Linearity Measurements on RFFE Components

Application Note

Products:

- R&S®FSW
- R&S®FSW-K18
- R&S®Forum
- R&S®SMW200A
- R&S®WinIQSIM2

Distortions caused by components in the RFFE (radio frequency front end) limit the performance and throughput of communications systems. Types of distortions include:

- AM-AM and AM-PM (complex variations of gain with amplitude)
- Non-linear frequency response (memory effect)

All RFFE components exhibit all of these distortions, only the proportions vary. In this Application Note, illustrative measurements of individual RFFE components, as well as a complete RFFE, will be made.

This is followed by the documentation of a more complete analysis, including comparison against theoretical limits, of a linearized commercial SatCom BUC product.

The R&S®FSW Signal and Spectrum Analyzer with FSW-K18 personality provides an extremely fast, flexible and easy-to-setup-and-use environment for characterization of distortions of RFFE components such as amplifiers, mixers, filters or complete frequency-converting receive or transmit frontends

Note:

Please find the most up-to-date version of this document on our homepage :

http://www.rohde-schwarz.com/appnote/1MA299

Application Note
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3.2017 – 1MA299_1e

ROHDE&SCHWARZ

Table of Contents

1 Introduction 4
1.1 Background 4
1.2 Reader's Guide 5
2 Getting Started 6
2.1 Bill of Materials 6
2.2 General Procedure 6
3 Mixers, Filters and Amplifiers 10
3.1 Filter 10
3.2 Mixer 13
3.3 Cascade of Mixer & Filter 17
3.4 The Complete Tx RFFE: Mixer, Filter and Amplifier 19
4 Measurement of an Off-The-Shelf RFFE 22
4.1 Background 22
4.2 Reference Performance Calculation 22
4.3 Measurement of DUT PSat (Saturated Power) 24
4.4 Measurement of Raw and Linearized DUT Linearity 25
4.5 Key SCPI Commands 26
5 Ordering Information 27
6 Appendices 28
6.1 Forum Script Example 28
6.2 Signal File Generation 30
6.2.1 Background 30
6.2.2 Use of WinIQSIM2 30
6.2.3 SMW Built-in Custom Waveform Generator 31
6.2.4 Using MATLAB 31
7 Glossary 33

This application note uses the following abbreviations for Rohde & Schwarz products:

- R&S® is a registered trademark of Rohde & Schwarz GmbH und Co. KG.
- The R&S®FSW Signal and Spectrum Analyzer is referred to as FSW.
- The R&S®SMW200A Vector Signal Generator is referred to as SMW.
- The R&S®WinIQSim2 Simulation Software is referred to as WinIQSim2.
- The R&S®Forum software tool is referred to as Forum.

Rohde & Schwarz® is a registered trademark of Rohde & Schwarz GmbH & Co. KG.

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1 Introduction

1.1 Background

Distortions caused by components in the RFFE limit the performance and throughput of communications systems. Types of distortions include:

- AM-AM and AM-PM (complex variations of gain with amplitude)
- Non-linear frequency response (memory effect)

All RFFE components exhibit all of these distortions. Only the proportions vary. Examples of RFFE components include mixers, amplifiers and filters.

In this Application Note, the exemplary measurement of each will be illustrated individually, along with a complete RFFE.

Historically, distortion specification and measurement was performed using a potpourri of metrics including, for example:

- P-1dB (the one dB gain compression point)
- IM3 (Two-tone Third Order Intermodulation level)
- IP3 (Third Order Intermodulation Intercept)

Such specification approaches served the industry very well, resulting in products that were robust, if a little power hungry.

Achieving optimum performance is increasingly important. While this may mean widening RF bandwidth for a given RFFE, for mobile and battery operated equipment, time between recharge events has become the most critical differentiator. For static equipment, overall power wasted (and therefore heat generated) is key alongside bandwidth.

Linearization, and especially digital pre-distortion (DPD), has become increasingly adopted across a range of radio platforms. Heavy investment in the R&D of DPD, especially in cellular infrastructure industries, helped to boost knowledge and awareness. Subsequently, DPD can almost always be found in radio transmitters of systems most sensitive to energy-use and/or heat dissipation, including satellite communications equipment and cellular handsets.

Specification and design of RFFE for linearized applications is different to that historic open-loop design. In predictive linearization architectures, such as DPD, it is usually more important for the DPD to be able to estimate the RFFE distortion, than to have good open-loop linearity; estimation accuracy decides the ultimate system linearity.

With up to 2 GHz internal modulation bandwidth, the R&S®SMW200A is the Vector Signal Generator for the most demanding applications. As a result of its baseband flexibility, RF performance and highly intuitive operation, it is the perfect tool for generating complex, digitally modulated signals of utmost quality.

The high-performance FSW Signal and Spectrum Analyzer was developed to meet demanding customer requirements. Offering low phase noise, wide analysis bandwidth and straightforward and intuitive operation, the analyzer makes measurements fast and easy. Models ranging from 8 to 85 GHz on the same input are currently available

The dedicated option FSW-K18 has been developed to provide a valuable and easy-to-use insight into the distortion characteristics of the RFFE and its building blocks.

1.2 Reader's Guide

Chapter 2 presents a guide to getting started. The powerful FSW-K18 personality may be used simply by connecting the SMW and FSW instruments together via a LAN. The FSW-K18 enables a plurality of parameter sweep measurements to automatically be made. A step-by-step guide to manually setting up measurements and environments is supported with screenshots.

In Chapter 3, example measurements are done on some of the most common RFFE components: mixers, filters and amplifiers. Illustrative distortions for each are shown. The devices are then combined in cascade to form a frequency converting RFFE.

In Chapter 4, measurements (including linearization by DPD) are made on an integrated, off-the-shelf SatCom BUC (block upconverter). A methodology for calculating the theoretical performance limit is presented. This allows a comparison of linearized performance not just with the open-loop device, but also shows how much performance potential remains.

A user manual for the FSW-K18 option used in this paper may be downloaded here.

2 Getting Started

2.1 Bill of Materials

The FSW-K18 measurement application was designed to enable operation of the measurement setup from a single GUI. This application note also provides tips on how to override this single-GUI aspect for some special use cases. The minimum setup required to test with the FSW-K18 personality is as follows:

- FSW with option FSW-K18
- SMW (the K541 option supports instrument based DPD, if required)
- Switch or Router (not shown), plus LAN cabling

The connection concept is shown in Fig. 2-1.

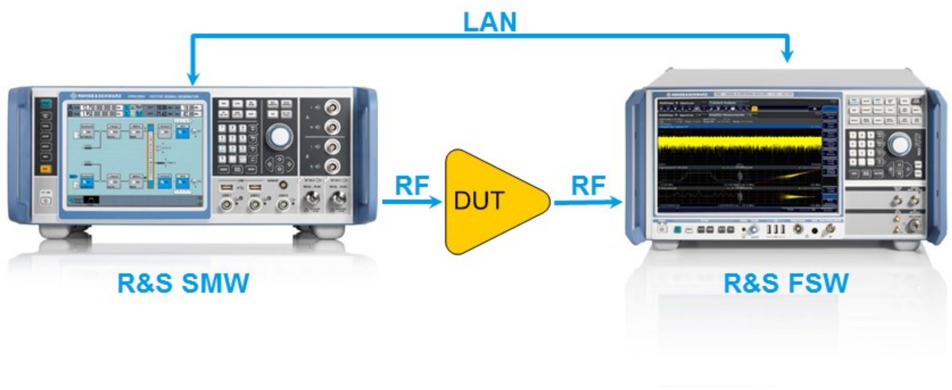

Fig. 2-1:-K18 test setup

The process by which the system operates is thus:

1. The SMW generates a test signal, which may be defined by the user, which is applied to the RFFE input.
2. The FSW measures the output of the RFFE.
3. The FSW-K18, using knowledge of both the input and output signal, compares both to calculate the transfer function of the RFFE.

2.2 General Procedure

After connection of the equipment described in 2.1, it may once be desirable to press the "Preset" button on the instrument front panels.

On the FSW front panel, press the "Mode" button, and select the "Amplifier" option.

Select the "Amplifier" option, and the FSW-K18 personality will be invoked (Fig. 2-2).

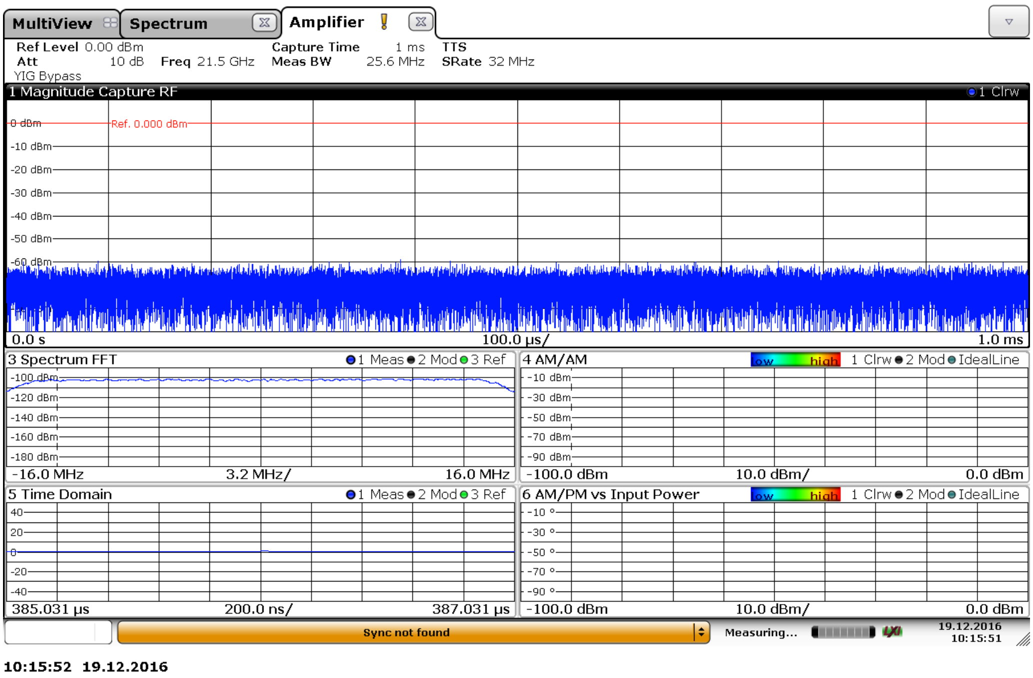

Fig. 2-2: FSW with FSW-K18 initialized

Press the "Input/Output" soft key, the following dialog (Fig. 2-3) will appear on the screen.

