Easy Generation of Wideband Signals
Application Note

Products:

- R&S®SMBV100A
- R&S®AFQ100B

This Application Note describes the generation of radio frequency signals from wideband I/Q waveforms using the R&S®AFQ100B UWB signal and I/Q modulation generator in combination with the R&S®SMBV100A vector signal generator.

Application Note

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ROHDE&SCHWARZ

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1 Note

The following abbreviations are used in this Application Note for Rohde & Schwarz test equipment:

- The R&S®SMBV100A vector signal generator is referred to as SMBV
- The R&S®AFQ100B UWB signal and I/Q modulation generator is referred to as AFQ
- The R&S®WinIQSIM2™ software is referred to as WinIQSIM2

The following notation is used to describe how to configure the instrument settings:

- (RF function block → RF On ✓)
  … to turn on the RF power
- (RF function block → NRP-Z Power Viewer → State: On)
  … to start the NRP-Z Power Viewer

The text in parentheses gives the sequence for making a setting via the graphical user interface of the instrument.

2 Overview

The R&S®AFQ100B UWB signal and I/Q modulation generator offers a bandwidth of 528 MHz (RF) and is thus perfectly suited for applications that require large bandwidth. Examples are the support of broadband digital communications systems such as ultra wideband (UWB) or radar applications requiring signals with extremely short pulses and well-defined rise and fall shapes. The AFQ converts digital I/Q waveforms to analog baseband I/Q signals that can be fed into the external I/Q baseband inputs of the R&S®SMBV100A vector signal generator for upconversion to RF (up to 3.2 GHz or 6 GHz). This Application Note describes in detail the generation of radio frequency signals from wideband I/Q waveforms using Rohde & Schwarz test equipment. As an example, the generation of UWB signals is demonstrated.

3 Waveform Generation

A digital signal can be described as a sequence of I/Q samples. This sequence of I/Q data can be stored as a file. The resulting file is called a digital waveform. Generators with ARB functionality are used to play back these files. Digital I/Q waveforms can be created via software. In the following, two sophisticated software tools for digital waveform generation are briefly introduced.

3.1 R&S®Pulse Sequencer

The R&S®Pulse Sequencer software makes it possible to flexibly generate complex pulses and bursts commonly used in radar applications. The R&S®Pulse Sequencer software is a stand-alone, PC-based application with an intuitive user interface and integrated waveform display including analysis capabilities. For example, wideband signals such as wideband chirps or signals with narrow pulses and very short rise and fall times can be created easily. Upload of the generated waveforms to a Rohde & Schwarz signal generator requires the appropriate K6 option installed on the instrument (e.g. R&S®AFQ-K6).

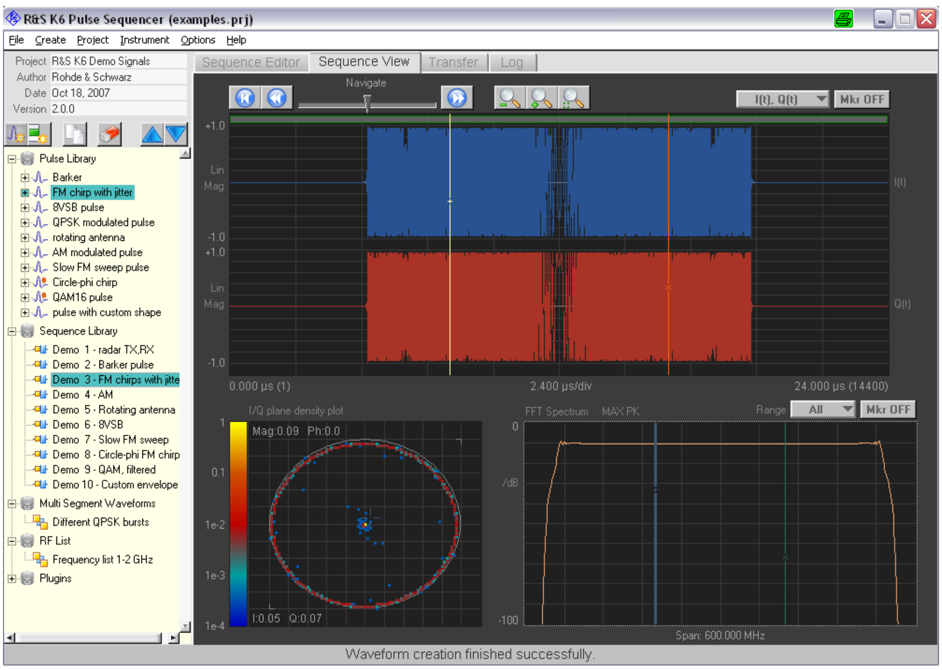


Fig. 1: R&S®Pulse Sequencer user interface showing a wideband (500 MHz) FM chirp.

3.2 R&S®WinIQSIM2™

The R&S®WinIQSIM2™ simulation software makes it possible to generate digital I/Q waveforms in line with various radio standards. For example, UWB signals compliant with the ECMA-368 standard can conveniently be created using the associated configuration window.
Note that it is important to configure the Arbitrary Signal Generator function block before creating the waveform, since WinIQSIM2 takes the generator properties (e.g. max. clock frequency, max. I/Q bandwidth) into account for waveform generation.

(Arb Sig Gen function block → config → Instruments → New → Instrument Type: AFQ100B)
(Baseband function block → UWB MB-OFDM)

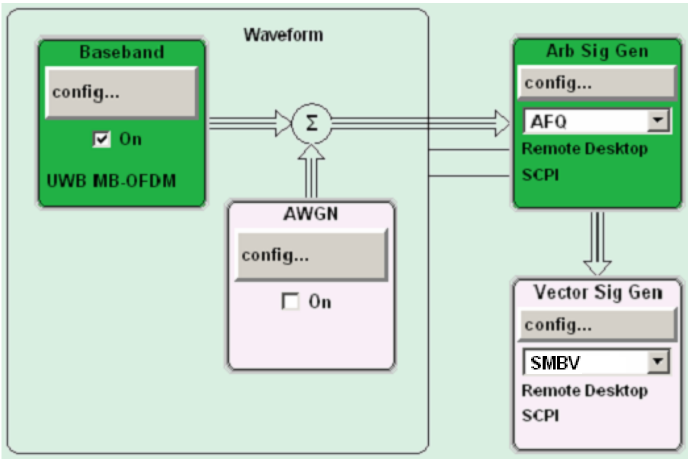


Fig. 2: WinIQSIM2 user interface.

