Carrier aggregation for IEEE 802.16m. Signal Generation and Analysis

Application Note

Products:

- R&S®SMU200A
- R&S®SMBV100A
- R&S®AMU200A
- R&S®FSQ
- R&S®FSG
- R&S®FSV
- R&S®FSL

This Application Note describes signal generation with carrier aggregation for 802.16m based on 802.16e signals in practical important configurations using one or more Vector Signal Generators R&S®SMU200A or R&S®SMBV100A. Various examples illustrate how to analyze these signals using the Vector Signal Analyzer R&S®FSQ, R&S®FSG or R&S®FSV.

ROHDE&SCHWARZ

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1 Introduction

The ITU (International Telecommunication Union) has coined the term IMT-Advanced to identify mobile system capabilities going beyond those of IMT-2000. The data rate requirements have been further increased in order to support advanced services and applications like mobile Internet. For WiMAX, these enhancements are being investigated for 802.16m or Release 2.0. The proposed high peak-data rate targets for 802.16m of 1 Gbps in can only be fulfilled with a further increase of the transmission bandwidth. Therefore transmission bandwidths up to 100 MHz are planned for 802.16m. Being an evolution of mobile WiMAX (802.16e), 802.16m will be backwards compatible in the legacy mode. It will be possible to deploy 802.16m in a spectrum already occupied by 802.16e with no impact on existing WiMAX terminals.
This can be achieved with the legacy support, where DL and UL are divided into an 802.16e and an 802.16m zone.
So first developments for 802.16m for basic components with long development cycles such as power amplifiers have already started. With the capability to generate and analyze multiple 802.16e carriers, measurements performed today are transferable to later real 802.16m systems.
The 802.16m release is planned for mid of 2010. With finalising the conformance specifications from the WiMAX Forum® which are related to Release 2.0 the commercial deployment is planned for End of 2011 onwards.
This Application Note describes WiMAX 802.16e signal generation with carrier aggregation for 802.16m in practical important configurations using one or more Vector Signal Generators R&S®SMU200A or R&S®SMBV100A. Various examples illustrate how to analyze these signals using the Vector Signal Analyzer R&S®FSQ, R&S®FSG or R&S®FSV.
The detailed modifications of the 802.16m carriers compared to 802.16e carriers are not assumed to have major influence on 802.16m component tests such as power amplifier tests.
With the capability to generate and analyze multiple 802.16e carriers, measurements performed today are transferrable to later real 802.16m systems.

Besides spectrum aggregation, 802.16m comprises further enhancements, including enhanced MIMO (Multiple Input - Multiple Output) schemes, FFR (fractional frequency reuse), CoMP (Coordinated Multiple Point transmission and reception) and more which are not covered by this application note. A complete 802.16m technology introduction is provided by application note 1MA167.

The following abbreviations are used in this application note for R&S® test equipment:
The R&S®SMU200A is referred to as the SMU.
The R&S®SMBV100A is referred to as the SMBV.
The R&S®AMU200A is referred to as the AMU.
The R&S®FSQ is referred to as the FSQ.
The R&S®FSB is referred to as the FSG.
The R&S®FSG is referred to as the FSV.
The FSQ, FSV, and FSG are referred to as the FSx.

2 Overview of 802.16m Frequency Bands and Spectrum Deployment

In order to meet the high data rate requirements of IMT-Advanced, 802.16m extends the support of multi carrier aggregation: Two or more carriers are coupled in order to support wider transmission bandwidths. To a WiMAX 802.16e terminal, each carrier will appear as an independent WiMAX carrier, while an 802.16m terminal can exploit the total aggregated bandwidth. All used carriers are independent in the PHY layer, they are combined in the MAC layer.

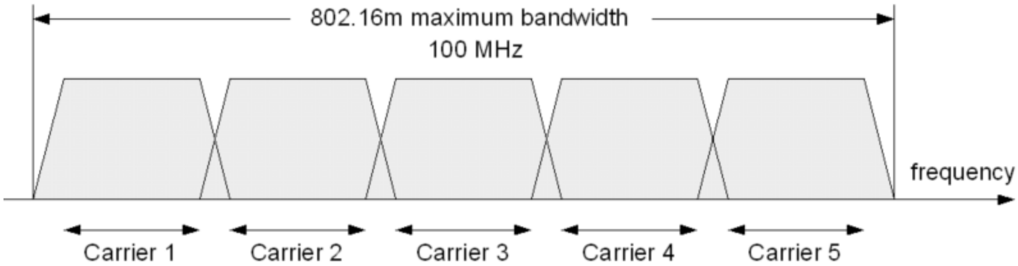


Figure 1: 802.16m maximum bandwidth in contiguous deployment

Spectrum deployment may be either contiguous with adjacent carriers as illustrated in Figure 1, or distributed with distributed carriers as illustrated in Figure 2. Data may be sent either in the same frequency band or in different frequency bands in the later case.

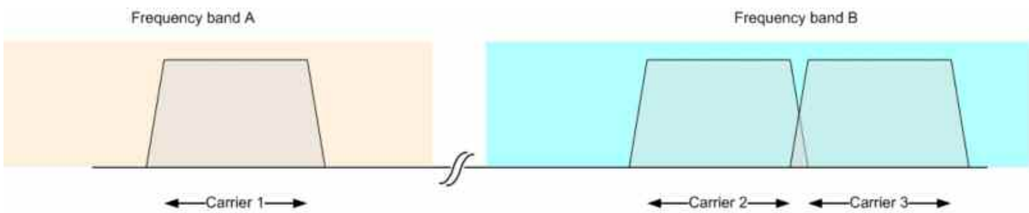


Figure 2: 802.16m distributed spectrum deployment

An 802.16m terminal simultaneously receives one or multiple carriers depending on its capabilities. It will be possible to aggregate a different number of carriers of possibly different bandwidths.
As the WiMAX Forum did not yet define possible deployment scenarios for the different carriers for 802.16m, the deployment scenarios that have been considered for initial investigation within the 3GPP feasibility study for LTE-Advanced are shown in Table 1. Agreed deployment scenarios for initial investigation in order to meet the ITU-R submission timescales are shaded in Table 1.
Latest discussions in the WiMAX Forum and IEEE show that 802.16m will likely focus in the first step on carrier aggregation with 2 carriers, i.e. 2x 20MHz, both in TDD. This will not preclude a higher number of aggregated carriers in later deployments. In 3GPP a similar discussion for LTE-Advanced takes place.

Table 1:
Deployment scenarios with the highest priority for the feasibility study (Table 5.1.2.1 of 3GPP TR 36.815 V0.3.0 (2009-10)).
Deployment scenarios for ITU-R submission 1, 2, 7 and 10 are shaded.

Scenario No.	Deployment Scenario	Transmission BWs of LTE-A carriers	No of LTE-A carriers	Bands for LTE-A carriers	Duplex modes
1	Single-band contiguous spec. alloc. @ 3.5 GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Contiguous 2x20 MHz component carriers (CCs) DL: Contiguous 4x20 MHz CCs	3.5 GHz band	FDD
2	Single-band contiguous spec. alloc. @ Band 40 for TDD	100 MHz	Contiguous 5x20 MHz CCs	Band 40 (2.3 GHz)	TDD
3	Single-band contiguous spec. alloc. @ 3.5 GHz band for TDD	100 MHz	Contiguous 5x20 MHz CCs	3.5 GHz band	TDD
4	Single-band, distributed spec. alloc. @ 3.5 GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Distributed 20 + 20 MHz CCs DL: Distributed 2x20 + 2x20 MHz CCs	3.5 GHz band	FDD
5	Single-band distributed spec. alloc. @ Band 8 for FDD	UL: 10 MHz DL: 10 MHz	UL/DL: Distributed 5 MHz + 5 MHz CCs	Band 8 (900 MHz)	FDD
6	Single-band distributed spec. alloc. @ Band 38 for TDD	80 MHz	Distributed 2x20 + 2x20 MHz CCs	Band 38 (2.6 GHz)	TDD
7	Multi-band distributed spec. alloc. @ Band 1, 3 and 7 for FDD	UL: 40 MHz DL: 40 MHz	UL/DL: Distributed 10 MHz CC@Band 1 + 10 MHz CC@Band 3 + 20 MHz CC@Band 7	Band 3 (1.8 GHz) Band 1 (2.1 GHz) Band 7 (2.6 GHz)	FDD
8	Multi-band distributed spec. alloc. @ Band 1 and Band 3 for FDD	30 MHz	Distributed 1x15 + 1x15 MHz CCs	Band 1 (2.1 GHz) Band 3 (1.8 GHz)	FDD
9	Multi-band distributed spec. alloc. @ 800 MHz band and Band 8 for FDD	UL: 20 MHz DL: 20 MHz	UL/DL: Distributed 10 MHz CC@UHF + 10 MHz CC@Band 8	800 MHz band Band 8 (900 MHz)	FDD
10	Multi-band distributed spec. alloc. @ Band 39, 34, and 40 for TDD	90 MHz	Distributed 2x20 + 10 + 2x20 MHz CCs	Band 39 (1.8 GHz) Band 34 (2.1 GHz) Band 40 (2.3 GHz)	TDD
11	Single-band Contiguous spec. alloc @ Band 7 for FDD	UL: 20 MHz DL: 40 MHz	UL: 1x20 MHz CCs DL: 2x20 MHz CCs	Band 7 (2.6 GHz)	FDD
12	Multi-band distributed spec. alloc. @ Band 7 and the 3.5 GHz range for FDD	UL: 20 MHz DL: 60 MHz	UL/DL: 20 MHz CCs @ Band 7 DL : Non- contiguous 20 + 20 MHz CCs @ 3.5 GHz band	Band 7 (2.6 GHz) 3.5 GHz band	FDD

Operating bands of 802.16m will involve E-UTRA operating bands as well as IMT bands identified by ITU-R. E-UTRA operating bands are shown in Table 2.

Table 2: Operating Bands for IMT-Advanced

Operating Band	Uplink (UL) operating band BS receive/UE transmit			Downlink (DL) operating band BS transmit /UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_hig}	F_{DL_low}	–	F_{UL_hig}	
1	1920 MHz	-	1980 MHz	2110 MHz	-	2170 MHz	FDD
2	1850 MHz	-	1910 MHz	1930 MHz	-	1990 MHz	FDD
3	1710 MHz	-	1785 MHz	1805 MHz	-	1880 MHz	FDD
4	1710 MHz	-	1755 MHz	2110 MHz	-	2155 MHz	FDD
5	824 MHz	-	849 MHz	869 MHz	-	894 MHz	FDD
6	830 MHz	-	840 MHz	865 MHz	-	875 MHz	FDD
7	2500 MHz	-	2570 MHz	2620 MHz	-	2690 MHz	FDD
8	880 MHz	-	915 MHz	925 MHz	-	960 MHz	FDD
9	1749.9 MHz	-	1784.9 MHz	1844.9 MHz	-	1879.9 MHz	FDD
10	1710 MHz	-	1770 MHz	2110 MHz	-	2170 MHz	FDD
11	1427.9 MHz	-	1447.9 MHz	1475.9 MHz	-	1495.9 MHz	FDD
12	698 MHz	-	716 MHz	728 MHz	-	746 MHz	FDD
13	777 MHz	-	787 MHz	746 MHz	-	756 MHz	FDD
14	788 MHz	-	798 MHz	758 MHz	-	768 MHz	FDD
15	Reserved			Reserved			-
16	Reserved			Reserved			-
17	704 MHz	-	716 MHz	734 MHz	-	746 MHz	FDD
18	815 MHz	-	830 MHz	860 MHz	-	875 MHz	FDD
19	830 MHz	-	845 MHz	875 MHz	-	890 MHz	FDD
20	832 MHz	-	862 MHz	791 MHz	-	821 MHz	FDD
21	1447.9 MHz	-	1462.9 MHz	1495.9 MHz	-	1510.9 MHz	FDD
22	3410 MHz	-	3500 MHz	3510 MHz	-	3600 MHz	FDD
...							-
33	1900 MHz	-	1920 MHz	1900 MHz	-	1920 MHz	TDD
34	2010 MHz	-	2025 MHz	2010 MHz	-	2025 MHz	TDD
35	1850 MHz	-	1910 MHz	1850 MHz	-	1910 MHz	TDD
36	1930 MHz	-	1990 MHz	1930 MHz	-	1990 MHz	TDD
37	1910 MHz	-	1930 MHz	1910 MHz	-	1930 MHz	TDD
38	2570 MHz	-	2620 MHz	2570 MHz	-	2620 MHz	TDD
39	1880 MHz	-	1920 MHz	1880 MHz	-	1920 MHz	TDD
40	2300 MHz	-	2400 MHz	2300 MHz	-	2400 MHz	TDD
41	3400 MHz	-	3600 MHz	3400 MHz	-	3600 MHz	TDD

Today's mobile WiMAX deployments focus on the bands 38, 40 and 41, like shown in Table 2.

Table 3 shows the defined WiMAX Forum profiles, which are defined for 802.16e. 802.16m likely will be deployed in the todays WiMAX profile bands and additionally in IMT-Advanced bands.

Table 3: WiMAX profiles (802.16e)

Profile Name	Frequency Range	Channel Bandwidth	FFT Size	Duplexing Mode
MP01	2.3 - 2.4 GHz	8.75 MHz	1024	TDD
MP02	2.3 - 2.4 GHz	5, 10 MHz	512, 1024	TDD
MP03	2.305 - 2.320 GHz, 2.345 - 2.360 GHz	5 MHz	512	TDD
MP04	2.305 - 2.320 GHz, 2.345 - 2.360 GHz	10 MHz	1024	TDD
MP05	2.496 - 2.69 GHz	5, 10 MHz	512, 1024	TDD
MP06	3.3 - 3.4 GHz	5 MHz	512	TDD
MP07	3.3 - 3.4 GHz	7 MHz	1024	TDD
MP08	3.4 - 3.8 GHz	5 MHz	512	TDD
MP09	3.4 - 3.6 GHz	5 MHz	512	TDD
MP10	3.4 - 3.6 GHz	7 MHz	1024	TDD
MP11	3.4 - 3.8 GHz	10 MHz	1024	TDD
MP12	3.4 - 3.8 GHz	10 MHz	1024	TDD

With the below described solutions, all discussed scenarios can be generated with Rohde & Schwarz signal generators.

As 802.16m might be deployed first in today's WiMAX bands, this Application Note focuses on 2.3 and 3.5 GHz, which are important WiMAX bands of today.
Even when first discussions focus on 2 carrier operations like 2 x 20 MHz in the first step and 2 x 10 MHz and 10 MHz with 25 MHz in the second setp, this Application Note describes deployment scenarios within different bands and up to 5 carriers.

3 Differences between 802.16e and 802.16m

The 802.16m standard, which is related to Release 2.0 certification, is compared to the Release 1.0 certification of the 802.16e (today 802.16-2009) standard. In chapter 2 the multi carrier operation of 802.16m is described. In chapter 3.1 the guard band usage, which has changed to Release 1.0 is described.
The following chapter 3.2 describes further physical Layer changes.
In detail, the differences are described in the technology Introduction Application Note 1MA167.