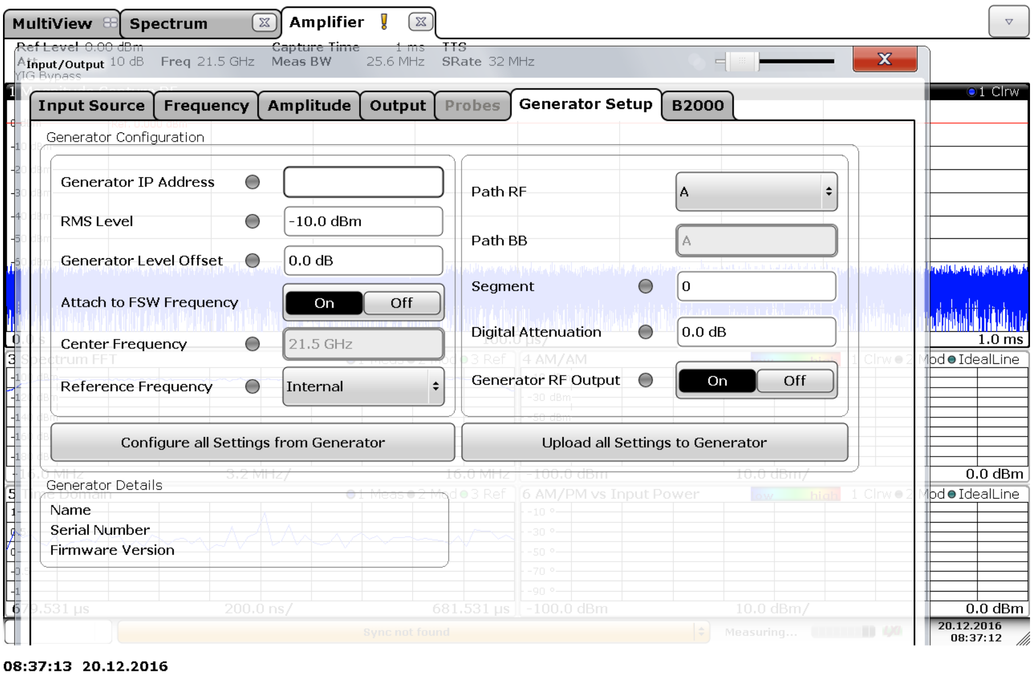

Fig. 2-3: Configuring the FSW-K18 - "Input/Output" dialog box.

Select the "Generate Own Signal" tab (Fig. 2-4). This feature will create a multicarrier signal with OFDM characteristics, for characterization of the DUT.

Press the "Generate and Load Signal and Export it to Generator" key.

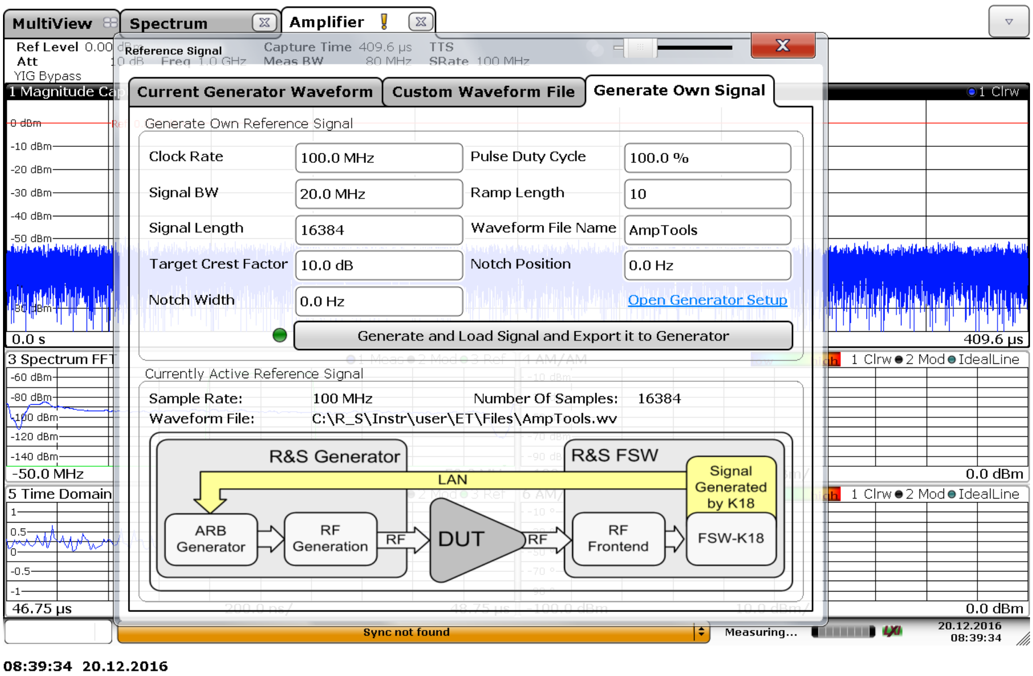

Fig. 2-4: Configuring the FSW-K18 - Exporting the test signal from the FSW, to the SMW, over LAN.

Re-open the "Input/Output" tab, and switch the "Generator RF Output" button to the "On" state (Fig. 2-5).

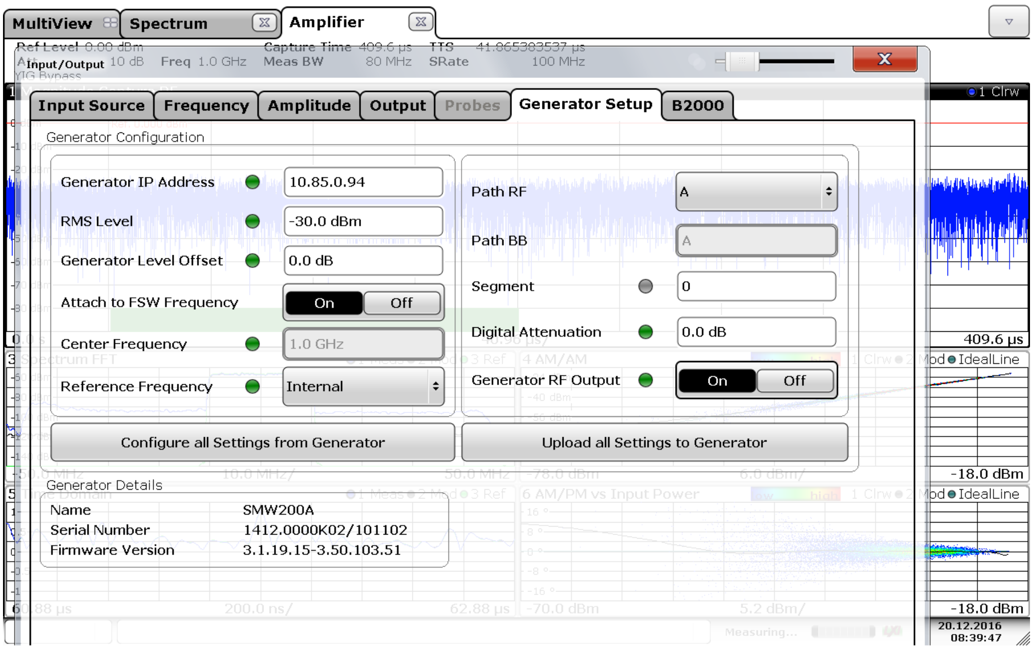

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Fig. 2-5: Configuring the FSW-K18 - Switching on the test signal to the DUT

Close the dialog box to reveal the live measurement (Fig. 2-6).

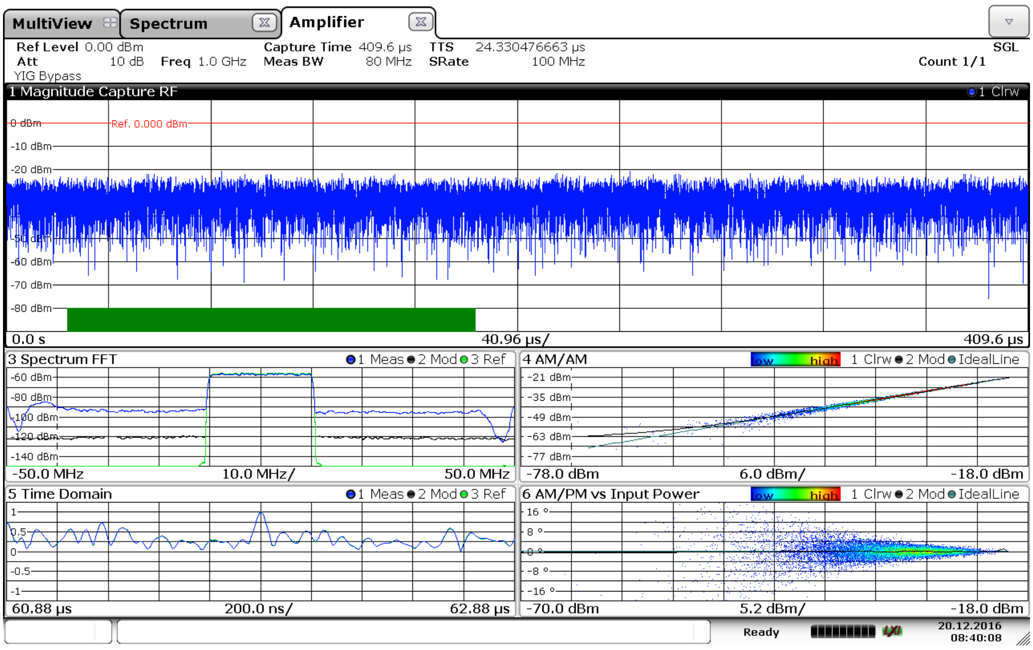

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Fig. 2-6: Configuring the FSW-K18 - First measurement on a cable, with default settings.

