Products: R&S®FSQ, R&S®SMU, R&S®SMJ, R&S®SMATE

WiMAX: 802.16-2004, 802.16e, WiBRO
Introduction to WiMAX Measurements

Application Note 1EF57

The new WiMAX radio technology – worldwide interoperability for microwave access – is based on wireless transmission methods defined by the IEEE 802.16 standard [1]. WiMAX has been developed to replace broadband cable networks such as DSL and to enable mobile broadband wireless access. Rohde & Schwarz offers a complete test solution for WiMAX applications by combining its Signal Generator R&S®SMU200A and Signal Analyzer R&S®FSQ plus the appropriate options.

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1 Overview

The IEEE 802.16-2004 standard specified OFDM as the transmission method for NLOS (Non Line Of Sight) connections. The OFDM signal is made up of many orthogonal carriers, and every individual carrier is digitally modulated with a relatively slow symbol rate. This method has distinct advantages in multipath propagation because more time is needed to transmit a symbol compared to the single carrier method at the same transmission rate. Adding a guard interval to every symbol ensures that multipath propagation does not disrupt radio transmission. The simultaneous, parallel transmission of multiple symbols also makes it possible to use error correction to reconstruct the contents of faulty carriers. These characteristics result in a stable connection with very low bit error ratios (BER). The BPSK, QPSK, 16QAM, and 64QAM modulation modes are used, and the modulation is adapted to the specific transmission requirements. This makes transmission rates of up to 75 Mbit/s possible. Unlike WiMAX's "little brother" WLAN, the bandwidth is not constant and can vary between 1.25 MHz and 28 MHz. In IEEE 802.16-2004, a distinction is made between two methods: **OFDM and OFDMA**. In the normal OFDM mode, 200 carriers are available for data transmission and both TDD and FDD methods are used. In the OFDMA mode, various subscribers

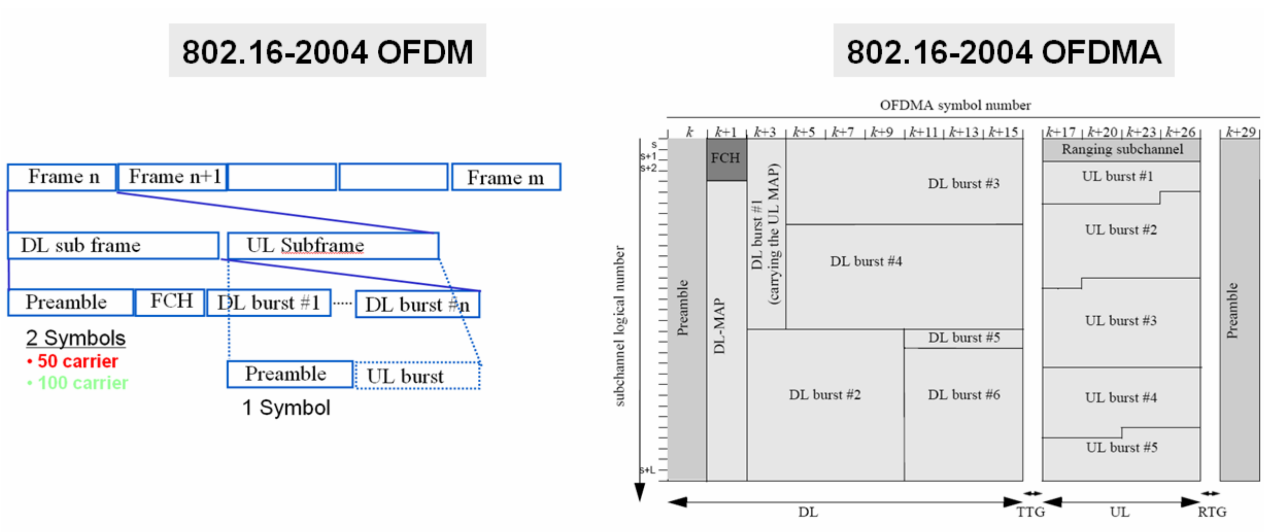

Figure 1: Comparison of frame structure of 802.16-2004 OFDM system and 802.16-2004 OFDMA. In OFDM e.g. the downlink consists of a preamble followed by an FCH field and the bursts for the different subscribers. In OFDMA mode the bursts are allocated according to downlink map.

can be served simultaneously by assigning every subscriber a specific carrier group (subchannelization) that carries the data intended for that subscriber. The number of carriers is also significantly increased. Figure 1 shows a comparison of the frame structure of OFDM and OFDMA mode. The 802.16e [2] standard is a further expansion of WiMAX in the frequency range up to 6 GHz with the objective of allowing mobile applications and even roaming. The number of carriers can vary over a wide range depending on permutation zones and FFT base (128, .. 2048). The Korean standard WiBro can be seen as special derivative of 802.16e.