3.1 Bandwidth and Synchronisation of 802.16m Signals

The 802.16e signal with carrier aggregation is a very good assumption for testing 802.16m components.
The 802.16m carrier bandwith is typically 10, 20 and 25 MHz. 802.16e supports typically 5 and 10 MHz, but the standard allows also bandwidths up to 28 MHz.
The Rohde & Schwarz instruments allow an easy parametrisation of the bandwidth up to 28 MHz, also for OFDMA signals and cover so all discussed carrier bandwidths for 802.16m.
The Test signals used in this Application Note are based on the 802.16-2009 standard, also referred to as 802.16e, which is conform to the brownfield mode of 802.16m.

802.16m reduced additionally in the MZone slightsly the guard bands and increased the used bandwidth for increasing the data rate. Some carriers from the guard bands are used for data and pilots. Additionally 802.16m supports a usage of the guard bands of contiguous carriers.
Both details can not exactly be simulated with 802.16e signals, but as you have eg. the carrier information of two contiguous carriers, you can make assumptions of the band inbetween two carriers, or you test in dedicated cases with higher bandwidth.
Both technical details are described in the Application Note: Technology Introduction of 802.16m 1MA167 and shown in Figure 3.

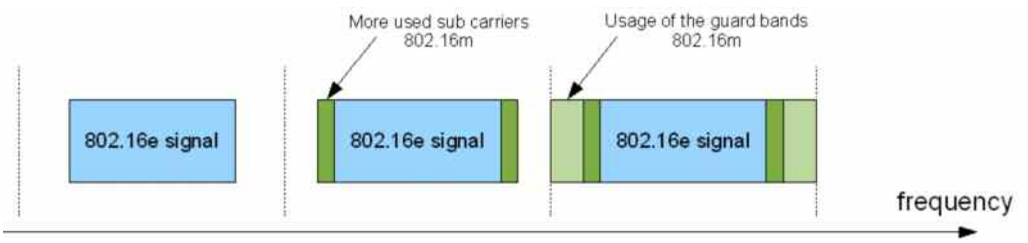


Figure 3:usage of the guard bands in 802.16m

3.2 802.16m compared to 802.16e

Beside the multi carrier operation, 802.16m improved the following functionality on the PHY Layer:

- MIMO support (2x2 is mandatory)
- Additional FDD support (Release 1.0 only supported TDD)
- Relay station support
- Femto cell support
- Self organising network (SON) support
- Cooperative multi point (CoMP) support
- Legacy support for backwards compatibility

4 802.16m Signal Generation with R&S Signal Generators

R&S signal generators offer many features that are recommended when generating signals with multi carrier aggregation according to 802.16m requirements. This is especially true for the 2-path concept of the SMU signal generator (Figure 4) which combines up to 2 independent signal generators in one single instrument.

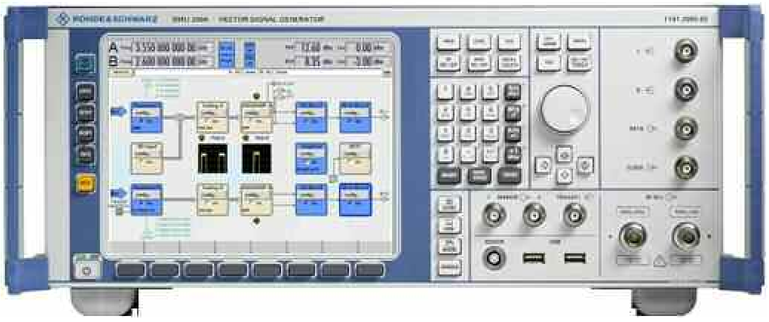


Figure 4: Vector Signal Generator SMU front view

In order to generate 802.16m signals with multi carrier aggregation according to Table 1, different principles can be used:

- Addition of signals in baseband: Within one SMU signal generator two baseband units can be configured, thus two carriers can be generated in real-time and added in baseband, either with contiguous or distributed placement. For scenarios with more than two carriers, with an additional AMU signal generator or a second SMU two extra carriers can be added in baseband via the digital baseband interface.
- Addition of signals in the RF domain: Of course the signals from different carriers can be added in the RF domain as well by using an RF power combiner.
- Using the Multi-carrier Arbitrary Waveform capability: This is a very cost-efficient approach available with all R&S signal generators.
- Mixed solutions: Combinations of the above-mentioned approaches may be required or useful for certain scenarios.

The following chapters explain the different approaches in more detail and highlight the benefits and possible limitations of each variant.

4.1 Signal Generation with an SMU

All the advantages of the SMU two-path concept become evident especially when generating 802.16m signals in various configurations. Because the baseband section of the SMU is digital, the signals of the two baseband generators can be added to one RF output without synchronization problems and without an external coupler or additional equipment being required. Each signal's frequency offset and relative power can be set accurately. Both baseband generators can generate a single carrier in real-time. The signals can then be added in the digital domain with a frequency offset, in contiguous placement or distributed placement.

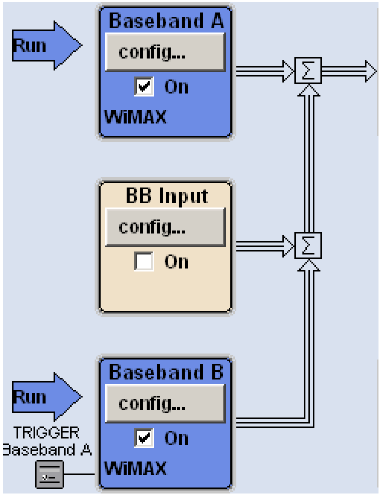


Figure 5: Baseband A and B are combined to path A with adjustable frequency offsets

Due to the SMU baseband generator's 80 MHz real-time bandwidth two carriers with 20 MHz bandwidth each can be placed with a maximum frequency offset of ± 30 MHz. Thus a maximum gap of 40 MHz is possible with 2 x 20 MHz carriers in distributed placement, see Figure 6.

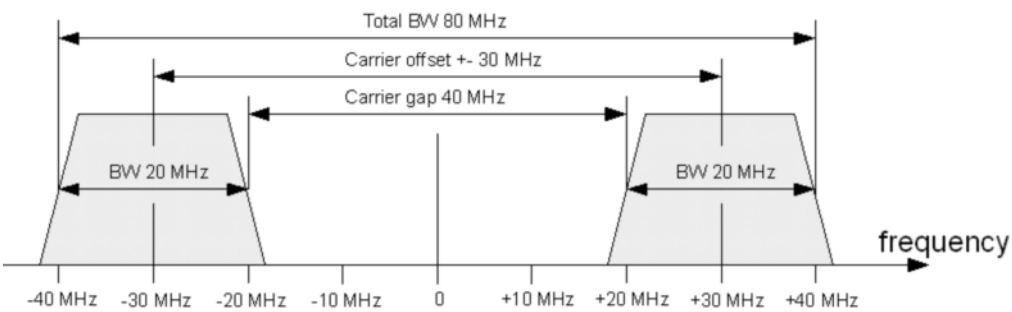


Figure 6: Two carriers with 40 MHz gap

Figure 7 shows a resulting test setup with one SMU and a signal analyzer that is used to investigate the spectrum of the 802.16m signal.

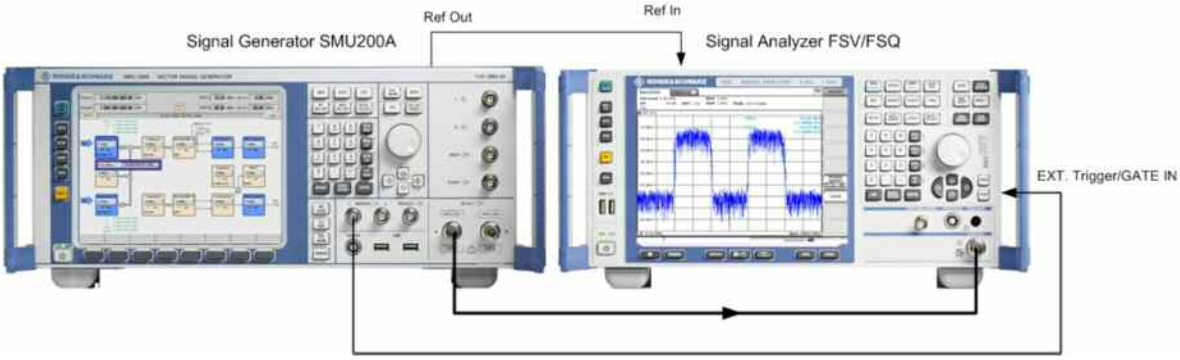


Figure 7: Test setup for generating a 2-carrier 802.16m signal in contiguous or distributed mode (addition in baseband)

Note:
All following pictures of the SMU show the model with 2 RF and 2 baseband channels, even if only one channel is used.

4.1.1 Contiguous Placement of 2 WiMAX Signals with 20 MHz Bandwidth (Addition in Baseband)

This chapter explains how to generate 2 carriers with each 20 MHz based on an 802.16e signal in TDD as an example.

Select a WIMAX 802.16e Signal in baseband A and set Channel Bandwidth to 20 MHz as seen below. Do the same in baseband B.

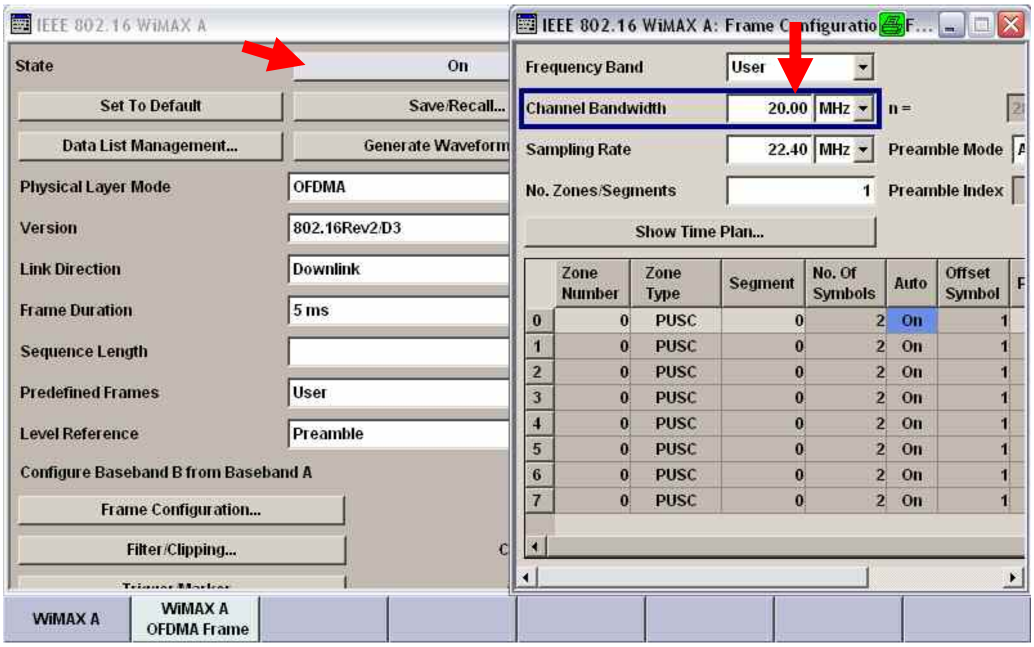


Figure 8: Generating an WIMAX 802.16e Signal with 20 MHz bandwidth

Set baseband A to a frequency offset of -10 MHz shifting the SMU output signal to 10 MHz below the selected RF Frequency (2.330 GHz).
Set baseband B to a frequency offset of +10 MHz shifting the SMU output signal to 10 MHz above the selected RF frequency.
Root baseband B to path A to combine it with baseband A to a contiguously placed 802.16e signal containing two 20 MHz carriers as seen in Figure 9 and Figure 10.

Hint:

It is recommended to set symmetrical offsets for baseband A and B. Thus the carrier feed through (as seen mid of Figure 14) will not affect the combined carriers. Intermodulation products are also minimized.

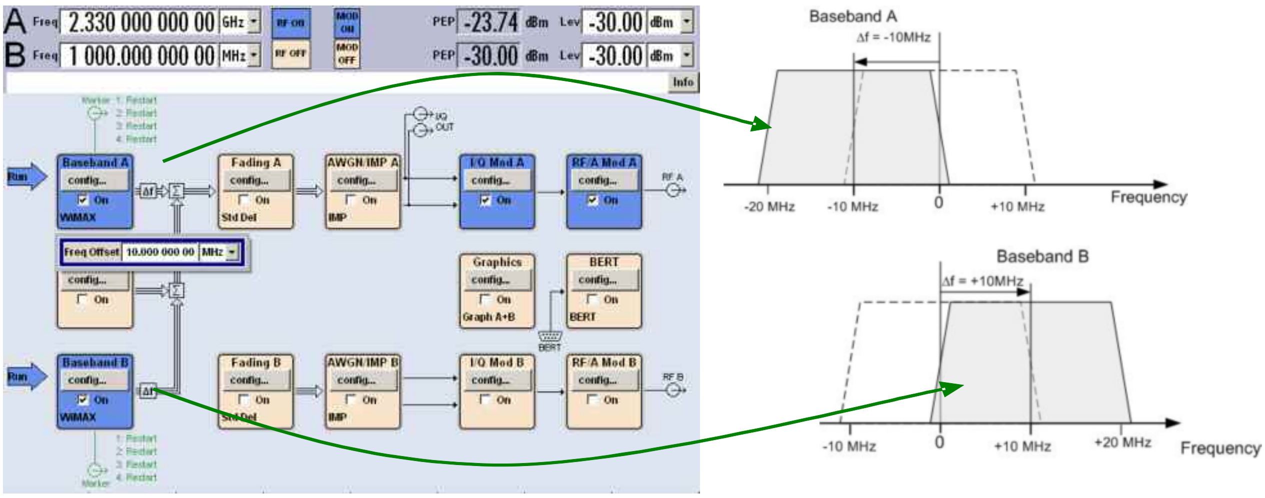


Figure 9: Baseband A is set to a frequency offset of -10 MHz, baseband B to a frequency offset of + 10MHz.

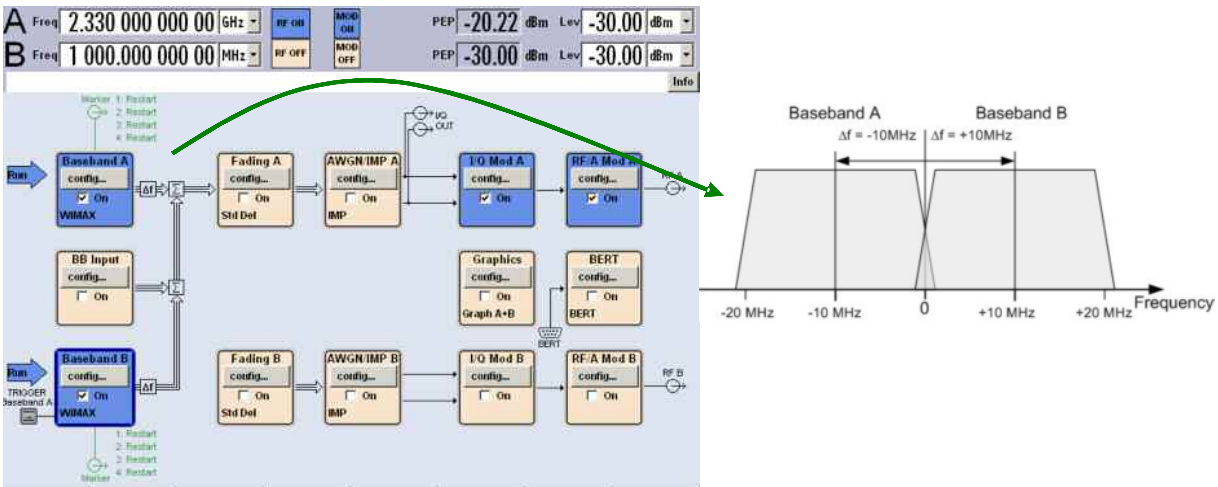


Figure 10: Baseband B is routed to baseband A to produce a contiguously placed 802.16m signal containing two carriers with 20 MHz bandwidth each.