3 Mixers, Filters and Amplifiers

In this section, an illustrative up-converting RFFE will be built using off-the-shelf components; a mixer, filter and amplifier to demonstrate some of the FSW-K18 measurements and typical distortion sources.

The expansive FSW-K18 measurement suite provide many useful measurement features. In this section, the following selection will be used:

- AM-AM
- Gain Compression
- AM-PM
- Result Summary

3.1 Filter

An RF filter is a component that, in the frequency domain, passes chosen or designed frequencies whilst blocking (usually by reflecting) others.

The filter DUT used is the K&L bandpass 3FV50-1950-T80-NP/N (Fig. 3-1). This filter has a nominal 3dB bandwidth of 80 MHz, with passband centered at 1950 MHz.

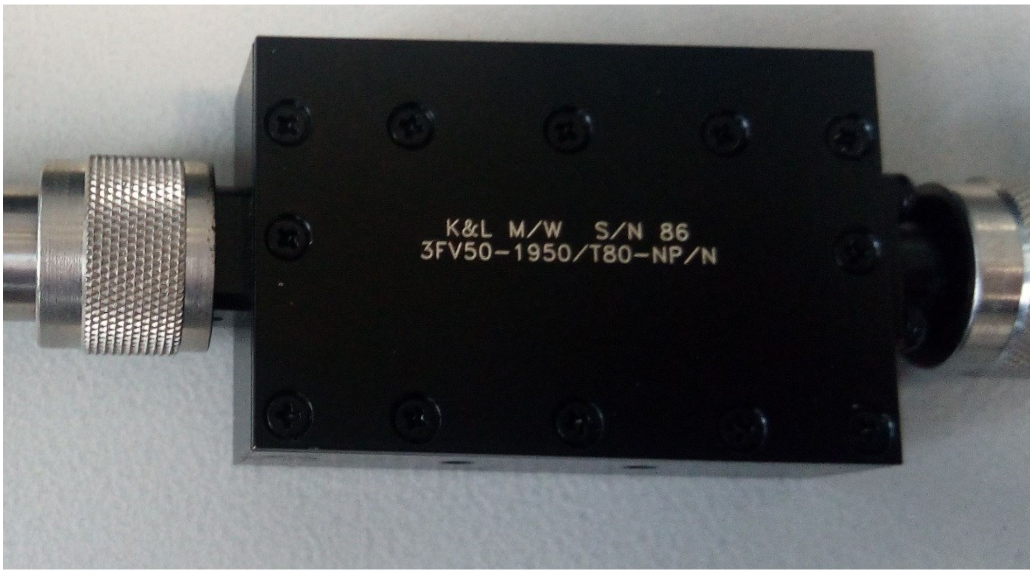

Fig. 3-1: Band Pass Filter DUT from K&L

The SMW output power level is set to a nominal 0 dBm. In order to simplify operation as much as possible, this is done from the "Input/Output" softkey in the FSW-K18 application, selecting "Generator Setup" tab, modifying the "RMS Level" value (Fig. 3-2).

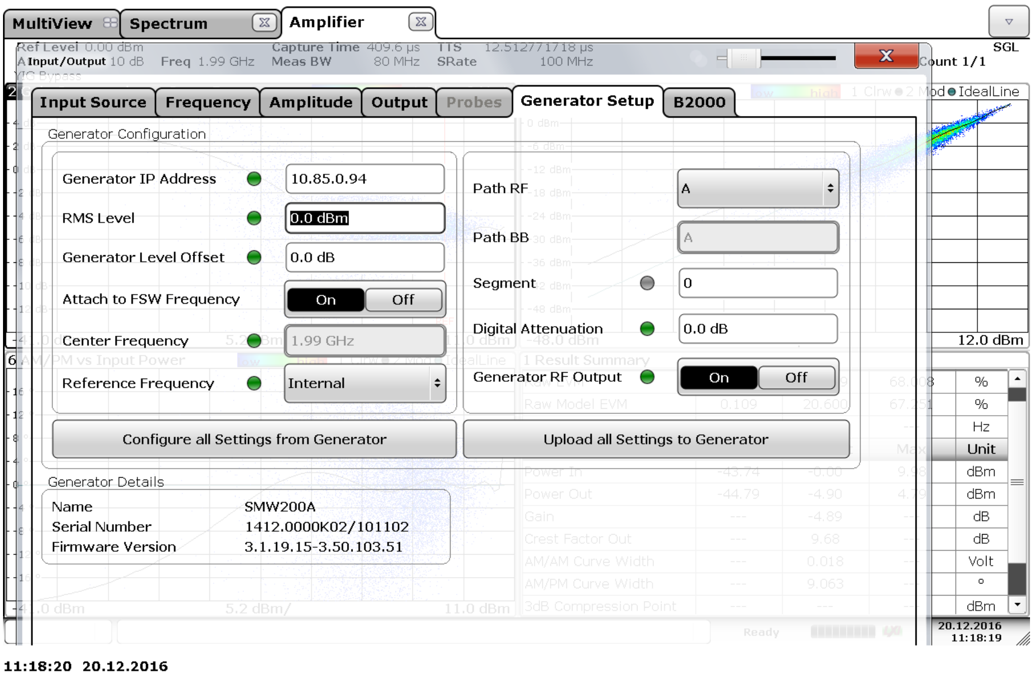

Fig. 3-2: Configuring the FSW-K18 - Modifying output level of the SMW from the FSW.

Note that in that same dialog, that the "Attach to FSW Frequency" is toggled to "On". Therefore, the FSW may directly control the frequency of the SMW too.

A manual frequency sweep of the filter, from the center of the band, to the band-edge, with the OFDM-like signal (see 2.2) yields an interesting, but not surprising, result.

As the filter is stimulated at frequencies approaching the band-edge, the filter becomes increasingly selective.

With that selectivity and roll-off, increasing amounts of linear distortion appear (Fig. 3-3). This is manifest as increases in "Raw EVM", "AM/AM Curve Width" and "AM/PM Curve Width".

Indeed, these tabulated values are accompanied by an increase in the dispersion observed in the plots.

The greater the selectivity or roll-off experienced by the signal (e.g. variations in complex gain over the frequency range), the greater the degradation in these quantities. All this is in spite of the expected infinitesimal non-linear distortion.

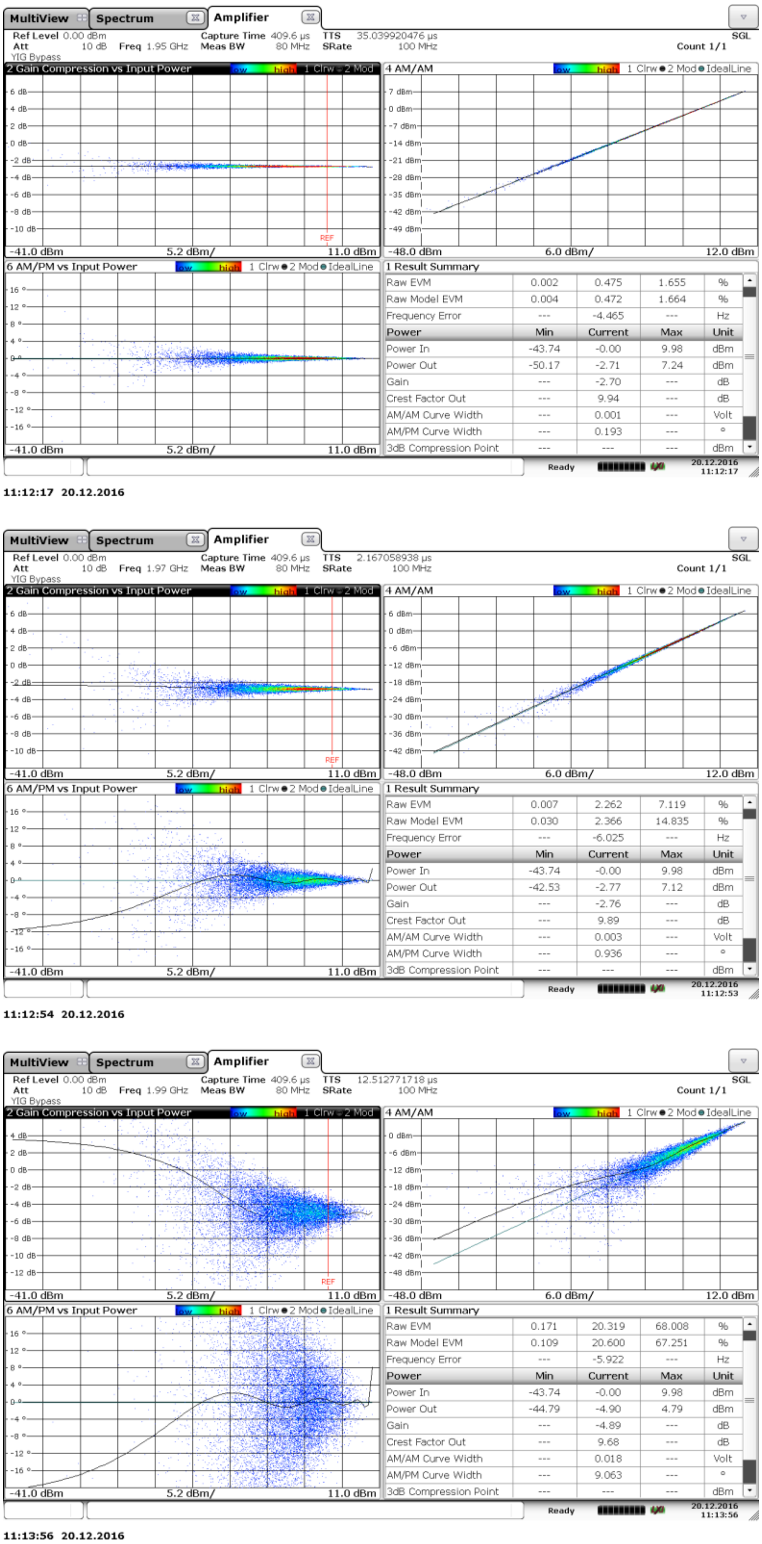

Fig. 3-3: Frequency sweep characteristic of the Band Pass Filter DUT with center frequencies 1.95, 1.97 and 1.99 GHz. Note the increasing dispersion, spreading in the AM-xM scatter plots, as the band edge is approached.