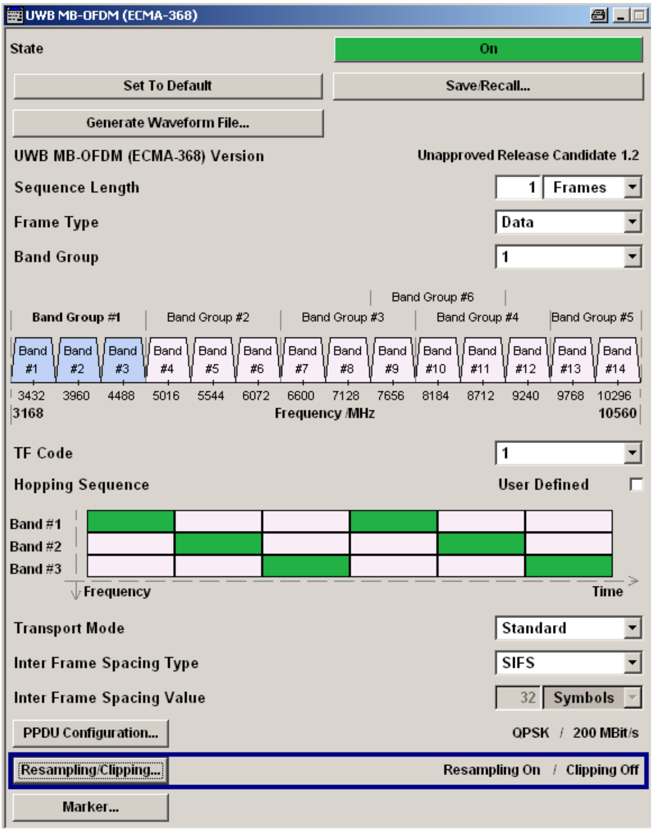


Fig. 3: WinIQSIM2 configuration menu for UWB MB-OFDM signals.

Before loading the digital I/Q waveforms into the arbitrary signal generator of the AFQ the waveforms should be resampled, since the instrument operates at a fixed sample rate of 600 MHz for wideband signals.

(Baseband function block → UWB MB-OFDM → Resampling/Clipping Settings
→ Resampling State: On
→ Resampling Target Frequency: 600 MHz)

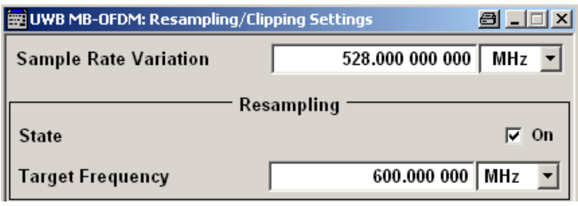


Fig. 4: Resampling settings for UWB MB-OFDM signals.

The generated I/Q waveforms are then loaded into the AFQ via GPIB, LAN or USB.

(Operating menu → Transmission → Instruments → Edit → Hardware Channel: TCPIP/ GPIB/ USB)
(Operating menu → Transmission → Transmit → Destination: Instrument, Automatically Load and Start Waveform ✓, Path and File name → Transmit Waveform)

The AFQ plays the digital waveforms back, i.e. converts them to analog I/Q signals.

4 Hardware Setup

4.1 R&S®SMBV100A

The SMBV is a powerful mid-range vector signal source with an optional internal baseband section. It can be used as a vector signal generator with internal signal generation and real-time functionality, or as a more cost-efficient signal generator with integrated arbitrary waveform generator, or simply as an I/Q upconverter. The SMBV offers excellent RF performance in combination with high output power as standard. It is available with a maximum operating frequency of either 3.2 GHz (R&S®SMBV-B103) or 6 GHz (R&S®SMBV-B106). The integrated I/Q modulator features a maximum RF bandwidth exceeding 500 MHz for external I/Q signal input. For example, this wide bandwidth makes it possible to upconvert UWB signals that are provided by the baseband signal generator AFQ.

4.2 R&S®AFQ100B

The AFQ is a flexible baseband source with a bandwidth of 528 MHz (RF) using a clock rate of 600 MHz and a waveform memory of up to 1 Gsample. Due to its wide bandwidth, the AFQ is able to provide I/Q signals for testing broadband digital communications systems such as UWB. The WinIQSIM2 software option (R&S®AFQ-K264) makes it possible to flexibly generate UWB standard-compliant (ECMA-368) signals.

4.3 Instrument Setup

The AFQ provides the analog wideband I/Q signals that are fed into the SMBV by connecting the I/Q output of the AFQ to the external I/Q input of the SMBV. The SMBV acts as an I/Q upconverter, providing the desired UWB signal at radio frequencies up to 6 GHz.

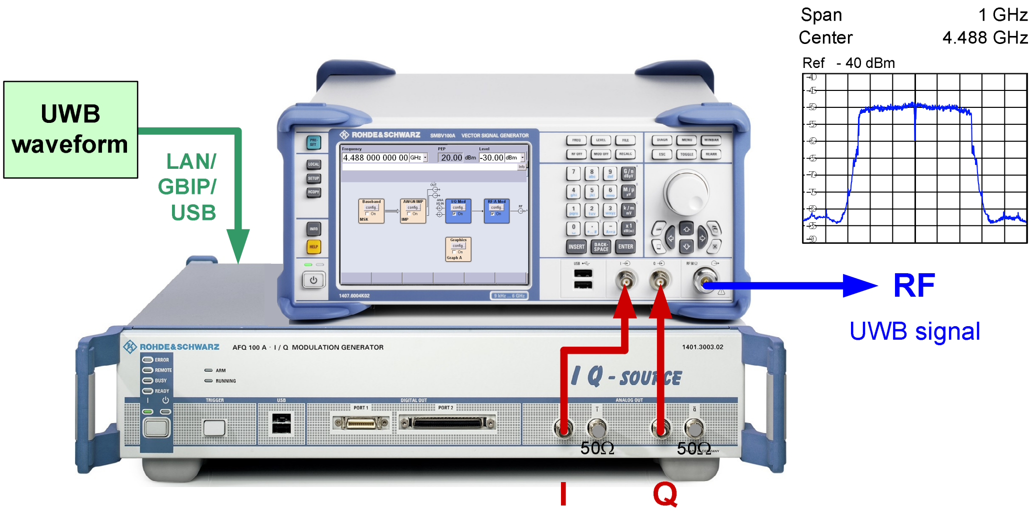


Fig. 5: Instrument setup for UWB signal generation.