To start the carriers produced by baseband A and B synchronously, set the trigger source of baseband B to *Internal (Baseband A)* in Mode *Armed Auto* as seen in Figure 11. Switch baseband A off and on afterwards to run baseband B.

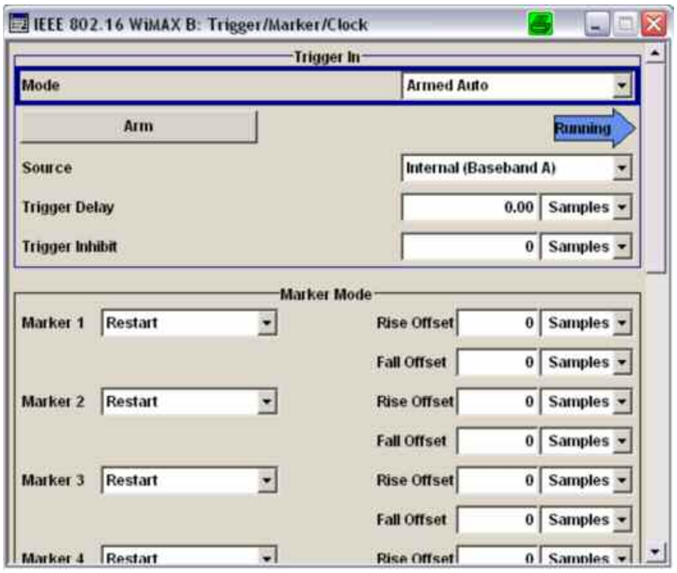


Figure 11: Trigger In of baseband B is set to trigger source Internal (baseband A) in mode Armed Auto, to start baseband A and B synchronously.

Figure 12 shows the output spectrum generated by an SMU as described above measured with an FSV.

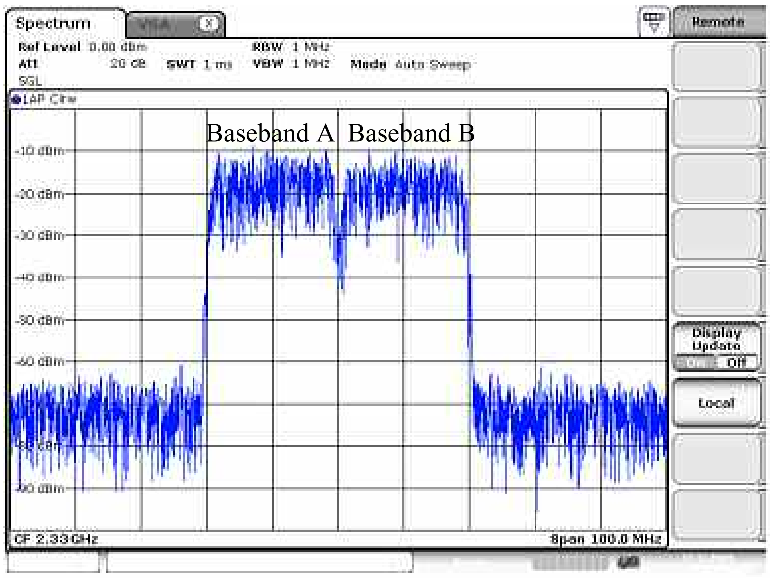


Figure 12: Spectrum of two contiguously placed 20 MHz WIMAX 802.16e Signals generated by an SMU as described above.

4.1.2 Distributed Placement of Two WIMAX 802.16e Carriers (Addition in Baseband)

Due to the large real-time bandwidth of 80 MHz, two WIMAX 802.16e signals with 20 MHz bandwidth each can be placed distributedly with a maximum offset up to 60 MHz (each baseband + or - 30 MHz). Setups for smaller bandwidths or offsets can be derived easily from this scenario.

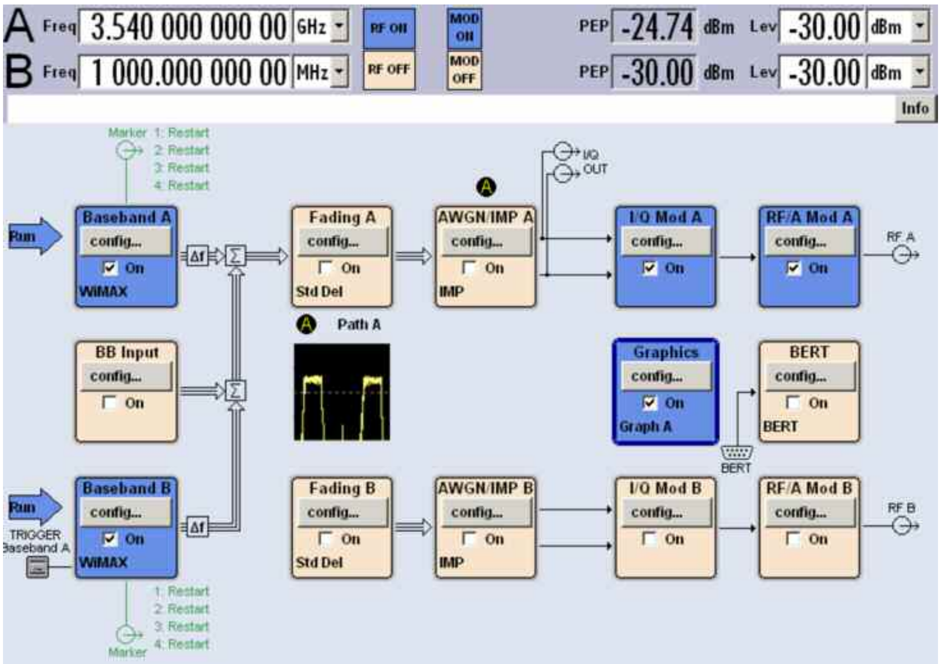


Figure 13: SMU Screen: Combining 2 baseband signals distributed in an SMU (addition in baseband)

The distributed placement of the carriers is shown in band 41, according to Table 2. Set the SMU's center frequency to 3.54 GHz and the offsets of baseband A to -30 MHz and baseband B to +30 MHz to generate two 2 uplink carriers at 3.51 GHz and 3.57 GHz.

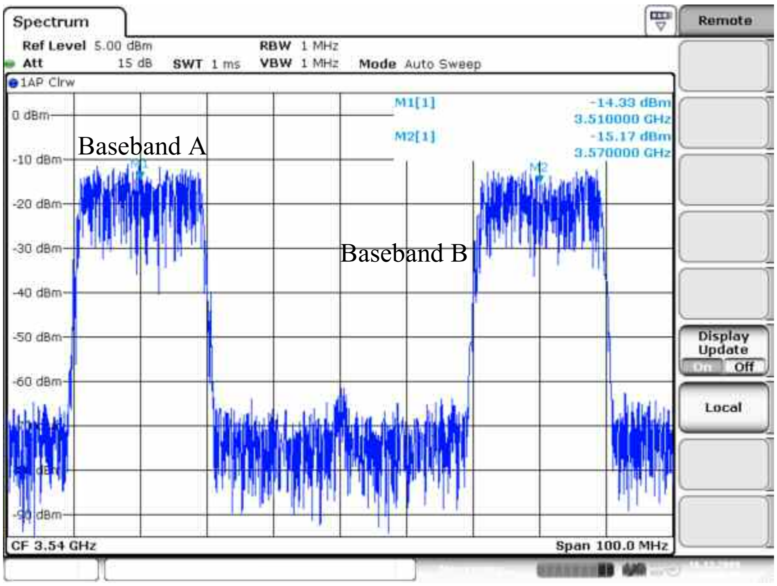


Figure 14: Distributed placement of 2 WIMAX 802.16e carriers with 20 MHz bandwidth each within the WIMAX 802.16e frequency band 3.5 GHz (addition in baseband).

4.1.3 Contiguous or Distributed Placement of 2 WIMAX 802.16e Signals (Addition in the RF Domain)

By using an SMU with 2 baseband and 2 RF channels 2 WIMAX 802.16e signals can also be added in the RF domain with an RF power combiner as illustrated in Figure 15.

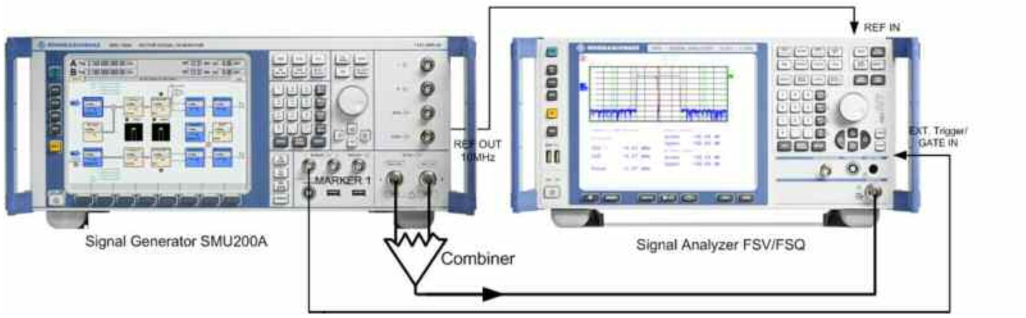


Figure 15: Adding 2 RF channels of an SMU externally with a power combiner to generate 2 WIMAX 802.16e carriers

Because the base band coders of the SMU are independent, both paths support the full bandwidth for multi-band distributed placement. Use an appropriate non-resistive power combiner with good isolation for optimum results.
This configuration exhibits best spectral performance, for example for critical ACLR tests on power amplifiers.
Setup SMU similar to chapter 4.1.1 but set the frequency offsets of baseband A and baseband B to 0 Hz. Set RF frequency A and B to the center frequencies of the wanted carriers, see also Figure 16.

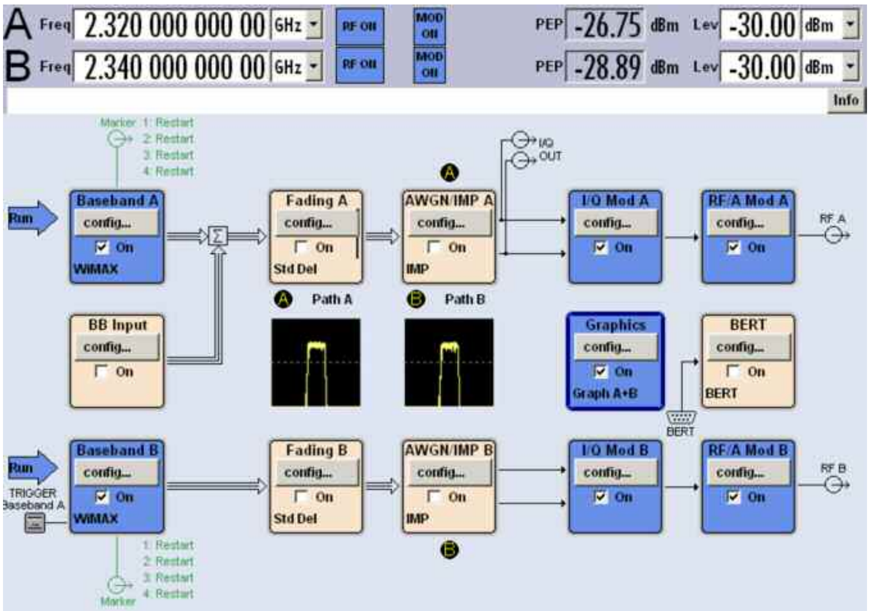


Figure 16: SMU configuration for adding 2 WIMAX 802.16e carriers at RF A and RF B externally with an RF power combiner.

Typical ACLR performance of a 2 carrier signal generated in this manner measured with an FSQ is shown in Figure 15. The ACLR values of -61 dB in the adjacent channels and -61 dB in the alterrnate channels are approximately 3 – 4 dB better as of a signal generated according to chapter 4.1.1.

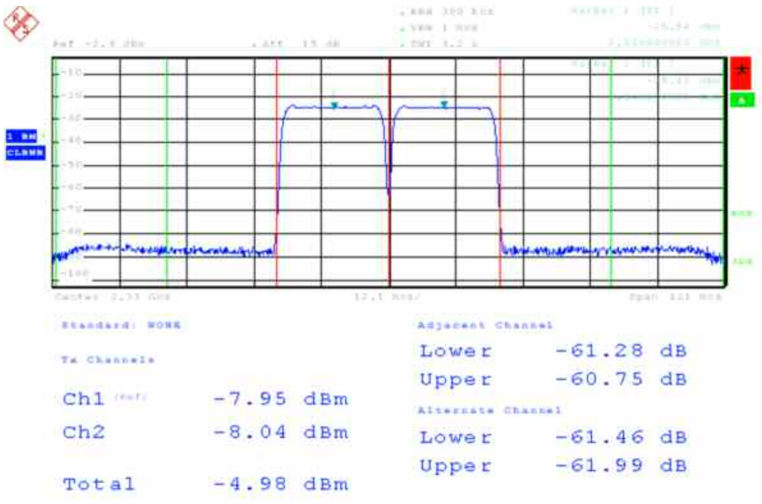


Figure 17: ACLR performance of 2 contiguously placed carriers with 20 MHz bandwidth each, measured with an FSQ.

4.2 Signal Generation with an SMU and Additional AMU or SMU (Addition in baseband)

A 3rd and 4th WIMAX 802.16e baseband can be superimposed to the RF A output signal of the SMU via the digital baseband input. A Baseband Signal Generator AMU200A or a 2nd Vector Signal Generator SMU delivers these additional baseband signals.
Up to 4 carriers with 20 MHz bandwidth each are combined to the SMU's RF output aggregating a total bandwidth of 80 MHz which fits in the 80 MHz real-time bandwidth of the SMU. The setup is shown in Figure 18.

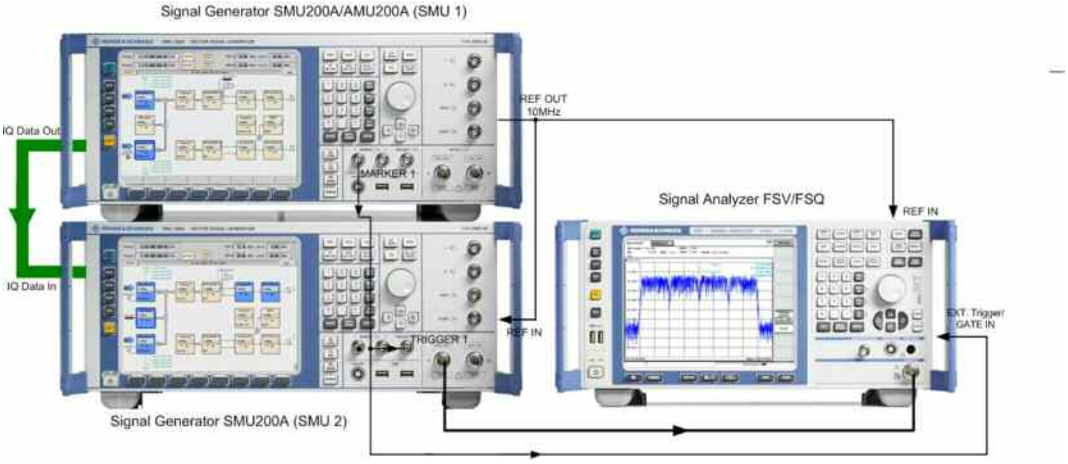


Figure 18: Combining the digital baseband output signal of a second generator

The upper AMU or SMU (SMU1 in Figure 18) is configured like in chapter 4.1.1 but rooted to Digital I/Q Out. Switch on the Digital I/Q Output as seen in Figure 19.

