Application Note

Anritsu

Making PHY Measurements On Mobile WiMAX Devices

MS2781B	MS269xA	MG3700A	MT8222A
Signature™	Signal Analyzer	Vector Signal Generator	BTS Master™

Introduction

Growth of personal broadband services is inevitable, given a seemingly insatiable consumer appetite for high-speed data, instant communications, and instant video. The urgency of having these services is pushing the development of new technology solutions, such as WiMAX, to provide services anywhere and at anytime in a metropolitan area, even if the subscriber is on the go. WiMAX has been called a wireless replacement for wired digital-subscriber-line (DSL) technology, which provides high-speed Internet services, but WiMAX is much more than just an alternative to DSL or cable-modem broadband access. WiMAX is designed to do for the Internet what cellular technology did for telephones–provide access anywhere at any time.

The latest version of the WiMAX standard addresses the mobile services required to free users from the tethers of a predetermined location. Of course, as with any new technology comes the need to test its hardware–in the research labs, for product qualification and conformance testing to the standard, on the production line, and for troubleshooting and maintenance. Fortunately, Anritsu Company has developed high-performance measurement solutions ideally suited for WiMAX fixed and mobile equipment testing, including the Anritsu Signature MS2781B High-Performance Signal Analyzer, the MS2690A/MS2691A Signal Analyzers, the MG3700A Vector Signal Generator, and the BTS Master™ MT8222A handheld base station analyzer.

Several of these instruments were used in the second public mobile WiMAX Forum® PlugFest (www.wimaxforum.org), an interoperability showcase hosted by AT4 wireless Labs (Malaga, Spain). The instruments were among the measurement equipment provided by leading test and measurement manufacturers to allow manufacturers of mobile WiMAX communications products the opportunity to evaluate their equipment in an open environment. More recently (May 13-19, 2007), WiMAX Forum members gathered in Sophia Antipolis, France for the third public mobile WiMAX Forum where some of the important features of mobile WiMAX, such as beamforming for smart antennas and multiple input multiple output (MIMO) operation, were evaluated.

One of the keys to the success of WiMAX, of course, is full interoperability of equipment from all manufacturers. The PlugFest provides opportunities for testing products intended for consumer and commercial markets prior to full compliance testing, which will ensure interoperability. Certification of Wave 1 mobile WiMAX products is scheduled to begin in mid 2007, with market availability of WiMAX Forum Certified mobile products beginning in late 2007.

What Is WiMAX?

WiMAX, which is short for Worldwide Interoperability for Microwave Access, is a form of broadband wireless access (BWA) Internet-Protocol (IP) based technology that provides high-data-rate communications for fixed-station subscribers at distances as great as 30 miles from a base station and for mobile station subscribers at distances as great as 10 miles from a base station. Because of its intended use in metropolitan areas, WiMAX is also known as a wireless metropolitan area network (WirelessMAN) technology. Technology in support of WiMAX has been in development by the IEEE for several years (see Table 1), with mobile access added to the most recent version of the standard. WiMAX is based on the 802.16 standard. The fixed-access WiMAX standard, IEEE 802.16-2004, was finalized by the IEEE in 2004, with the mobile access standard finalized in the following year (see Table 2 for an evolution of the WiMAX standards).

European Telecommunications Standards Institute (ETSI)	
Frequency range	3410 to 4200 MHz, 10.0 to 10.68 GHz
Channel bandwidths	1.75, 3.5, 7, 14, 28 MHz
Multichannel Multipoint Distribution Service (MMDS)	
Frequency range	2150 to 2162 MHz, 2500 to 2690 MHz
Channel bandwidths	1.5, 3, 6, 12, 24 MHz
Wireless Communications Service (WCS)	
Frequency range	2305 to 2320 MHz, 2345 to 2360 MHz
Channel bandwidths	2.5, 5, 10, 15 MHz
Unlicensed National Information Infrastructure (UNII)	
Frequency range	5250 to 5360 MHz, 5725 to 5825 MHz
Channel bandwidths	unspecified

Table 1. IEEE 802.16 OFDM Frequency Bands

Standard	Defined in	Frequencies covered
IEEE 802.16	2002	10 to 66 GHz
IEEE 802.16a	2003	2 to 11 GHz
IEEE 802.16b	2003	5 to 6 GHz
IEEE 802.16c	2003	10 to 66 GHz
IEEE 802.16d	2003	2 to 11 GHz
IEEE 802.16-2004	2004	2 to 66 GHz
IEEE 802.16e	2005	2 to 66 GHz

Table 2. Tracing the evolution of IEEE 802.16 standards

As Table 1 shows, the range of frequencies is wide for the different forms of WiMAX. For fixed WiMAX operation, licensed frequencies fall around 2.5 and 3.5 GHz while unlicensed frequencies are around 5.2 and 5.8 GHz. Within the IEEE 802.16-2004 standard, there are five fixed methodologies that vary by application, execution, and access method:

1. WirelessMAN SC, a single-carrier approach without non-line-of-sight (NLOS) provision;

2. WirelessMAN SCa, single-carrier approach with NLOS provision;

3. WirelessMAN OFDM, using multiple carriers in an orthogonal-frequency-division-multiplex (OFDM) arrangement;

4. WirelessMAN orthogonal frequency-division-multiple-access (OFDMA), using a multiple-user version of OFDM; and

5. WirelessHUMAN (wireless high-speed unlicensed MAN)

The single-carrier (SC and SCa) versions of the fixed WiMAX standards are based on several modulation schemes, including binary-phase-shift-keying (BPSK), quadrature-phase-shift-keying (QPSK), 16-state quadrature-amplitude-modulation (16-QAM), and 64-state QAM (64-QAM) formats. Channel bandwidths for fixed LOS systems are 20, 25, and 28 MHz at carrier frequencies ranging from 10 to 66 GHz. Fixed NLOS systems employ channel bandwidths of 1.25, 1.75, 3.5, 5.0, 7.0, 8.75, 10.0, 14.0, and 15.0 MHz at carrier frequencies spanning 2 to 11 GHz.

Because WiMAX is intended as a solution for metropolitan BWA applications, multipath effects from buildings and other obstructions must be overcome. For that reason, the orthogonal frequency-division-multiplex (OFDM) versions of WiMAX were developed. In an SC system, a single carrier is digitally modulated with a relatively fast symbol rate. In an operating environment with severe multipath conditions, the use of a fast symbol rate can result in lost data and poor signal performance. An OFDM signal actually consists of many orthogonal carriers, and each signal is digitally modulated with a relatively slow symbol rate. Because of the slower symbol rates, such signals are less affected by multipath interference, which creates delayed and reflected versions of transmitted signals. By transmitting one symbol on multiple carriers, it is possible to use forward error correction (FEC) to reconstruct the contents of faulty carriers.

In WiMAX systems with OFDM, a number of different modulation formats— BPSK, QPSK, 16-QAM, and 64-QAM – are used, with the modulation adapted to the particular transmission requirements. By this adaptive modulation approach, raw transmission rates as fast as 73 Mb/s are possible for a 20 MHz bandwidth. The IEEE 802.16-2004 MAN standard makes a distinction between the use of OFDM and orthogonal frequency division multiple-access (OFDMA).

The OFDM symbols used in fixed WiMAX systems are based on an inverse 256-point Fast Fourier Transform (FFT) to make the frequency-to-time conversion. In essence, OFDM is many carriers, each with slow modulation for resistance to the effects of multipath interference. Some of the 256 subcarriers are set aside as guard bands; the subcarrier for the center frequency is not used as it would be susceptible to RF carrier feedthrough. For fixed WiMAX, only 200 (of the 256) subcarriers are used, allocated as 192 carriers for data and 8 as pilot carriers. The pilot carriers always employ BPSK while the data carriers can use BPSK, QPSK, 16-QAM, or 64-QAM.

A single user in an OFDM WiMAX system can use all subcarriers at any given time. In OFDMA, subsets of subcarriers are assigned to multiple users, allowing a number of subscribers to be served simultaneously. Using a technique known as subchannelization, specific carrier groups are used for each subscriber. These subcarrier assignments change dynamically to overcome the effects of multipath interference.

Subchannelization is a key concept for effective WiMAX network operation. The technique makes it possible to group a number of OFDM carriers into blocks, and then assign each block to a different WiMAX Base Station (BS) sector. The blocks, which contain a number of adjacent carriers, can be spread over the full operating frequency range. By using adjacent BS sections, the effects of interference can be minimized. A WiMAX network's subchannel index controls the use of different blocks over its operating frequency spectrum.

WiMAX systems can be used in time-division-duplex (TDD), frequency-division-duplex (FDD), or half-duplex FDD configurations. In a TDD approach, the base station (BS) and the subscriber station (SS) each transmit on the same frequency, although separated in time. The BS transmits a downlink subframe, followed by a short gap called a transmit/receive transition gap (TTG), and then individual subscribers transmit the uplink subframes. Subscribers are accurately synchronized so that their transmissions do not overlap each other when they arrive at the BS. Following all uplink subframes, another short gap called a receive/transmit transition gap (RTG) is allocated before the BS can start transmitting again. The use of preambles at the beginning of each subscriber uplink subframe allows the BS to synchronize on each SS.