The instrument settings of the two generators necessary for successful operation are listed in the following two sections.

4.3.1 AFQ

- Waveform generation and transmission to the AFQ using WinIQSIM2 simulation software
  (See section 3)

- Waveform loading
  (Baseband function block → ARB → Load Waveform → Select file)

  Note: *If the sample rate differs from 600 MHz, the waveform must be resampled before it can be loaded. The resampling can be done easily on the instrument: (Baseband function block → ARB → Resample Waveform → Select file)*

- Baseband section enabled
  (Baseband function block → BB On ✓)

- Output settings
  (Output function block → Active Output: BB Out
  → Amplitude: 178 mV
  → Enable Bias: Off (i.e. no ✓ in check box))

  Remark: *In contrast to the baseband signal generator R&S®AFQ100A, the AFQ100B is always running in balanced operating mode (differential I/Q output). The nominal output level of the AFQ100B is 500 mV for differential output (50 Ω system), i.e. for utilizing non-inverting and inverting outputs. Therefore, with an amplitude setting of 500 mV the output level at the non-inverting I/Q outputs is 250 mV. This should be kept in mind, since the AFQ100B is operated single-ended in this application, i.e. only the non-inverting outputs are utilized.*

  Note: *In order to keep out-of-band spurious effects low for wideband signals (bandwidth >200 MHz), the output level should be decreased. A level reduction by 15 dB is recommended, i.e. the level should be decreased from 500 mV (default) down to 178 mV. Lowering the level improves the signal purity, however at the expense of a degraded signal-to-noise ratio at RF. In cases where a high dynamic range or high RF levels are required, an output level of 500 mV should be used.*

- Output section enabled
  (Output function block → BB Out On ✓)

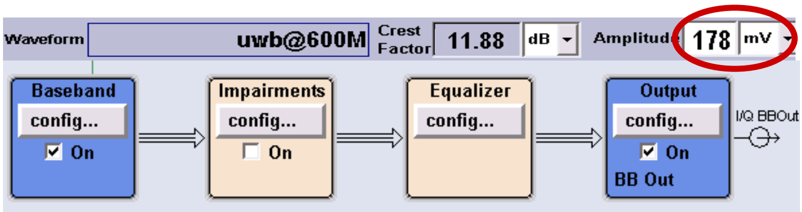


Fig. 6: User interface of the AFQ configured for UWB signal generation.

- Inverting $\overline{I}/\overline{Q}$ outputs terminated with 50 Ω
  (50 Ω terminators come with every AFQ100B as standard)

4.3.2 SMBV

- External I/Q signals
  (I/Q Mod function block → I/Q Mod In: Analog Wideband I/Q In ✓)

- I/Q Modulator and RF section enabled
  (I/Q Mod function block → I/Q On ✓)
  (RF function block → RF On ✓)

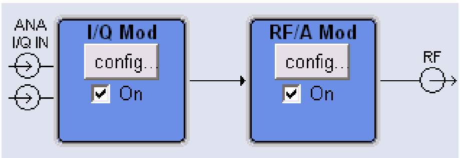


Fig. 7: Display detail of the SMBV user interface.

- I/Q settings
  (I/Q Mod function block → I/Q Settings → I/Q Wideband On ✓
  → Crest Factor: Crest Factor of waveform)

Remarks: *'I/Q Wideband' is an optimized setting for wideband modulation signals achieved by shifting the switching frequencies of the lowpass filters in the output section.*

The Crest Factor of the waveform is displayed on the AFQ − in this example it is 11.88 dB (see Fig. 6). The Crest Factor is determined by taking the ratio of the peak value of the modulation envelope to its rms value (envelope method). This Crest Factor is stored in the waveform file created with WinIQSIM2. The AFQ reads out this value and displays it. In the SMBV, this data is necessary to allow the correct output power to be generated at the RF output.

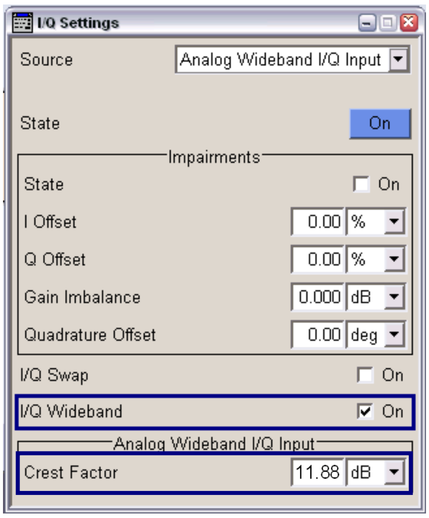


Fig. 8: I/Q settings of the SMBV for UWB signal generation.

- Level offset
  (RF function block → Level / EMF → Offset: -15 dB)

  Note: *The SMBV expects an input level of 500 mV at the analog I/Q inputs. However, when operated single-ended, the AFQ100B delivers less than the nominal 500 mV at the I/Q outputs. For this reason, the level displayed on the SMBV does not match the actual RF output level. The displayed level should thus be "corrected" by setting a negative level offset on the SMBV. In a sense, the level offset is slightly "misused" here for compensating the insufficient input level delivered by the AFQ. Note that the level offset just influences the level display not the RF output. For an amplitude setting of 500 mV on the AFQ, a level offset of -6 dB (factor 1/2) should be set; for an amplitude of 178 mV, -15 dB should be set.*

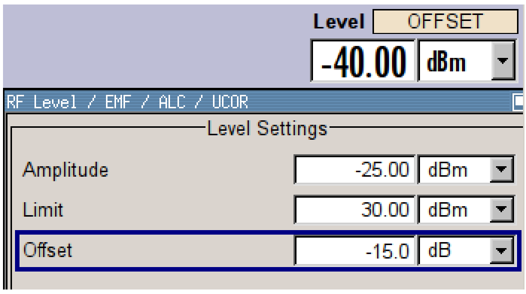


Fig. 9: RF level settings of the SMBV. Additionally, the level display in the header of the user interface is shown.

Remark: *The level offset value is determined the following way: The nominal level of 500 mV corresponds to +7.0 dBm when converted from voltage to power in a 50 Ω system. An amplitude setting of 178 mV on the AFQ results in an actual output level of 89 mV at the I/Q outputs due to single-ended operation. Converting 89 mV to dBm yields -8.0 dBm. The level offset value is given by the difference of the actual and the nominal power level, i.e. -8.0 dBm – 7.0 dBm = -15 dBm.*

5 System Equalization

The AFQ provides unrivaled baseband performance in terms of frequency response. However, connected devices such as I/Q modulators for example may exhibit an intrinsic frequency response over their range of operation. Especially for wideband applications this may affect the signal quality (e.g. EVM) in case the frequency response is not perfectly flat over the used bandwidth. For such cases, the AFQ is able to compensate the magnitude and phase of a non-ideal frequency response of subsequent external components by means of settable correction filters[1]. For example, the frequency response of the I/Q modulator (in the SMBV) can be compensated in order to achieve excellent UWB signal quality with the AFQ-SMBV setup shown in Fig. 5.