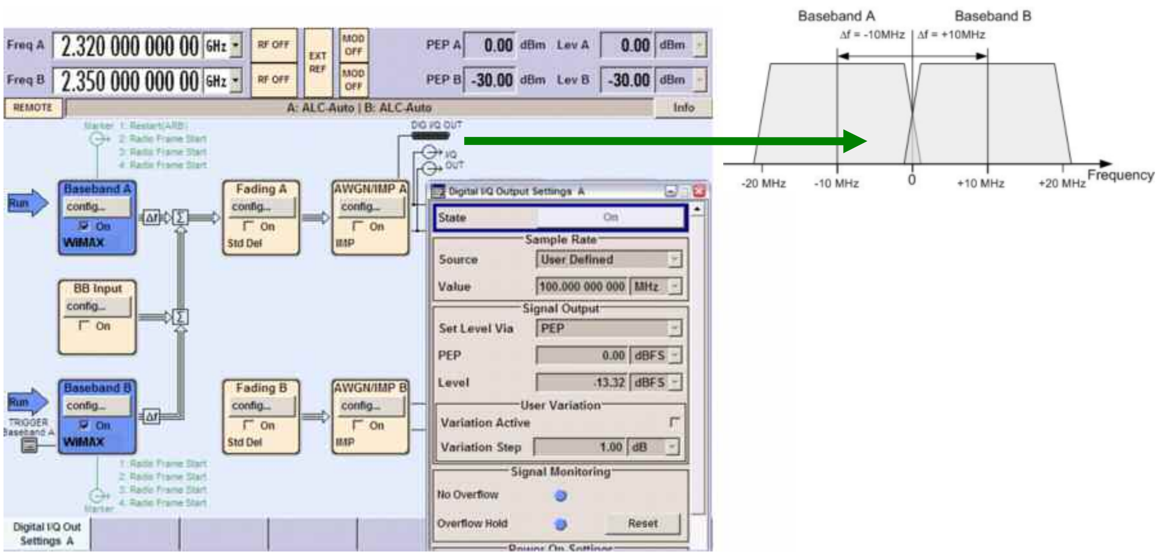


Figure 19: Upper SMU Screen: baseband A&B are combined and output at Digital IQ Out.

The Marker 1 of baseband A in SMU1 is setup to *Restart(ARB)* to get a trigger signal for the lower SMU.

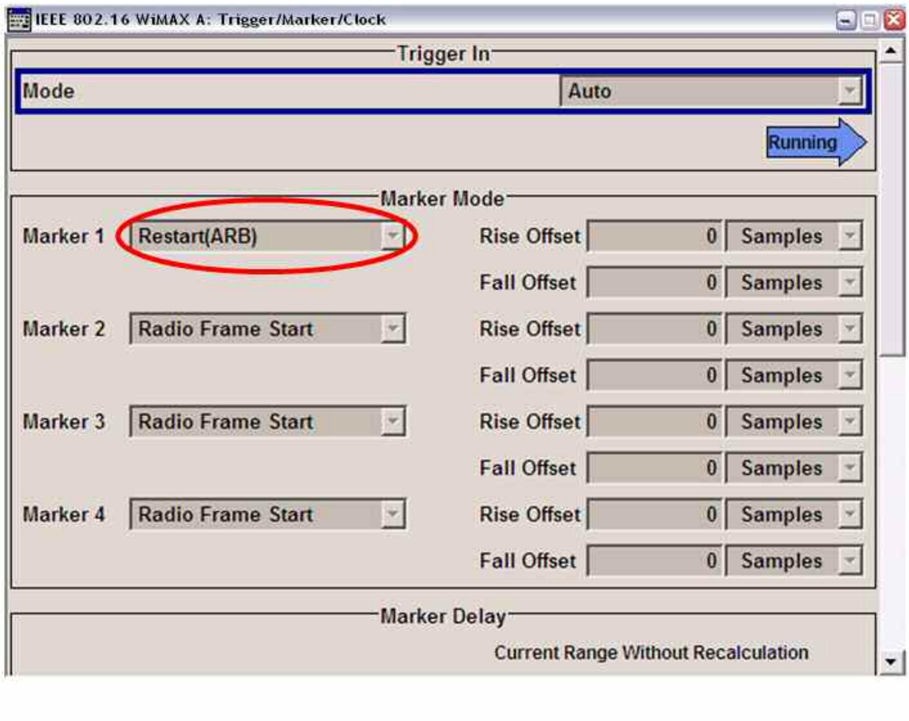


Figure 20: Marker/Trigger Settings of SMU1. Marker 1 is set to Restart(ARB) to get a trigger signal for SMU2 of Figure 18.

Switch on the Digital Baseband Input of the lower SMU (SMU2) and set Sample Rate to *User Defined 100 MHz* as seen in Figure 21.

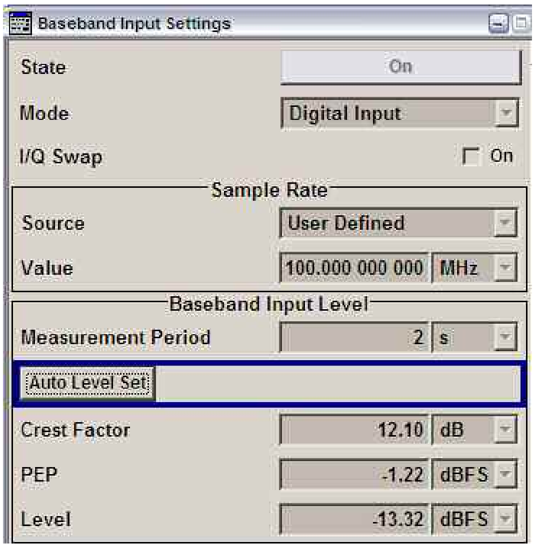


Figure 21: Baseband input settings of SMU2. The sample rate is set to 100 MHz.

Switch on the WIMAX 802.16e Signal in SMU2 baseband A & B, set Channel Bandwidth to 20 MHz for both basebands.

Set baseband A to frequency offset -30 MHz shifting the SMU output signal to 30 MHz below the set RF Frequency. Set baseband B to a frequency offset of +30 MHz shifting the SMU output signal to 30 MHz above the set RF frequency. Root baseband B to path A to combine it with baseband A.

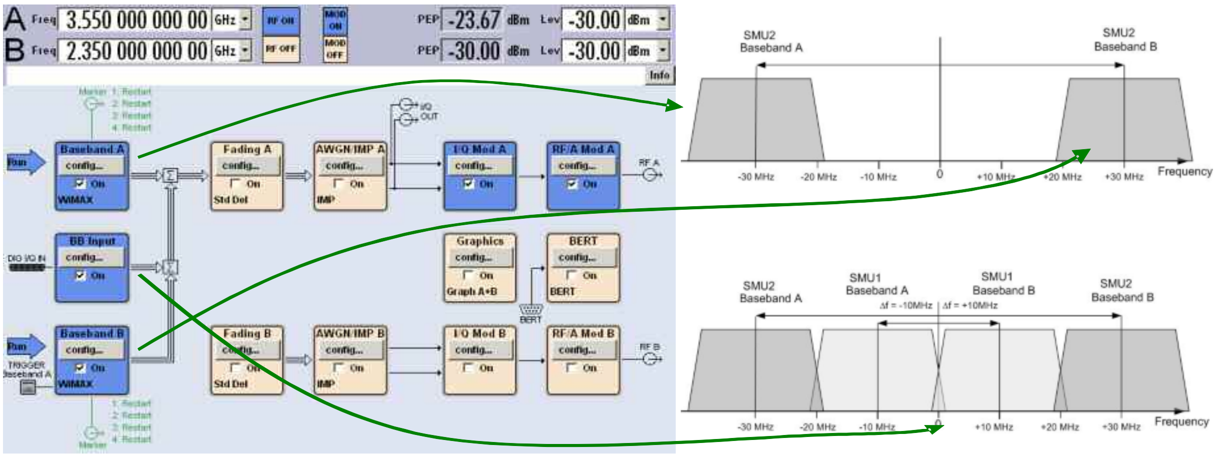


Figure 22: The SMU2 digital baseband input receives the digital baseband signal of SMU1 and combines it with its own baseband A and B to a signal with 4 contiguously placed carriers.

Baseband A and B are triggered by SMU1 Marker1 Output (set to *Restart (ARB))* signal to achieve a synchronous start of all 4 WIMAX 802.16e signals. A trigger delay of approximately 243 samples must be set for a synchronous start of all 4 baseband signals. (Measured with FSx and WIMAX 802.16e Analysis Software, see Figure 40).

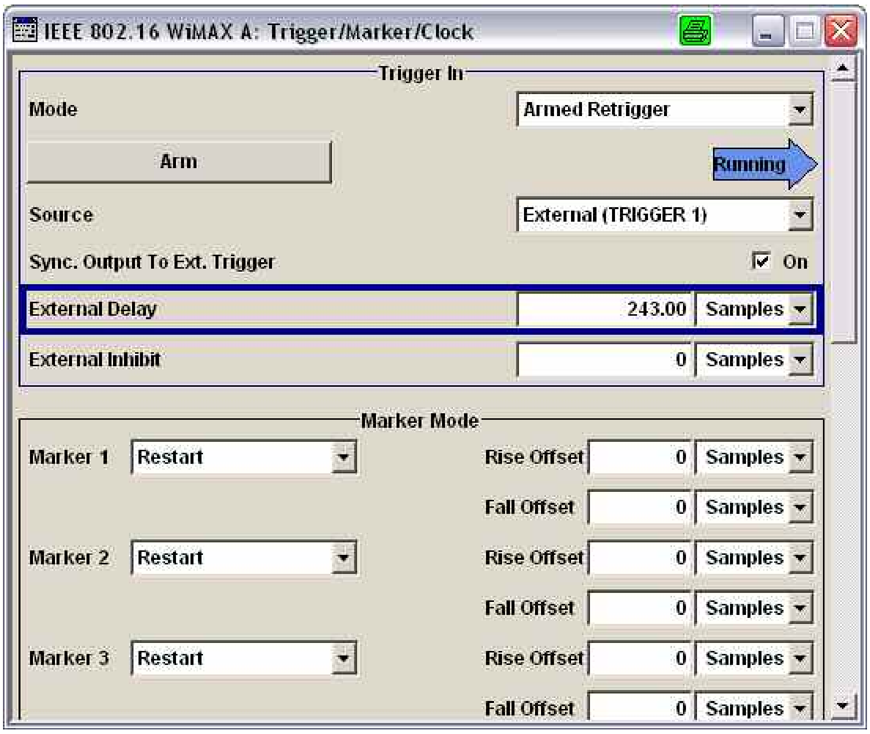


Figure 23: Trigger Settings of SMU2. Adjust External Delay to the same Trigger to Frame Start Offset as the SMU1 signal has.

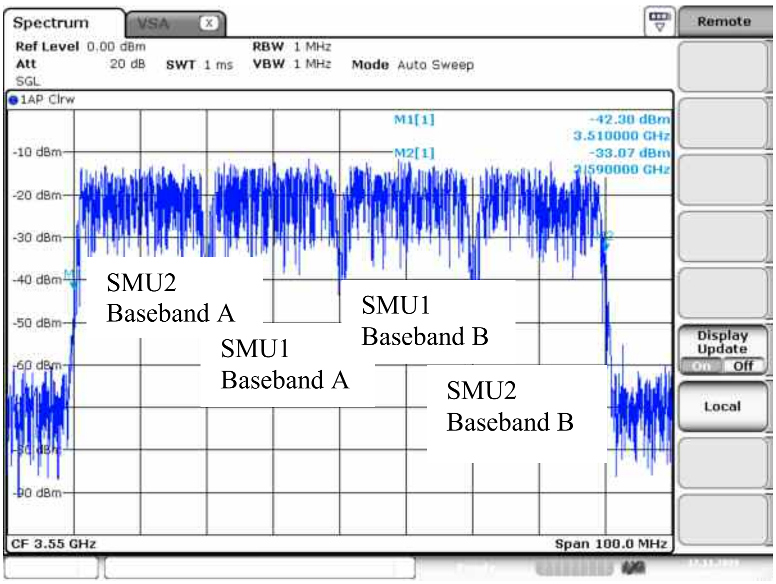


Figure 24: Example carrier aggregation in operating band 24.Up to 4 WIMAX 802.16e carriers with 20 MHz bandwidth each are combined to the SMU's RF A output.

4.3 Using Multi-carrier Arbitrary Waveform

Besides its universal possibilities to create real-time digital modulated signals in different mobile radio standards, the R&S Vector Signal Generators contain a powerful arbitrary waveform generator allowing playback of pre-calculated waveforms. An SMU or SMJ with a waveform memory (up to 128 Msamples) and a clock-rate of 100 MHz is capable of generating pre-calculated complex modulated multi-carrier waveforms with a total RF bandwidth up to 80 MHz. Up to 4 contiguously deployed carriers with 20 MHz bandwidth each can therefore be created with a single 1 channel SMU. The SMBV even has more waveform memory and a higher clock-rate. Its total RF bandwidth of 120 MHz is also wide enough for the proposed contiguously deployed 100 MHz bandwidth. Also distributedly spaced carriers can be generated as long as the total RF bandwidth of 80 or 120 MHz respectively is not exceeded.
Using the Multi-carrier ARB mode is a cost-efficient way to generate 802.16e signals. A single SMBV or SMJ or a one-channel SMU is sufficient. However, changing of the configuration of the different carriers may be more time consuming compared to the other approaches described before.

Following steps are necessary to generate a multi-carrier arbitrary waveform:

1. Setup a real-time WIMAX 802.16e carrier with the desired configuration, then generate and store the waveform file.
2. Repeat step 1 if different configurations are needed in the various carriers.
3. Select the Multi-carrier menu within the arbitrary Waveform Modulation functionality in the baseband generator.
4. Combine the (optionally different) waveform files to a multi-carrier waveform file by filling the ARB multi-carrier table.
5. Press *Create and Load*.

These steps are illustrated in more detail in the following.

4.3.1 Generating 4 Carriers with Contiguous Allocation with an SMU200A or SMBV100A

Setup a real-time WIMAX 802.16e carrier with the wanted configuration, generate a waveform file and store it under a meaningful name (in this example *WIMAX_BW20MHz*).