In WiMAX, a frame is a structured sequence of data of fixed duration comprised of a downlink (DL) burst and an uplink (UL) burst (Fig. 1). These bursts or subframes contain different data for different users. A subchannel is essentially a set of OFDM subcarriers. A slot is a unit of time for allocating bandwidth, while a zone is a number of contiguous OFDMA symbols using the same permutation formula. The frame structure makes use of different power levels for efficiency and robustness. For example, the fixed WiMAX PHY layer has a DL subframe structure with preamble, frame control header (FCH), and data bursts. The preamble consists of two OFDM symbols with QPSK modulation, transmitted with 3 dB more power than rest of the subframe. The FCH is one OFDM symbol with BPSK modulation. In contrast to the preamble, all symbols in the FCH and data bursts are transmitted with equal power.

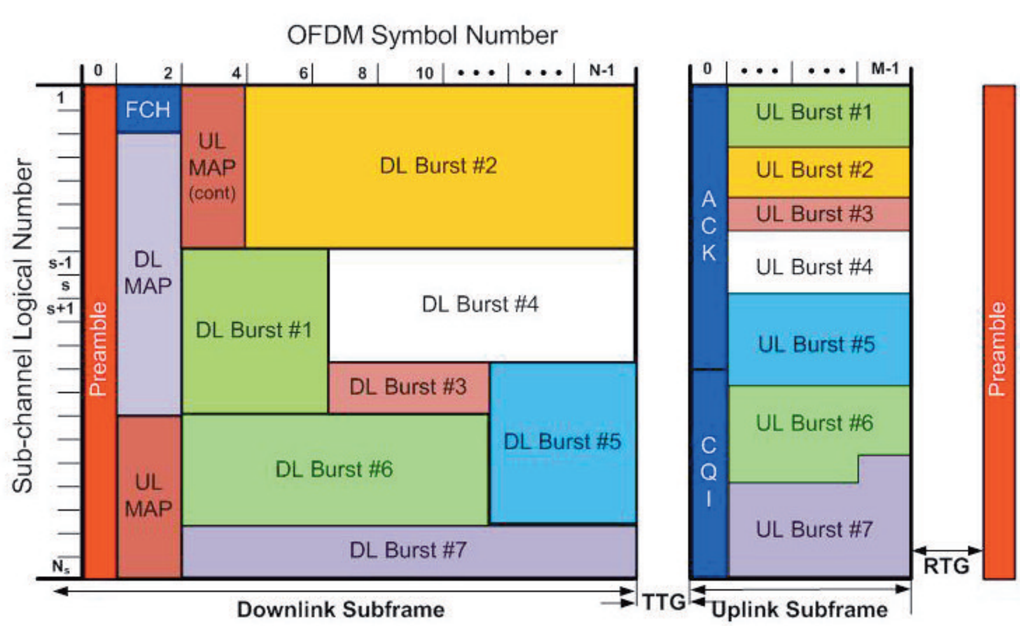

Figure 1. Mobile and fixed WiMAX communications systems employ burst signals with a complex frame structure to send data and information about the transmission (modulation) scheme.

DL and UL data bursts are generally comprised of multiple symbols within the burst and subcarriers. The modulation type within each burst is constant, although the modulation type can change from one burst to another. These changes in modulation follow a logical pattern of more robust to less robust, or from BPSK, through QPSK and 16-QAM, and ending with 64-QAM.

In December 2005, the IEEE 802.16e-2005 standard was finalized as an expansion of 802.16 technology into mobile applications, with modifications to the standard's media access control (MAC) layer as well as the physical (PHY) layer, and a number of corrections to the 802.16-2004 standard (see Table 3). The mobile WiMAX standard supports roaming in the manner of a cellular network, as well as dynamic power control to make efficient use of the limited power transmitted by mobile subscriber units. At that time, three air interfaces were agreed upon for IEEE 802.16e-2005: single-carrier WirelessMAN SCa, WirelessMAN OFDM, and WirelessMAN OFDMA with initial operation in the 2.3, 2.5, 3.3, and 3.4 to 3.8 GHz frequency bands (Table 4). At the same time, IEEE 802.16e-2005 supports all five of the MAN PHY interfaces.

Parameter	Fixed WiMAX	Mobile WiMAX
Access	Fixed	Fixed, portable, and mobile
Air inteface	OFDM	OFDMA
Duplex type	TDD or FDD	TDD or FDD
Modulation type	BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM
FFT size	256	128, 512, 1024, 2048
Handoffs	No	Yes

Table 3. A quick comparison of fixed and mobile WiMAX

Channel bandwidth (MHz)	FFT size (points)	2.30 to 2.40 GHz	2.305 to 2.320 GHz	2.345 to 2.360 GHz	2.496 to 2.690 GHz	3.30 to 3.40 GHz	3.40 to 3.80 GHz
5.0	512	TDD	TDD	TDD	TDD	TDD	TDD
7.0	1024*	–	–	–	–	TDD	TDD
8.75	1024*	TDD	–	–	–	–	–
10.0	1024*	TDD	TDD	TDD	TDD	TDD	TDD

* For 7 and 8.75 MHz channel bandwidths, the sampling factor, rather than the FFT size, is made variable.

Table 4. Mobile WiMAX channel and FFT profiles

The OFDMA version was also developed with an eye towards the use of multiple-input multiple-output (MIMO) functionality and antenna beamforming techniques for improved performance. The channel bandwidths for mobile WiMAX is similar to that for fixed WiMAX, with a range of 1.25 to 28 MHz. The modulation types are also the same, with a lower limit of BPSK and an upper limit of 64-QAM. Mobile WiMAX is designed for mobile users at radial speeds relative to the BS to about 120 km/hour (about 75 miles/hour). In contrast to fixed WiMAX, IEEE 802.16e-2005 has been designed to hand over user connections and maintain connections across different base stations and coverage areas.

In fixed WiMAX with OFDM, subscribers are handled one by one, with all carriers assigned to one and only one subscriber with the same modulation type and power value per time slot. In mobile WiMAX with OFDMA, a number of subscribers can be handled simultaneously. In order to do so, a number of physical carriers are combined into subchannels, and each subscriber is assigned a specific number of subchannels depending on the bandwidth required for that subscriber's services at that usage. Physical carriers are allocated to subchannels by means of permutation algorithms; these algorithms change over time and define different regions of a frame known as zones. In contrast to the 192 carriers in fixed WiMAX, mobile WiMAX with OFDMA allows a variable number of carriers in values of 128, 512, 1024, or 2048 carriers. By using a variable number of carriers, the network can optimally adapt the modulation format to the transmission requirements.

As in the fixed version, mobile WiMAX uses TDD technology, but can also support the FDD technology commonly used in 2G and 3G cellular networks. The FDD approach uses different frequency assignments for uplink and downlink in contrast to TDD, where the same frequency assignment is used for the uplink and downlink, separated by a guard time. Use of a single-frequency channel simplifies implementation of MIMO and beamforming techniques in WiMAX networks (see sidebar page 14, "Making The Most of MIMO").

In South Korea, mobile WiMAX is known as WiBro, short for wireless broadband. WiBro is based on the same IEEE 802.16e-2005 standard as mobile WiMAX, but designed to be slightly more robust in terms of the subscriber's speed relative to the BS. WiBro uses TDD only and a 8.75 MHz maximum channel bandwidth. WiBro, which uses the 2.3 GHz band, is interoperable with WiMAX equipment and will compete with cable, DSL, and WLANs in South Korea.

The Business of WiMAX

Although the marketplace adoption of a new wireless standard is never a certainty (the marketplace was slow at first to embrace the IEEE 802.11b/g WLAN standard), the many benefits of fixed and mobile WiMAX make the BWA technology quite appealing to a wide range of users. The markets for mobile data and voice are already strong, with rapid growth projected over the latter part of the decade for mobile data. Most of this growth in mobile data services will be fueled by broadband networks and equipment, providing the functionality of a wired broadband network but as part of a cellular-like network capable of full functionality in a mobile environment.

In terms of its commercial success, WiMAX can take advantage of large existing bases of portable device users. For example, WiMAX modules are expected to be embedded into many portable electronic devices, such as cellular telephones, Personal Digital Assistants (PDAs), and laptop computers. These lower-power modules will support low-latency applications like VoIP, video gaming, video conferencing and video streaming. For fixed WiMAX users, the superior performance made possible by OFDMA multiplexing and advanced IP-based architecture should compete favorably with cable-modem and DSL-based broadband access technologies.

WiMAX was never meant to be a replacement for existing cellular or other wireless services, but to work in conjunction with those existing and emerging networks. Although not meant to replace 2G or 3G technologies for voice communications, one of the largest early applications projected for WiMAX is voice-over-Internet-Protocol (VoIP) communications. In fact, as WiMAX infrastructure becomes available and operational, some cellular operators may even move voice traffic to the WiMAX infrastructure to boost the capacity of their existing networks. Mobile WiMAX technology also provides the wide bandwidth needed for a host of applications, including streaming audio services, videoconferencing, and gaming. In addition, many vertical applications, including fleet management, surveillance, and Public Safety, will likely take advantage of the cost-effective, wide bandwidth offered by WiMAX networks.