[1] Equalizer functionality for signal bandwidths >200 MHz available from Q4 2009 on

5.1 Frequency Response Measurement

For performing system equalization, the frequency response of the complete setup is measured. For this measurement a CW signal (single carrier) with a frequency offset is generated by the AFQ and upconverted by the SMBV to a fixed radio frequency (e.g. 4.488 GHz – center frequency of UWB band #3). The frequency offset is varied in steps over a range of ±264 MHz to cover the full UWB bandwidth and a measurement of the RF output level is taken at every step. A step size of 10-20 MHz is recommended for this setup. The RF level measurement is best performed using a power sensor (e.g. an R&S®NRP-Z sensor), which yields the most precise measurements due to its exceptionally flat frequency response. If a spectrum analyzer is used to measure the RF power, one should keep in mind that the frequency response of the instrument might not be ideal. The following figure illustrates the measurement concept.

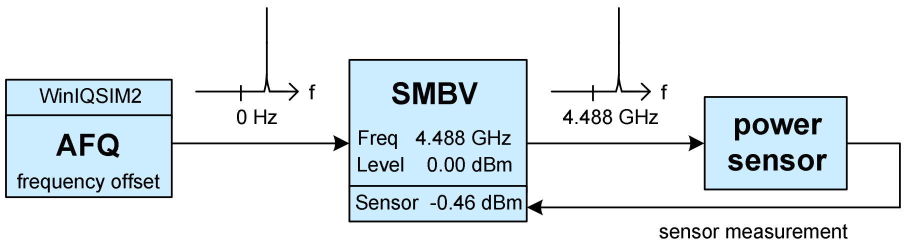


Fig. 10: Concept of measuring the frequency response (magnitude) of the AFQ-SMBV instrument setup.

5.1.1 Test Signal

As mentioned, the test signal is a single carrier CW signal with a frequency offset that can be generated with the WinIQSIM2 software. For example, a signal with a frequency offset of +100 MHz can be created by using the Multi Carrier Waveform configuration window to specify two carriers separated by 200 MHz with the first carrier disabled. The input signal for the multicarrier waveform is a CW signal created using the Custom Digital Modulation menu.

(Baseband block → Custom Digital Mod. → Data Source: All 0
→ Modulation: BPSK
→ State: On
→ Generate Waveform File: File name
(e.g. BPSK ALL 0) → Save)

(Baseband block → Multi Carrier → Number of Carriers: 2
→ Carrier Spacing: 200 MHz
→ Carrier Table: File 0/1: File name
(e.g. BPSK ALL 0)
State 0: Off
State 1: On
→ Output File → File name (e.g. CWTestSig) → Save
→ State: On)

ARB Multi Carrier Table A

	State	Gain [dB]	Phase [deg]	Delay [ns]	File	Info...
0	Off	0.00	0.00	0	c:/BPSK All 0	Info...
1	On	0.00	0.00	0	c:/BPSK All 0	Info...

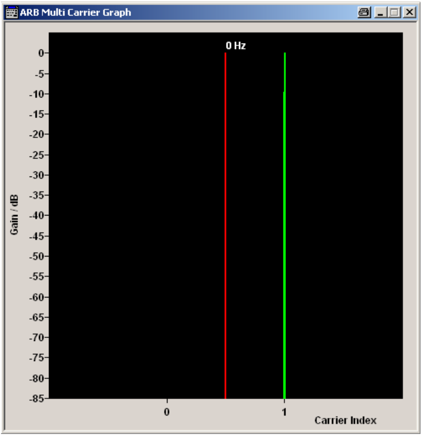


Fig. 11: Carrier Table and corresponding Carrier Graph of the Multi Carrier Waveform function of WinIQSIM2.

The resulting multicarrier waveform (e.g. CWTestSig) is the desired test signal, i.e. a single carrier CW signal with frequency offset. The length of this waveform can be limited to a user-selectable signal period (e.g. 1 ms). This also limits the resulting file size of the multicarrier waveform.

(Baseband block → Multi Carrier → Signal Period Mode: User
→ Signal Period: e.g. 1.0 ms)

In order to facilitate loading and playback of the different test signals, the individual test waveforms (e.g. CWTestSig1, CWTestSig2, …) can be combined into a multisegment waveform (e.g. MultiSegTestSig). Each of the individual test signals represents one segment of the multisegment waveform. This multisegment waveform is then loaded once into the ARB of the AFQ. The segment, i.e. test signal, intended to be played back can be selected by the user. The advantage of the multisegment waveform is that different test signals can be played back without experiencing any delay due to the loading operation. This multisegment waveform is also generated with WinIQSIM2.

(Baseband block → Multi Segment → Append → e.g. CWTestSig1 → Select
→ Append → e.g. CWTestSig2 → Select
→ Append → …

→ Level: Equal RMS
→ Clock: Highest
→ Output File: e.g. MultiSegTestSig
→ State: On)

To speed up the calculation and to keep the file size of the multisegment waveform moderate, the signal periods of the individual test waveforms should not be too long (e.g. <10 ms).

An example multisegment waveform file ("MultiSegTestSig.wv") is attached to this Application Note. This waveform consists of 27 test signals with frequencies spanning -260 MHz to +260 MHz in 20 MHz steps. This example or any other custom multisegment waveform is transferred to the ARB of the AFQ for playback.