3.2 Mixer

An RF mixer is a multiport device that shifts a signal from one frequency to another. Usually there are 3 ports, RF (a signal port, usually the highest frequency), LO (local oscillator, whose frequency sets the difference between the RF and IF signals) and IF (whose signal is the almost the same as the RF port, except at a usually lower frequency).

The mixer used for up-conversion in the RFFE is the off-the-shelf ZX05-C60MH-S+ (Fig. 3-4), from Mini-Circuits.

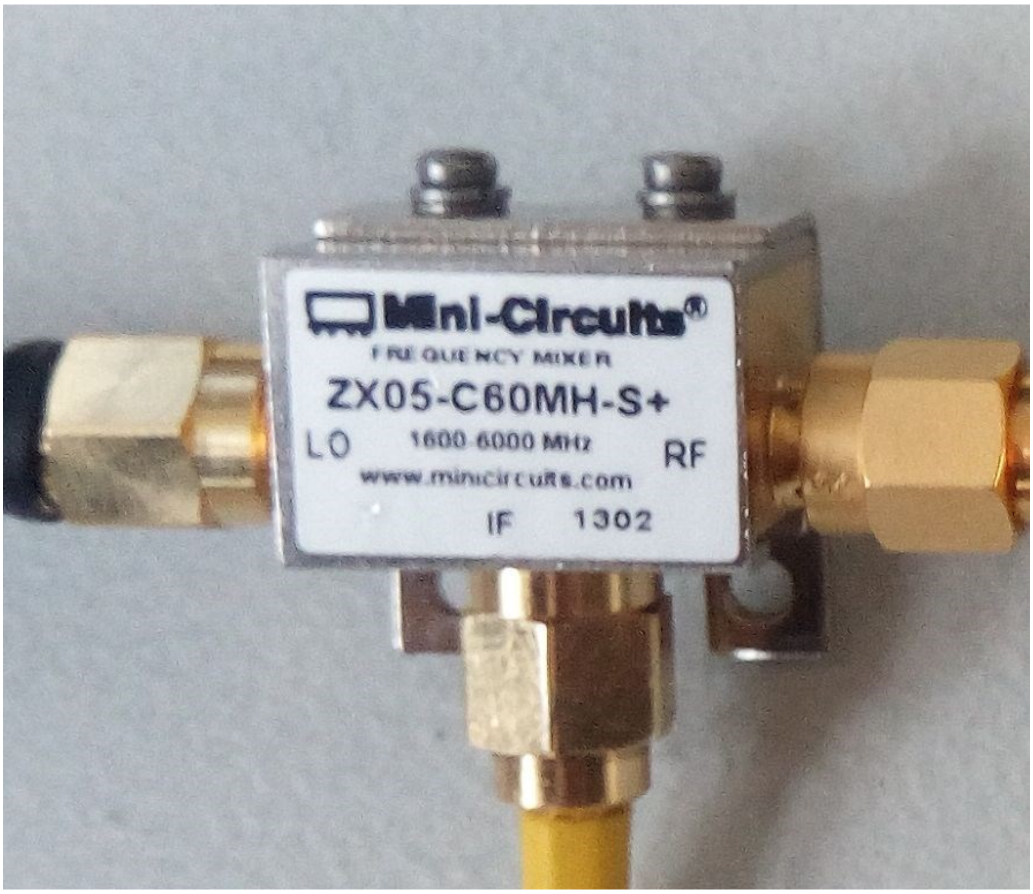

Fig. 3-4: Mixer DUT, the ZX05-C60MH-S+ from Mini-Circuits

It will be configured with a 1.7 GHz LO, which will be sourced from the 2nd RF output of the SMW. The IF frequency range will be 210~290 MHz thus placing the high-side RF signal in the 1910~1990 MHz band.

In this example, low-side up-conversion products will appear in the frequency range 1410~1490 MHz. Those will be rejected by the band pass filter shown in 3.1.

With this FSW-K18 platform, it is possible for the designer to investigate a range of LO/IF frequency pairs, as well as drive level. For example, the designer may investigate the use of a high sided up-conversion (which with this specific mixer would allow a much greater range of choice of LO/IF variants to be investigated).

To test this frequency converting device, some configuration changes need to be made.

Firstly, the "Input/Output" softkey menu of the FSW-K18 application, "Generator Setup" tab, set the "Attach to FSW Frequency: to "Off" (Fig. 3-5).

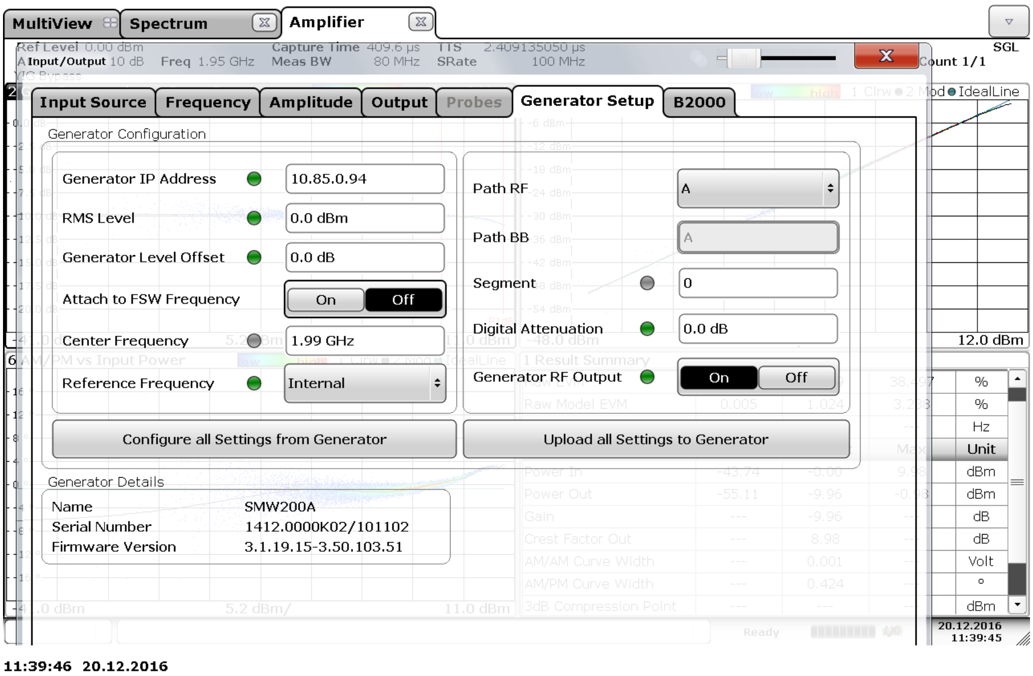

Fig. 3-5: Configuring the FSW-K18 - Decoupling the SMW and FSW operating frequencies to test frequency conversion devices.

On the SMW, exit "Remote" mode (e.g. by pressing "Remote" softkey in the top left of the display) and set-up the 2 channels for the frequency and power combinations given (Fig. 3-6):

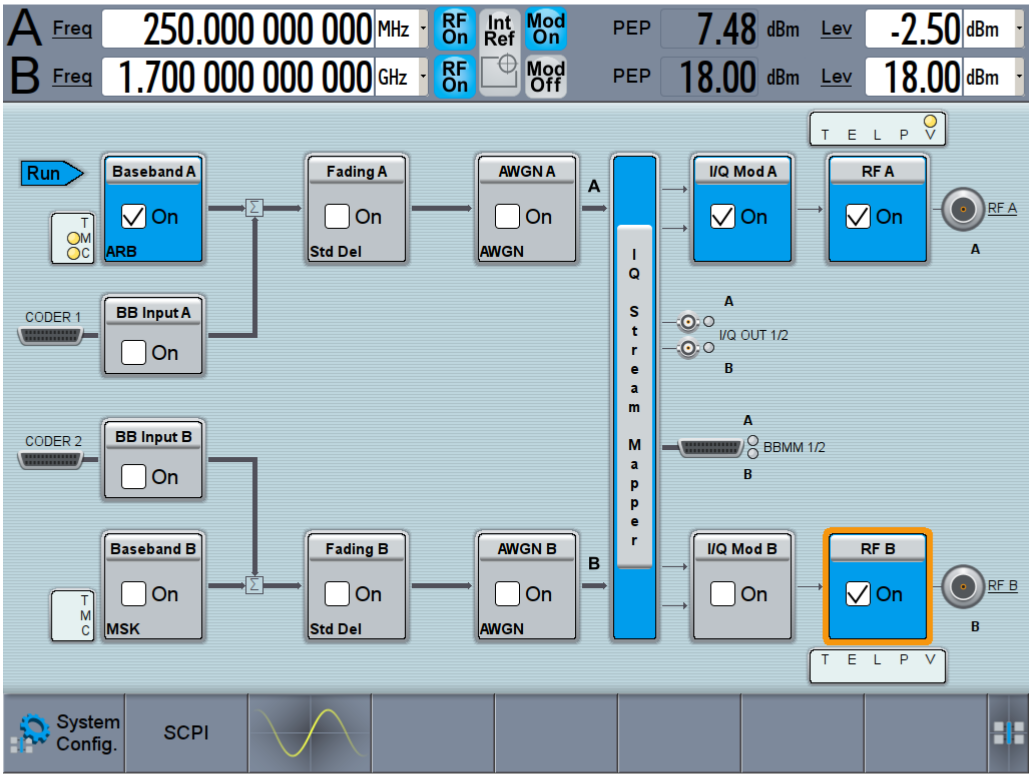

Fig. 3-6: Configuring the SMW - Modifying the two SMW output frequencies and levels to drive the Mixer DUT

The output level of the SMW Channel A has been adjusted on the SMW to create 1dB Gain Compression on the FSW-K18. The onset of 1dB Compression can be seen in the Gain Compression curve, shown in the top left of Fig. 3-7, thus:

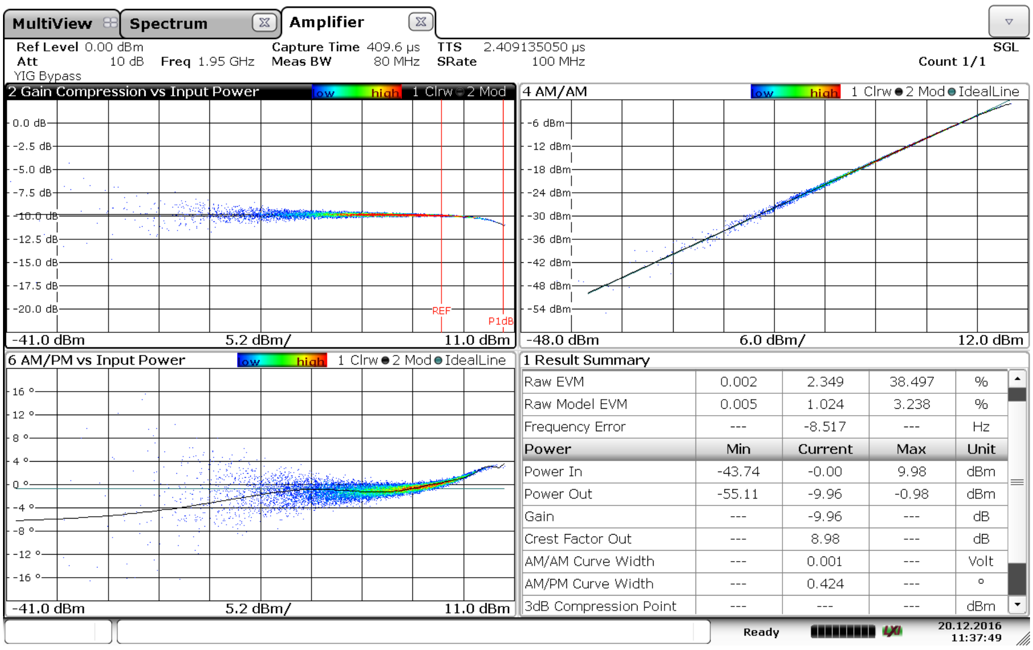

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Fig. 3-7: Mixer DUT operating with signal peak envelope power (PEP) set to one dB gain compression point (P-1dB) at 1.95 GHz

Modifying the IF frequency on the SMW from 250 MHz to 290 MHz, increases the RF output frequency to 1.99 GHz. The output measurement (Fig. 3-8) is thus:

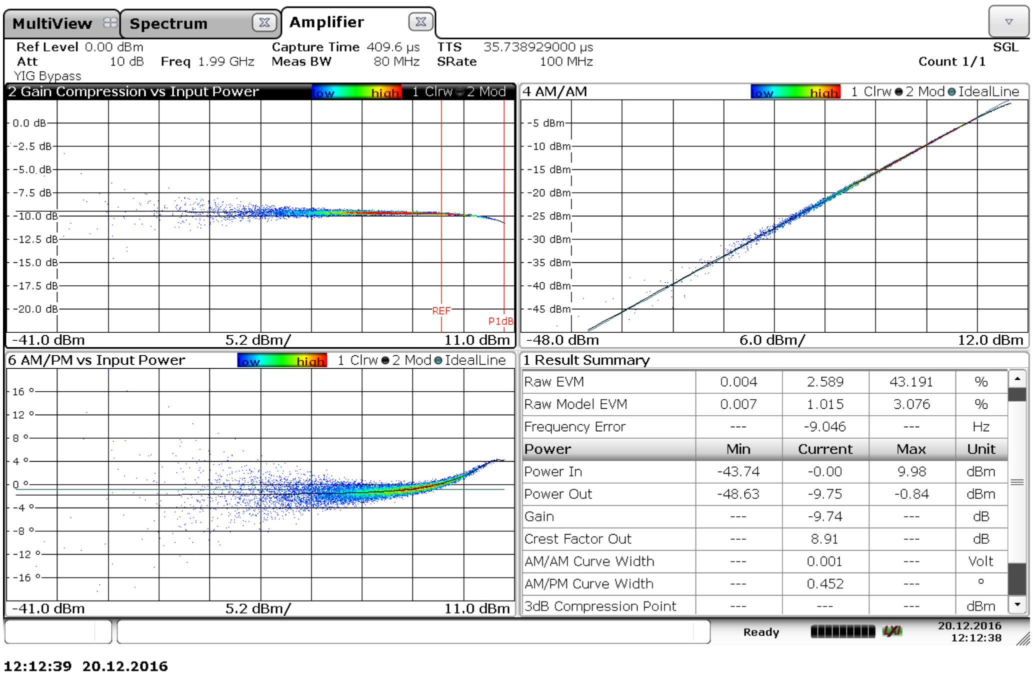


Fig. 3-8: Mixer DUT operating with signal peak envelope power (PEP) set to one dB gain compression point (P-1dB) at 1.99 GHz

Unlike the filter, the mixer has exhibited little change in its characteristics, by moving from 1.95 GHz to 1.99 GHz.

3.3 Cascade of Mixer & Filter

With the Mixer and Filter components individually verified, they may now be connected together (shown in Fig. 3-9).

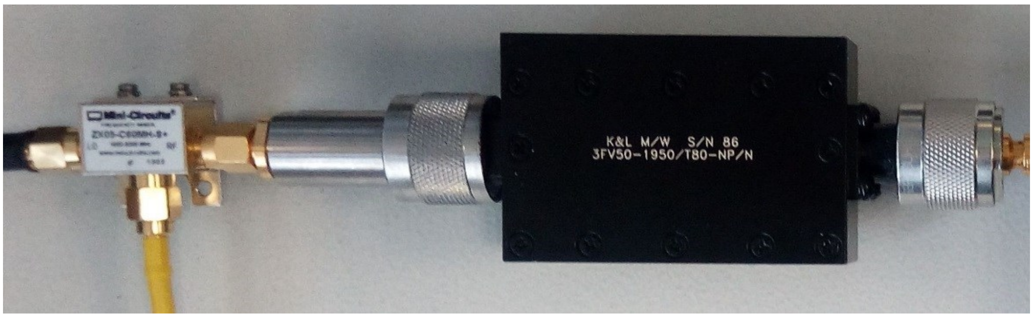


Fig. 3-9: Cascade of mixer and band pass filter

Measurements at IF frequencies of 250 MHz and 280 MHz, corresponding to RF frequencies of 1950 MHz and 1980 MHz yields (Fig. 3-10):

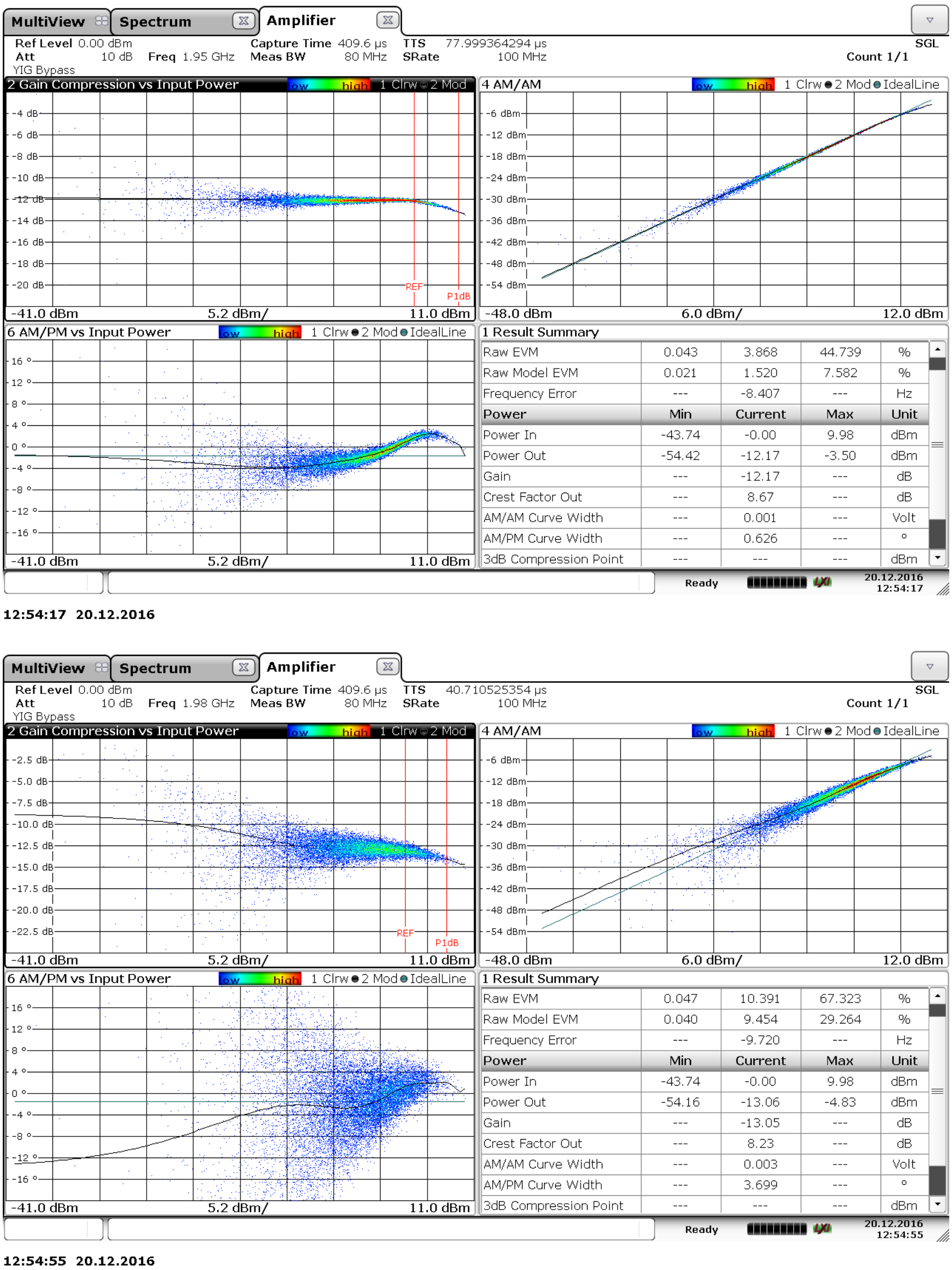


Fig. 3-10: Cascade of Mixer and Band Pass Filter, operating with signal peak envelope power (PEP) set to one dB gain compression point (P-1dB) at 1.95 GHz and 1.98 GHz, i.e. filter band center and filter band-edge

It is interesting to note that the composite distortion of Fig. 3-10 comprises linear and non-linear distortion; but that in this case, they are mostly generated by different components.