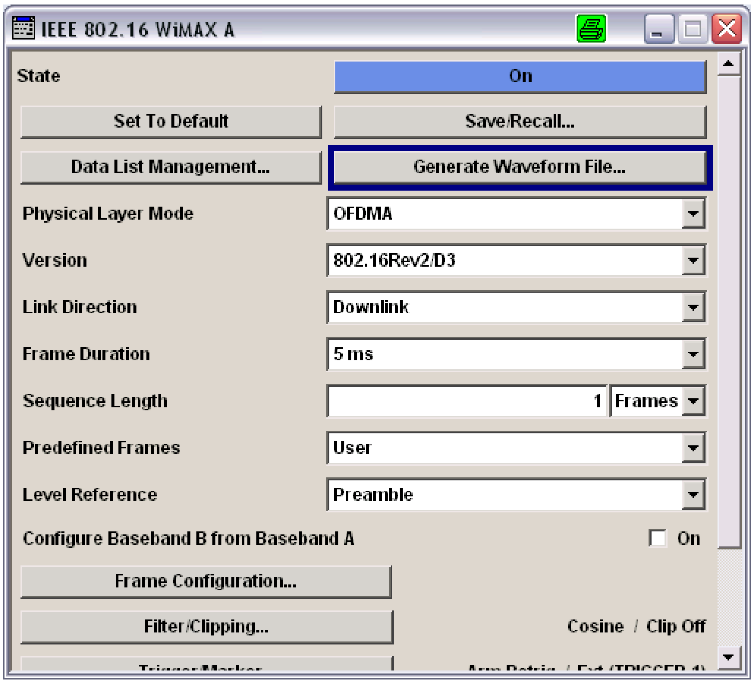


Figure 25: The currently setup WIMAX 802.16e signal is saved as an arbitrary waveform file via the softkey "Generate Waveform File…"

Select ***MENU****:ARB:Multicarrier* and set *Number of Carriers* and *Carrier Spacing* like in Figure 26. Then select *Carrier Table.*

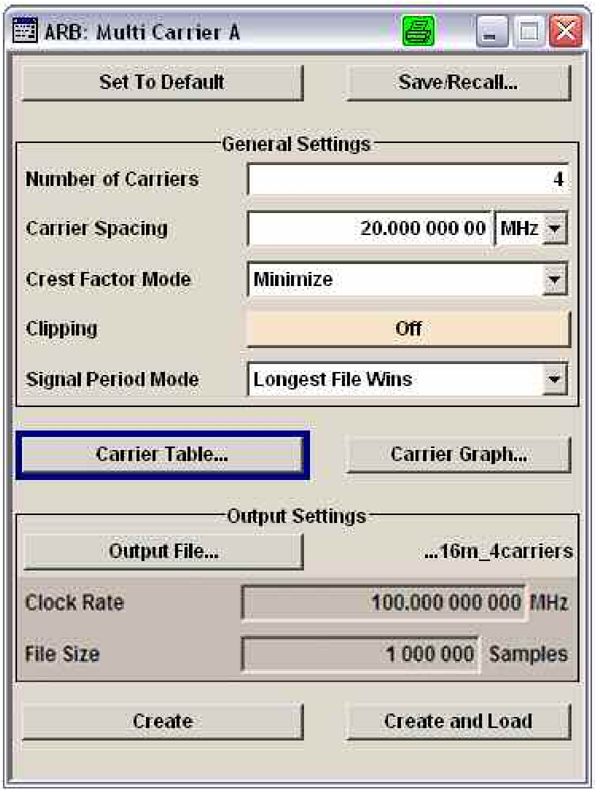


Figure 26:SMU/SMBV screen detail: setup the multi-carrier signal with 4 carriers with a spacing of 20 MHz

Fill the multi-carrier table as shown in Figure 27. Within the column *File* the appropriate waveform files are referenced (different files could be set for different carriers if necessary). Each carrier can be switched on or off in the column *State.* Optionally also different levels, phases and delays can be set for the different carriers via *Gain[dB*], *Phase[deg]* and *Delay[ns]*.
Press ***Escape*** after completing the multi-carrier table.

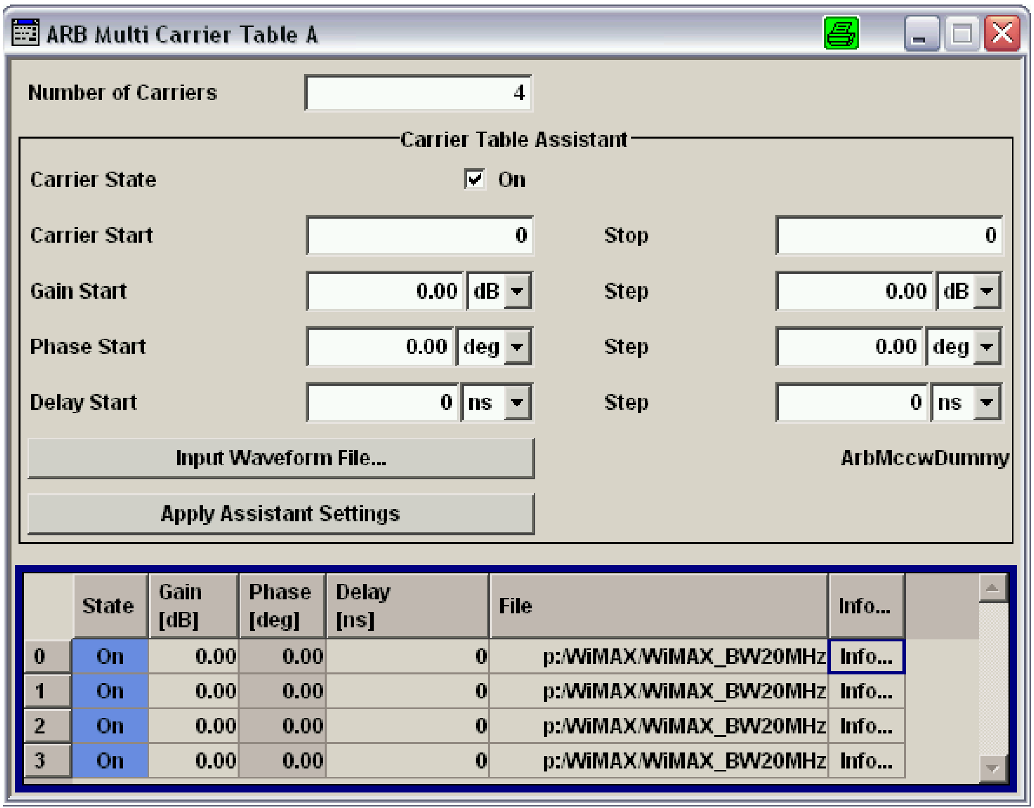


Figure 27: SMU/SMBV Screen Detail: multi-carrier table configuration

Set Output File name (via *Output File ….)* for a later reload of the multi-carrier waveform, then press *Create and Load:*

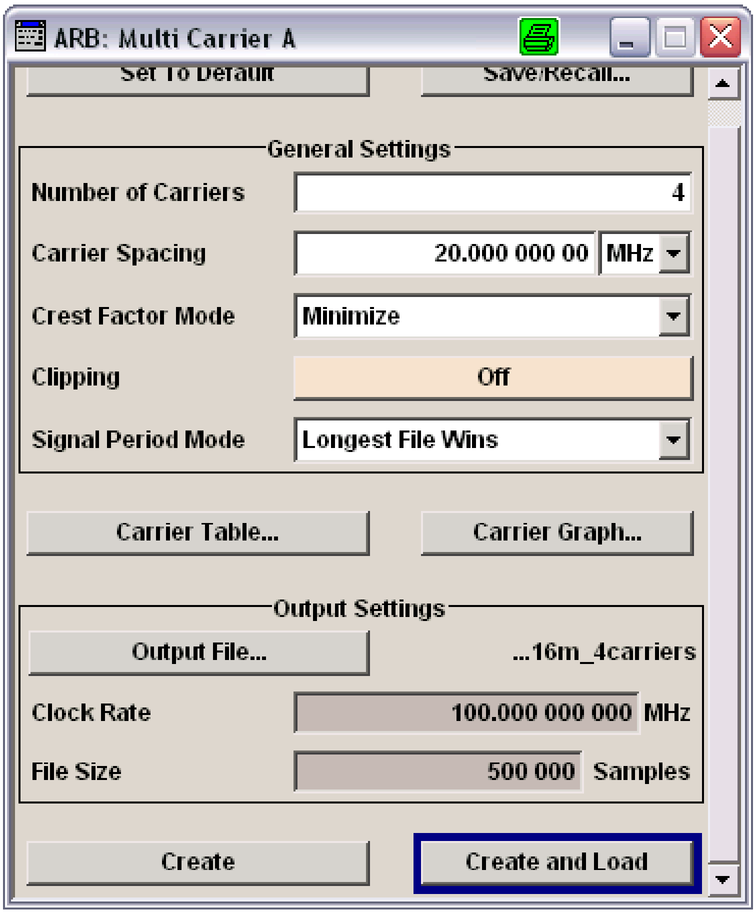


Figure 28: SMU/SMBV Screen detail: The 4-carrier signal is created and loaded via "Create and Load"

The multi-carrier waveform file is now generated.

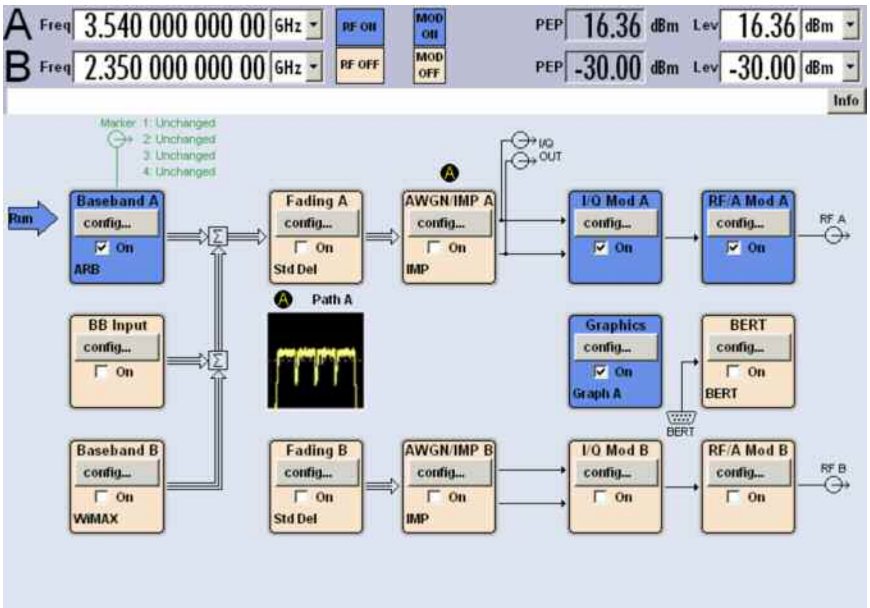
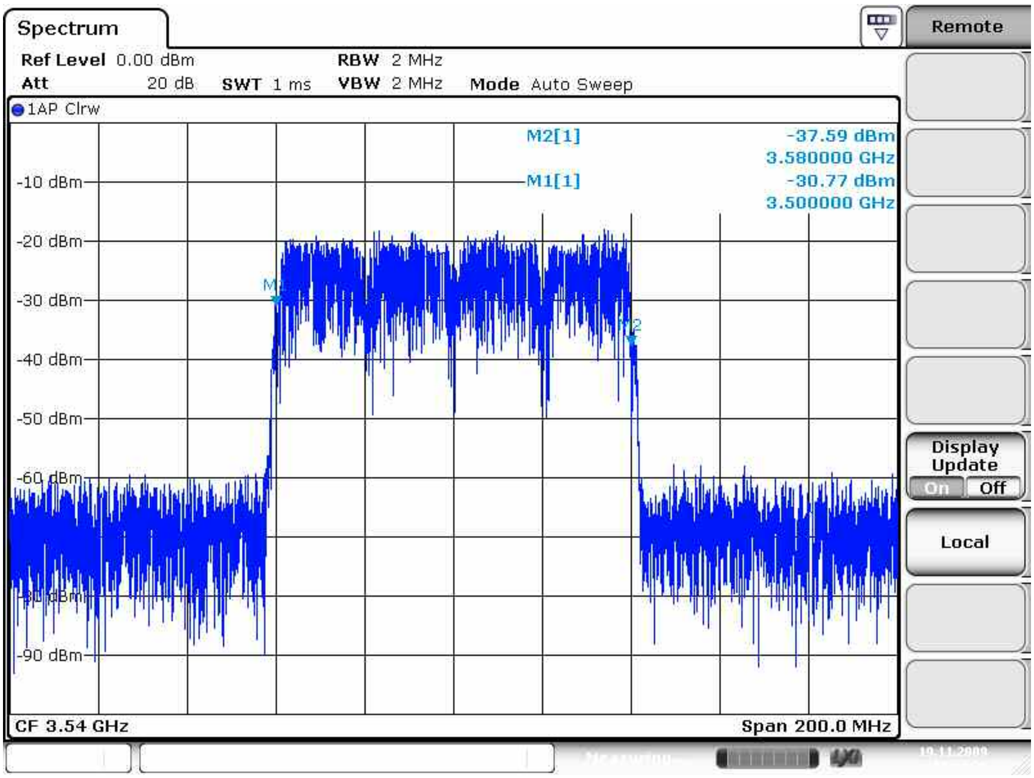


Figure 29: SMU Screen: 802.16m signal with 4 contiguously placed carriers, each with 20 MHz bandwidth using the Multi-carrier arbitrary Waveform mode.



Date: 19.NOV.2009 17:21:36

Figure 30: Contiguous placement of 4 x20 MHz carriers (Multi-carrier arbitrary Waveform mode)

4.3.2 Generating 5 Carriers with Contiguous Allocation with an SMU200A or SMBV100A

There are 2 recommendable ways for generating a contiguous transmission bandwidth of 100 MHz (5x 20 MHz WIMAX 802.16e Carriers). By using a 2-channel SMU (with 2 RF and 2 baseband modules) and combining RF A and RF B outputs externally via a combiner (Note: By using an SMATE with an AMU, both RF outputs can generate signals up to 6 GHz, in the SMU,the RF output B is limited to 3 GHz).

⇒ Or by using the Multi-Carrier arbitrary Waveform mode of a single SMBV.

4.3.2.1 Using a 2-Channel SMU (Mixed Solution)

Baseband A generates a 4-carrier multi-carrier signal in the ARB and is routed to the RF A output, baseband B generates a real-time WIMAX 802.16e signal and is routed to the RF B output.
RF A and RF B are combined as shown in Figure 31.

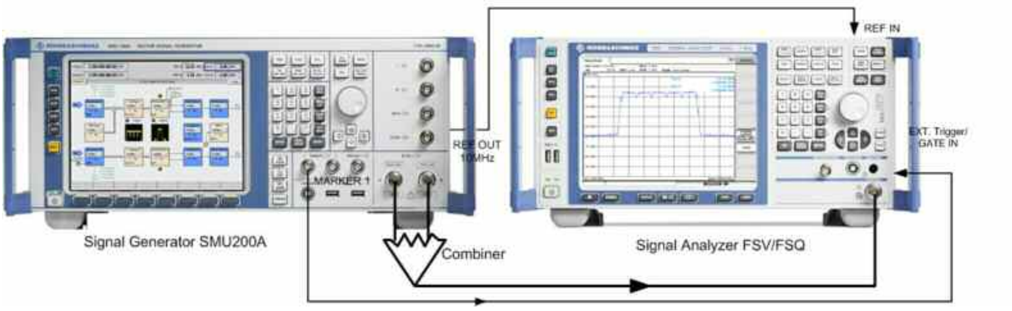


Figure 31: Test setup with a 2-channel SMU200A (2 baseband modules, 2 RF modules)

The multi-carrier signal at baseband A is setup similar to chapter 4.3.1.

