WiMAX – a brief introduction

The WiMAX standard is not restricted to defining a single concrete implementation of the transmission method, but rather describes many different solutions. The WiMAX IEEE 802.16 proposal adopted in 2001 deals with line of sight (LOS) transmissions in the frequency range 10 GHz to 66 GHz. The RF carrier is directly modulated using digital phase shift keying (QPSK, 16QAM or 64QAM). This yields transmission rates of up to 134 Mbit/s at a bandwidth of 28 MHz. However, the Los requirement with the outside antennas that are needed makes this implementation somewhat inflexible.

The ratified version IEEE 802.16-2004 adopted in October 2004 defines distinctly more versatile applications that provide end users with attractive broadband access options. Radio transmission is feasible without direct line of sight (non line of sight, NLOS) in the specified frequency range of 2 GHz to 11 GHz. Like the 802.11a / g (WLAN) standard, the IEEE 802.16-2004 version specifies OFDM as the transmission method for NLOS communications.

Unlike the carrier signal in single-carrier transmission, an OFDM signal is made up of many orthogonal carriers, each of them modulated separately. A large number of symbols is transmitted in parallel, which results in a symbol duration many times that encountered in single-carrier transmission, the transmission rate being the same in either case. This has a very beneficial effect in multipath propagation, as the extended symbol duration considerably reduces interference caused by consecutive symbols overlapping each other. Moreover, the detrimental effect of multipath propagation is practically eliminated for another reason: a guard interval is added to each symbol. In addition, the parallel transmission of multiple symbols makes it possible to retrieve the contents of impaired carriers by means of error correction. All these characteristics combine to yield stable connections with very low bit error ratios. Modulation is adapted to match transmission conditions; BPSK, QPSK, 16QAM and 64QAM are used as modulation modes. Thus, transmission rates up to 75 Mbit/s can be attained. In contrast to its “little brother”, WLAN, the 2004 WiMAX version does not provide for a constant bandwidth; rather the bandwidth may vary between 1.25 MHz and 28 MHz.

The IEEE 802.16-2004 standard differentiates between the OFDM and the OFDMA mode. In the conventional OFDM mode, 200 carriers are available for data transmission. Both TDD and FDD transmission are used. With the OFDMA method, multiple subscribers can be served simultaneously. This is achieved by assigning each subscriber a defined group of carriers (which is referred to as subchannelization); this carrier group...
Test methods

High-end Signal Analyzer R&S® FSQ.

conveys the information intended for a specific subscriber. The OFDMA mode employs a significantly higher number of carriers, i.e. 1682 to 1729.

A forthcoming expansion of WiMAX is the IEEE 802.16e standard, which enables mobile applications and even roaming. Ratification of this standard is expected in late 2005. The standard specifies transmission rates of up to 15 Mbit/s in a frequency range of up to 6 GHz and employs a variable number of carriers.

WiMAX calls for high-end measurement technology

To develop and produce complete WiMAX applications or WiMAX components, it is necessary to analyze the corresponding high-frequency characteristics accurately and in detail. Analyzing the modulation quality of a WiMAX OFDM signal is not possible using conventional spectrum analyzers. This task requires a high-end signal analyzer such as the R&S®FSQ, which is capable of demodulating the broadband WiMAX signals (demodulation bandwidth 28 MHz, or 120 MHz with option R&S®FSQ-B72). To measure transmit signals or test receivers with the R&S®FSQ, WiMAX signals of excellent modulation quality are needed. You can generate such signals very conveniently by means of the Signal Generator R&S®SMU 200A and option R&S®SMU-K49. This option is also available for the Signal Generators R&S®SMJ 100A and R&S®SMATE 200A.

Generating WiMAX signals with the R&S® SMU 200A

The Signal Generator R&S®SMU 200A produces test signals for OFDM receiver tests in conformance with IEEE 802.16-2004 (Fig 1), requiring only minimum operating effort. A single-path generator is ideal for testing receiver sensitivity or determining the maximum input level. An R&S®SMU 200A with two paths can in addition provide an OFDM-modulated interference signal — an optimal condition for measuring adjacent-channel rejection with a single instrument. The AWGN module (option R&S®SMU-K62) superimposes defined channel noise as required for high-accuracy sensitivity measurements. The R&S®SMU-B14 fading simulator option enables tests under fading conditions.