Among the organizations fostering the growth of WiMAX markets, The WiMAX Forum (www.wimaxforum.org) may be one of the largest and most influential. Currently counting more than 420 companies and organizations as members, including operators, component suppliers, and equipment companies and almost every major test and measurement instrument supplier in the industry, the not-for-profit organization was formed to certify and promote the compatibility and interoperability of broadband wireless products based on the IEEE 802.16 and ETSI HiperMAN standards. One of the goals of the WiMAX Forum is to accelerate the introduction of WiMAX equipment and products into the marketplace. When a product has earned the WiMAX Forum Certified™ status, it is guaranteed to be fully interoperable with other tested WiMAX products. The WiMAX Forum works closely with service providers and regulators to ensure that WiMAX Forum Certified systems meet customer and government requirements. Given the flexibility of the IEEE 802.16 standards, organizations such as the WiMAX Forum are critical to achieving true interoperability of WiMAX equipment.

Tools of the Trade

Fixed and mobile WiMAX are obviously advanced wireless communications standards with very complex requirements in terms of characterization. In fact, just performing basic RF transmitter measurements on WiMAX requires high-performance test equipment with advanced measurement functionality that was not commercially available until recently. Fortunately, with the availability of sophisticated signal generation and analysis equipment nominally developed for evaluating digitally modulated wireless networks, tools already exist for performing the complex measurements needed to characterize a WiMAX RF transmitter.

Basic RF communications measurements of any kind require an instrument to substitute for the transmitter, such as a signal generator, and an instrument to serve as a receiver, such as a spectrum analyzer or signal analyzer. To evaluate the operation of a WiMAX transmitter in a BS or handheld device, the analyzer must at least meet the frequency and channel (modulation-bandwidth) requirements of the WiMAX standard for that particular equipment. Current WiMAX frequency allocations extend to about 5.8 GHz with channel bandwidths ranging from 1.25 through 28.0 MHz depending on whether it is fixed or mobile WiMAX equipment and whether OFDM or OFDMA is being used. In addition, because of the number of modulation schemes used in WiMAX (BPSK, QPSK, 16-QAM, and 64-QAM), a signal analyzer must have flexible demodulation analysis capabilities.

Generating Test Signals

For evaluating WiMAX receivers and components, the known test signals from a signal generator take the place of signals from a WiMAX transmitter. In order to emulate signals for receiver evaluation, the generator must provide the frequency range, modulation types, and modulation bandwidth necessary to match the signal requirements of the WiMAX standard for that equipment under test. Because the WiMAX signal has a burst nature, with differences in amplitude level from the start (preamble) of the burst through the burst data, a signal generator for WiMAX receiver testing should also provide programmable power control to order to mimic the dynamic power characteristics of WiMAX signals.

The MG3700A Vector Signal Generator (Fig. 2) provides the raw performance needed to create test signals needed for WiMAX receiver testing. It offers a standard frequency range of 250 kHz to 3 GHz with optional coverage to 6 GHz. The signal generator features a built-in 120 MHz-bandwidth arbitrary waveform generator for creating digital modulation, external 150 MHz-bandwidth vector-modulation (I and Q) input ports, and generous memory for the arbitrary waveform generator to create the advanced digital modulation formats found in modern wireless communications systems, including both fixed and mobile WiMAX. The MG3700A offers outstanding amplitude accuracy, with typical linearity of ±0.2 dB and absolute level accuracy of ±0.5 dB. The instrument also has a built-in bit-error-rate (BER) tester (BERT) with standard capability to 20 Mb/s and optional capability to 120 Mb/s.

Figure 2. The MG3700A Vector Signal Generator aids WiMAX receiver testing by substituting for the WiMAX system's transmitter.

The MG3700A has two built-in memory locations for the arbitrary waveform generator to support independent waveform generation. When the memories are used for two different waveforms, the MG3700A can combine the two waveforms and generate a composite output waveform for testing a WiMAX device. Independent waveform generation is useful for evaluating co-channel or "blocker" interference as well as for controlled tests of receiver signal-to-noise ratio (SNR).

Of course, since standardized test signals have yet to be established for WiMAX, programmed WiMAX waveforms are not included with the MG3700A. However, the wide array of different WiMAX waveforms can be created by combining the MG3700A with the IQproducer waveform generation software from Anritsu. The software aids in creating custom digitally modulated waveforms (see the sidebar page 14, "IQproducer Directs Waveform Generation," page 14), including mobile WiMAX, WCDMA (including HSDPA and HSUPA), QAM/PSK, 1xEV-DO, QAM/PSK, and digital-video-broadcast (DVB) signals. In addition, the software can also be used to import files from other signal generation programs.

Analyzing Signals

Once WiMAX test signals are generated, they must be analyzed, and the Anritsu Signature MS2781B High-Performance Signal Analyzer (Fig. 3) provides the necessary measurement capabilities. Testing a BS unit or portable devices for mobile WiMAX essentially requires a signal analyzer that can emulate the operation of an IEEE 802.16e base station, since the analyzer must be able to detect and record the full range of frequencies and modulation formats used by a WiMAX system. The Anritsu Signature High Performance Signal Analyzer meets the bandwidth requirements, with a range of 100 Hz to 8 GHz and 1 Hz frequency resolution, achieved through a unique "high-side" downconversion scheme (Fig. 4). In the triple-downconversion approach, fundamental-frequency signals from 9.5 to 17.5 GHz are used in the first local oscillator (LO) to yield a first intermediate frequency of 9.5 GHz. The second and third LOs use fixed sources at 8.4 and 1.025 GHz to translate signals to a third IF of 75 MHz for digital processing. The high-side triple-downconversion approach captures input signals from 100 Hz to 8 GHz without band switching or preselector filtering (which can degrade amplitude accuracy and modulation quality).

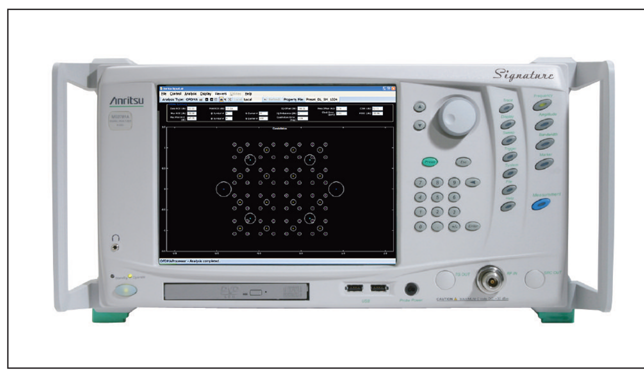

Figure 3. The Signature MS2781B High Performance Signal Analyzer provides WiMAX fixed and mobile transmitter tests by substituting for the receiver in a WiMAX system.

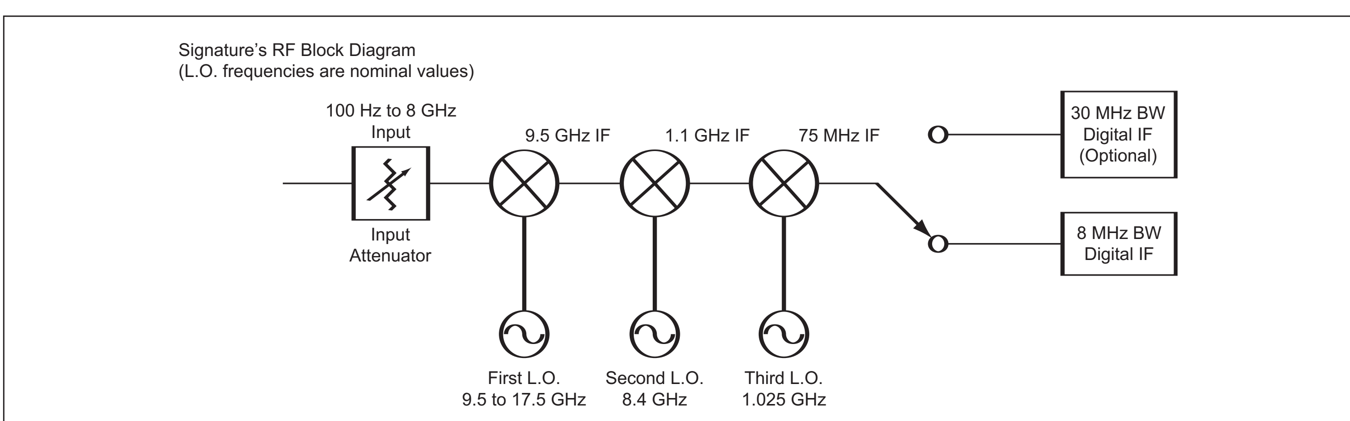

Figure 4. The high-side triple-downconversion scheme in Signature accounts for its relatively spurious-free, wide instantaneous bandwidth over its full 8-GHz frequency range.

The use of fundamental-frequency LOs helps achieve high signal sensitivity along with a wide dynamic range by the merit of also handling high-level input signals without distortion (the typical third-order intercept for signals above 100 MHz is +25 dBm while the displayed average noise level, or DANL, is better than –163 dBm for all signals). The Anritsu Signature analyzer is available with standard resolution bandwidths from 0.1 Hz to 8 MHz, and optional 30 MHz demodulation bandwidth (Option 22). By shutting off the analyzer's anti-aliasing filter, the digital demodulation bandwidth can be extended to 50 MHz for analysis of truly wideband modulated signals. Option 22 also includes the inputs for measuring baseband devices such as demodulators and DAC outputs.