- The non-linear distortion, causes variations in Gain Compression and AM-PM, most clearly seen in the 1950 MHz plot (top). It is broadly equal at both measurement frequencies
- The linear distortion, manifest as a spreading of the measurement points in the y-domain, is mostly caused by the filter. Its effect is much more significant in the 1990 MHz plot (bottom). The filter's frequency response is rolling off at the band-edge, causing variations in transfer gain and phase that are much more significant (bottom) than the in-band gain/phase ripple (top).

3.4 The Complete Tx RFFE: Mixer, Filter and Amplifier

The power amplifier (Mini Circuits ZHL-42) is added to the output of the filter and the RFFE is complete (Fig. 3-11).

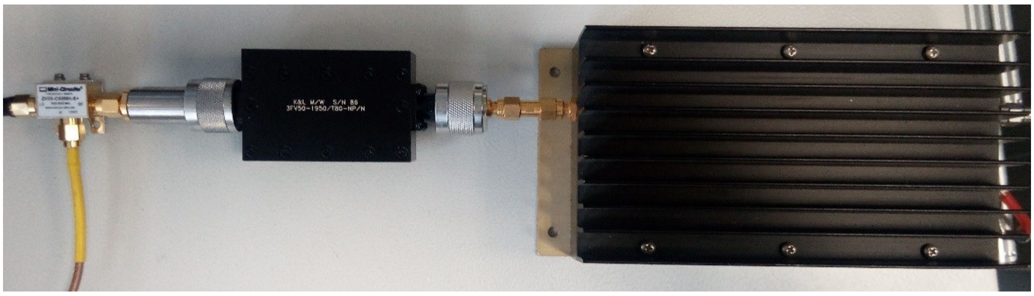
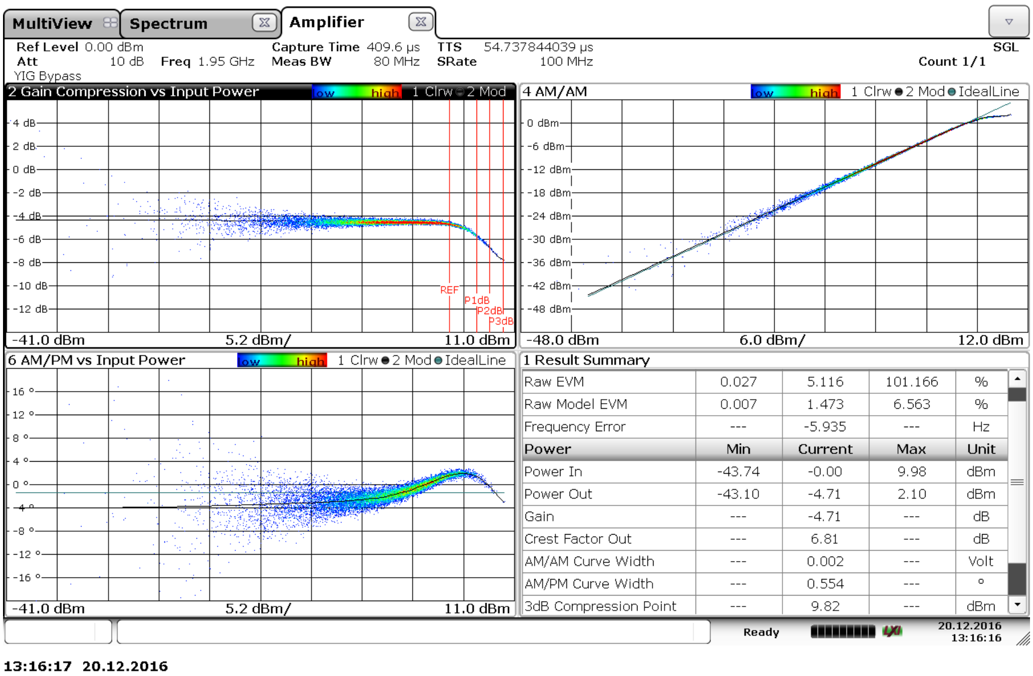


Fig. 3-11: The complete, discrete, RFFE, comprising a cascade of mixer, band pass filter and power amplifier.

Measurement, on the cascade, is now performed at 1950 MHz and 1980 MHz.



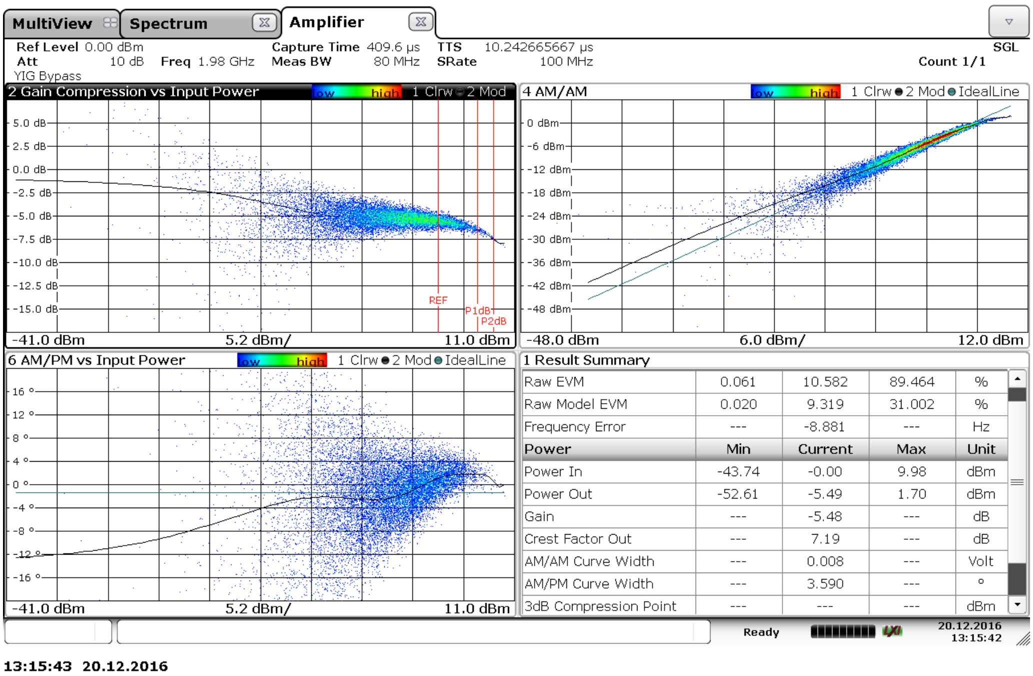


Fig. 3-12: Measurement of the complete RFFE, at 1.95 GHz and 1.98 GHz, with input power set to generate approximately 1dB gain compression at the mixer output.

Note in the measurement results for the complete RFFE (Fig. 3-12), that the overall gain compression (non-linear distortion) for the RFFE is at least 2 dB. With the input power levels used, the mixer accounts for about 1 dB of that compression (see Fig. 3-10).

This RFFE chain therefore is relatively lean and efficient, with all substantially non-linear components contributing to the non-linear distortion. This would appear to lend itself to a cost and power efficient solution (assuming relevant yield analyses were satisfactory), particularly so for linearization.

4 Measurement of an Off-The-Shelf RFFE

4.1 Background

In this chapter, measurements will be made on an integrated, off-the-shelf, RFFE. This RFFE comprises at least one of each of the basic RFFE building blocks, in a cascade similar to that demonstrated in section 3.4.

There are three steps to the process of assessing RFFE linearity performance and capability:

1. Establish the performance of a reference RFFE (usually a hard clipper) to the modulation and linearity measurement
2. Measure PSat (the saturated output power of the DUT)
3. Measure linearity of the DUT (with and without Linearization)

To demonstrate this principle, a NJR8302 Ku-band SatCom BUC will be tested with 64 QAM modulation (roll-off = 0.1).

Linearity of the BUC will be tested with, and without, DPD.

In which case, the DPD model in FSW-K18 is limited to the quasi-default settings presented in Fig. 4-1.

Fig. 4-1: DPD Modeling settings for Linearization of the NJT8302 BUC

4.2 Reference Performance Calculation

The reference performance may be calculated for any linearity metric.

In this case, the reference signal is an arbitrary 10 MSym/s 64-QAM signal, generated with RRC filter with roll-off 0.1 constant. The linearity metric will be spectral regrowth, measuring power within a 10MHz channel bandwidth, located at a 12MHz offset from the carrier. Note that any, or combination of, linearity metric(s) may be used.

This signal is played through a hard clipper, and increasing amounts of clipping applied.

The result is a characteristic of spectral regrowth versus PAPRo (shown in Fig. 4-2).

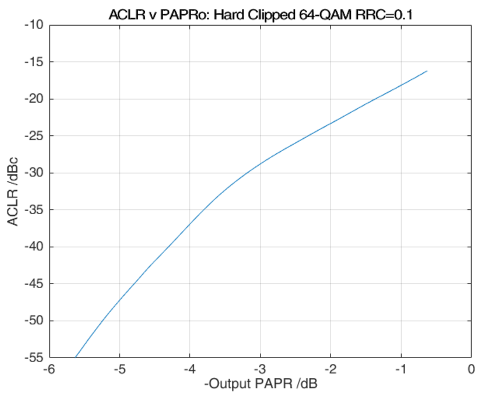


Fig. 4-2: ACLR v PAPRo (spectral regrowth versus output peak-to-average-power ratio) behavior for the 64-QAM (RRC=0.1) test signal played through a hard clipper

This curve demonstrates the minimum PAPRo that can support a given ACLR (or other linearity). The difference between PAPRi (input) and PAPRo (output) represents a degradation or reduction.

The test signal itself has a PAPRi of approximately 6 dB. To be completely linear, the PAPRo must also be 6 dB (but the reverse is not true). If the DUT is completely linear, there is no distortion when the average power is at least 6dB backed off from the saturated.