Setup a real-time WIMAX 802.16e signal at baseband B and set RF frequencies as shown in Figure 32 for the scenario 2 configuration of Table 1.
Trigger baseband B by baseband A with Mode *Armed Auto* for a synchronous start of the different combined carriers.

Hint:
Power of one carrier dependent on number of carriers (equal levels of all carriers assumed)

When more than one 802.16e carrier of equal bandwidth is generated by the SMU's baseband section and output at RF output, the total power (P_{Tot}) corresponds to the set power (indicated in the SMU's Level display). The power of one carrier (P_c) is reduced correspondingly. The formula to calculate the power of one carrier is:

P_c =10 log P_{Tot} /N where N = number of generated carrier

Power of one carrier dependent on the number of total generated carriers :	
Number of carriers:	**Power of 1 carrier P_c:**
2	P_{Tot} - 3 dB
3	P_{Tot} – 4.8 dB
4	P_{Tot} - 6 dB
5	P_{Tot} - 7 dB (valid for SMBV, see chapter 4.3.2.2)

Table 4: Power of one carrier dependent on the number of total generated carriers (equal levels of all carriers assumed).

This means if a single carrier generated in channel B is added externally to a 4 carriers signal generated in channel A, the set level in channel B has to be 6 dB lower than the set level in channel A for equal levels of all the 5 carriers (example of Figure 32).

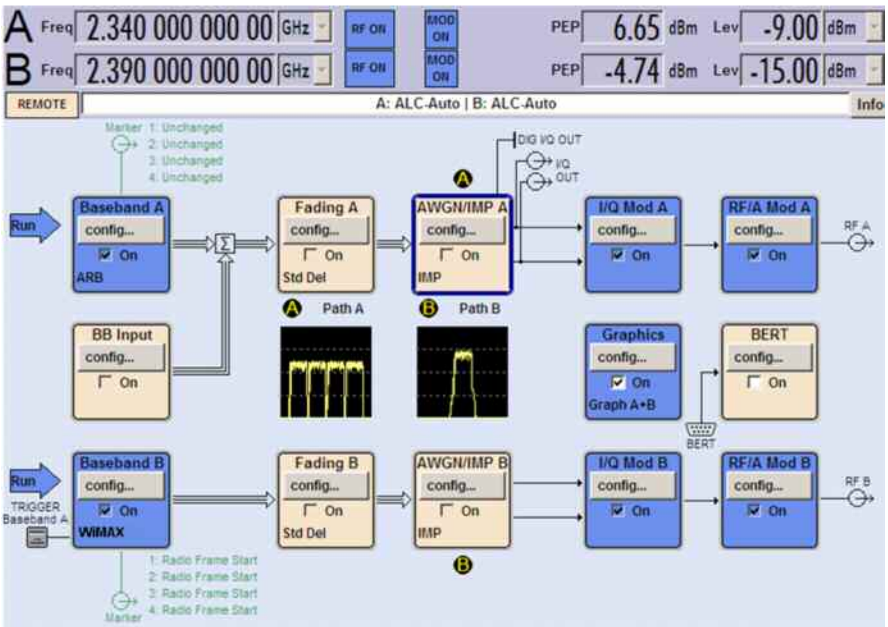


Figure 32: Configuration of a 2-channel SMU for generating 5 x 20 MHz WIMAX 802.16e carriers in band 40

4.3.2.2 Using an SMBV (Multi-carrier Solution)

The SMBV's internal baseband generator allows 120 MHz bandwidth and is capable of generating 5 x 20 MHz carriers in multi-carrier arbitrary waveform mode. Thus scenario No. 2 or 3 with 100 MHz transmission bandwidth can be generated with a single SMBV.

Setup the SMBV similar to chapter 4.3.1 but with 5 carriers.

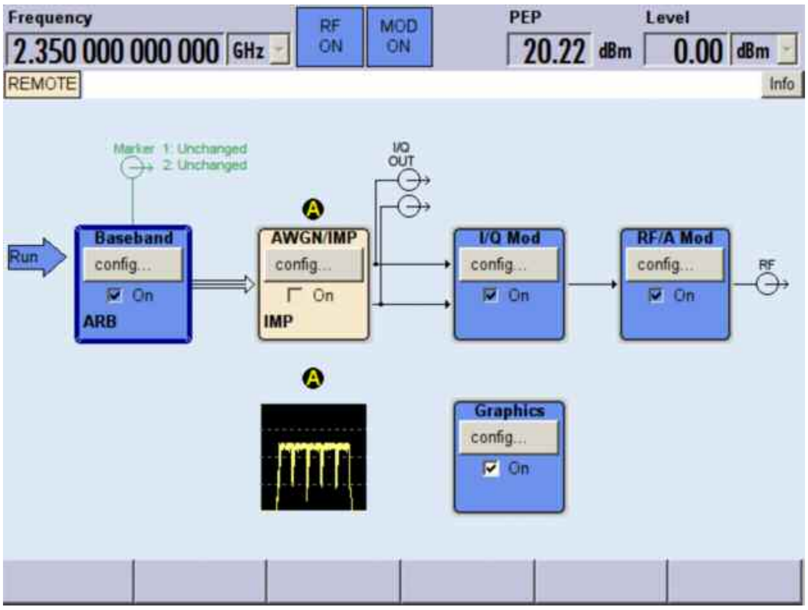


Figure 33: Generating deployment scenario 2 or 3 (5x20 MHz carriers) with a single SMBV using the multi-carrier ARB mode.

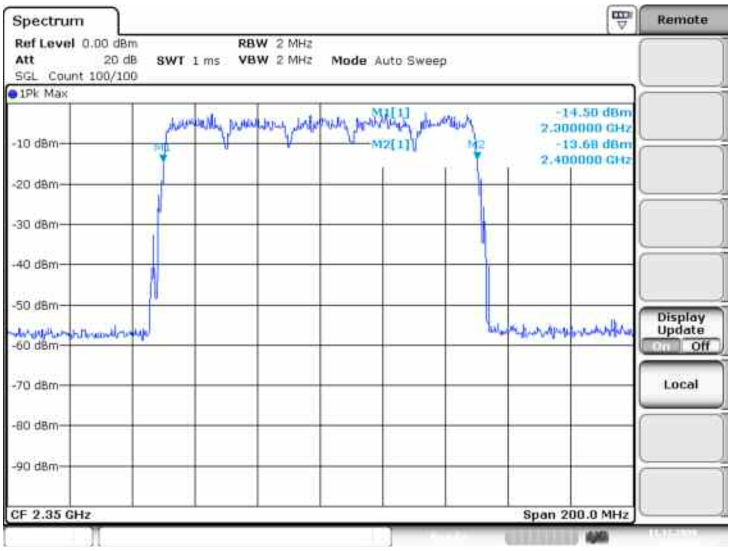


Figure 34: Output spectrum of contiguous 5x20 MHz carriers

4.4 Generating Multi-Band 802.16e Signals (Mixed Solutions)

4.4.1 Generating an 802.16e Dual-Band Signal in Distributed Placement with a Single SMU

Adding dual-band signals has to be done in the RF domain, because of the bandwidth limitation of the baseband generator. Two 2 RF signals must be combined externally via an appropriate RF signal combiner. A 2-channel SMU can provide these 2 RF signal outputs. Alternatively, 2 SMBV's can be used.
For generating scenario 12 of Table 1 with an SMU, path A of the SMU delivers 2x20 MHz carriers in distributed placement using its multi-carrier ARB function at 3.5 GHz band (similar to chapter 4.3.1). Path B delivers a single real-time modulated 20 MHz carrier at 2.6 GHz band. RF A and RF B are externally combined with an RF combiner.
Trigger baseband B with baseband A as shown in chapter 4.1.1.

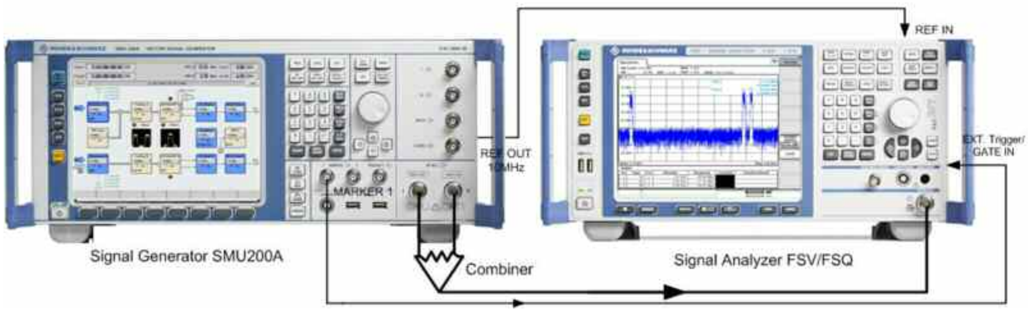


Figure 35: Test setup with a 2-channel SMU200A (2 baseband modules, 2 RF modules)

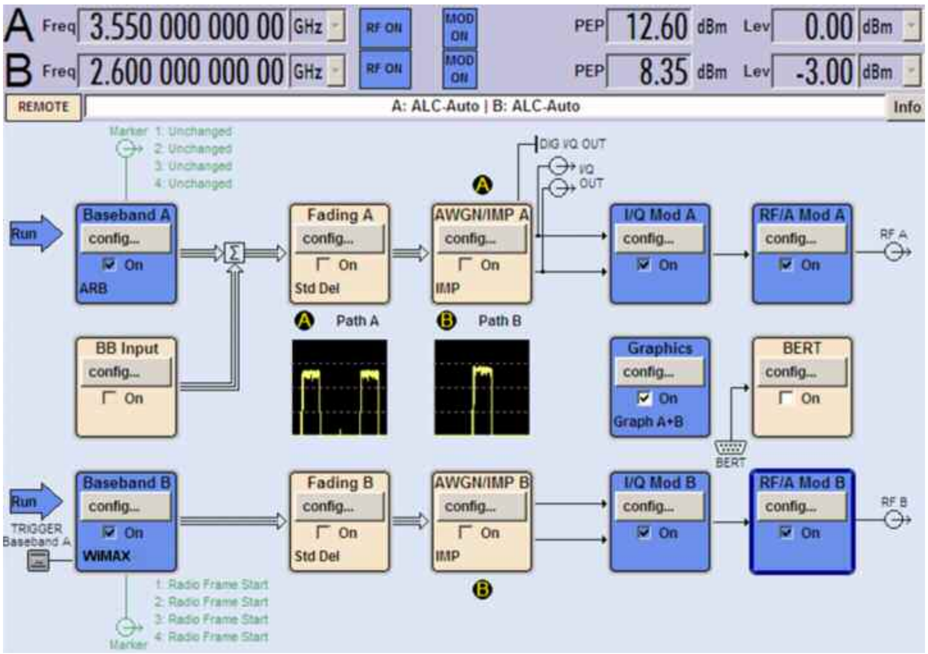


Figure 36: Generating scenario 12 of Table 1 with a 2-path SMU. Path A delivers 2x20 MHz carriers in distributed placement using its multi-carrier ARB function at 3.5 GHz band. Path B delivers a single 20 MHz carrier at 2.6 GHz band. RF A and RF B are externally combined.

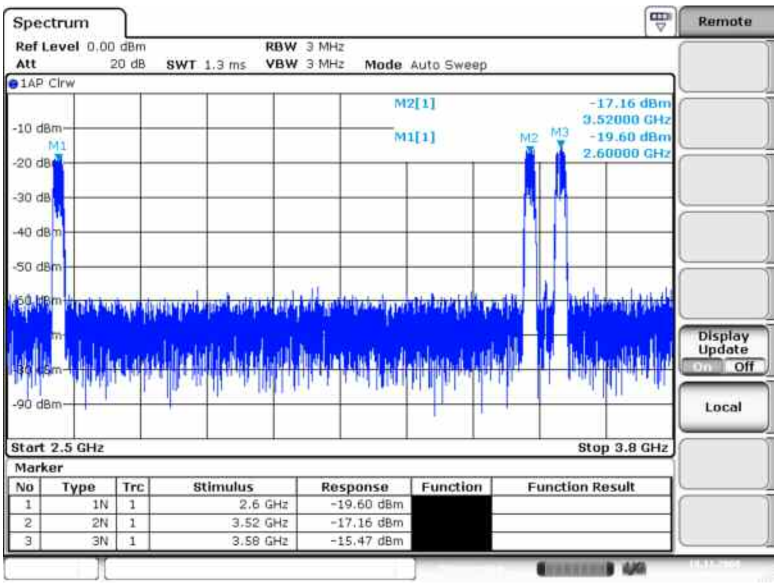


Figure 37: Example multi-band distributed spectrum allocation at band 7 (2.6 GHz) and at band 41 (3.5 GHz) (scenario 12 of Table 1) generated with a 2-path SMU.

4.4.2 Generating a 3-band 802.16m Signal in Distributed Placement

A 3-band 802.16e signal in distributed placement requires 3 RF channels. This can be arranged in the following ways:

a. Using 3 SMBV's combined with an external power combiner
b. Using an SMU with 2 RF channels and 2 baseband units and 1 SMBV with an external power combiner
c. Using an SMU with 2 RF channels and 2 baseband units and an SMU with 1 RF channel and 1 baseband unit (as shown in Figure 38) with an external power combiner

Each carrier is generated using real-time modulation as described in chapter 4.1.1. Trigger baseband A and B of signal generator 2 (lower SMU) by signal Generator 1 (upper SMU) via its Marker 1 output similar to the description in chapter 4.2.

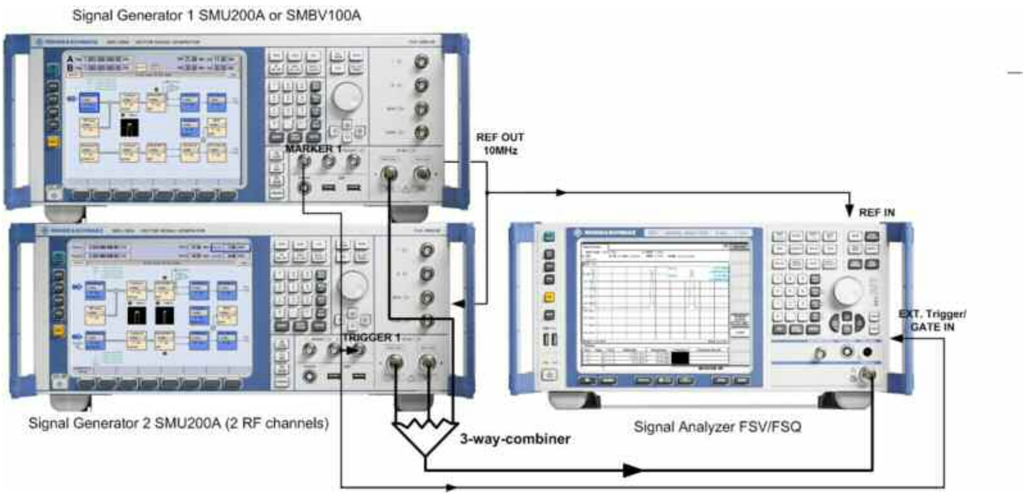


Figure 38: Configuration for multi-band deployment scenarios 7 or 10 of Table 1. Three RF channels are combined externally.