Additional options for the Anritsu Signature analyzer include capability for WCDMA/HSDPA measurements (Option 30), which supports a number of modulation quality measurements on WCDMA and HSDPA base station (Node B) transmitters and their components, and fully integrated vector signal analysis (Option 38), which provides full QAM and PSK modulation analysis capability. This latter option allows operators to select symbol rate and modulation type, and set filter parameters in order to demodulate signals of interest. It supports such measurements as error vector magnitude (EVM), carrier leakage, and in-phase (I)/quadrature (Q) imbalance.

Two options for Anritsu Signature are of particular interest to those performing transmitter measurements on fixed and mobile WiMAX equipment. The first (Option 40) provides integrated compatibility with the MATLAB™ mathematical analysis software program from The MathWorks (www.mathworks.com). The second (Option 41) is the SignalLab application software and its suite of factory-programmed fixed and mobile WiMAX measurements. These WiMAX measurements include relative constellation error (RCE), carrier frequency offset, I/Q offset, and a variety of display screens for detailed analysis of results. The low residual RCE of the Anritsu Signature analyzer (typically better than 0.5%) makes it well suited for evaluating high-performance WiMAX amplifiers, for example. The SignalLab application works with the MG3700A to generate signals that can then be analyzed by Signature. It is launched from Signature's main graphical user interface (GUI).

Signature is capable of conformance testing according to IEEE 802.16 OFDMA mobile and OFDM fixed WiMAX equipment. The analyzer can capture signals for durations ranging from 200 ms to 1.28 s, depending upon the bandwidth, with signal bandwidths from 1.25 to 20 MHz supported. It handles TDD and FDD modes and features manual preamble detection for OFDMA signals and automatic preamble detection for OFDM signals.

Signature handles signals based on 256-point FFTs for OFDM and 128-, 512-, 1024-, and 2048-point FFTs for OFDMA. The instrument analyzes one zone at a time for both OFDM and OFDMA and performs automatic pilot tracking and equalizer training to simplify WiMAX OFDM and OFDMA signal measurements.

The analyzer features a variety of automatic RF and modulation measurements, including received signal strength indication (RSSI) power, burst carrier to interference and noise ratio (CINR) power, power versus time, spectral flatness, complementary cumulative distribution function (CCDF), and crest-factor (peak-to-average) power measurements. Modulation measurements include error vector magnitude (EVM) or relative constellation error (RCE) measurements, EVM versus carrier and versus symbol, IQ offset, IQ gain imbalance, quadrature error, carrier frequency error, and symbol clock error measurements.

Production Testing

For production environments looking to save the space of a separate analyzer and signal generator, the MS2690A (Fig. 5) Signal Analyzer is a unique measurement tool that is actually capable of functioning both as an analyzer and a generator. Developed for the demanding requirements of mobile WiMAX testing as well as next-generation wireless communications measurements, the MS2690A features an innovative fundamental-frequency downconversion scheme that eliminates the need for preselection filtering over its frequency range of 50 Hz to 6 GHz. The preselector is included in its higher-frequency counterpart, the 50 Hz to 13.5 GHz model MS2691A Signal Analyzer.

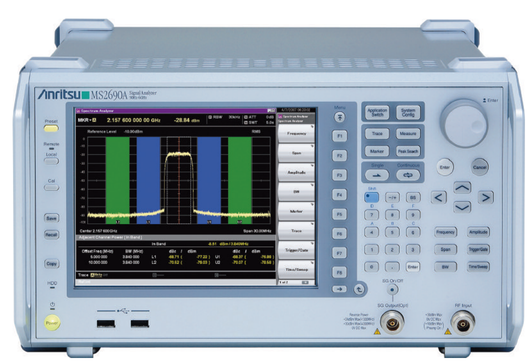

Figure 5. The MS2690A Signal Analyzer was developed specifically with mobile WiMAX testing in mind. It operates from 50 Hz to 6 GHz with analysis bandwidths to 31.5 MHz, and is essentially a spectrum analyzer, vector signal analyzer, FFT analyzer, and signal generator in one box.

Developed for high-speed testing, the instruments incorporate an advanced architecture with two built-in calibration oscillators, eliminating the need for external power meters and calibration sources. A phase calibration oscillator compensates for the frequency variations that are typical of intermediate-frequency (IF) filters used in frequency downconversion circuitry prior to a spectrum analyzer's digitizer and display sections. A level calibration oscillator spans the 50 Hz to 6 GHz range of the MS2690A and contributes to its outstanding amplitude accuracy of ±0.5 dB across that full span.

With a third-order intercept of +22 dBm, residual RCE of 0.6%, and displayed average noise level (DANL) of –155 dBm at 2 GHz, the MS2690A provides much of the measurement power of Signature for WiMAX OFDMA testing, with insightful displays of constellation information, spectrum versus subcarrier, and power versus time for uplink and downlink signals, as well as screens showing map information, spectral flatness, error vector versus symbol, error vector versus subcarrier, and I/Q data versus subcarrier for downlink signals. In fact, the MS2690A can read the allocation settings from a downlink map and automatically make measurements accordingly. The MS2690A handles TDD and 5 ms frame lengths for 5 MHz channels using 512 point FFTs and 7, 8.75, and 10 MHz signals using 1024-point FFTs.

In addition to functioning as mobile WiMAX spectrum analyzers, the MS2690A and MS2691A instruments can optionally operate as vector signal analyzers. They can make vector signal measurements to 6 GHz with analysis bandwidths ranging from 1 kHz to 31.25 MHz, with support for WiMAX modulated signals at bandwidths to 10 MHz. Adding the Mobile WiMAX Measurement Software helps to automate the uplink and downlink measurements listed earlier.

The MS2690A and MS2691A analyzers feature a high-performance digitizer with 16-b resolution. Sampling rates can be set automatically according to the choice of resolution bandwidth, or adjusted manually at rates from 2 kSamples/s to 50 MSamples/s. Inclusion of the digitizer opens up another possibility for the MS2690A or MS2691A: in addition to analyzing signals, the instruments can also generate them, when equipped with the MS2690A/MS2691A-020 Vector Signal Generator option. Captured waveform data can be used to regenerate signals allowing, for example, the use of captured mobile WiMAX signals as test signals for WiMAX receiver testing. The generator option supports signals with modulation bandwidths as wide as 120 MHz at carriers from 125 MHz to 6 GHz with excellent spectral purity.

Transmitter Measurements

What types of tests are needed for mobile WiMAX transmitter testing? Transmitter tests defined by the WiMAX standards include maximum output power, transmitter spectral flatness, transmitter relative constellation error (RCE) and error vector magnitude (EVM), transmitter power level control, transmit spectral mask (for unlicensed-band operation), adjacent-channel power ratio (ACPR), spurious levels, and harmonic levels. Licensing authorities generally establish spectral masks with specific requirements for their areas. Armed with a wideband signal analyzer such as the Anritsu Signature or the MS2690A/MS2691A analyzers, all of these WiMAX RF transmitter measurements can be made, including tests of frequency, power level, interference, and modulation quality. Since WiMAX systems are so dependent on accurate digital modulation and demodulation functions, many of the measurements that characterize a mobile WiMAX device's transmitter relate to modulation quality.

To avoid interference, transmitted channels must remain within their specified limits and at specified power levels; thus, two of the more basic WiMAX transmitter measurements have to do with characterizing the frequency and power of a WiMAX device's transmitted signal. Because WiMAX signals are transmitted in bursts, transmitter tests for frequency accuracy require a signal analyzer with enough instantaneous bandwidth to capture the full signal of interest. The channel bandwidths for the various WiMAX operating frequency ranges and standards are spelled out in IEEE 802.16-2004 and IEEE 802.16e-2005 (Table 5).

Measurements of frequency accuracy require that a WiMAX signal be demodulated prior to the measurement. Signal analyzers such as Signature and the MS2690A Signal Analyzer provide wide modulation bandwidths for this purpose, with analysis capabilities for 20 and 10 MHz WiMAX channels, respectively. The pertinent WiMAX specifications call for a WiMAX transmitter that is within 2 PPM of its set frequency, which is equal to 7 kHz for a 3.5 GHz WiMAX device. The WiMAX standards also refer to a "mesh-capable" device has having looser frequency requirements, with a specification of 20 PPM of the set frequency.