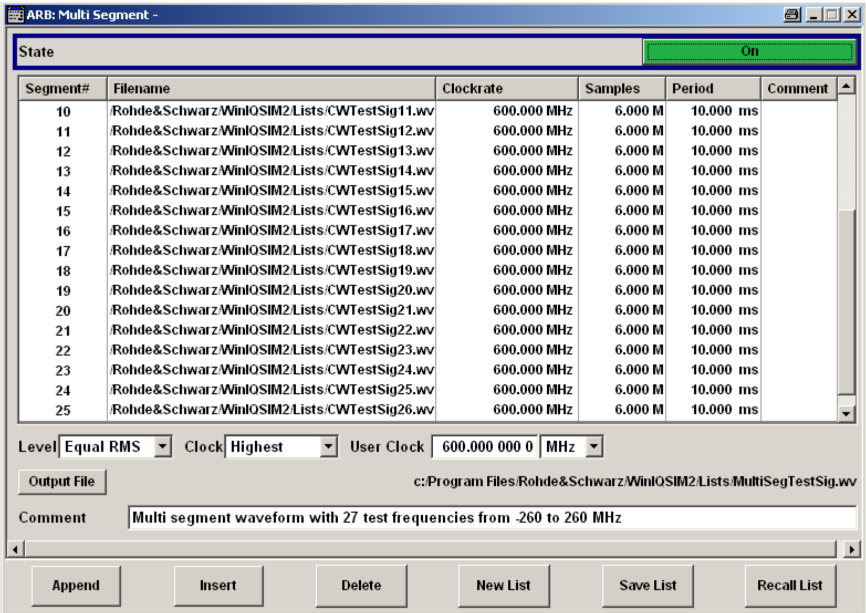


Fig. 12: Multi Segment configuration menu of WinIQSIM2.

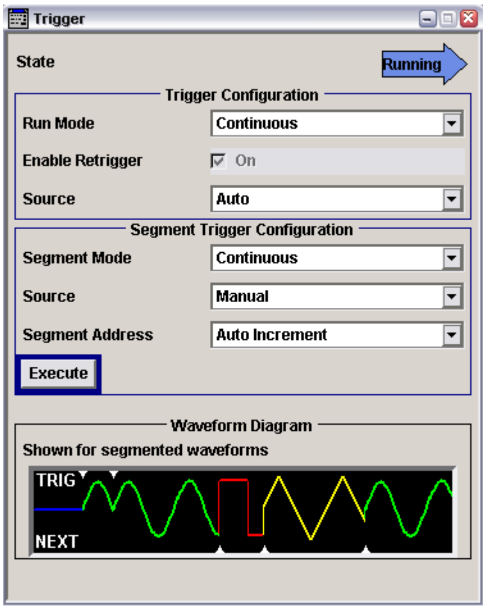


Fig. 13: Trigger menu of the AFQ for multisegment waveforms.

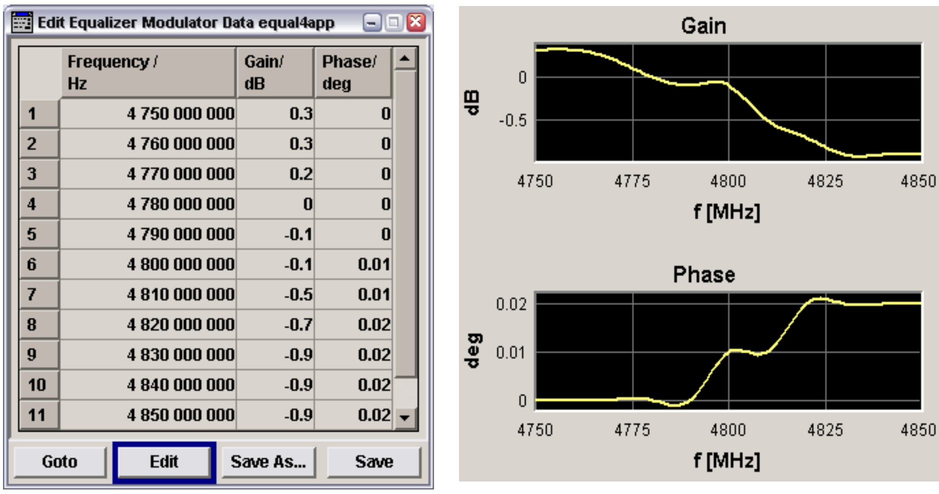
Once the multisegment waveform is loaded the trigger menu of the AFQ offers an additional section “Segment Trigger Configuration”. The playback of the waveform is controlled via the settings made for Trigger and Segment Trigger. While the Trigger Configurations apply to the multisegment waveform as a unit, the Segment Trigger Configurations apply to the individual waveforms within the multisegment waveform. For example, in order to playback an individual waveform for performing a measurement at a certain test frequency, the settings shown in Fig. 13 can be used. With these settings an individual waveform will be played back continuously until the button “Execute” is pressed. Then, the adjacent waveform within the multisegment waveform is played back until “Execute” is pressed again, and so on. In this way, one can run through the different test signals contained in the multisegment waveform.

5.1.2 Equalizer Data – Frequency

The equalization is performed according to a data list that contains the custom test frequencies and the corresponding measurement results for gain and phase. The equalizer data list can be created and edited in the AFQ.

(Equalizer function block → Modulator → List Data → New List: filename
→ Edit Data: list values → Save)

The test frequencies are entered in the first row. They can be chosen arbitrarily and serve as nodes for a cubic spline interpolation. As a start, the step size between the different test frequencies could be 20 MHz. For more accuracy, the step size may be decreased to smaller frequency intervals later on. For example, for a radio frequency of 4.488 GHz set on the SMBV and a baseband offset frequency of +100 MHz provided by the AFQ, the resulting frequency to be entered in the list is 4.588 GHz. Make sure that the frequency set on the SMBV remains fixed. The test frequency is varied by varying the offset frequency generated by the AFQ (!), because the frequency response of the I/Q modulator at a fixed radio frequency is to be characterized.



	Frequency / Hz	Gain/ dB	Phase/ deg
1	4 750 000 000	0.3	0
2	4 760 000 000	0.3	0
3	4 770 000 000	0.2	0
4	4 780 000 000	0	0
5	4 790 000 000	-0.1	0
6	4 800 000 000	-0.1	0.01
7	4 810 000 000	-0.5	0.01
8	4 820 000 000	-0.7	0.02
9	4 830 000 000	-0.9	0.02
10	4 840 000 000	-0.9	0.02
11	4 850 000 000	-0.9	0.02

Fig. 14: Equalizer data list of the AFQ and corresponding graphical display of the entries.

Remark: In the equalizer data list the entries for gain /dB are displayed with one decimal place but for calculation two decimal places are taken into account.

5.1.3 Equalizer Data – Gain

The test signals are created with WinIQSIM2 and the resulting multisegment waveform is loaded into the arbitrary waveform generator of the AFQ and played back as described above. The SMBV is set to a *fixed* frequency. The power level of the SMBV should be set to the intended operating level, since the frequency response can vary with the set output level. The sensor reading can be monitored on the SMBV with the NRP-Z Power Viewer.

