Products: R&S®FSQ, R&S®FSL, R&S®FSP, R&S®FMU

Power Measurement and Power Calculation of IEEE 802.16 WiMAX OFDMA signals

Application Note 1EF60

The R&S WiMAX application firmware R&S®FSx-K93 calculates several different power parameters. This application note describes the basic power measurements of WiMAX OFDMA signals and gives an overview of the calculation of the different values.

Contents

1   Overview

A **typical TDD WiMAX signal** is not continuous, but has a burst structure. The following figure shows the power versus time graph of a WiMAX signal.
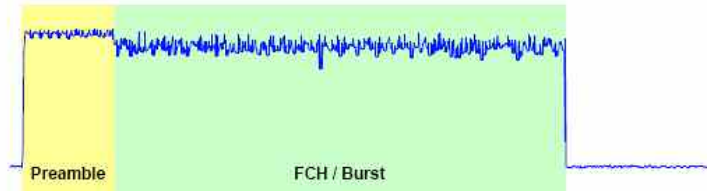

Figure 1:   Power vs. time graph of a WiMAX signal [1]

The start of every downlink frame is the preamble followed by the frame control header (FCH) / burst. The preamble, used for synchronisation, contains BPSK-modulated carriers and is one OFDMA symbol long. It is **power boosted** and the level is a few dB higher than the level of the following data burst [2].

As an example the **following signal parameters** are assumed for all the measurements described and all figures in this application note:

- WiBro DL signal (OFDMA)

- 1 PUSC zone with 30 symbol and all subchannels used

- 16QAM1/2 modulation

- 1 segment, #0 used

- Total frame length 5 ms

- FFT size, N_{FFT} = 1024 carriers

Within the WiMAX application firmware R&S®FSx-K93 there are two tables which show all important parameters at a glance and thus help you to optimize your system. Beside EVM, RSSI, CINR, IQ constellation,… different power parameters of WiMAX signals are calculated. The first table 'List 1' shows the results of power measurement in time domain (TD) (see section 2). On the second table 'List 2' you can see the results of power measurement in frequency domain (FD) (see section 3).

Result Summary of Analyzed Subframes						
	Min	Mean	Limit	Max	Limit	Unit
TD Power DL Preamble	- 8.74	- 8.74		- 8.74		dBm
TD Power Subframe	- 12.38	- 12.38		- 12.38		dBm
TD Power Zone	- 12.56	- 12.56		- 12.56		dBm

Figure 2:   This list shows the power of certain parts of the signal measured in time domain: TD power DL preamble, TD power subframe and TD power zone.

Result Summary of Analyzed Zone/Segment						
	Min	Mean	Limit	Max	Limit	Unit
Power DL Preamble	- 3.16	- 3.16		- 3.16		dBm
Power Data and Pilots	- 11.71	- 11.71		- 11.71		dBm
Power Data	- 12.17	- 12.17		- 12.17		dBm
Power Pilots	- 9.68	- 9.68		- 9.68		dBm

Figure 3:   This list displays power values measured in frequency domain: power DL preamble, power data and pilots, power data and power pilots.

2   WiMAX – Time Domain Power Measurement

This section describes typical time domain measurements on a WiMAX OFDMA signal in spectrum analyzer mode.

Settings

The time domain power parameters of a WiMAX signal as displayed in 'List 1' (figure 2) can be easily measured with a spectrum analyzer using the **time domain** power function. This function is a standard measurement function of R&S spectrum analyzers ('Meas' softkey → 'Time Domain Power Function'). To make a correct measurement the resolution bandwidth (**RBW**) of the spectrum analyzer has to be wider than the bandwidth of the RF signal [1]. For an optimum measurement result you have to switch on the **RMS detector**. Then you can use the **limit lines** to evaluate the power in certain areas of the burst (e.g. in the preamble and the data part).