2 WiMAX – Complex Measurement Technology Required

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 signal is not possible using conventional spectrum analyzers. This task requires a high-end signal analyzer such as the R&S FSQ [3,4], which is capable of demodulating the broadband WiMAX signals. To measure transmit signals or test receivers with the R&S FSQ, WiMAX signals of excellent modulation quality are needed. Such signals can be generated very conveniently by means of the Signal Generator R&S®SMU200A [5,6] and option R&S®SMU-K49. This option is also available for the Signal Generators R&S®SMJ100A and R&S®SMATE200A.

Generating WiMAX OFDM Signals

The Signal Generator R&S®SMU200A produces test signals for OFDM receiver tests in conformance with IEEE 802.16-2004, requiring only minimum operating effort. A single-path generator is ideal for testing receiver sensitivity or determining the maximum input level. An R&S®SMU200A 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 (Additional White Gaussian Noise) module (option R&S®SMU-K62) superimposes defined channel noise as required for high-accuracy sensitivity measurements. The Fading Simulator R&S®SMU-B14 option enables tests under fading conditions.

In addition to choosing predefined test signals, signal scenarios can be configured to create any possible situation. Up to 64 bursts with user-definable power and payload can be set both in the downlink and the uplink. The payload of the bursts is fully channel-coded during modulation. Moreover, a MAC header can be defined 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®SMU200A displays the power, duration and position of each burst in a clear-cut table.

In automatic test systems, it is vital that the test signals can be generated by remote control. All WiMAX signal parameters offered by the R&S®SMU200A can be set by means of SCPI commands, i.e. the generator is fully remote-controllable via the IEC/IEEE bus or LAN.

Analyzing WiMAX OFDM Signals with a Signal Analyzer

Modern spectrum analyzers can already measure several important parameters [7]. In the frequency domain, measurements can be made of the bandwidths, power in the adjacent channels, and spurious emissions at other frequencies. In the time domain, the spectrum analyzer can measure the timing of the WiMAX signal. However, the resolution bandwidth of the spectrum analyzer has to be greater than the bandwidth of the RF signal –

i.e. it must exceed 28 MHz in the mode with the greatest bandwidth – to measure the burst power directly in the time domain. The spectrum analyzer can also measure the Crest Factor. This parameter, which is especially important for digital modulation, indicates how much higher the peak power can go compared to the average signal power. The Crest Factor has a significant effect on the dimensioning of transmit amplifiers, for example. Peak power values cannot be truncated because this would cause too much deterioration in the modulation quality. The spectrum analyzer must provide sufficiently large resolution bandwidths for this purpose, as well.

However, normal spectrum analyzers cannot analyze the modulation quality of a WiMAX OFDM signal. This requires an analyzer that can demodulate the broadband signal (demodulation bandwidth about 28 MHz). A high-end Signal Analyzer like the R&S®FSQ can record 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/K93, the R&S®FSQ can analyze WiMAX signals. The R&S®FSQ-K92/K93 firmware option allows the analysis of WiMAX signals in accordance with standard 802.16-2004 OFDM. All WiMAX measurement applications are fully remote-controllable via the IEC/IEEE bus or LAN, using SCPI commands.

At the beginning of a measurement, not only the standard parameters such as the frequency, recording length, etc have to be set, but also the bandwidth and the length of the guard interval, since these parameters are variable in WiMAX. 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.