In addition to choosing predefined test signals, you can configure signal scenarios to create any possible situation. Up to eight bursts with user-definable power and payload can be set both in the downlink and the uplink (Fig 2). The payload of the bursts is fully channel-coded during modulation. Moreover, you can define a MAC header and an optional CRC. In the uplink, the time position of each burst in a frame can be varied as desired by introducing gaps, for example to simulate mobile stations operating at various distances. The R&S®SMU 200A displays the power, duration and position of each burst in a clear-cut table.

In automatic test systems, it is vital that your test signals can be generated by remote control. All WiMAX signal parameters offered by the R&S®SMU 200A can be set by means of SCPI commands, i.e. the generator is fully remote-controllable via the IEC/IEEE bus or VXI 11.

With the functions described, the R&S®SMU 200A provides the complete range of receiver tests, including those currently defined by the WiMAX forum as part of the IEEE 802.16-2004 specification (Radio Conformance Test, RCT). The R&S®SMU 200A is thus an ideal choice in development, design, verification and production.

Analyzing WiMAX signals with the R&S® FSQ

The high-end Signal Analyzer R&S® FSQ from Rohde & Schwarz records signals with a bandwidth of up to 28 MHz (120 MHz with option R&S®FSQ-B72). Using WiMAX Application Firmware R&S®FSQ-K92, the R&S®FSQ can analyze WiMAX signals — with the optional R&S®FSQ-B71 baseband inputs even directly in the baseband. The R&S®FSQ-K92 firmware option allows the analysis of WiMAX signals in accordance with standard 802.16-2004 OFDM. Further WiMAX expansions such as 802.16-2004 OFDMA or 802.16e will be supported in forthcoming releases of the firmware. The R&S®FSQ comes in various models up to a maximum frequency of 40 GHz. All WiMAX measurement applications are fully remote-controllable via the IEC/IEEE bus or VXI 11, using SCPI commands.

At the beginning of a measurement, you not only have to set the standard parameters such as the frequency, recording length, etc, as would be the case in WLAN, but also the bandwidth and the length of the guard interval, since these parameters are variable in WiMAX (Fig 3). With the R&S®FSQ-B71 option installed, WiMAX signals can be analyzed directly in the baseband, for example to determine any signal degradation originating in the I/Q modulator or during RF transmission.
Setting of demodulation parameters.

In addition to choosing predefined frame lengths, you can define your own frame lengths or select the Continuous mode. The Continuous mode generates a signal without a burst.

Depending on the sample rate and frame duration, a total signal length of up to 511 frames may be attained. This length is ideal for BER tests with PN9 as a data source.

Here, you can choose the Short, Mid and Long test sequences specified in the standard. In the User mode, you can configure any desired signals.

The R&S®SMU20A supports channel bandwidths up to 28 MHz.

Up to eight bursts can be configured per frame. BPSK, QPSK, 16QAM or 64QAM modulation can be selected for each burst.

The crest factor of the signal can be reduced by means of scalar or vector clipping.

The generator output power can be referenced to the preamble or to the average power of the overall signal.

Predefined frequency bands simplify channel bandwidth setting.

In addition to conventional PN data sources, you can select your own specific data lists.

A MAC header and a CRC can be added to each burst.

Gaps can be introduced between bursts to simulate propagation times (round trip delay), for example.

FIG 1 WiMAX main menu of the R&S®SMU200A.

FIG 2 Typical frame configuration in the uplink mode.

FIG 3 General settings in the WiMAX Application Firmware R&S®FSQ-K92 option.

FIG 4 Setting of demodulation parameters.
In accordance with the standard, the bursts allocated to the different subscribers in the downlink path of a WiMAX signal can be differently modulated. Bursts with the same modulation mode are combined in groups, the groups being sent in the order corresponding to the requirements made on transmission reliability, i.e., first BPSK, then QPSK, then 16QAM and finally 64QAM modulated groups. The R&S®FSQ-K92 firmware automatically detects the modulation mode. You can define what modulation mode, or part of the signal, should be analyzed (FIG 4). With the settings shown in FIG 5, for example, only signal parts with 64QAM modulation will be considered. Automatic modulation detection can also be deactivated; in this case, the complete signal will be analyzed applying the preset modulation. The WiMAX signal contains eight pilot carriers to synchronize the 200 carriers of the OFDM signal. The pilot carriers are always BPSK-modulated and transmit a known bit sequence. You can choose whether, in addition to their phase, the amplitude and the timing of the OFDM signal carriers should be synchronized, and whether channel estimation should be performed during the entire signal rather than during the preamble only (the latter being the standard specification).