(RF function block → NRP-Z Power Viewer → State: On)

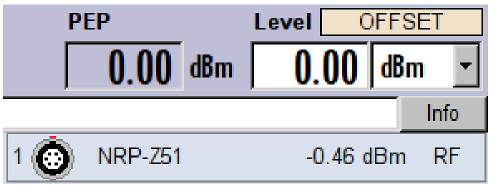


Fig. 15: Display detail of the SMBV showing part of the user interface header and the R&S®NRP-Z sensor reading.

The second row of the equalizer data list contains the gain correction values, i.e. the difference between the nominal power set on the generator and the actual output level measured by the sensor. For the current test frequency, the sensor reading at the RF output is entered in the equalizer data list. For example, for a nominal RF level of 0.00 dBm and a sensor reading of -0.46 dBm the value to be entered is -0.46 dB.

In the next step, the same gain measurement is repeated for a different test frequency. The entire measurement procedure is to vary the frequency offset in steps over a range from -264 MHz to +264 MHz in order to cover the full UWB bandwidth. At every step a measurement of the RF output level is taken and the determined gain correction value is entered into the list. A step size of 10-20 MHz is recommended.

Note: For optimal results this measurement should be performed with the same power level as will be used later during operation using the target signal. The test signals for the equalization measurement are CW signals with a crest factor of 0 dB, while the actual target signal (e.g. a UWB waveform) may have a certain crest factor (e.g. 10 dB). Obtaining the same power level for CW signals as for signals with a crest factor requires different amplitude levels. Using the same power level during the equalization measurement as will be used later during operation ensures that the thermal conditions at the output/input stages of the AFQ/SMBV are the same under both measurement modes. This is important, since otherwise the frequency response of the system during the equalization measurement may differ from the frequency response during operation using the target signal (since the frequency response is temperature-dependent). Therefore, the amplitude level of the AFQ should be reduced by the crest factor of the target signal during the equalization measurement. For example, if the intended operating level of the AFQ is 178 mV and the target signal has a crest factor of 10 dB, then the level should be reduced to 178 mV – 10 dB = 56 mV for the equalization measurement. For this example the appropriate settings on the SMBV for Crest Factor and Level Offset would be the following:

- Crest Factor:
  (I/Q Mod function block → I/Q Settings → Crest Factor: 10.00)
  The crest factor of the target signal is entered.
- Level Offset:
  (RF function block → Level / EMF → Offset: -15 dB)
  The level offset corresponding to the later operating level (here 178 mV) is entered.

The following table summarizes the settings for the AFQ and the SMBV required during the equalization measurement and during operation using the target signal. The second table gives an example with numeric values.

Setting Parameters			
Instrument	**Parameter**	**Equalization**	**Operation**
AFQ	**Signal**	CW test signals	Target signal
	Amplitude	Operating level minus crest factor of target signal	Operating level
SMBV	**Offset**	Offset corresponding to operating level	Offset corresponding to operating level
	Crest Factor	Crest factor of signal	Crest factor of signal

Example - Setting Parameters			
Instrument	**Parameter**	**Equalization**	**Operation**
AFQ	**Signal**	CW test signals (crest factor is 0 dB)	UWB signal (crest factor is 10 dB)
	Amplitude	56 mV	178 mV
SMBV	**Offset**	-15 dB	-15 dB
	Crest Factor	10 dB	10 dB

Note: As mentioned above, the frequency response can vary with the set RF level of the SMBV. The internal step attenuator of the generator is adjusted according to this RF level. As long as the attenuation level stays unchanged, i.e. the attenuation remains in a fixed state, the measured frequency response is virtually the same for different RF output levels. However, a change in the attenuation level results in a significant change of the frequency response. The step attenuator can be forced to remain in a fixed state by configuring the Attenuator Settings.

(RF function block → Level / EMF → Attenuator Settings Mode: Fixed)

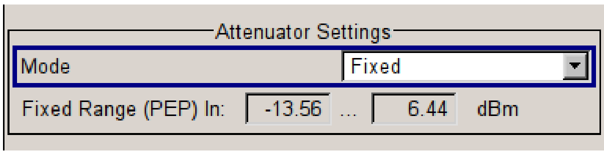


Fig. 16: Display detail of the SMBV showing the Attenuator Settings.

With this attenuator setting, the RF level settings are made without altering the step attenuator, which results in a limited range of achievable output powers. Thus, setting the attenuator mode to “Fixed” means reducing the dynamic level range. If the intended operating level of the SMBV changes by a few dBs only, it is advisable to use the fixed attenuator mode, since the frequency response will then hardly vary with the RF level and a single gain correction measurement is sufficient. In this case, the response curves measured for different RF levels vary typically by <0.10 dB. In contrast, if the intended operating level of the SMBV spans a wide range, then the default attenuator mode “Auto” must be used. In this case, the response curves measured for different RF levels can vary by up to 1.0 dB. Thus, the gain correction measurement has to be repeated for the different RF levels, since varying the output level can provoke a change of the attenuation level and thus cause a change of the frequency response. (The auxiliary PC program attached to this Application Note performs the gain correction measurement for a certain RF level or level range. See section 5.1.6 for details.)

5.1.4 Equalizer Data – Phase

The third row of the equalizer data list may contain values to correct the phase of a non-ideal frequency response. However, these phase correction values are generally small for the AFQ-SMBV setup. For this reason, a phase correction can be omitted.

5.1.5 Measurement Procedure – Summary

1) Set fixed RF frequency and power level on the SMBV

2) Generate test signals with WinIQSIM2 and combine them into a multisegment waveform

3) Transfer the waveform to AFQ

4) Play back a test signal
   → Single CW carrier with frequency offset

5) Measure RF output power on the SMBV using a power sensor
   → Difference of measured value (sensor) to nominal RF value (SMBV)
   → Gain correction value for current test frequency

6) Enter result into equalizer data list
   → Enter current test frequency
   → Enter corresponding gain correction value
   → Enter "0" as corresponding phase correction value

7) Play back next test signal
   → Single CW carrier with different frequency offset

8) Repeat steps 5) to 7)

Notes:

- Test signals, i.e. baseband frequency offsets, should span the range from -264 MHz to +264 MHz in order to cover the full UWB bandwidth.

- The measurements should be performed with the same power level as will be used later during operation using the target signal (e.g. a UWB signal). Thus, during the equalization procedure the amplitude level of the AFQ should be reduced by the crest factor of the target signal.