Measurement using a Spectrum Analyzer

The figure below shows the measurement of the TD Power DL Preamble. The measured value correlates with the one in 'List 1' (figure 2).
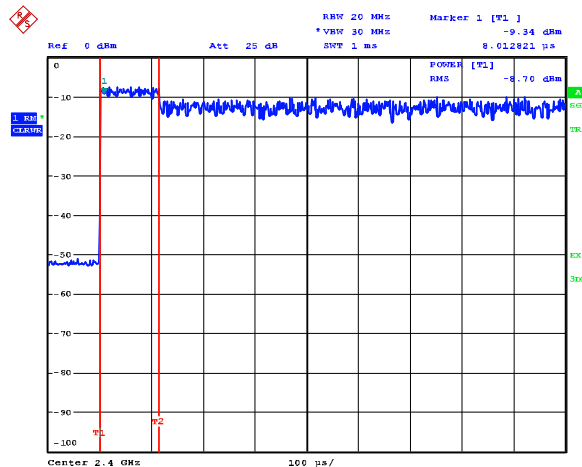

Figure 4:   Time Domain measurement – TD Power DL Preamble

Between the other two TD Power parameters, measured in figure 5, and the values of 'List 1' there is also a good correlation:

	'List 1' (figure 2)	TD power measurement
TD Power DL Preamble	- 8.74 dBm	- 8.70 dBm (figure 4)
TD Power Subframe	-12.38 dBm	-12.38 dBm (figure 5, left)
TD Power Zone	-12.56 dBm	-12.54 dBm (figure 5, right)

The inconvenience of this measurement method is that the limits for the burst power measurement need to be set manually. For the determination of TD Power DL Preamble only the preamble part of the WiMAX frame (see figure 1 preamble part) is measured. The measurement range of TD Power Subframe includes the preamble and FCH/burst part of figure 1, the measurement range of TD Power Zone includes only the FCH/burst part.
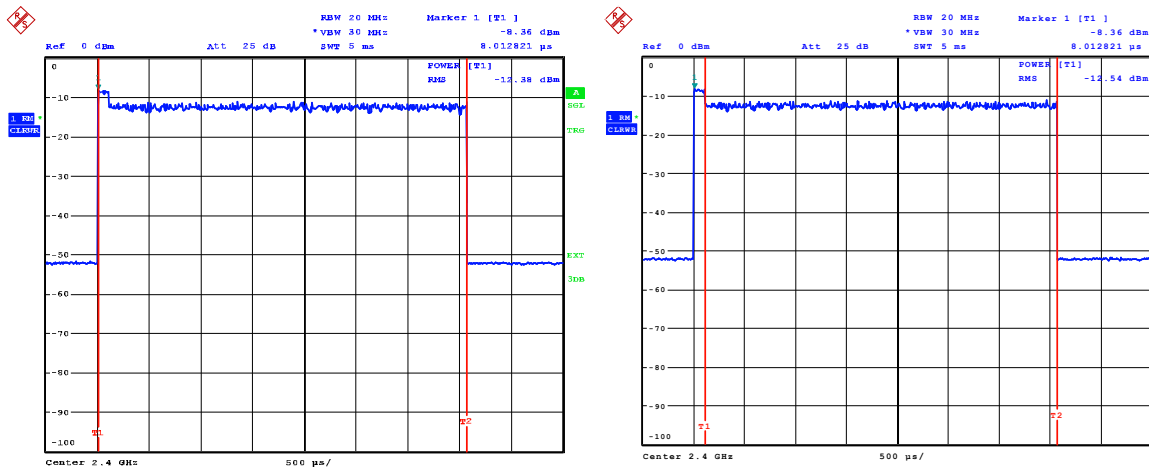
Figure 5:   Time Domain measurement – left: TD Power Subframe, right: TD Power Zone

3   WiMAX – Frequency Domain Power Measurement

This section describes the calculation of the boosting factors and the mathematical relations of the power parameters in frequency domain and in time domain.

