1

Conducting OFDM measurements

The WiMAX Forum has selected the OFDM technology as an air interface modulation format for frequencies below 11 GHz. The OFDM air interface provides adaptive functions as well as many optional features. It allows, for example, adaptation of modulation/coding format and adaptation of the cyclic prefix.

The IEEE 802.16 standard includes some transmitter and receiver test requirements. These requirements need to be tested for and conformance demonstrated. Many of these measurements are common, such as:

- Relative Constellation Error (RCE) in percent or decibels (dB)
- RCE vs. symbol number
- RCE vs. subcarrier number
- Spectral flatness
- Crest factor
- Peak, average, and minimum Error Vector Magnitude (EVM)
- Error vector spectrum/time, including Root-Mean-Square (RMS) error vector

Other measurements are also important for measuring WiMAX transceivers. Among these are frequency error, sample clock error, Received-Signal-Strength Indication (RSSI), Carrier-to-Interference-Ratio (CIR), Carrier-to-Interference-plus-Noise Ratio (CINR), Signal-to-Interference-Ratio (SIR), Signal-to-Noise Ratio (SNR), and Signal-to-Interference-plus-Noise Ratio (SINR). A brief discussion of each of these measurements follows.

Frequency error

Frequency error measures the difference between carrier frequencies generated by the local oscillators at the transmitter and receiver. This parameter is often measured from the time domain signal, but it is also possible to measure it using frequency-domain samples.

Sample clock error

A sample clock error measurement is used to determine the sampling clock differ-ence at the transmitter and receiver. This measurement in an OFDM system is often performed during the pilot tracking period. Since a sampling clock error introduces a phase rotation that depends on the carrier and OFDM symbol index, variation of the rotation can be used to estimate the sample clock error. Sample clock error is popularly estimated using frequency-domain samples after channel equalization.

Received-Signal-Strength indication

A simple indication of signal strength at the front end of a receiver is determined by RSSI. If the received signal strength is higher than a threshold value, the link is considered to be good. Compared to other measurements, such as CINR and Bit Error Rate (BER), RSSI estimation is simple and computationally less complex, as it does not require the processing and demodulation of the received samples. The received signal includes noise, interference, and other channel impairments, so receiving a strong signal is not an indication of the channel or signal quality. Rather, it provides an indication of whether a strong signal is present in the channel of interest.

If the measurement is performed on a wireless channel with a portable measure-ment device, the received signal power fluctuates rapidly due to fading. In order to obtain reliable estimates, the signal needs to be averaged over a time window to compensate for short-term fluctuations. The averaging window size depends on the system, application, channel variation, and other factors.

CIR, CINR, SIR, SNR, and SINR

Most wireless communication systems are interference limited, and therefore, CIR and CINR are most commonly used. CIR and CINR are the measurements of choice in many cases because they are more accurate and provide more reliable estimates than RSSI. The trade-off is that these measurements introduce addition-al computational complexity and delay. Engineers also perform SIR, SNR, and SINR to acquire information on how strong the desired signal is compared to the interferer (or noise, or interference plus noise).

CINR estimation can be accomplished by approximating signal power and in-terference power separately and then taking the ratio of the two. The signal power can be calculated using the channel parameter estimates, whereas noise-plus-interference-power measurements can be obtained by using EVM values, which measures the error between what is re-ceived and what is expected.

Often, the impairment – either noise or interference – is assumed to be white and Gaussian distributed in order to obtain estimates. In wireless systems, however, the impairment may be caused by a strong interferer that is colored. For example, in OFDM systems in which there is a wide channel bandwidth and the interference is not consistent over the entire band, it is highly likely that some part of the spectrum is affected more by the interferer than other parts. Because of this, it is important to determine not only the average CINR but also the carrier-based CINR and symbol-based CINR of the signal with regard to noise for each carrier and for each OFDM symbol.

The channel and interferer conditions for the desired signal may change rapidly, so both short-term and long-term estimates (depending on the application) should be deter-mined. Bit-Error-Rate (BER), Symbol-Error-Rate (SER), Frame-Error-Rate (FER), and Cyclic-Redundancy-Check (CRC) information are the measurements used for long term estimates. BER is the ratio of the bits that have errors relative to the total number of bits received during the transmission. FER is similar, only it is the ratio of frames, not bits. CRC is used to confirm the quality of a frame and can be calculated using parity check bits through a known cyclic generator polynomial. FER can be computed by testing for CRC errors over a number of frames. Calculating BER requires the receiver to know the actual transmitted bits, which is not possible in practice. An alternative method that can be used, provided Forward Error Correction (FEC) can fully correct a frame, is to compare data before and after the FEC decoder. The bit errors observed thus can then be attributed to BER.