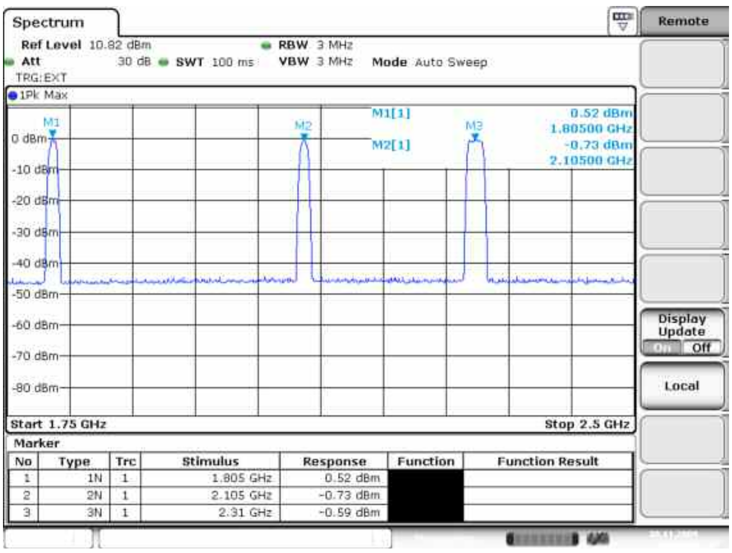


Figure 39: Example spectrum deployment scenario 7 of Table 1

4.5 Overview: Recommended Arrangements for Signal Generation

With one or more R&S signal generators every planned scenario of Table 1 can be generated. Recommended arrangements are listed in Table 5.

Table 5: Recommended arrangements for generation of WIMAX 802.16e-A signal scenarios acc. to Table 1

Scenario No.	No of LTE-A carriers	Bands for LTE-A carriers	Duplex modes	Recommended arrangement with multiple Instruments / Combiners	Recommend arrangement with one Instrument
1	UL: Contiguous 2x20 MHz CCs DL: Contiguous 4x20 MHz CCs	3.5 GHz band	FDD	UL: SMU with 2 baseband units DL: 2 SMU with 2 baseband units	UL and DL: 1 single Channel SMU or SMBV
2	Contiguous 5x20 MHz CCs	Band 40 (2.3 GHz)	TDD	1 SMU with 2 RF chan. ext. coupled	1 SMBV
3	Contiguous 5x20 MHz CCs	3.5 GHz band	TDD	1 SMU with 2 RF chan. ext. coupled	1 SMBV
4	UL: Distributed 20 + 20 MHz CCs DL: Distributed 2x20 + 2x20 MHz CCs	3.5 GHz band	FDD	UL: 1 SMU with 2 BB& 2 RF chan. DL: 2 SMU with 2 BB& 2 RF chan. ext coupled	1 SMBV
5	UL/DL: Distributed 5 MHz + 5 MHz CCs	Band 8 (900 MHz)	FDD	1 SMU with 2 BB units and 1 RF unit	1 SMBV or 1 single channel SMU
6	Distributed 2x20 + 2x20 MHz CCs	Band 38 (2.6 GHz)	TDD	UL: 1 SMU with 2 BB& 2 RF chan. DL: 2 SMU with 2 BB& 2 RF chan ext coupled	1 SMBV
7	UL/DL: Distributed 10 MHz CC@Band 1 + 10 MHz CC@Band 3 + 20 MHz CC@Band 7	Band 3 (1.8 GHz) Band 1 (2.1 GHz) Band 7 (2.6 GHz)	FDD	1 SMU with 2 BB units and 2 RF units, 1 SMU with 1 BB units and 1 RF units or 3 SMBV	--
8	Distributed 1x15 + 1x15 MHz CCs	Band 1 (2.1 GHz) Band 3 (1.8 GHz)	FDD	1 SMU with 2 BB units and 2 RF units or 2 SMBV	--
9	UL/DL: Distributed 10 MHz CC@UHF + 10 MHz CC@Band 8	800 MHz band Band 8 (900 MHz)	FDD	1 SMU with 2 BB units and 2 RF units or 2 SMBV	--
10	Distributed 2x20 + 10 + 2x20 MHz CCs	Band 39 (1.8 GHz) Band 34 (2.1 GHz) Band 40 (2.3 GHz)	TDD	1 SMU with 2 BB units and 2 RF units and 1 SMU with 1 BB unit and 1 RF path or 3 SMBV	--
11	UL: 1x20 MHz CCs DL: 2x20 MHz CCs	Band 7 (2.6 GHz)	FDD	UL: 1 SMU with 1 BB unit and 1 RF unit or 1 SMBV DL: 1 SMU with 2 BB units and 2 RF units or 2 SMBV	1 SMBV or 1 single channel SMU
12	UL/DL: 20 MHz CCs @ Band 7 DL : Non- contiguous 20 + 20 MHz CCs @ 3.5 GHz band	Band 7 (2.6 GHz) 3.5 GHz band	FDD	UL: 1 SMU with 1 BB unit and 1 RF unit or 1 SMBV DL: 1 SMU with 2 BB units and 2 RF units and 1 SMU with 1 BB unit and 1 RF path or 3 SMBV	--

5 Signal Analysis with FSQ, FSG or FSV

The universal WIMAX 802.16e analysis capabilities of FSQ, FSG, FSV and FSL are applicable also for WIMAX 802.16e multi carrier signals. As every carrier of the multi carrier signal can be analysed in the physical layer like a single carrier, all measurements can be done for the carriers seperatly. Additionally, is in 802.16m the legacy and brownfield mode defined. As the FSx can analyse the 802.16e signal, this measurement is conform to the brownfield mode and the LZone in the legacy mode. In the following it is described how to configure the FSx accordingly.
The technical details of the 802.16m physical Layer signal in comparison of the 802.16e signal is described in the Application Note 1MA167 802.16m technology Introduction.

5.1 Modulation Analysis of the Different Carriers

With the WIMAX 802.16e Analysis Software each carrier with configurable bandwidth (in this example with 20 MHz bandwidth) can be analyzed separately by setting the center frequency to the center of the 802.16e carrier. Thus all the measurement functions of the WIMAX 802.16e Analysis software are applicable. In following figures, some measurement examples are shown.
Figure 40 shows the demodulation of a 20 MHz carrier centered at 2.34 GHz with an FSQ. The time delay between the external trigger reference and the analysed WiMAX signal is measured and shown in the Time to Capture Buffer measurement, which is marked here with a red circle. This indication can be used for synchronisation of all WiMAX carriers.

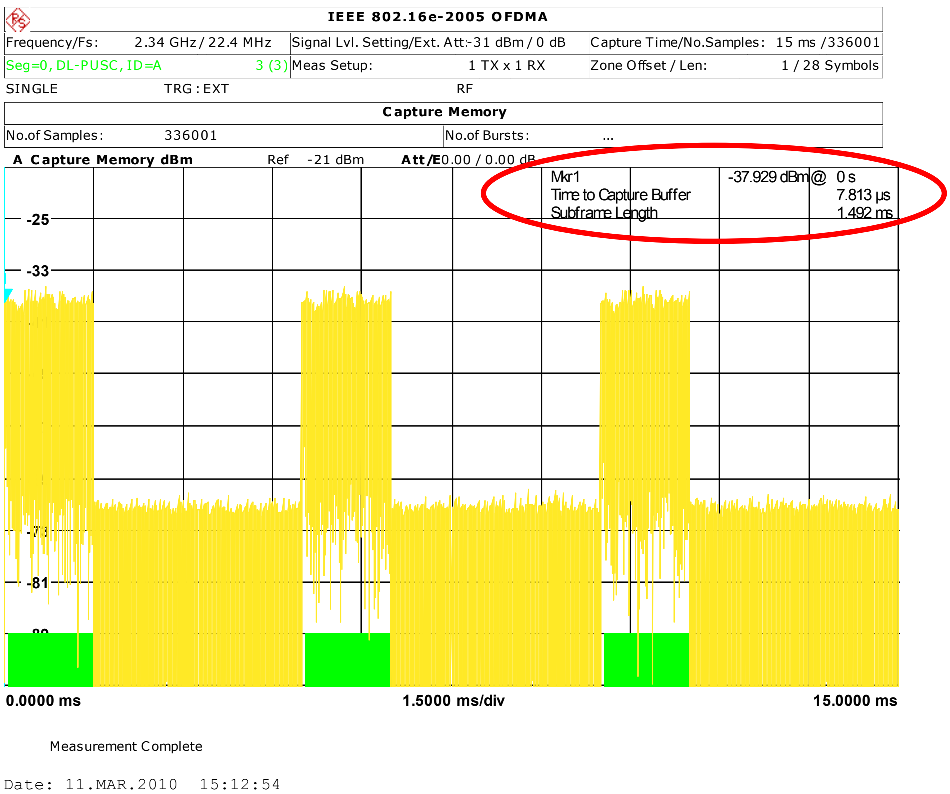


Figure 40:The Ttime to Capture buffer indication can be used to adjust a synchronous start of the different carriers (via Marker delay of SMU).

The result list summary table is displayed for I/Q measurements when the display mode is set to LIST. This table shows the overall measurement results and optionally provides limit checking for EVM values in accordance with the selected standard, see Figure 41.

IEEE 802.16e-2005 OFDMA		
Frequency/Fs: 2.34 GHz / 22.4 MHz	Signal Lvl. Setting/Ext. Att:-31 dBm / 0 dB	Capture Time/No.Samples: 15 ms /336001
Seg=0, DL-PUSC, ID=A 3 (3)	Meas Setup: 1 TX x 1 RX	Zone Offset / Len: 1 / 28 Symbols

SINGLE TRG : EXT RF

Result Summary of Analyzed Zone/Segment

No. of Zones/Segments	3					
	Min	Mean	Limit	Max	Limit	Unit
BER Pilots	**0.00**	**0.00**	0.00	**0.00**	0.00	%
EVM Data and Pilots	**- 32.10**	**- 32.10**	- 30.00	**- 32.09**	- 30.00	dB
EVM Data	**- 31.81**	**- 31.80**	- 30.00	**- 31.79**	- 30.00	dB
EVM Pilots	**- 34.46**	**- 34.38**		**- 34.28**		dB
EVM Preamble	**- 39.81**	**- 39.55**		**- 39.31**		dB
Unmod. Subcarrier Error	**- 66.83**	**- 66.81**		**- 66.80**		dB
IQ Offset	**- 50.72**	**- 50.30**	- 15.00	**- 49.99**	- 15.00	dB
Gain Imbalance	**- 0.01**	**- 0.00**		**- 0.00**		dB
Quadrature Error	**0.069**	**0.086**		**0.098**		°
Power DL Preamble	**- 36.42**	**- 36.41**		**- 36.41**		dBm
Power Data and Pilots	**- 44.96**	**- 44.96**		**- 44.96**		dBm
Power Data	**- 45.44**	**- 45.44**		**- 45.44**		dBm
Power Pilots	**- 42.94**	**- 42.94**		**- 42.94**		dBm

Measurement Complete

Date: 11.MAR.2010 16:05:13

Figure 41: The result list summary Table shows overall IQ measurement results and optionally provides EVM limit checking in accordance with the selected standard.

In the WiMAX Analysis option many physical parameters are measured and displayed. Beside the power versus time in the capture buffer, shown in screen A of Figure 42, also the constellation diagram of the analysed WiMAX signal is shown in Screen B of Figure 42.

In this example the bandwidth of the analysed WiMAX signal is 20 MHz.

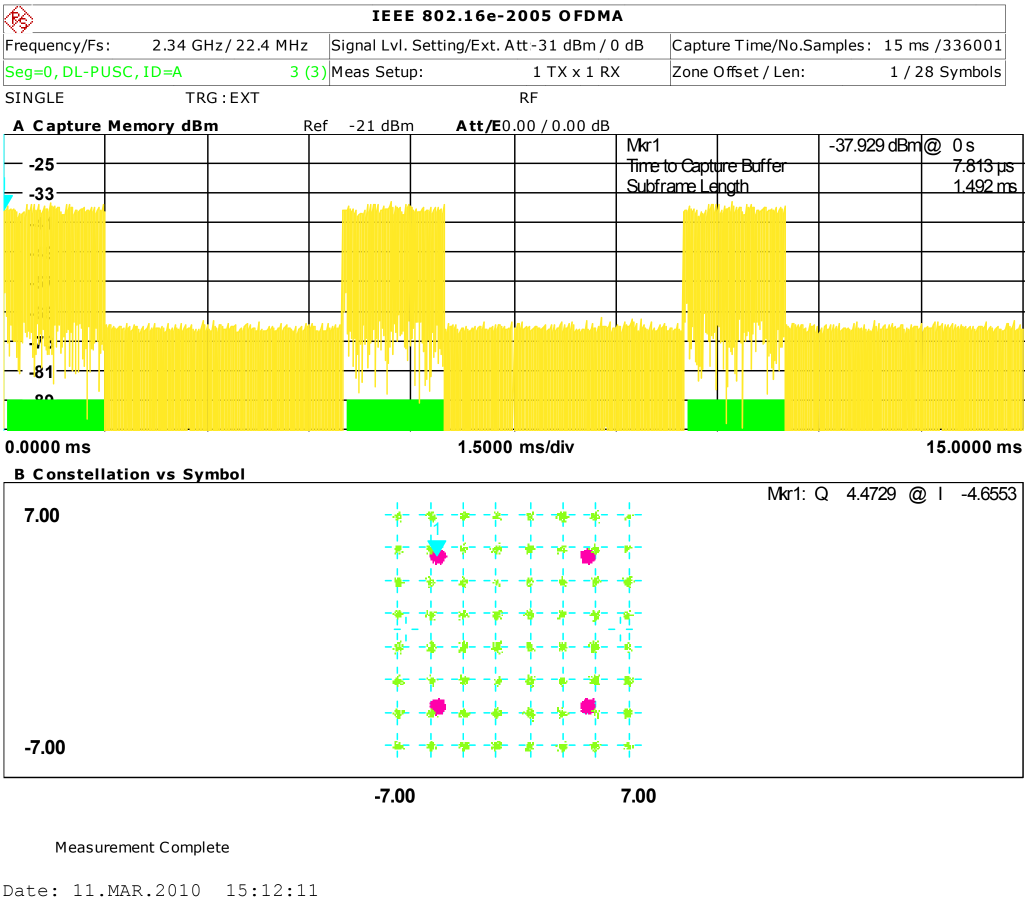


Figure 42: In screen A (upper) power vs. time in the capture buffer, in screen B (lower) the constellation diagram is shown.

Screen B of Figure 43 shows the CCDF (Complementary Cumulative Distribution Function), while screen A shows again the capture buffer.