Boosting Factor

All constellations (BPSK, QPSK, 16QAM, 64QAM) in the diagram are normalized to achieve equal average power, e.g. QPSK data is normalized by multiplying the constellation point with $c = 1/\sqrt{2}$. According to standard [16-2004] the subcarriers are boosted by the factor $2(1/2-w_k)$ compliant with the subcarrier index k and with $w_k = \{0,1\}$. For QPSK modulated data you obtain (figure 6):

$$Re\{data,QPSK\} = 1/\sqrt{2} * 2(1/2-w_k) = \sqrt{2} * (1/2-w_k)$$

$$Im\{data,QPSK\} = 1/\sqrt{2} * 2(1/2-w_k) = \sqrt{2} * (1/2-w_k).$$

The pilot carriers within the symbol and the preamble are BPSK modulated. Thus the imaginary part is not necessary and only the real part in the IQ domain is boosted. The **pilot carriers within the symbol** are boosted according to [16-2004] equation 135:

$$Re\{pilot\} = 8/3*(1/2-w_k) = 4/3 * 2(1/2-w_k)$$

$$Im\{pilot\} = 0.$$

The power of the pilots (with $w_k = \{0,1\}$) is

$$Re\{pilot\}_{max} = 4/3 \quad \text{and in log scale}$$

$$20 \quad * \quad \log \ (4/3) = \textbf{2.5 dB}$$

above the data subcarrier power level i.e. the pilots are power boosted by 2.5 dB. This is a fixed value for all permutations except UL PUSC (partial usage of subchannels), UL Ranging and DL FUSC (full usage of subchannels). For those permutations the boosting factor for the pilots is 0 dB (figure 6).

The **carriers in the downlink preamble** are boosted according to [16-2004] equation 136:

$Re\{preamble\} = 4*\sqrt{2}*(1/2-w_k) = 2*\sqrt{2}*2(1/2-w_k)$

$Im\{preamble\} = 0.$

Consequently the boosting factor of the preamble amounts to

$Re\{preamble\}_{max} = 2*\sqrt{2}$ and in log scale

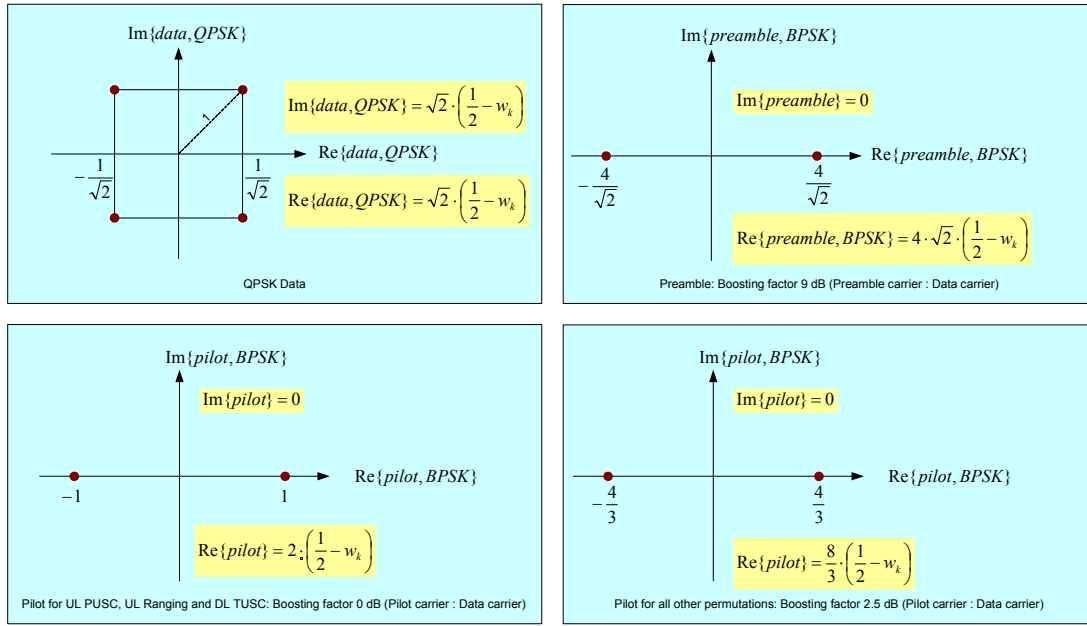$20 \quad * \quad log \ (2*\sqrt{2}) = \textbf{9.0 dB}.$