Channel Frequency Response

CFR estimates provide a measure of the desired signal's power variation across frequency carriers. It is much more reliable than RSSI because this measurement is typically made after compensation of signal impairments. However, it is less reliable than CINR or SINR estimates. For white noise such as AWGN, CFR estimates can provide an idea about expected CINR at each carrier, thereby providing an indirect measure of the EVM.

In measurement scenarios where the receiver is connected to the Unit Under Test (UUT) via a cable, CFR can provide an idea about responses of the filters used at the transceivers. CFR is also useful in measuring spectral flatness, a measurement specified by the IEEE standard.

Measurement performance can also be affected by the accuracy of the receiver algorithms. For example, if the channel estimation algorithm is improperly designed, a measurement might indicate poor spectral flatness, leading an engineer to conclude that the filters used at the transmitter do not have good spectral properties. The problem may not be the filter but the channel-estimation algorithm that is being used.

When measuring a UUT, other impairments caused by different parts of the transceiver chain must be compensated for (or calibrated out). This should be done in such a way that the impairments caused by the UUT itself are not compensated for. Another important consideration is the location of the measurement tapping point in the receiver chain where a particular measurement is performed since making the estimation at a wrong point in the receiver chain could lead to misleading conclusions.

A powerful VSA

In a 2006 report entitled "State of the Art WiMAX Test Equipment," the WiMAX Forum listed suitable vector signal analyzers, including Anritsu's Signature (Figure 2), for testing use along with a vector signal generator such as Anritsu's MG3700A.

With optional WiMAX modulation analysis capability, along with other smart measure-ment capability and connectivity including USB, Ethernet, and optional SATA, the Signature can form the basis of an advanced WiMAX test system.

The complexity of WiMAX signals creates testing challenges. Various measurements can be used to analyze the quality of a received WiMAX signal, and well designed tests can help ensure reliable systems operation. Powerful new instrumentation is making this task easier. PXI

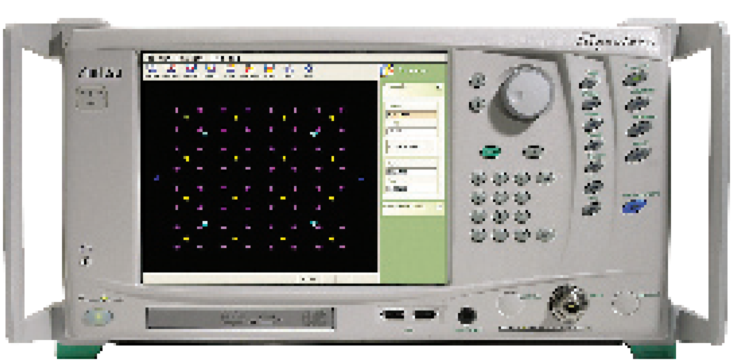


Figure 2

"For example, if the channel estimation algorithm is improperly designed, a measurement might indicate poor spectral flatness, leading an engineer to conclude that the filters used at the transmitter do not have good spectral properties."

__Daljeet Singh__ earned a B.Sc (Hons.) in Electrical Engineering from Punjab University, Chandigarh, and a MS in Electrical Engineering from the University of Alabama. He has 20+ years of experience in engineering/manage-ment and is presently a member of Anritsu Company's Signal Analysis group.

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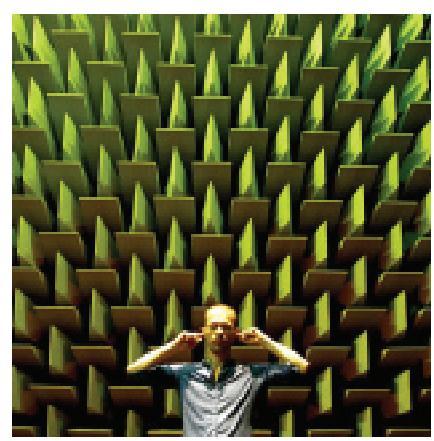

Photo by J. Kirkegaard, Ørsted DTU - Acoustic Technology, Denmark 2007

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