Parameter	802.16	802.16-2004	802.16e	WiBRO
Bandwidth range	1.25 to 28.0 MHz	1.25 to 28.0 MHz	1.25 to 28.0 MHz	8.75 MHz
Modulation type	BPSK QPSK 16-QAM 64-QAM	QPSK 16-QAM 64-QAM	QPSK 16-QAM 64-QAM	QPSK 16-QAM 64-QAM
FFT size	–	256	128, 256, 512, 1024, 2048	1024
Duplex type	TDD/FDD	TDD/FDD	TDD/FDD	TDD
Guard period	1/4, 18, 1/16, 1/32	1/4, 1/8, 1/16, 1/32	1/4, 1/8, 1/16, 1/32	1/8
MIMO	Yes	Yes	Yes	Yes

Table 5. WiMAX-related standards at a glance

In terms of power, again it is important to remember that WiMAX devices send signals in frames in which the amplitude varies from one end of the frame to the other. The power at the beginning of the frame, or the preamble, for example, is generally at least 3 dB higher than the power level of the data part of the frame. The WiMAX specifications require relative amplitude accuracy within ±0.5 dB for basic WiMAX power measurements, which matches the amplitude accuracy of the MS2690A/MS2691A Signal Analyzers and is well within the range of the Signature's specified relative amplitude accuracy of ±0.07 dB. It should be noted that many of the measurements detailed here for mobile WiMAX transmitters can also be applied to testing the transmitter's key component, the power amplifier (see the sidebar page 15, "Testing WiMAX Power Amplifiers").

In addition to the transmitted power of a signal burst, a WiMAX transmitter supports power level control over a relatively wide dynamic range. According to the IEEE 802.16e-2005 PHY requirements, for a subscriber station (SS) not supporting subchannelization, the WiMAX transmitter must support monotonic power level control of at least 30 dB with a minimum step size of ≤1 dB. For an SS supporting subchannelization, the transmitter supports a monotonic power level control of at least 50 dB. The relative accuracy of the power control mechanism is specified in the standard as ±1.5 dB for step sizes not exceeding 15 dB and ±3 dB for step sizes from 15 to 30 dB, and ±5 dB for step sizes greater than 30 dB. For a BS, the transmitter shall support a minimum monotonic power level control of 10 dB.

In a WiMAX burst signal, received-signal-strength indication (RSSI) is used, but only in the preamble part of the burst. Because of the complexity of the WiMAX burst signal, more than just a basic power meter must be used for accurate power measurements. In addition, because of the wide modulation bandwidth of WiMAX signals, it is not possible to evaluate their modulation quality with a conventional spectrum analyzer. Rather, accurate WiMAX transmitter measurements require a programmable signal analyzer such as Signature or the MS2690A and MS2691A analyzers armed with optional application software.

Although the various versions of IEEE 802.16 were meant as solutions for wireless MAN applications, which implies operating environments with large amounts of interference and multipath effects, no interference requirements are called out in the IEEE 802.16 PHY standard documentation. Interference control (and testing) is generally dictated by local regulatory requirements, although interference-testing requirements can often be handled by testing according to a spectral mask which defines acceptable in-band and out-of-band interference levels.

More advanced fixed and mobile WiMAX transmitter measurements are often presented as a function of time due to the burst nature of the WiMAX signals. Transmitter quality measurements include received time signals (power versus time of received signals), EVM/RCE, spectral flatness, EVM versus time, adjacent-channel power ratio (ACPR), adjacent-channel spectral flatness, power spectral density (PSD), and cumulative complementary distribution functions (CCDFs). A variety of tabular and graphic display formats can be used to evaluate WiMAX transmitter modulation performance, such as constellation diagrams, and performance plots as functions of both frequency and time.

Spectral flatness is a measure of the consistency in power level of the subcarriers making up the WiMAX OFDMA signal. Per WiMAX specifications, adjacent subcarriers are required to be within 0.1 dB in amplitude level. Some deviation is assumed in the overall levels of the carrier, with a window defined by the standard. The close-in or inner one-half subcarriers in a WiMAX burst signal should be within ±2 dB from the average power level of the burst signal, while the outer one-half of the subcarriers should be within +2 and –4 dB of the average power level of the burst signal. Measurements of spectral flatness can be performed by triggered measurements, using the start of the preamble as a trigger point. In a display of WiMAX OFDMA spectral flatness measured with the Anritsu Signature analyzer, spectral flatness is plotted as a function of the carrier number (Fig. 6).

The top of the display screen provides an OFDMA signal summary with information about signal modulation quality in terms of the average and peak relative constellation error (RCE). The RCE is essentially the error vector of the received modulation constellation expressed in dB, while error vector magnitude (EVM), expressed in percent, also shows modulation quality.

Both EVM and RCE are practical measures of signal modulation quality and serve as effective means of determining the impact of a component, such as an amplifier, on signal modulation accuracy and quality. EVM essentially compares a received signal's I and Q modulation characteristics to those of a reference or ideal signal as defined by a particular standard, such as IEEE 802.16e-2005.

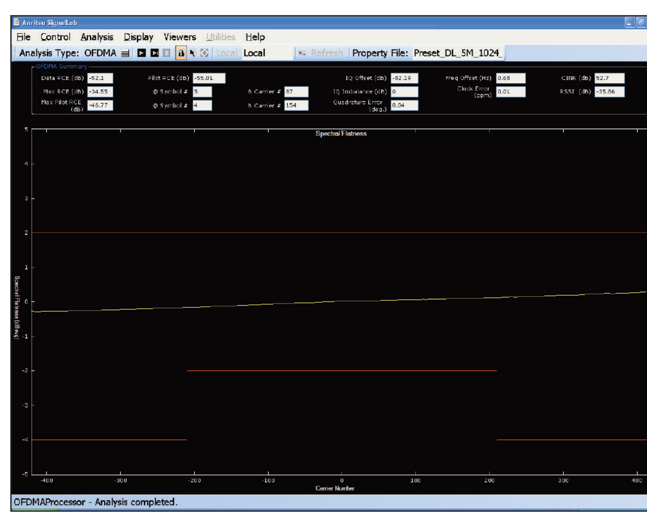

Figure 6. In a spectral flatness measurement, the power of the spectral lines is compared to a reference, such as the total transmitted power in a burst, to determine transmitter compliance to the WiMAX standard.

RCE (in dB) is similar to EVM (in %) in that it is an overall measure of modulation quality. Depending upon the modulation format and the error coding method used, acceptable values of transmitter RCE range from -13 to -31 dB (for fixed WiMAX). To understand better its effects on system-level performance, RCE is often presented as a relative value (average or maximum RCE) or versus subcarrier and versus symbol. For example, displays of RCE as a function of time are effective for troubleshooting, showing how EVM or RCE varies throughout a DL or UL subframe. This capability of showing RCE as a function of time is useful for evaluating such problems as power-supply sagging, LO settling or drift, signal clipping, or automatic-gain-control (AGC) malfunctions. For WiMAX testing, Signature's display screens can be color coded to differentiate the various modulation formats that make up a WiMAX burst signal. A display of RCE versus time is also useful for identifying frequency drift and instances of low-rate modulation.

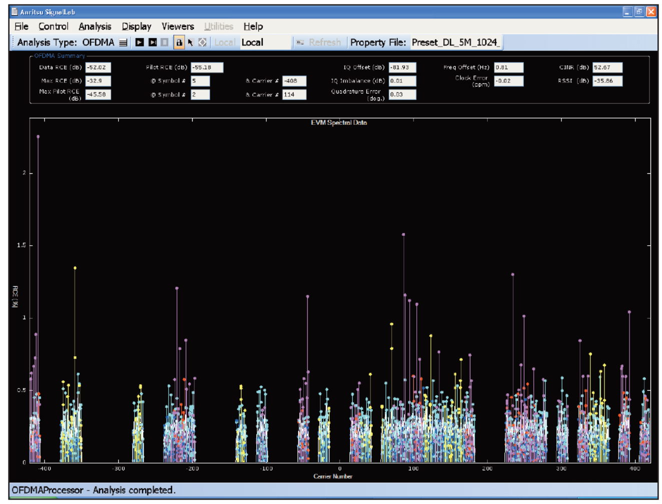

Figure 7. Error vector magnitude (EVM) is a powerful tool for evaluating the modulation quality of a WiMAX transmitter. Here is shown as an EVM spectrum.

With the help of Anritsu's SignalLab application software, Signature allows several different views of measured EVM performance, including an EVM spectrum screen (Fig. 7) and a view of EVM versus time (Fig. 8). In the EVM spectrum screen, wireless OFDMA signal components are shown by carrier number and color-coded by modulation type. As with the spectral flatness display screen, information at the top of the screen provides other insights into signal and modulation quality, with measurements of frequency offset, clock jitter, IQ offset, RSSI, and other important signal quality parameters. EVM versus time data can also be shown as EVM versus symbol index, providing a simple comparison of different symbols making up the OFDMA mobile WiMAX transmission signals.

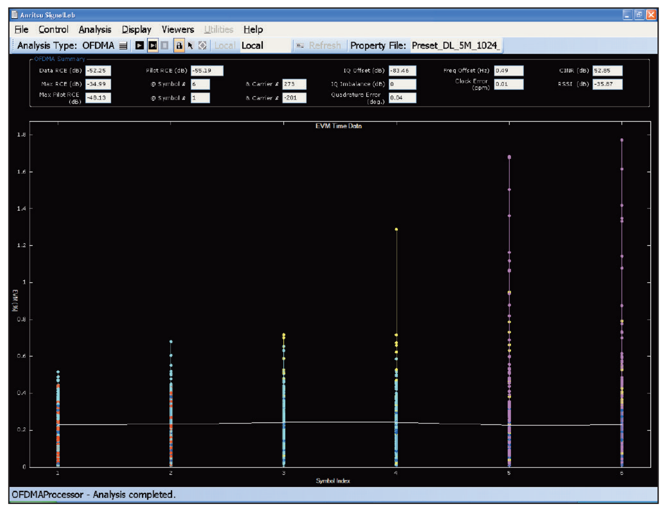

Figure 8. For evaluating trends in EVM performance, this plot of EVM as a function of time can help isolate events of interest.