Figure 6:   Modulation Symbol Power – Modulation and boosting factor of QPSK data, preamble and pilots

When not all subchannels are used within the first DL PUSC zone, **zone boosting** is applied (acccording to [16e-2005] section '8.4.9.6 Zone boosting') and thus the data and pilot subcarriers in the corresponding zone are boosted. The subcarrier level of the zone is increased as follows:

$10 * log(N_{useful} / N_{allowed})$

N_{useful} – all useful subcarriers (of all subchannels) depending on permutation scheme (according to [16e-2005] Table 310x) and excluding DC subcarrier

$N_{allowed}$ – subcarriers of the selected subchannels (that are allowed to be used in the zone)

The following equations summarize the relations for the boosting factors in frequency domain:

Boosting:		
$P_{FD,Preamble}$	$= 9\ dB + P_{FD,Data}$	(all subchannels used) (1)
$P_{FD,Preamble}$	$= 9\ dB + P_{FD,Data}$	$+ 10 * log(N_{useful} / N_{allowed})$
		(limited usage of subchannels) (2)
$P_{FD,Pilot}$	$= 2.5\ dB + P_{FD,Data}$	(3)

where $P_{FD,Preamble}$ is the power level of the preamble in frequency domain, $P_{FD,Data}$ of the data, and $P_{FD,Pilot}$ of the pilots.

Constellation vs Symbol
Modulation: All   Burst: All   Symbol: All   Carrier: All
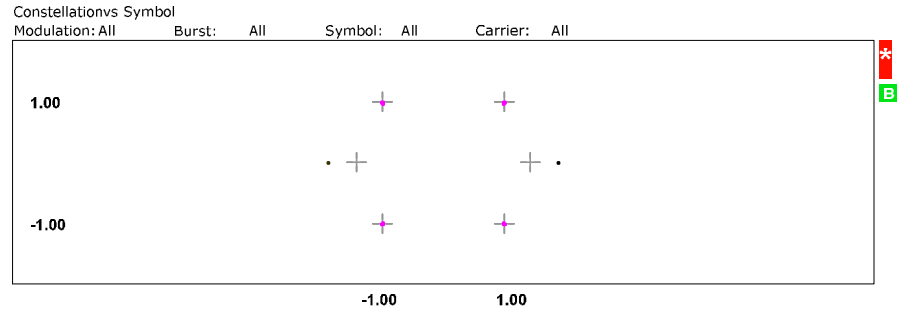

Figure 7: Constellation diagram of a WiMAX OFDMA signal with a QPSK modulated data burst. The pilots are BPSK modulated. As they are power boosted they do not correspond with the indicated BPSK constellation points.

There is only one parameter of 'List 2' (figure 3) that has not been explained yet: the power value for data and pilots in frequency domain $P_{FD,Data/Pilots}$. It can be calculated from $P_{FD,Data}$ and $P_{FD,Pilot}$ as follows:

$$P_{FD,Data/Pilots[mW]} = (N_{Data} * P_{FD,Data[mW]} + N_{Pilot} * P_{FD,Pilot[mW]}) / (N_{Data} + N_{Pilot}) \quad (4)$$

For this calculation the power must be noted in mW [3]. The number of data carriers N_{Data} and pilot carriers N_{Pilot} depends on the FFT size and the permutation scheme and is defined in the standard [16e-2005] Table 310. For an example please refer to section 5 in this application note.