Similarly, a -40 dB ACLR figure can be supported with a minimum PAPR of ~4.2 dB and the maximum average output power of the device with -40 dBc is -4.2 dB lower than PSat. Conversely, a PAPR of 4.2 dB at the device output, can support ACLRs of -40 dBc or worse.

Fig. 4-3 shows the Power v Time waveforms for the reference and a hard clipped to -40 dBc version. Note the "ZOH" (zero order hold) type waveform, created by the perfect action of the clipper.

The PEP or maximum values for the raw (input) signal and the clipped (output) signal are set to 0 dB. An inspection of the waveforms shows that there is however, a difference in the average level. In this case, the average level is approximately 2 dB higher for the clipped (output) waveform, than for the reference (input). Therefore the PAPR for input and output is different.

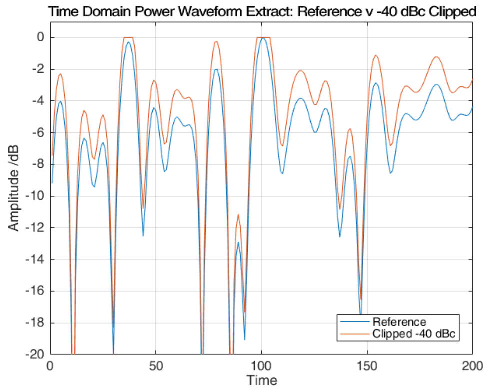


Fig. 4-3: Power v Time curves for a clean reference waveform, and the same clipped to -40 dB ACLR

With this calculation, the theoretical limit of linearization is known.

4.3 Measurement of DUT PSat (Saturated Power)

One method for assessing PSat of a device is to power sweep a representative signal through the DUT, measuring PAvg and PEP (alternatively PAPRo).

It is important to note that the PSat of a device is related to the test signal, especially its bandwidth and PAPRi. Measurement of PSat using, for example, a power swept CW tone will likely yield a different result to that of a digitally modulated signal. This does not mean that the measurement is correct, more that the device actually has a different PSat and performance for different stimulus.

The device was power swept with the modulated signal and those parameters (PAvg, PAPRo) were measured. PEP is the sum of PAvg and PAPRo at each measurement point.

The result is shown in Fig. 4-4, with the x-axis (abscissa) representing the average measured device output power level, PAvg, and the y-axis (ordinate) representing PEP = PAvg + PAPRo.

The PEP (y-axis) tends towards PSat as the input is increasingly driven. The device PSat is the maximum value measured during the power sweep (slightly more than 35 dBm).

PSat is the maximum achieved value for PEP during the measurement.

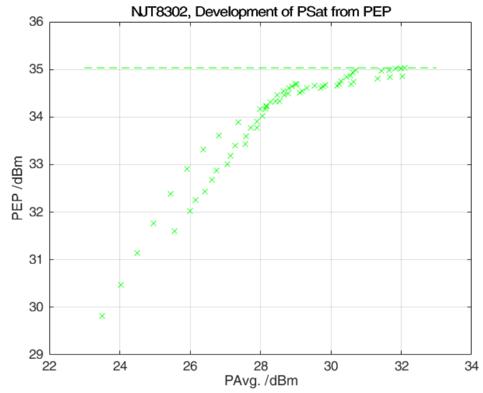


Fig. 4-4: PSat (Saturated output power) measurement of the NJT8302) with 10 MSym/s RRC=0.1 64-QAM test signal, with PAvg x-axis and PEP = PAvg + PAPRo on the y-axis.

4.4 Measurement of Raw and Linearized DUT Linearity

In this final step, a power sweep is performed, with exemplary (but not optimized) DPD performed at each power level.

The DPD is performed using the "Generate Predistorted Waveform File" feature of FSW-K18.

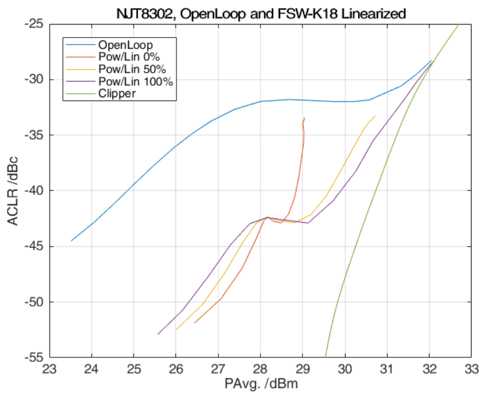


Fig. 4-5: Measurement of Open Loop and (Exemplary) DPD Linearized performance of the NJT8302, with 10 MSym/s RRC=0.1 64-QAM test signal

The measurement result, combined with the normalized hard clipper calculation is presented in Fig. 4-5.

From the graph it can be seen, for example, that:

- At 28 dBm, the ACLR has been improved by approximately 10 dB with the example DPD settings

- At -40 dBc, the output power has been increased by approximately 4-5dB with the example DPD settings
- A further 1-2 dB of output power could possible by achieved if linearization was made perfect AND if the resultant system could support the requisite hard-clipping.
- At higher ACLR levels (~-30 dBc), then the open-loop and DPD linearized device performance asymptote, also with the (proposed) theoretical limit

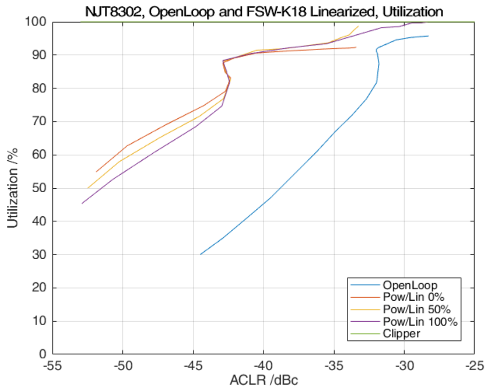


Fig. 4-6: Utilization (i.e. the ratio of PEP to PSat) of the Open Loop and Linearized NJT8302 device

In Fig. 4-6, the curves demonstrate the Utilization of the NJT8302 in Open Loop and DPD Linearized forms.

At -40 dBc, the amount of device capability being used at PEP increases from ~47% to ~90%.

These observations raise a number of possibilities. For example, with Utilization increasing from 47% to 90% for a given linearity, then a ~48% smaller (and presumably cheaper and more efficient) device (with the exemplary DPD) could be used to support the same output power.

4.5 Key SCPI Commands

The most important FSW-K18 SCPI commands used in this Chapter are as follows:

CONF:DPD:TRAD 50 Sets the DPD Output Power/Linearity Trade Off to 50% (or other value in the range 0~100%).

CONF:DPD:FILE:GEN Instructs the FSW-K18 to generate the predistorted waveform files and send them to the SMW.

CONF:DPD:AMXM ON/OFF This command, sent to the FSW, will relay the instruction to the SMW to load and play the predistorted waveform file.

5 Ordering Information

The following equipment specifications represent the minimum configurations (base equipment plus options) required to support the R&S based application(s) described in this document.

Designation	Type	Order No.
Vector signal generator, base unit; freq.opt.& BBmodule req.	**SMW200A**	**1412.0000.02**
Frequency range : 100kHz to 3GHz for RF path A (HW opt.)	SMW-B103	1413.0004.02
Frequency range : 100kHz to 3GHz for RF path B (HW opt.)	SMW-B203	1413.0804.02
Baseband main module, two I/Q paths to RF section (HW opt.)	SMW-B13T	1413.3003.02
Baseband generator with realtime coder and ARB (HW opt.)	SMW-B10	1413.1200.02
Signal- and Spectrum analyzer 2Hz to 8GHz	**FSW8**	**1312.8000.08**
Power amplifier measurement application (SL)	FSW-K18	1325.2170.02

Note:

- The SMW product line is, at the time of writing, available with 2 x 20 GHz outputs (alternatively, 1 x 40GHz)
- The FSW product line is, at the time of writing, available with 85 GHz direct input.

For more up-to-date information, visit the R&S website.

6 Appendices

6.1 Forum Script Example

Forum is a free program from R&S, based on the Python language, enabling easy scripting for automated control and test. For more information, see 1MA196.

This prototype script is used for reset and initial configuration of the test set-up.

It can, and may, be easily modified to include for example, swept variable testing etc.

The user should take care to modify the following parameters, if necessary:

- Filename of the test signal
- Frequencies for LO and IF
- IP address for the SMW

```
#
#SMW Reset and Initialization

#Reset
SMW.write("*RST")
SMW.write("*CLS")
SMW.query("*OPC?")

#Baseband configuration (Triggering, Waveform)
SMW.write(":SOURce1:BB:ARBitrary:WAVeform:SELect
'/var/user/256qam_0p1_10M'")
SMW.write(":SOURce1:BB:ARBitrary:STATe 1")

#RF configuring
SMW.write(":SOURce1:POWer:POWer 0")
SMW.write(":SOURce1:FREQ:CW 0.38 GHZ")
SMW.write(":OUTPut:STAT 1")
SMW.write(":SOURce2:FREQ:CW 1.60 GHZ")
SMW.write(":OUTPut:STAT 1")
SMW.write(":SOURce2:POWer:POWer 13")
SMW.query("*OPC?")

#
# FSW Reset and Initialization

#Reset everything...
FSW.write("*RST")
FSW.write("*CLS")
FSW.query("*OPC?")

#Create an Amplifier Measurement Window
#Configure Measurement Window
FSW.write(":INST:CRE:NEW AMPL, 'K18 Distortion'")
FSW.query("*OPC?")
FSW.write(":LAY:REM '1'")
FSW.write(":LAY:REM '3'")
```

```
FSW.write(":LAY:REM '4'")
FSW.write(":LAY:REM '5'")
FSW.query(":LAY:ADD? '2', ABOV, RTAB")
FSW.query("*OPC?")
FSW.query(":LAY:ADD? '4', RIGH, ACP")
FSW.query("*OPC?")
FSW.query(":LAY:ADD? '1', BEL, AMPM")
FSW.query("*OPC?")
FSW.query(":LAY:ADD? '3', LEFT, GCOM")
FSW.query("*OPC?")
FSW.write(":LAY:REM '6'")

#Configure FSW to read reference signal from SMW
FSW.write("CONF:GEN:IPC:ADDR '10.85.0.94'")
FSW.write("CONF:REFS:CGW:READ")
FSW.query("*OPC?")

#Configure basic RF settings
FSW.write(":FREQ:CENT 1.98 GHz")
FSW.write(":INP:ATT 5dB")
FSW.query("*OPC?")
FSW.write("TRAC:IQ:SRAT:AUTO ON")
FSW.write("POW:ACH:AABW ON")
FSW.query("*OPC?")

#Configure DPD Modeling
FSW.write("CONF:MOD:SEQ PMF")
FSW.query("*OPC?")
FSW.write("CONF:MOD:LRAN 20")
FSW.query("*OPC?")
FSW.write("CONF:DPD:SHAP:MODE POLY")
FSW.query("*OPC?")

#Detach SMW frequency from FSW
SMW.write(":SOURce1:FREQ:CW 0.38 GHZ")

#Scale AMxM Plots
FSW.write("DISP:WIND4:TRAC:X:SCAL:AUTO OFF")
FSW.query("*OPC?")
FSW.write("DISP:WIND4:TRAC:X:PDIV 2DBM")
FSW.query("*OPC?")
FSW.write("DISP:WIND3:TRAC:X:SCAL:AUTO OFF")
FSW.query("*OPC?")
FSW.write("DISP:WIND3:TRAC:X:PDIV 2DBM")
FSW.query("*OPC?")

#Set channel bandwidths and spacings
FSW.write("POWer:ACHannel:TXCHannel:COUNt 1")
FSW.write("POWer:ACHannel:BANDwidth 10MHZ")
FSW.write("POWer:ACHannel:BANDwidth:ACHannel 10MHZ")
FSW.write("POWer:ACHannel:SPACing:CHANnel 11MHZ")


SMW.query("SYSTem:ERRor?")
FSW.query("SYSTem:ERRor?")
```