The complementary cumulative distribution function (CCDF) of the transmit output power is another important measurement of WiMAX transmitter quality. Because OFDM signals tend to exhibit high peak-to-average ratios, due to the AM of the subcarriers, CCDF measurements can help analyze WiMAX transmitter or power amplifier performance.

While EVM is a direct measure of modulation accuracy and transmitter performance, with all transmitter impairments contained in a single number, CCDF measurements indirectly show the probability of clipping. The peak EVM of a transmitter may be extremely high, but only occur once in a frame. CCDF measurements show the probability that the signal power is greater than a given peak-to-average power ratio and provide valuable insights into nonlinearities plaguing transmitter performance.

Signature and the SignalLab software were used to provide an example of a CCDF measurement on OFDMA mobile WiMAX signals. The display screen (Fig. 9) shows the trends for different received signals plotted as dB above an average level, allowing engineers to compare quickly the performance of a DUT under different conditions.

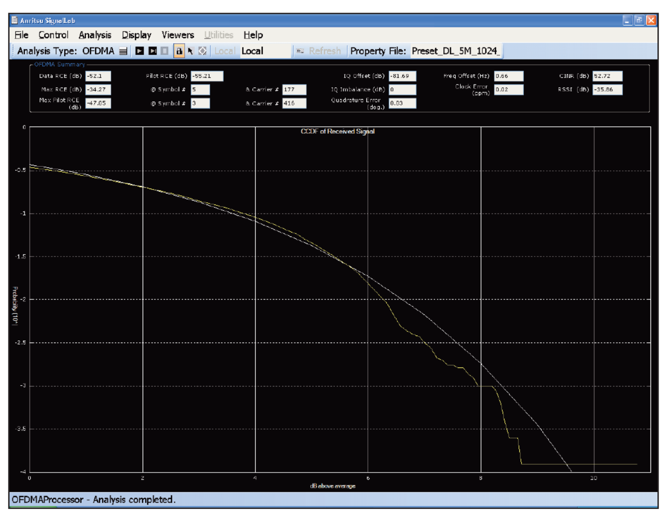

Figure 9. The CCDF plot is a versatile method of evaluating WiMAX transmitter and power amplifier nonlinear behavior.

The plot of PSD is straightforward, displaying the power spectrum of a received signal as a function of frequency (Fig. 10), showing the amount of power per unit density of frequency. In this case, Signature was used as a mobile WiMAX receiver to capture and display the WiMAX burst signal across a 5 MHz channel. The power can be examined across the 5 MHz OFDMA mobile WiMAX channel for unexpected variations in level at different points in the operating channel, although the displayed signal shows well-behaved characteristics meeting the level requirements of IEEE 802.16e for mobile WiMAX transmitted signals.

In contrast, a plot showing the received time of an OFDMA mobile WiMAX signal (Fig. 11) allows engineers to examine information like that found in the PSD plot, but in the time domain. Using both the frequency-domain and time-domain characteristics of signals from a WiMAX transmitter allows investigators to isolate performance problems by comparing information from the two domains.

In addition to these individual plots of a mobile WiMAX transmitter, it might be useful, for creating reports, for example, to group performance plots together into a single view or for better understanding the complex interactions among the performance parameters (Fig. 12). By combining several performance plots together, record keeping on the performance of a design becomes greatly simplified, and allows for quick comparison of key performance parameters over time (for example, to compare an older design with new modifications).

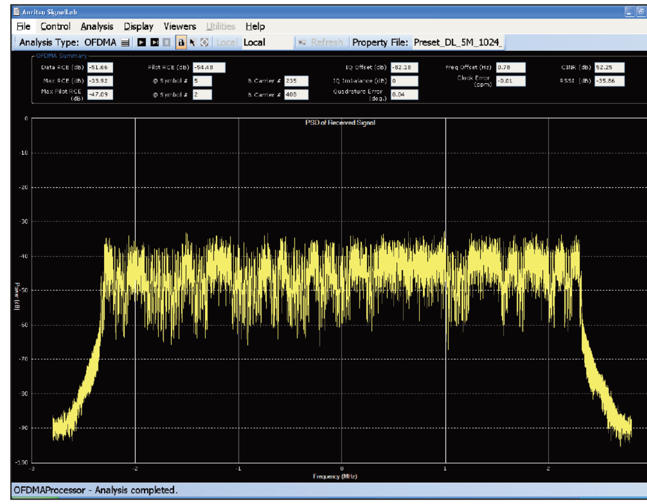

Figure 10. The power spectral density (PSD) plot shows the power spectrum of a received WiMAX signal as a function of frequency.

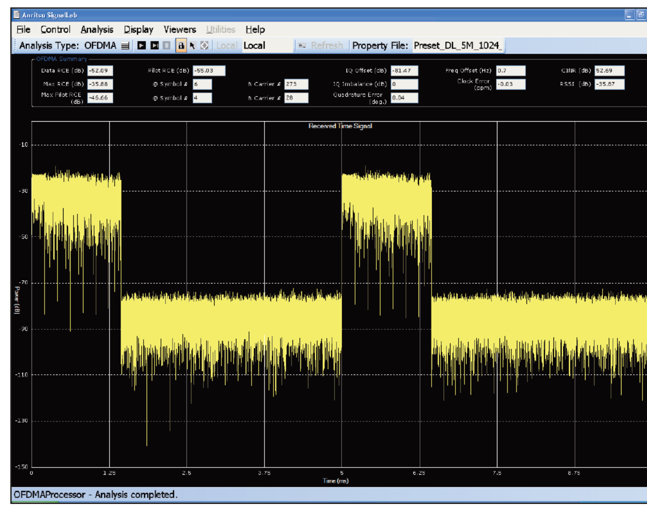

Figure 11. This received time signal shows the signal power in a received mobile WiMAX OFDMA burst, but as a function of time.

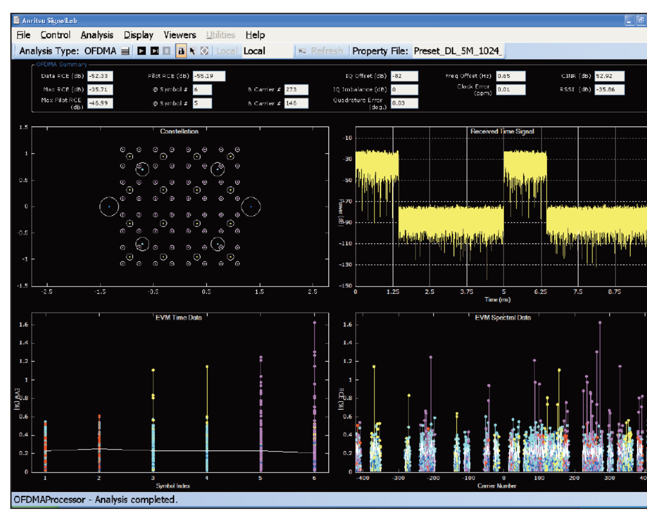

Figure 12. Composite screens such as this can be created with the SignalLab measurement application to simplify documentation and comparison of different WiMAX performance parameters.

Evaluating WiMAX Receivers

For WiMAX receiver testing, a methodology similar to transmitter testing is used, but a high-performance signal generator such as the MG3700A is used in place of a WiMAX system's normal transmitter. In addition, a solution such as the MS2690A or MS2691A Signal Analyzer with the MS2690A/MS2691A-020 Vector Signal Generator option has the capability of recording actual mobile WiMAX UL and DL signals and regenerating those signals for receiver testing.

For test purposes, the signal generator must cover a frequency range that encompasses all the WiMAX bands of interest, along with an output-power range that enables testing a WiMAX device's low-level sensitivity. Typical WiMAX receiver measurements including testing for sensitivity, maximum input level, adjacent-channel and alternate-channel rejection, reference timing accuracy, and SS uplink transmit time tracking accuracy, which is similar to reference timing accuracy in that the SS is instructed to change timing.

For WiMAX receiver sensitivity testing, for example, the receiver is required to maintain a bit-error rate (BER) of 10–6 at a given sensitivity level, which ranges from –110 to –50 dBm, depending upon bandwidth, coding, receiver quality, and modulation format. The test is generally performed with a calibrated RF/microwave signal generator and a BER tester (BERT). The signal parameters are set according to the requirements of the WiMAX standard, the signal is applied to the device under test (DUT), and the BER is measured. For convenience, the Anritsu MG3700A Vector Signal Generator has a built-in BERT that enables WiMAX receiver testing with a single instrument, since the generator is capable of producing WiMAX-compliant test signals. The MS2690A or MS2691A Signal Analyzer with the MS2690A/MS2691A-020 Vector Signal Generator option also supports BER testing for standard and user-defined measurement patterns to 10 Mb/s.