Mathematical Relations Time Domain / Frequency Domain

Beside measuring the preamble power in time domain $P_{TD,Preamble}$ you can also calculate this value from the preamble power in frequency domain $P_{FD,Preamble}$:

$$P_{TD,Preamble} = 10 * log(N_{used,Preamble}/N_{FFT}) + P_{FD,Preamble} \quad (5)$$

The number of preamble carriers used $N_{used,Preamble}$ depends on the number of used segments. The DL supports up to three segments. A segment is a subdivision of the available OFDMA subchannels (one segment may include all sub-channels). As previously mentioned the transmission begins with a preamble. Further to synchronisation the preamble indicates which of the three segments of the zone are used. Therefore the preamble subcarriers are divided into three carrier-sets. Carriers 0,3,6… indicate that segment 0 is to be used, carriers 1,4,7,.. indicate that segment 1 is to be used, and carriers 2,5,8,… indicate that segment 3 is to be used. For every active segment a third of the carriers is used:

$$N_{used,Preamble} = N_{avail\_p} * N_{segments}/3$$

The number of subcarriers available for the preamble symbol N_{avail_p} depends on the FFT size N_{FFT} and the number of guard carriers N_{guard_p}:

$$N_{avail\_p} = N_{FFT} - N_{guard\_p}$$

The number of guard carriers N_{guard_p} can be found in the standard [16e-2005] section '8.4.6.1.1 Preamble'.

A similar equation is valid for the zone power $P_{TD,Zone}$ of a WiMAX signal:

$$P_{TD,Zone} = 10 * log((N_{useful} + 1) /N_{FFT}) + P_{FD,Data/Pilots} \quad (6)$$

4 Summary

Figure 8 illustrates the relation of both lists displayed in the application firmware FSx-K93 in brief. The numbers signify the associated equation:

Frequency Domain	Time Domain
(1) ↑ Power DL preamble (5) ← →	TD power DL preamble
(2) Power data and pilots	TD power subframe
↓ Power data (6)	TD power zone
Power pilots ↓(3)	

Figure 8: Relation of the parameters displayed in 'List 1' and 'List 2'

5 OFMDA Calculation Example

The following example shows how to calculate the main power parameter of an OFDMA system signal. As mentioned in the first section we have a 1024-FFT OFDMA downlink PUSC signal with one segment and all subchannels used.

Values according to standard

Based on the defined signal there are some fix parameters specified in the standard [16e-2005]. The number of pilots, data, and guard subcarriers varies for different subchannelization schemes. The values below are valid for a WiMAX 1024-FFT OFDMA DL PUSC signal (according to standard [16e-2005] Table 310a, page 528):

N_{used} = 841 (incl. DC subcarrier)

N_{Data} = 720

N_{Pilot} = 120

For the preamble symbol there will be 86 guard band subcarriers on both sides of the spectrum (according to standard [16e-2005] section '8.4.6.1.1 Preamble'):

$N_{avail\_p} = N_{FFT} - N_{guard\_p} = 1024 - 86*2 = 852$

In our example only one segment is used and thus only a third of all preamble carriers:

$N_{used,Preamble} = N_{avail\_p} * N_{segments}/3 = 852 * 1/3 = 284$

Frequency Domain Power Calculation

The power of the data carriers in frequency domain $P_{FD,Data}$ is given in 'List 2' and necessary to calculate the other power parameters:

$P_{FD,Data}$ = -12.17 dBm ('List 2': Power Data)

The WiMAX signal uses **all subchannels**. Thus zone boosting is not applied and the power of the preamble (according to formula (1)) and the power of the pilots (according to formula (3)) result in:

$P_{FD,Preamble}$ = 9.03 dB – 12.17 dBm = **-3.14 dBm** ('List 2': Power DL Preamble = -3.16 dBm)

$P_{FD,Pilot}$ = 2.49 dB – 12.17 dBm = **-9.68 dBm** ('List 2': Power Pilots = -9.68 dBm)

The power of data and pilots $P_{FD,Data/Pilots}$ is calculated as follows (according to formula (4)):

$P_{FD,Data}$ = -12.17 dBm $\hateq$ 0.061 mW

$P_{FD,Pilot}$ = -9.68 dBm $\hateq$ 0.108 mW

$P_{FD,Data/Pilots}$ = 0.067 mW $\hateq$ **-11.71 dBm** ('List 2': Power Data and Pilots = -11.71 dBm)

Additional example:

If you have a signal with **limited usage of subchannels** (e.g. only 20 of 30 subchannels used) zone boosting is applied. In this case 560 subcarriers are useful (N_{useful} = (841–1)*20/30 = 560) and 840 are allowed ($N_{allowed}$ = 841–1). Thus the difference between $P_{FD,Preamble}$ and $P_{FD,Data}$ is 7.27 dB (9.03 dB + 10 * log(560/ 840)) instead of 9 dB.