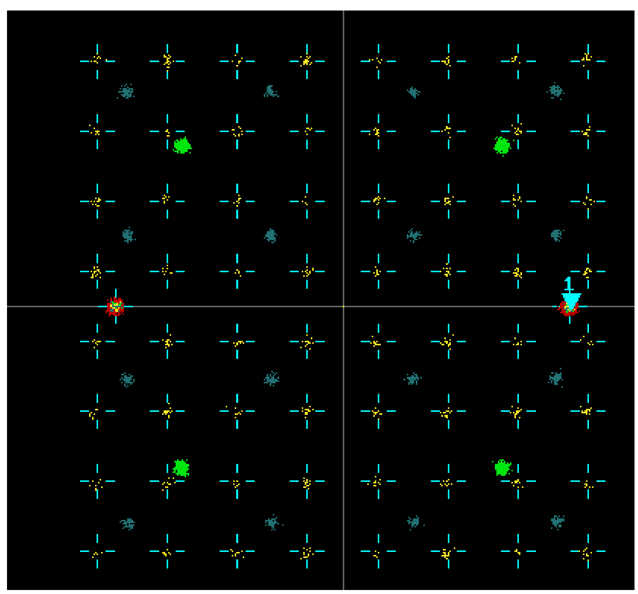

Figure 2: Constellation diagram of a downlink subframe with 4 different bursts with different modulation: BPSK (red), QPSK (green), 16QAM (blue) and 64QAM (yellow)

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/K93 firmware automatically detects the modulation mode. It can be defined, what modulation mode, or part of the signal, should be analyzed or whether all modulation modes should be analyzed. The constellation diagram then shows all demodulated symbols in one diagram (Figure 2). 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. The user 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. 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 R&S®FSQ displays the EVM as an average over all carriers and separately for data carriers and pilot carriers, 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. A 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. Many other quantities can be displayed graphically, e.g. frequency and phase error, frequency response, group delay, etc. Typical conformance tests measurements [8], for example, adjacent-channel power or spectrum mask, are conveniently performed by means of predefined settings.

Demo of Generating and Analyzing WiMAX OFDM signals

The video: **RuS_WiMAX_OFDM.EXE** shows, how convenient it is to generate and analyze a WiMAX OFDM signal with R&S equipment and gives a starting point for every measurement setup. It is a Flash nimation and therefore Makromedia Player has to be installed (http://www.macromedia.com/shockwave/download/triggerpages_mmcom/yflash-de.html)

Generating and Analyzing WiMAX 802.16-2004 OFDMA / 802.16e Signals

Generating and analyzing of WiMAX 802.16-2004 OFDMA or 802.16e signals seems to be more complex due to the enhanced and variable carrier number (FFT base 128 ..2048) and due to subchannelisation. Nevertheless signals according to standard can be generated with the signal generator R&S SMU, R&S SMJ and R&S SMATE and analyzed with signal analyzer R&S FSQ. The displayed results are the same as with WiMAX OFDM. The big difference is the definition of the waveform at the signal generator and signal analyzer. A map has to be clearly defined for downlink and uplink for analyzing the signals, the used subchannels, and zone types have to be defined as well. In OFDMA mode the allocation of physical carriers to logical subchannels has to be calculated considering complex permutation algorithms, which can vary according to these different zones (PUSC, FUSC, ..). Moreover different segments can be defined for allocating subchannels to different base stations working in parallel Further details about the standard are listed in the operating manual of the options R&S®FSQ-K93 and R&S®SMU-K49 [4,6]. After this clear definition all important parameters like EVM, burst power, etc. can be calculated and displayed similar to OFDM mode. Due to complex map definition it is most important to provide the user with a comfortable editor for downlink and uplink map. For signal generator R&S®SMU200A as well as for the OFDMA solution for signal analyzer (R&S FSQ-K93) all parameters can easily be adjusted. Waveforms already defined at signal generator can be loaded into the analyzer solution, even directly by GPIB connection, no additional data entry is necessary.

3 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 (802.16e) 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.

4 References

[1] Institute of Electrical and Electronics Engineers Inc., IEEE P802.16-2004/Cor12/D5 Standard for Local and metropolitan area networks; Part 16: Air Interface for Fixed Broadband Wireless Access Systems, IEEE. 2004

[2] Institute of Electrical and Electronics Engineers Inc.,IEEE P802.16e/D12, Standard for Local and metropolitan area networks; Partt 16: Air Interface for Fixed Broadband Wireless Access Systems, Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, IEEE. 2005

[3] Rohde & Schwarz, Signal Analyzer R&S FSQ: Operating Manual Vol 1, R&S 2005

[4] Rohde & Schwarz, Application Firmware R&S®FSQ-K92: Software Manual, R&S 2005, Rohde & Schwarz, Application Firmware R&S®FSQ-K93 Software Manual, R&S 2006

[5] Rohde & Schwarz, Vector Signal Generator R&S®SMU200A, Operating Manual Vol 1, R&S 2005

[6] Rohde & Schwarz, Vector Signal Generator R&S®SMU200A - Supplement Standard WLAN-WiMAX, R&S 2005

[7] Christoph Rauscher, Fundamentals of Spectrum Analysis, R & S 2004

[8] European Telecommunication Standards Institute, ETSI EN 301 021 V 1.6.1, ETSI 2003

5 Additional Information

This application note and the associated videos are updated from time to time. Please Gloris in order to download new versions.