To evaluate adjacent-channel and alternate-channel (or non-adjacent-channel) rejection, often referred to as receiver "blocking" measurements, the test signal source is again programmed for WiMAX compliant signals in terms of modulation and other parameters, and the amplitude of the test signal is adjusted to 3 dB above the sensitivity level of the DUT according to the WiMAX standards for the frequency band of interest. An interferer signal with OFDMA is tuned as the adjacent or non-adjacent channel, although it is not synchronized to the first test signal. The BER specification of 10–6 must be met by the receiver for interference levels from 4 to 30 dB above the level of the test signal. The signal classes defined for this test include signals with 16-QAM with 3/4 coding and signals with 64-QAM with 2/3 coding, although the other signal classes (BPSK and QPSK) are not defined in the WiMAX standards.

For determining the maximum input level of a mobile WiMAX receiver, the test generator is again set for the proper WiMAX signal parameters in terms of modulation, frequency, and level. The receiver of the DUT must work properly with input levels as high as –30 dBm (at a BER specification of 10–6), and must withstand a signal level as high as 0 dBm without damage.

For WiMAX reference timing measurements, the IEEE 802.16e-2005 standard documentation states that "The start of the preamble symbol shall be time aligned with the 1-pps timing pulse" (Section 8.4.12.4). In a WiMAX system, the timing pulse is used for network synchronization and is optional. The standard suggests the use of a 1-pps signal from a Global Positioning System (GPS) receiver, although this is also not required for a WiMAX system or test. Tolerances or test methods are not included in the standard for WiMAX reference timing measurements, although the measurements can be performed with a high-performance signal analyzer such as Signature or with a microwave spectrum analyzer, if a 1-pps signal is available for use as a trigger and the analyzer is set up for a zero-span display. A mobile unit for test such as a WiMAX SS must be synchronized as well with a trigger output from a high-performance signal generator such as the Anritsu MG3700A or some other 1-pps source.

Sizing Up The Results

Even the best measurement capability is meaningless without the ability to interpret the test results. Because of the complexity of IEEE 802.16e-2005 OFDMA signals, and the need for accurate digital demodulation in order to perform many of the mobile WiMAX transmitter measurements, it is easy to miss a problem or misinterpret test results. Incorrectly defined data bursts, for example, can cause demodulation during the test process to fail. As a result, attention to detail and sound measurement practices should always be exercised for maximum accuracy in WiMAX measurements.

Some WiMAX measurements, including tests of power and coarse frequency, can be performed with a conventional spectrum analyzer with the proper frequency span and resolution-bandwidth filters. More accurate measurements, however, generally require the ability to time-gate a measurement by means of a trigger, as in an oscilloscope. Modern wideband signal analyzers, such as the Anritsu Signature, provide the capability of triggering on burst waveforms and displaying results in statistical form or useful graphical formats, such as spectrograms and CCDF displays.

Measuring time-gated signals demands proper coordination of time-domain and frequency-domain measurements. For example, by verifying time-domain parameters through time-domain measurements, the information can be then used to create accurate triggers and gating windows for frequency-domain measurements of time-sequenced signals.

To analyze signal frames or bursts, specific portions of a signal must be measured using triggers and positive or negative trigger delays, much in the manner of setting a digital storage oscilloscope. Either an external frame trigger can be used for these measurements, or a trigger can be formed by sampling the input signal under test. Because WiMAX OFDMA signals are characterized by wide amplitude variations, those changes in signal level can cause false triggers when trying to measure a WiMAX burst signal. For this reason, trigger holdoff is a parameter that must be understood and properly applied to avoid false triggering on both fixed and mobile WiMAX signals. In addition, for signals comprised of different bursts, such as UL and DL bursts, a combination of trigger holdoff and IF triggering helps to select a practical trigger point for an RF burst signal. The latest software version for the Signature High Performance Signal Analyzer supports dual-level triggering, which can greatly assist in the analysis of both fixed and mobile WiMAX signals.

Both fixed WiMAX (IEEE 802.16-2004) and mobile WiMAX (IEEE 802.16e-2005) are sophisticated communications formats. Both use advanced modulation and timing techniques to minimize the effects of multipath in large metropolitan areas, breaking transmissions into signal bursts that must be evaluated to ascertain the “health” of a WiMAX system and its components. The Anritsu Signatures unique dual-level triggering eases capturing bursted signals with modulation, as found in WiMAX” (See figure 13).

Fortunately, high-performance measurement tools such as the Signature High Performance Signal Analyzer, the MS2690A/MS2691A Signal Analyzers, and the MG3700A Vector Signal Generator from Anritsu Company provide the performance levels and built-in measurement capabilities to complete the complex measurements needed to evaluate mobile and fixed WiMAX transmitters and receivers worldwide.

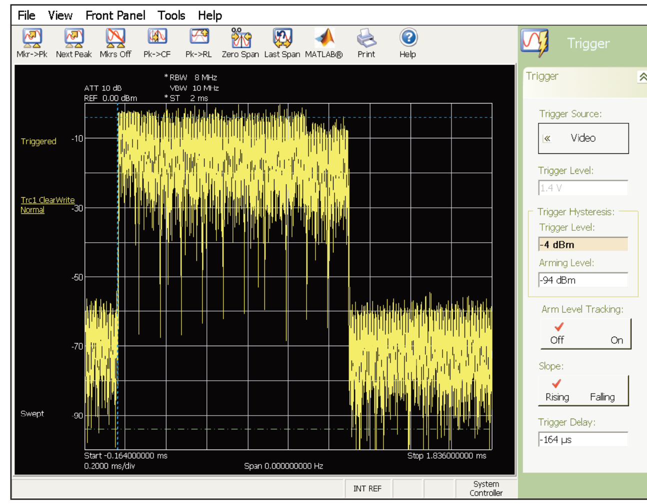

Figure 13. The Anritsu Signatures unique dual-level triggering eases capturing bursted signals with modulation, as found in WiMAX

Glossary of Terms

AAS	Adaptive Antenna System
BS	Base Station
CCDF	Cumulative Complementary Distribution Function
DL	Downlink (from the BS to the SS)
FCH	Frame Control Header (the header within a WiMAX frame)
FFT	Fast Fourier Transform (for conversion between time and frequency domains)
FUSC	Full Usage of Subchannels
ICI	Inter-Carrier Interference
ISI	Inter-Symbol Interference
MAC	Media Access Control layer of a wireless communications system
MAN	Metropolitan Area Network
MIMO	Multiple Input Multiple Output (system approach for improved performance using multiple transmit and receive antennas)
MS	Mobile Station
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PHY	Physical layer of a wireless communications system
PUSC	Partial Usage of Subchannels
RCE	Relative Constellation Error
RCT	Radio Conformance Test
RTG	Receive Transmission Gap (gap between UL and subsequent DL burst)
SC	Single Carrier
Slot	Minimum possible data allocation unit for OFDMA PHY
SS	Subscriber Station (often a portable unit in a mobile WiMAX system)
TTG	Transmit Transition Gap (gap between the DL and subsequent UL burst)
WiMAX	Worldwide Interoperability for Microwave Access
3GPP	Third-General Partnership Program

SIDEBARS FOR WiMAX APPLICATION NOTE

Making the Most of MIMO

Multiple Input Multiple Output (MIMO) and antenna diversity techniques are options to the IEEE 802.16e-2005 mobile WiMAX standard meant to help combat the effects of multipath distortion in wireless metropolitan area network (MAN) environments. MIMO was established in IEEE 802.11n, 802.16-2004 and 802.16e as well as in 3GPP to minimize the effects of signal fading and multipath distortion on wireless system performance. The MMO function can also be used to increase capacity without increasing bandwidth.

MIMO systems create multiple signal links on the same frequency. The concept of diversity is simple: if one signal path is corrupted, another can be used to "deliver the data." One of the challenges in a MIMO system, especially one based on small, portable wireless devices, is the proper separation and equalization of the signal paths. In a MIMO system, the number of antennas can be increased to boost capacity, increase system robustness, or a combination of the two. Antennas can be added at either the transmit side or the receive side, or both. For example, a 2 x 1 MIMO system has two input antennas (receiver side) and one output antenna (transmit side).

Transmission of multiple data streams over more than one antenna is called spatial multiplexing. Spatial multiplexing provides a near-linear gain in capacity in relation to the number of transmit/receive antennas. Spatial multiplexing can provide higher capacity, but no better signal quality. Instead of improving signal quality, spatial multiplexing decreases it. Spatial diversity can improve signal quality and achieve a higher SNR at the receiver. The larger the network environment, the higher the signal strength must be.

Spatial diversity depends upon structured redundancy. The redundancy can be transmitted at any time, from any antenna, at any frequency. The two kinds of spatial diversity are transmit diversity and receive diversity. The former uses multiple transmit antennas to send signals to a single receive antenna; the latter uses a single transmit antenna to send signals to multiple receive antennas.

For effective MIMO implementation, antenna arrays are often used with beam forming techniques to create and control the composite radiation pattern. Smart antennas fall into two groups: phased-array and adaptive-array systems. The first can only switch from a finite number of patterns while the second can create an infinite number of patterns that can be selected according to the dynamic needs of the network. An adaptive array is particularly useful for the dynamic adjustments needed with a mobile WiMAX subscriber moving in reference to the base station.