The signal analyzer measures the parameters relevant to characterizing a WiMAX signal and displays the results in a table (FIG 6). An essential parameter is the error vector magnitude (EVM), which allows assessment of the modulation quality. The EVM indicates the deviation of a measured (actual) point in the constellation diagram from the ideal point, the points representing the I/Q value pairs of the symbols of the OFDM carriers. The bottom half of FIG 5 shows a typical constellation diagram of a 64QAM WiMAX signal. The yellow points indicate the measured values; the blue pattern shows the ideal positions of the constellation points. The R&S®FSQ displays the EVM as an average over all carriers and separately for data carriers and pilot carriers (FIG 6), where the pilot carriers are always BPSK-modulated. Further parameters important for assessing signal quality include I/Q offset, quadrature error, and imbalance between the signal’s in-phase and quadrature component. Moreover, the frequency error and the symbol clock error as well as the burst power and the crest factor are displayed. The table shows all important parameters at a glance and thus helps you optimize your system.

In many applications, it is useful to display results in greater detail. The R&S®FSQ shows EVM versus time, for example, thus facilitating the analysis of transient effects. The analyzer also shows EVM versus frequency, or versus the carriers, respectively, thus allowing the detection of frequency-specific problems (FIG 7). Many other quantities can be displayed graphically, e.g., frequency and phase error, frequency response, group delay, etc. Typical conformance tests measuring, for example, adjacent-channel power or spectrum mask (FIG 8), are conveniently performed by means of predefined settings.

**Summary**

WiMAX technology appears to be on the road to great economic success for two reasons: First, it can provide greater transmission ranges than possible with WLAN. Second, its ability to support mobile applications (80.16e) is very promising. As a result, even leading chip manufacturers are vigorously driving this technology forward. While the commercial use of the standard is still in its infancy, the T&M equipment that is necessary for development and certification is needed today. Rohde & Schwarz has taken on this challenge and already provides the WiMAX options shown in FIG 9.

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**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AWGN</td>
<td>Additive white Gaussian noise</td>
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<tr>
<td>BPSK</td>
<td>Binary phase shift keying</td>
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<td>CRC</td>
<td>Cyclic redundancy check</td>
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<td>EVM</td>
<td>Error vector magnitude</td>
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<tr>
<td>FDD</td>
<td>Frequency division duplex</td>
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<tr>
<td>LOS</td>
<td>Line of sight</td>
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<td>MAC</td>
<td>Medium access control layer</td>
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<tr>
<td>NLOS</td>
<td>Non line of sight</td>
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<tr>
<td>OFDM</td>
<td>Orthogonal frequency division multiplexing</td>
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<tr>
<td>OFDMA</td>
<td>Orthogonal frequency division multiple access</td>
</tr>
<tr>
<td>QPSK</td>
<td>Quadrature phase shift keying</td>
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<tr>
<td>QAM</td>
<td>Quadrature amplitude modulation</td>
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<tr>
<td>TDD</td>
<td>Time division duplex</td>
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<td>WiMAX</td>
<td>Worldwide interoperability for microwave access</td>
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FIG 5 WiMAX signal with constellation diagram. The 64QAM burst parts highlighted in green are demodulated and results shown in the constellation diagram.

FIG 6 List of all parameters important for WiMAX signal characterization.

FIG 7 Display of EVM versus carriers (frequency domain, top) and versus symbols (time domain, bottom).

FIG 8 Using predefined limit lines, the analyzer determines, at the press of a button, whether the spectrum conforms to specified requirements.

FIG 9 Options for testing WiMAX applications.

R&S®SMU-K49 Digital Standard IEEE 802.16
R&S®SMU-K62 Additive White Gaussian Noise (AWGN)
R&S®SMU-B14 Fading Simulator
R&S®SMU-B203 RF Path B (100 kHz to 3 GHz)
R&S®FSQ-K92 Application Firmware WiMAX 802.16-2004
R&S®FSQ-B71 Analog Baseband Inputs
R&S®FSQ-B72 I/Q Bandwidth Extension to 120 MHz (f > 3.6 GHz)