- The entire measurement procedure of changing the baseband frequency in steps and measuring the gain correction values (steps 4) to 8)) has to be repeated if:
  - the radio frequency set on the SMBV changes, since this changes the overall frequency response of the system (I/Q modulators show different behavior at different radio frequencies).

- the power level set on the SMBV changes while simultaneously the step attenuator mode is set to “Auto”, since a change of the overall frequency response can then not be excluded.
- the crest factor of the target signal changes significantly, since this may also change the frequency response of the system due to the altered thermal conditions at the output/input stages of the AFQ/SMBV.

- Attached to this Application Note is the little auxiliary PC program “R&S GainEqualization”, which performs steps 4) to 8) of the measurement procedure. See next section for details.

5.1.6 PC Program – R&S GainEqualization

R&S GainEqualization is an auxiliary program that performs the gain correction measurement across the UWB bandwidth for a certain RF power level or level range. The program processes steps 4) to 8) of the measurement procedure for different, user-defined RF power levels of the SMBV.

Requirements

- PC (operating system: Microsoft Windows or Linux) with LAN
- R&S®NRP-Z power sensor
- VISA library (for remote control of the instruments)

Input parameters

The program provides a graphical user interface for setting the input parameters. Besides the mandatory parameters, various optional input parameters can be edited. The default settings of the optional parameters are in line with the supplied multisegment waveform. The following input parameters are available:

- Visa Device String SMBV (mandatory)
  Visa device string of the SMBV, e.g. TCPIP::RSSMBV100A255001::INSTR or TCPIP::100.11.101.18::INSTR
- Visa Device String AFQ (mandatory)
  Visa device string of the AFQ.
- RF Frequency SMBV (mandatory)
  RF frequency of the SMBV.
- BB Frequency Increment (mandatory)
  Step size between the different test frequencies. By convention “BB Frequency Increment” is a positive value, e.g. +20 MHz.
- Start Power (mandatory)
  RF power level of the SMBV. The program can be used to measure the gain correction for a series of different RF levels. The parameter “Start Power” defines the first RF level of this series, i.e. the starting value.

- BB Start Frequency (optional)
  Frequency offset of the first test signal. Note that for custom multisegment waveforms the combination “BB Start Frequency”, “BB Stop Frequency” and “BB Frequency Increment” must match the applied waveform.
- BB Stop Frequency (optional)
  Frequency offset of the last test signal. Note that “BB Stop Frequency” must be numerically greater than “BB Start Frequency”, e.g. +260 MHz “BB Stop Frequency” and -260 MHz “BB Start Frequency”.
- Power Increment (optional)
  Step size between different RF power levels. After a measurement cycle (steps 4) to 8)) the current RF level is changed by the value specified for “Power Increment” and another measurement cycle is started. By convention “Power Increment” is a negative value, e.g. -0.1 dB.
- Stop Power (optional)
  Last RF power level of the series. The overall measurement run is completed after the last measurement cycle is performed for the RF level specified by “Stop Power”. Note that “Stop Power” must be equal to or less than “Start Power”, e.g. -10.8 dBm “Stop Power” and -10.2 dBm “Start Power”.
- Power Limit (optional)
  RF power limit of the SMBV. This value specifies the upper limit of the level at the RF output connector. An RF power level can be set to protect the used power sensor from possible power overload.
- Power Offset (optional)
  RF power offset of the SMBV.
- Amplitude (optional)
  Intended operating amplitude of the AFQ. This value denotes the amplitude level that will be used after system equalization for playback of the target waveform.
- Crest Factor WV (optional)
  Crest factor of the target waveform that will be played back after system equalization. This value is used to calculate the amplitude level on the AFQ used during the equalization measurement.

Preparation

- Connect the power sensor to the RF output of the SMBV
- Perform zeroing of the sensor (with RF turned off)
- Plug the PC to the SMBV and the AFQ using LAN or GPIB cables
- Load the supplied multisegment waveform (or a custom one) into the AFQ and start the waveform (this can take a while depending on the file size)
- Configure the input parameters

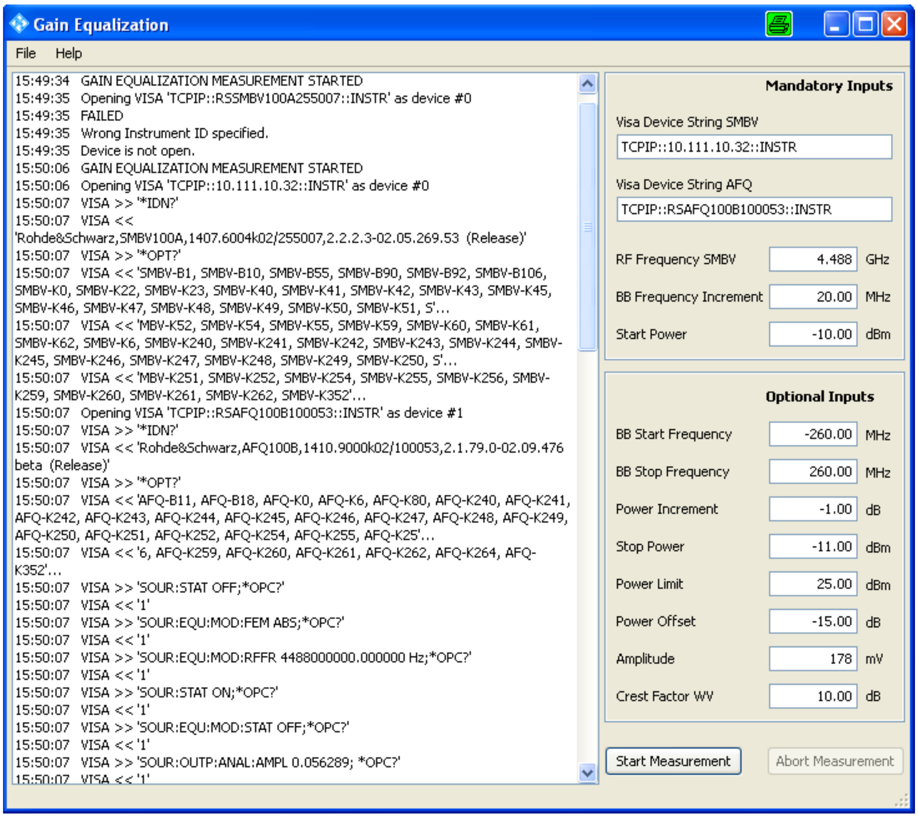


Fig. 17: Graphical user interface of the program R&S GainEqualization (V1.0.1).