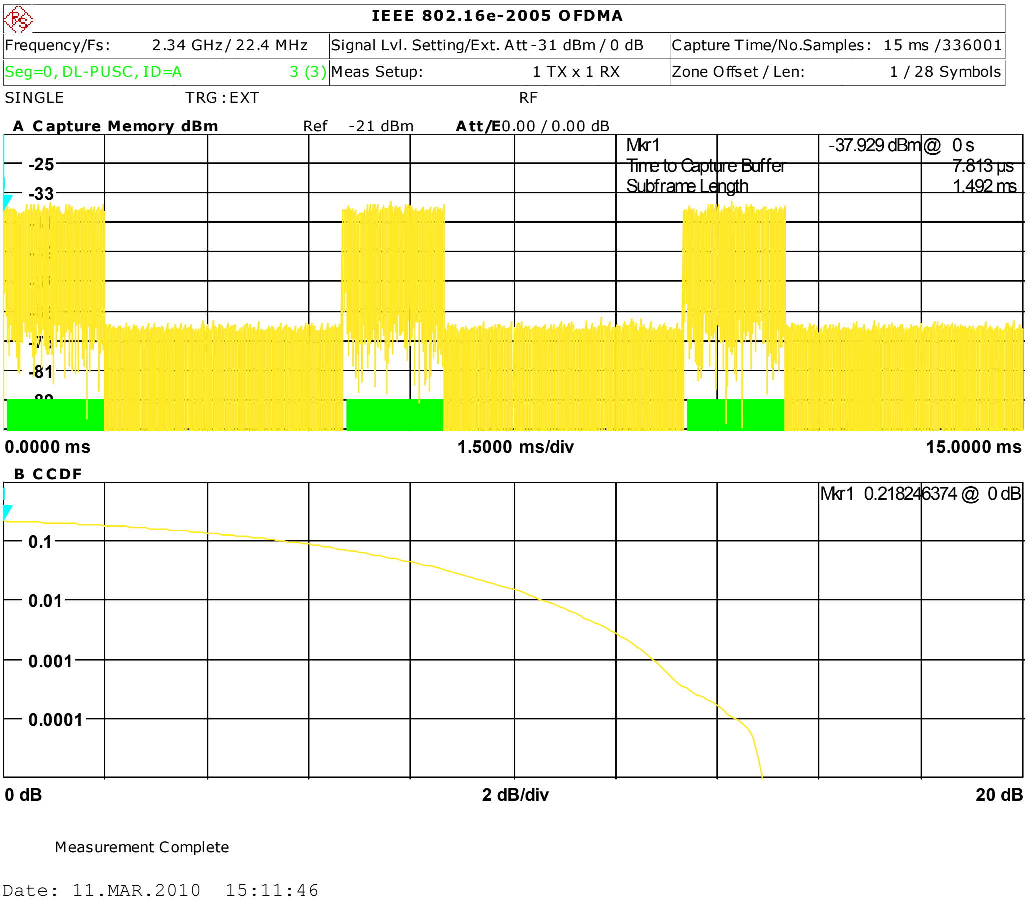


Figure 43: In screen A (upper) the capture buffer, in screen B (lower) the CCDF is shown.

For the measurements, also statistical results are useful. As an example, ***Figure 44*** shows the power versus time of a defined number of WiMAX bursts is shown in the screen B (lower screen). So the minimum and maximum level of several bursts is shown.

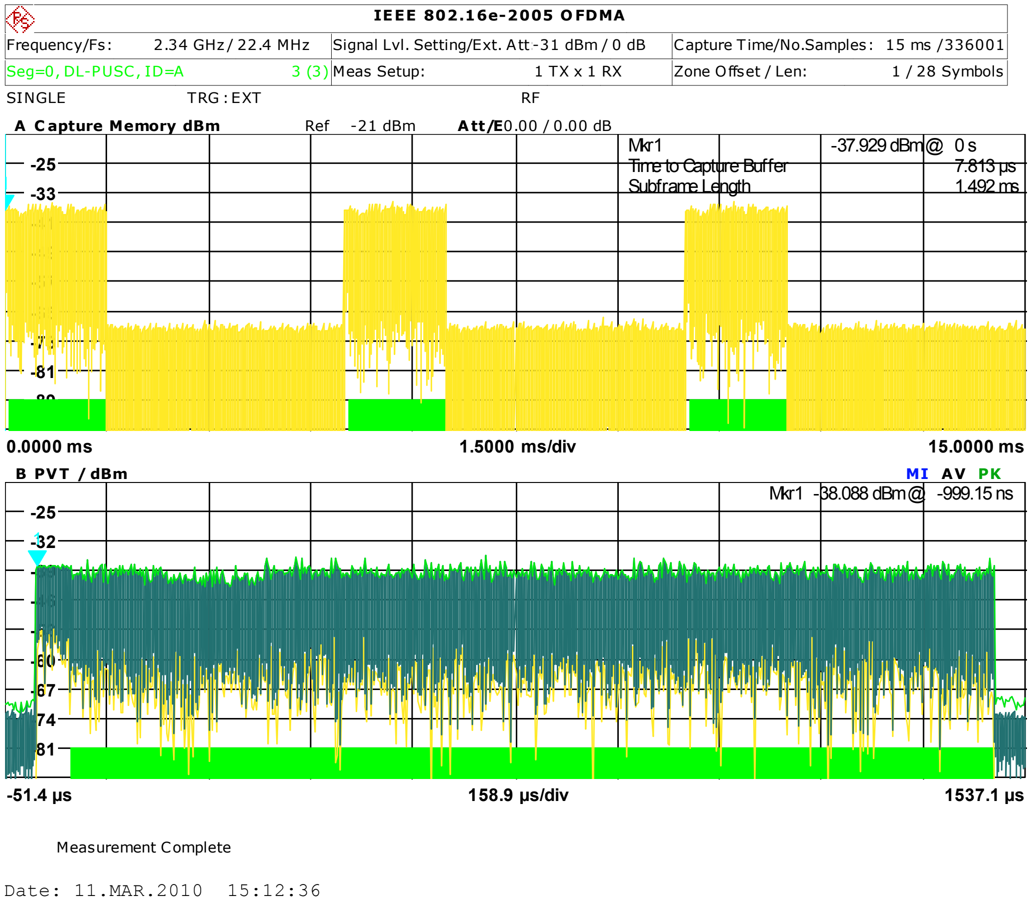


Figure 44: In screen A (upper) the capture buffer, in screen B (lower) the power versus time of many bursts is shown with its maximum and minimum levels.

5.2 ACLR-Test with Configurable Multi-carrier ACLR Measurement Function

The WIMAX 802.16e - ACLR measurement function of FSx is easily configurable also for contiguously or distributedly placed 802.16e signals. Within the Channel Power/ACLR function switch on the IEEE/WIMAX 802.16e Square standard. Change the Number of TX Channels and Channel Settings accordingly (Number of TX Channels: 2, Channel Bandwidth: TX1: 20 MHz, ADJ: 20 MHz, Channel Spacing: 20 MHz) for a configuration as described in chapter 4.3.1. See measurement examples of FSQ in Figure 45.

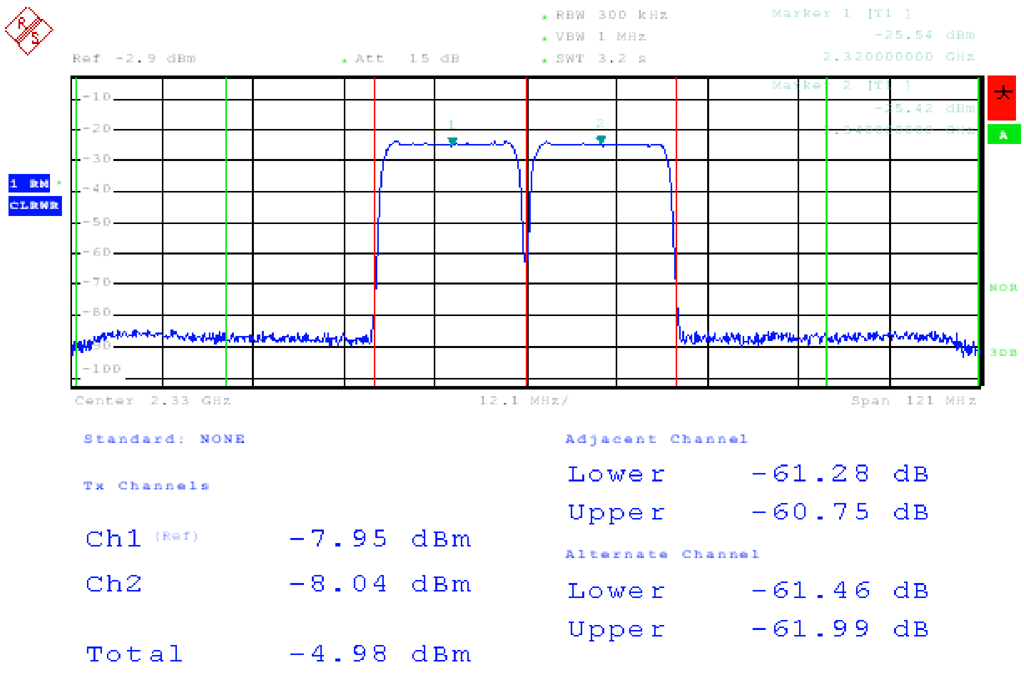


Figure 45: Multi-carrier ACLR measurement of FSQ on two 802.16e signal (2 carriers each with 20 MHz bandwidth)

5.3 Test of Operating Band Unwanted Emissions (Spectrum Emission Mask)

The measurement of unwanted emissions in the operating band (spectrum emission mask) is also configurable for 802.16e / 802.16m signals. Figure 46 shows the test of Operating Band Unwanted Emissions (Spectrum Emission Mask) on an 802.16m signal containing 2 x 20 MHz carriers with an FSQ. The example emission mask (WIMAX_BW_40MHz.XML) included in this application note was generated by modifying the file WIMAX_BW_40MHz.XML (IEEE).
In order to use it copy the file to the directory C:\R_S\INSTR\sem_std\WIMAX\DL\IEEE on the instrument and activate it by pressing the *Load Standard* softkey.

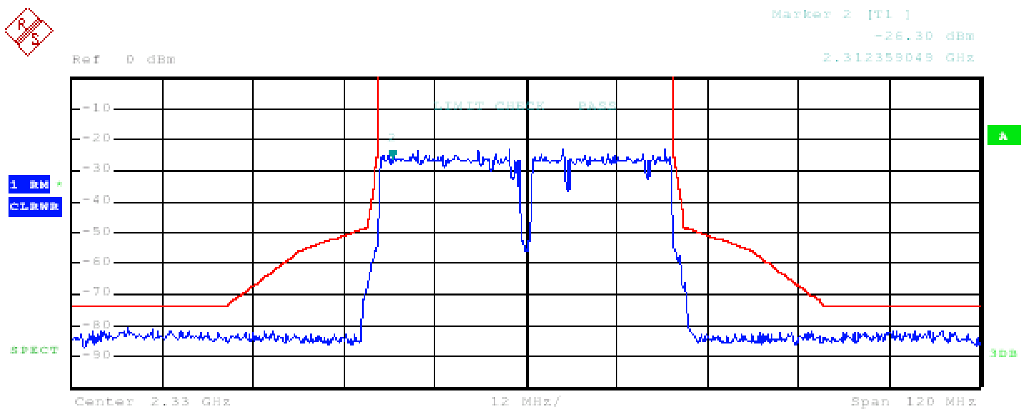


Figure 46: Spectrum emission mask measurement with an FSQ on a contiguously placed 802.16m signal (2 x 20 MHz carriers) generated by an SMU

6 Literature

1. IEEE 802.16m Draft 4
2. IEEE 802.16e standard amendment
3. IEEE 802.16-2009 standard
4. ITU IMT-Advanced Requirements
5. IEEE 802.16m Systems Requirements Document (Release 9)
6. **3GPP TR 36.815 V0.3.0** (2009-10) 3rd Generation Partnership Project-Technical Specification Group Radio Access Network-Further Advancements for E-UTRA 802.16m feasibility studies in RAN WG4 (Release 9)
7. **3GPP TR 36.913 V 8.0.1**, Technical Specification Group Radio Access Network; Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) 802.16m, Release 8;
8. Rohde & Schwarz: 1MA167 "WiMAX 802.16m Technology Introduction" Application Note
9. Rohde & Schwarz: Operating Manual: Vector Signal Generator R&S®SMU200A
10. Rohde & Schwarz: Operating Manual: Vector Signal Generator R&S®SMBV100A
11. Rohde & Schwarz: Operating Manual Baseband Signal Generator R&S®AMU200A
12. Rohde & Schwarz: Operating Manual: Vector Signal Analyzer R&S®FSQ
13. Rohde & Schwarz: Operating Manual: Vector Signal Analyzer R&S®FSV

7 Additional Information

This Application Note is subject to improvements and extensions. Please visit our website in order to download new versions. Please send any comments or suggestions about this Application Note to TM-Applications@rohde-schwarz.com.

8 Ordering Information

Ordering Information		
Vector Signal Generator		
SMU200A		**1141.2005.02**
SMU-B10	Baseband Generator	1141.7007.02
SMU-B13	Baseband Main Module	1141.8003.04
SMU-B14	Fading Simulator	1160.1800.02
SMU-B10**x**	1st RF path	
SMU-B20**x**	2nd RF path	
SMU-B17	Baseband Input	1142.2880.02
SMU-K49	Digital Standard WIMAX 802.16e	1161.0366.02
SMATE200A		**1400.7005.02**
SMATE-B106	1st RF Path 6GHz	1401.1200.02
SMATE-B206	2nd RF Path 6GHz	1401.1600.02
SMATE-K49	Digital Standard WIMAX 802.16e	1404.6803.02
SMBV100A		**1407.6004.02**
SMBV-B106	RF 9 kHz – 6 GHz	1407.9703.02
SMBV-B10	Baseband Generator with Digital Modulation (real-time) and ARB (32 Msample), 120 MHz RF BW	407.8907.02
SMBV-K49	Digital Standard WIMAX 802.16e	1415.8119.02
SMBV-K18	Digital Baseband Connectivity	1415.8002.02
Baseband Signal Generator		
AMU200A		**1402.4090.02**
AMU-B10	Baseband Generator with ARB	1402.5300.02
AMU-B13	Baseband Main Module	1402.5500.02
AMU-B18	Digital IQ output	1402.6006.02
AMU-K49	Digital Standard WIMAX 802.16e	1402.7002.02

Ordering Information		
Signal Analyzers		
FSQ	**Up to 3, 8, 26, 31 or 40 GHz**	**1155.5001.xx**
FSG	**Up to 8 or 13 GHz**	**1309.0002.xx**
FSV	**Up to 3, 7, 13, 30, 40 GHz**	**1307.9002.xx**
FSQ-K93	Digital Standard WIMAX 802.16e	1300.8600.02
FSV-K93	Digital Standard WIMAX 802.16e	1310.8955.02
FSL-K93	Digital Standard WIMAX 802.16e	1302.0736.02
FSQ-K94	Digital Standard WIMAX 802.16e with MIMO	1308.9770.02

xx stands for the different frequency ranges (e.g. 1155.5001.26 up to 26 GHz)

Note: Available options are not listed in detail. Please contact your local Rohde & Schwarz sales office for further assistance.

9 Glossar

A

A	Advanced
AAI	Advanced Air Interface
AMC	Adaptive Modulation and Coding

B

BF	Beamforming
BS	Base Station
BW	Bandwidth

C

CCDF	Complementary Cumulative Distribution Function

F

F	Frame
FDD	Frequency Division Duplex

I

IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
ITU	International Telecommunications Union

L

LTE	Long Time Evolution
LZone	Legacy Zone

M

MAC	Media Access Control
MIMO	Multiple In Multiple Out
MS	Mobile Station
MZone	802.16m Zone

O

OFDMA	Orthogonal Frequency Division Multiple Access

P

PHY	Physical

T

TDD	Time Division Duplex

U

UL	Uplink

W

WiMAX™	Worldwide Interoperability of Microwave Access
WMF	WiMAX Forum®

About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Environmental commitment
- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

Certified Quality System
ISO 9001

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