Time Domain Power Calculation

According to formula (5) the power of the DL preamble is:

$P_{TD,Preamble}$ = -3.16 dBm + 10 * log(284/1024) = **-8.73 dBm** ('List 1': TD Power DL Preamble = -8.74 dBm)

and the time domain power of the zone (according to formula (6)):

$P_{TD,Zone}$ = -11.71 dBm + 10 * log(841/1024) = **-12.56 dBm** ('List 1': TD Power Zone = -12.56 dBm)

6   References

[16-2004] **IEEE 802.16-2004**
IEEE Standard for Local and metropolitan area networks
Part 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

[16e-2005] **IEEE 802.16e-2005**
IEEE Standard for Local and metropolitan area networks
Part 16: Air Interface for Fixed Broadband Wireless Access Systems
Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and *Corrigendum 1*

[1] **WiMAX – Generating and Analyzing 802.16-2004 and 802.16e-2005 signals**
Rohde & Schwarz, Application Note 1MA97, Available for free download:
http://www.rohde-schwarz.com/appnote/1MA97

[2] **WiMAX – General Information about the standard 802.16**
Rohde & Schwarz, Application Note 1MA96, Available for free download:
http://www.rohde-schwarz.com/appnote/1MA96

[3] **dB or not dB?**
Rohde & Schwarz, Application Note 1MA98, Available for free download:
http://www.rohde-schwarz.com/appnote/1MA98

7 Additional Information

This application note is updated from time to time. Please visit the website 1EF60 in order to download new versions.

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

8 Ordering Information

Signal Analyzer FSQ and FMU

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 FMU36	DC … 36 MHz	1303.3500.02

WiMAX Option for FSQ and FMU

R&S FSQ-K92	Application Firmware IEEE 802.16-2004	1300.7410.02
R&S FSQ-K93	Application Firmware IEEE 802.16e-2005	1300.8600.02
R&S FSQ-K92U	Upgrade from FSQ-K92 to FSQ-K93	1300.8500.02

Hardware Options for FSQ

R&S FSQ-B71	Baseband Inputs DC to 36 MHz	1157.0113.02
R&S FSQ-B72	I/Q Bandwidth Extension to 120 MHz	1157.0336.02

Spectrum Analyzer FSL

R&S FSL3	9 kHz ... 3 GHz	1300.2502.03
R&S FSL3	9 kHz ... 3 GHz with Tracking Generator	1300.2502.13
R&S FSL6	9 kHz ... 6 GHz	1300.2502.06
R&S FSL6	9 kHz ... 6 GHz with Tracking Generator	1300.2502.16

WiMAX Option

R&S FSL-K92	Application Firmware IEEE 802.16-2004	1302.0236.02
R&S FSL-K93	Application Firmware IEEE 802.16e-2005	1302.0736.02
R&S FSL-K92U	Upgrade from FSL-K92 to FSL-K93	1302.0307.02

Spectrum Analyzer FSP

R&S FSP3	9 kHz ... 3 GHz	1164.4391.03
R&S FSP7	9 kHz ... 7 GHz	1164.4391.07
R&S FSP13	9 kHz ... 13.6 GHz	1164.4391.13
R&S FSP30	9 kHz ... 30 GHz	1164.4391.30
R&S FSP40	9 kHz ... 40 GHz	1164.4391.40

WiMAX Option

R&S FSP-K93	Application Firmware IEEE 802.16e-2005	1308.5500.02

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

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