Program run

The gain correction measurement is started by pressing the button "Start Measurement". At first, a connection to the instruments is opened. The instruments are then configured by sending SCPI commands, which are monitored in the command prompt. (The amplitude level of the AFQ is automatically calculated from the entered values for "Amplitude" and "Crest Factor WV".) A gain correction measurement (i.e. steps 4) to 8) of the measurement procedure) is performed for the RF level defined by "Start Power". The corresponding equalizer list is created and saved in the AFQ (e.g. GainList-10.00dBm). Subsequently, the current RF level is decreased by the specified "Power Increment" and the gain correction measurement is repeated for the new RF level. The corresponding new equalizer list is created and saved in the AFQ under a different name (e.g. GainList-11.00dBm). This measurement loop continues until the RF level defined by "Stop Power" is reached. The measurement loop can be aborted at any time by pressing the button "Abort Measurement". Note that a saved equalizer list is overwritten when a new list is created for the same RF level.

5.2 Equalizer Functionality

Once the equalizer data list is created, the equalizer functionality of the AFQ can be utilized to compensate the frequency response of the system.

(Equalizer function block → Modulator → Frequency Entry Mode: Absolute
→ RF Frequency: frequency as set on SMBV
→ State: On)

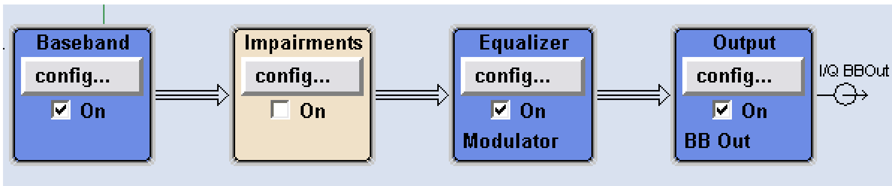


Fig. 18: User interface of the AFQ with enabled equalizer functionality.

With equalization in the AFQ enabled, matching inverse filters compensate the effects of connected devices (in this example: the I/Q and RF domain of the SMBV) achieving an ideal frequency response at the output of the system. Note that the equalization is accomplished by utilizing integrated hardware components running in real-time and *not* by predistortion of the waveform. Thus, a recalculation of the waveform to incorporate predistortion is not required. The beneficial effect of the system equalization is illustrated by means of a multicarrier signal in Fig. 19.

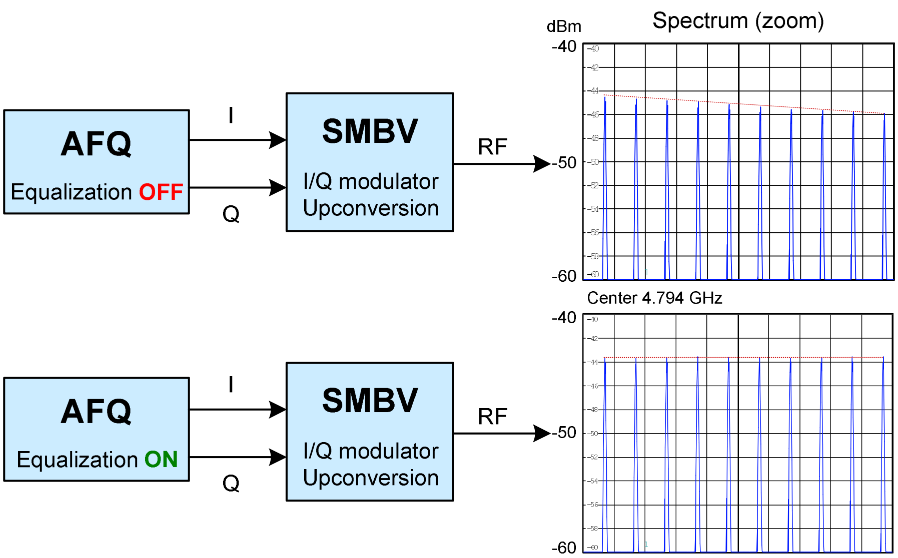


Fig. 19: Effect of system equalization.

Note that a spectrum analyzer may also have a non-ideal frequency response. Thus, despite equalization enabled, one may observe a residual frequency response in the spectrum that is caused by a non-ideal spectrum analyzer.

6 Summary

This Application Note described the generation of wideband signals using the AFQ UWB signal and I/Q modulation generator in combination with the SMBV vector signal generator. In particular, the generation of UWB signals was demonstrated along with a detailed description of the instrument settings. The signal quality of wideband signals can be improved by employing the equalizer functionality of the AFQ. The benefits and the usage of this instrument functionality were also explained.

7 Ordering Information

R&S®SMBV100A	**Vector Signal Generator**	1407.6004.02
R&S®SMBV-B103	9 kHz to 3.2 GHz	1407.9603.02
R&S®SMBV-B106	9 kHz to 6 GHz	1407.9703.02
R&S®SMBV-B1	Reference Oscillator OCXO	1407.8407.02
R&S®SMBV-B90	Phase Coherence	1407.9303.02
R&S®SMBV-K22	Pulse Modulator	1415.8019.02
R&S®SMBV-K23	Pulse Generator	1415.8025.02
R&S®SMBV-B10	Baseband Generator with Digital Modulation (realtime) and ARB (32 Msample), 120 MHz RF Bandwidth	1407.8607.02
R&S®SMBV-B50	Baseband Generator with ARB (32 Msample), 120 MHz RF bandwidth	1407.8907.02
R&S®SMBV-B51	Baseband Generator with ARB (32 Msample), 60 MHz RF bandwidth	1407.9003.02
R&S®SMBV-B55	Memory Extension for ARB to 256 Msample	1407.9203.02
R&S®SMBV-B92	Hard Disc (removable)	1407.9403.02
R&S®SMBV-K18	Digital Baseband Connectivity	1415.8002.02
R&S®SMBV-K6	Pulse Sequencer	1415.8390.02

R&S®AFQ100B	**UWB Signal and I/Q Modulation Generator**	1410.9000.02
R&S®AFQ-B11	Waveform Memory 1 Gsample	1401.5206.02
R&S®AFQ-B12	Waveform Memory 512 Msample	1411.0007.02
R&S®AFQ-B18	Digital I/Q Output	1401.5306.02
R&S®AFQ-K80	Bit Error Ratio Tester	1401.5006.02
R&S®AFQ-K6	Pulse Sequencer	1401.5606.02
R&S®AFQ-K264	Digital Standard ECMA-368 (UWB)	1410.8504.02

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