6.2 Signal File Generation

6.2.1 Background

In addition to the method for creating a signal in the FSW, the user may also generate their own test signal using a variety of methods.

Regardless of which of the following methods is used to create the signal file, the FSW-K18 personality may be repointed by pressing the "Reference Signal" softkey to bring up the following dialog.

Then select "Read and Load Current Signal from Generator" (Fig. 6-1).

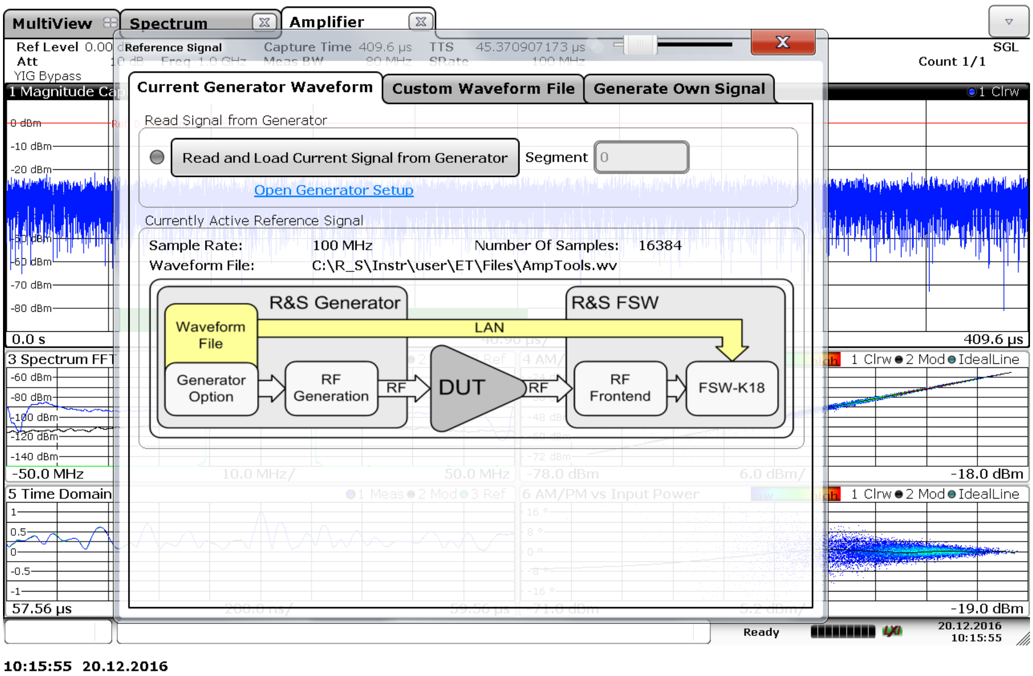


Fig. 6-1: Driving the FSW-K18 using an ARB waveform resident on the SMW

6.2.2 Use of WinIQSIM2

R&S®WinIQSIM2 is a free-of-charge simulation software used for generating arbitrary (ARB) waveforms for use with signal generators. The software and associated documentation is available for download here.

Once the waveform file is created, it may be used in FSW-K18 by following the procedure described in 6.2.1.

Note that additional license(s) for the SMW, might be required to play proprietary waveforms generated by the software.

The user may generate signals from custom constellations, using the Mapwiz software, (free-of-charge download from the Rohde & Schwarz website). Those constellation definitions may be imported into WinIQSIM2.

6.2.3 SMW Built-in Custom Waveform Generator

Building and using ARB waveforms in the SMW is intuitive, specific instructions can be found in the SMW200A User Manual. Note however that the ARB must be used, e.g. it is not possible to use the real-time source.

Once the .wv file is created, it may be ported to FSW-K18 by following the procedure described in 6.2.1.

6.2.4 Using MATLAB

Creating signal files for the ARB feature of the SMW to play is straightforward. A MATLAB function for converting IQ vectors into the .wv format used by the SMW is presented.

```
function mat2wv(vfcSignal, sFilename, fSampleRate, bNormalize)
% mat2wv(vfcSignal, sFilename, fSampleRate, bNormalize)
% MAT2WV creates an SMU waveform file from a MATLAB vector.
%
% Input parameters:
% vfcSignal: Input data vector
% sFilename: Filename of the generated waveform file
% fSampleRate: Sample rate of the signal in Hz
% bNormalize:
%   True: The signal is normalized by the max. magnitude
%  False: The signal is not normalized. The maximum magnitude
%         of the signal shall not exceed 1.0.
% Copyright    : Rohde & Schwarz GmbH & Co. KG, Munich,
Germany
% File version : \main\4    21 Jul 2008 16:20:08   ramian
% Revision     : V2.0
% Date         : 2008/08/18 12:03:56

% Force row vector
vfcSignal = vfcSignal(:).';

% Number of samples
iNOfSamples = length(vfcSignal);

% Normalize signal
if bNormalize

  fprintf('Normalize signal\n');
  vfcSignal = vfcSignal / max(abs(vfcSignal));
  % Remark:
  % We do not normalize to max RE/IM to allow arbitrary phase
offsets
  % or frequency shifts without overflow
```

```
  vfcSignal = vfcSignal / max(abs(vfcSignal));

  % Calculate the peak value
  fPeakPower = max(abs(vfcSignal).^2);
  fPeakPowerdBfs = -10*log10(fPeakPower);
  % Calculate the RMS value
  fMeanPower = mean(abs(vfcSignal).^2);
  fRMSdBfs = -10*log10(fMeanPower);

else

  % Do not normalize the signal
  fPeakPowerdBfs = 0;
  fRMSdBfs = 0;

end

% Quantization to 16 bit
iMaxInt = 32767;
vicData = vfcSignal*iMaxInt;
clear vfcSignal;

viDataInterleaved =
reshape([real(vicData);imag(vicData)],1,2*iNOfSamples);
clear vicData;

viDataInterleaved = int16(viDataInterleaved);

% Write waveform file
fid = fopen(sFilename,'w');
fprintf(fid,'%s','{TYPE: SMU-WV,0}');
fprintf(fid,'%s','{COMMENT: Generated by mat2wv.m}');
fprintf(fid,'%s',['{DATE: ' datestr(now,'yyyy-mm-dd;HH:MM:SS')
'}']);
fprintf(fid,'%s',['{LEVEL OFFS: ' num2str(fRMSdBfs) ', '
num2str(fPeakPowerdBfs) '}']);
fprintf(fid,'%s',['{CLOCK: ' num2str(fSampleRate) '}']);
fprintf(fid,'%s',['{SAMPLES: ' num2str(iNOfSamples) '}']);
fprintf(fid,'%s',['{WAVEFORM-' num2str(4*iNOfSamples+1)
':#']);
fwrite(fid,viDataInterleaved,'int16');
fprintf(fid,'%s','}');
fclose(fid);
```

Once the .wv file is created, it may be ported to FSW-K18 by following the procedure described in 6.2.1. Other similar software may be utilized in a similar way as exemplified here for MATLAB.

The test signal file may also initially reside on the FSW itself, and be copied to the SMW using the "Custom Waveform File" tab of the "Reference Signal" softkey dialog in the FSW-K18 personality.

7 Glossary

AM-AM: A distortion metric, variation in transmitter gain as a function of the instantaneous input amplitude

AM-PM: A distortion metric, the creation of transmission phase distortion as a function of the instantaneous input amplitude

AM-xM: A distortion metric, the creation of either transmission phase or transmission gain distortion as a function of the instantaneous input amplitude

BUC: Block Up-Converter. Colloquial name given to a radio transmitter used for uplink to a satellite.

DPD: Digital PreDistortion. A linearization method, for improving the signal quality or integrity, usually in a radio transmitter.

PAPR: Peak to average power ratio of a signal.

PAPRi: Peak to average power ratio of the input signal. In non-linear systems, the peak-to-average ratio is modified by AM-AM. Thus the Peak to average ratio varies according to the measurement point in a system.

PAPRo: Peak to average power ratio of the output signal. In non-linear systems, the peak-to-average ratio is modified by AM-AM. Often, but not exclusively, PAR is reduced as is passes through successive components in a quasi-linear RFFE, reaching its lowest value at the output.

PEP: Peak envelope power. The instantaneous maximum signal level at a specific point in the RFFE. Equal to the average power plus to the PAR (Peak to average power ratio)

PSat: Saturated output power. The maximum output level which cannot be exceeded, regardless of how high the input signal level is.

RFFE: Radio or RF Frontend. The analog component nearest to the ANT or channel interface, responsible for conditioning a signal entering or leaving the communication channel.

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