Teamed with OFDM and OFDMA modulation formats, MIMO can provide tremendous resistance to multipath and propagation fading effects. MIMO is used in fixed WiMAX 802.16-2004 (with OFDM/OFDMA) and mobile WiMAX 802.16e-2005 (with OFDMA) as well as in IEEE 802.11n WLAN systems and 3GPP Release 7 and 3GPP Release 8 (LTE) cellular networks. Of course, MIMO adds yet another dynamic parameter to mobile WiMAX systems, adding to the challenges of developing effective test procedures for those systems and their components.

IQproducer Directs Waveform Generation

The IQproducer software is provided as a standard feature with the MG3700A. It is a powerful application software package designed to run on Windows 2000 and XP operating systems on a personal computer (PC). The software can be used to create advanced waveform files that can then be transferred to the Anritsu MG3700A Vector Signal Generator or the MS2690A/91A analyzers with vector signal generator option for testing. It requires a Pentium III or higher microprocessor running at 1 GHz or faster and at least 10 GB of hard disk memory.

IQproducer provides functions for setting parameters in custom-programmed waveforms, simulating the function and appearance of a created waveform, generating files, and transferring data. The software can work with ASCII format files to create waveform patterns for the MG3700A Vector Signal Generator or the MS2690A/91A analyzers with vector signal generator option. It can also combine waveforms, such as the desired signal and a noise signal, into a composite signal-with-noise signal for evaluating receivers in WiMAX equipment.

The IQproducer software supports a wide range of communications standards, with waveform parameters included in the program. This software performs a parameter setup of waveform data and can generate an arbitrary waveform pattern file that is downloaded to MG3700A using a local-area-network (LAN) connection or a Compact Flash (CF) memory card.

The model MX370105A Mobile WiMAX IQproducer application software for the MG3700A has been developed to generate the waveform patterns recommended by the IEEE 802.16e-2005 WiMAX standard. Using this software, even complex OFDMA waveforms can be generated quickly and accurately. The software supports Mobile Certification Wave2 and MIMO waveform patterns for evaluating the receiver performance of mobile WiMAX equipment.

Testing WiMAX Power Amplifiers

Power amplifiers for WiMAX systems must face rigorous testing similar to that of WiMAX transmitters, with additional parameters such as peak-to-average power (crest factor) included in the mix. Power amplifier measurements include testing of output burst power, EVM/RCE, ACPR, spectral flatness, and adjacent-channel spectral flatness. Amplifier testing requires a high-quality signal source, such as the MG3700A Vector Signal Generator, and a wideband signal analyzer, such as the Anritsu Signature High Performance Signal Analyzer.

Because WiMAX signals are characterized by fast-changing amplitude behavior, they are not ideal signals for any amplifier. With high peak-to-average power ratios (crest factors) these WiMAX signals can easily test the linearity performance of a power amplifier. Designing an amplifier for WiMAX is very much a tradeoff between providing the highest possible linearity but also minimizing power consumption (and optimizing efficiency). Like many engineering tradeoffs, the two parameters are in conflict. In order to save power, some degree of amplifier compression must be tolerated. The key to design is finding an optimum operating point that meets WiMAX transmitter requirements with relatively high efficiency.

Evaluating WiMAX power amplifier performance requires most of the same tests used for WiMAX transmitter testing. Because of the time-domain nature of WiMAX signals, and the dynamic amplitude behavior of the burst signals, conventional power meters lack the response time to measure amplifier power levels accurately when operated with WiMAX signals. In addition, measurements must be properly gated in order to measure actual power levels and not gaps between bursts.

Comparing output burst power versus input burst power is a check of an amplifier's linearity, especially under WiMAX signal conditions. Under linear operation, output signals increase linearly with applied input signals. Once the input signal level exceeds the area of linear operation, output signals begin to compress and the relationship of input increase to output increase is no longer on a dB/dB basis.

As noted for transmitter modulation-quality measurements, EVM is a key test for determining both transmitter and amplifier performance. It can be used to ensure that a WiMAX receiver's SNR does not degrade due to the transmitter's or amplifier's SNR. An amplifier driven into nonlinear operation will distort an input signal, and EVM or RCE measurements can reveal this distortion. EVM measurements make it possible to check amplifier quality with reference to the EVM results when different modulation schemes are used. ACPR, which is the ratio of the amount of power measured in the adjacent channel to the amount of power in the main channel, is useful for characterizing whether an amplifier's distortion results in interference with neighboring WiMAX channels.

Another test that is useful for evaluating amplifier nonlinearities is CCDF. Some compression is acceptable in a WiMAX transmit amplifier. Too much compression can degrade transmit modulation quality. Analyzing amplifier compression requires more than a simple power measurement. A measurement of CCDF output power can show the degree of compression in an amplifier. It can also be correlated with measured EVM results to gauge the effects of that compression on modulation quality. When an amplifier exhibits nonlinear (compressed) behavior, pulsed or burst signals are clipped, with a reduction in the peak-to-average power ratio performance. On a CCDF plot, the curve will shift to the left due to the effects of the compression, providing amplifier designers with a "flag" for nonlinear amplifier behavior.

Anritsu Corporation
5-1-1 Onna, Atsugi-shi, Kanagawa, 243-8555 Japan
Phone: +81-46-223-1111
Fax: +81-46-296-1264

• U.S.A.
Anritsu Company
1155 East Collins Boulevard, Suite 100,
Richardson, Texas 75081
Toll Free: 1-800-ANRITSU (267-4878)
Phone: +1-972-644-1777
Fax: +1-972-671-1877

• Canada
Anritsu Electronics Ltd.
700 Silver Seven Road, Suite 120, Kanata,
Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

• Brazil
Anritsu Electrônica Ltda.
Praca Amadeu Amaral, 27-1 andar
01327-010 - Paraiso, São Paulo, Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3886940

• U.K.
Anritsu EMEA Ltd.
200 Capability Green, Luton, Bedfordshire LU1 3LU, U.K.
Phone: +44-1582-433280
Fax: +44-1582-731303

• France
Anritsu S.A.
16/18 Avenue du Québec-SILIC 720
91961 COURTABOEUF CEDEX, France
Phone: +33-1-60-92-15-50
Fax: +33-1-64-46-10-65

• Germany
Anritsu GmbH
Nemetschek Haus, Konrad-Zuse-Platz 1
81829 München, Germany
Phone: +49 (0) 89 442308-0
Fax: +49 (0) 89 442308-55

• Italy
Anritsu S.p.A.
Via Elio Vittorini, 129, 00144 Roma, Italy
Phone: +39-06-509-9711
Fax: +39-06-502-2425

• Sweden
Anritsu AB
Borgafjordsgatan 13, 164 40 Kista, Sweden
Phone: +46-8-534-707-00
Fax: +46-8-534-707-30

• Finland
Anritsu AB
Teknobulevardi 3-5, FI-01530 Vantaa, Finland
Phone: +358-20-741-8100
Fax: +358-20-741-8111

• Denmark
Anritsu A/S
Kirkebjerg Allé 90 DK-2605 Brondby, Denmark
Phone: +45-72112200
Fax: +45-72112210

• Spain
Anritsu EMEA Ltd.
Oficina de Representación en España
Edificio Veganova
Avda de la Vega, nº 1 (edf 8, pl1, of 8)
28108 ALCOBENDAS - Madrid, Spain
Phone: +34-914905761
Fax: +34-914905762

• United Arab Emirates
Anritsu EMEA Ltd.
Dubai Liaison Office
P O Box 500413 - Dubai Internet City
Al Thuraya Building, Tower 1, Suite 701, 7th Floor
Dubai, United Arab Emirates
Phone: +971-4-3670352
Fax: +971-4-3688460

• Singapore
Anritsu Pte. Ltd.
60 Alexandra Terrace, #02-08, The Comtech (Lobby A)
Singapore 118502
Phone: +65-6282-2400
Fax: +65-6282-2533

• India
Anritsu Pte. Ltd.
India Liaison Office
Unit No.S-3, Second Floor, Esteem Red Cross Bhavan,
No.26, Race Course Road, Bangalore 560 001 India
Phone: +91-80-32944707
Fax: +91-80-22356648

• P. R. China (Hong Kong)
Anritsu Company Ltd.
Units 4 & 5, 28th Floor, Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P.R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

• P. R. China (Beijing)
Anritsu Company Ltd.
Beijing Representative Office
Room 1515, Beijing Fortune Building,
No. 5 , Dong-San-Huan Bei Road,
Chao-Yang District, Beijing 100004, P.R. China
Phone: +86-10-6590-9230
Fax: +82-10-6590-9235

• Korea
Anritsu Corporation, Ltd.
8F Hyunjuk Bldg. 832-41, Yeoksam-Dong,
Kangnam-ku, Seoul, 135-080, Korea
Phone: +82-2-553-6603
Fax: +82-2-553-6604

• Australia
Anritsu Pty Ltd.
Unit 21/270 Ferntree Gully Road, Notting Hill
Victoria, 3168, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

• Taiwan
Anritsu Company Inc.
7F, No. 316, Sec. 1, Neihu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

Application Note No. 11410-00420, Rev. A Printed in United States 2007-9