Please send any comments or suggestions about this application note to **TM-Applications@rsd.rohde-schwarz.com**.

6 Ordering information

Vector Signal Generator SMU200A

R&S SMU200A	Basic Instrument	1141.2005.02

RF Options

R&S SMU-B103	100 kHz ... 3 GHz for 1st path	1141.8603.02
R&S SMU-B106	100 kHz ... 6 GHz for 1st path	1141.8803.02
R&S SMU-B203	100 kHz ... 3 GHz for 2nd path	1141.9500.02

Baseband Options

R&S SMU-B13	Baseband Main Module	1141.8003.02
R&S SMU-B10	Max. 64 Msamples I and Q, Dig. Modulation	1141.7007.02
R&S SMU-B11	Max. 16 Msamples I and Q, Dig. Modulation	1159.8411.02
R&S SMU-K49	Digital Standard IEEE 802.16	1161.0366.02
R&S SMU-K62	Additive White Gaussian Noise (AWGN)	1159.8511.02

Fading Option

R&S SMU-B14	Fading Simulator	1160.1800.02
R&S SMU-B15	Fading Simulator Extension	1160.2288.02
R&S SMU-K71	Enhanced resolution and dynamic fading	1160.9201.02

Vector Signal Generator SMJ100A

R&S SMJ100A	Basic Instrument	1403.4507.02

RF Options

R&S SMJ-B103	100 kHz ... 3 GHz	1403.8502.02
R&S SMJ-B106	100 kHz ... 6 GHz	1403.8702.02

Baseband Options

R&S SMJ-B13	Baseband Main Module	1403.9109.02
R&S SMJ-B10	Max. 64 Msamples I and Q, Dig. Modulation	1403.8902.02
R&S SMJ-B11	Max. 16 Msamples I and Q, Dig. Modulation	1403.9009.02
R&S SMJ-K49	Digital Standard IEEE 802.16	1404.1101.02
R&S SMJ-K62	Additive White Gaussian Noise (AWGN)	1404.0805.02

Vector Signal Generator SMATE200A

R&S SMATE200A	Basic Instrument	1400.7005.02

RF Options

R&S SMATE-B103	100 kHz ... 3 GHz for 1st path	1401.1000.02
R&S SMATE-B106	100 kHz ... 6 GHz for 1st path	1401.1200.02
R&S SMATE-B203	100 kHz ... 3 GHz for 2nd path	1401.1400.02
R&S SMATE-B206	100 kHz ... 6 GHz for 2nd path	1401.1600.02

Baseband Options

R&S SMATE-B13	Baseband Main Module	1401.2907.02
R&S SMATE-B10	Max. 64 Msamples I and Q, Dig. Modulation	1401.2707.02
R&S SMATE-B11	Max. 16 Msamples I and Q, Dig. Modulation	1401.2807.02
R&S SMATE-K49	Digital Standard IEEE 802.16	1404.6803.02
R&S SMATE-K62	Additive White Gaussian Noise (AWGN)	1404.5807.02

Signal Analyzer and Options

R&S FSQ3	20 Hz ... 3.6 GHz	1155.5001.03
R&S FSQ8	20 Hz ... 8 GHz	1155.5001.08
R&S FSQ26	20 Hz ... 26,5 GHz	1155.5001.26
R&S FSQ40	20 Hz ... 40 GHz	1155.5001.40
R&S FSQ-K92	Application Firmware 802.16-2004 OFDM	1300.7410.02
R&S FSQ-K93	Application Firmware 802.16e	1300.8600.02
R&S FSQ-K92U	Upgrade from FSQ-K92 to FSQ-K93	1300.8500.02

For additional information about Rohde & Schwarz measurement equipment, see the Rohde & Schwarz website www.rohde-schwarz.com.

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