

Versatile RF Fading Simulator With R&S[®]FSQ/FSG/FSV and R&S[®]SMU

Application Note

Products:

R&S [®] SMU200A	R&S [®] FSQ
R&S [®] SMU-B17	R&S [®] FSG
R&S [®] SMU-B14	R&S [®] FSQ-B17
	R&S [®] FSV
	R&S [®] FSV-B17
	R&S [®] FSV-B70

Fading in the baseband of the R&S[®]SMU200A signal generator or R&S[®]AMU200A base band generator is well proven and widely accepted for testing any mobile radio standard. However, there are applications where an RF signal must be faded. A versatile RF Fading Simulator can easily be built using an R&S[®]FSQ, R&S[®]FSG or R&S[®]FSV signal analyzer with Digital Base Band Interface and an R&S[®]SMU signal generator with digital baseband inputs and fading simulator option. This Application Note describes how.

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1 Abstract

Fading in the baseband of the R&S[®]SMU200A signal generator or R&S[®]AMU200A base band generator is well proven and widely accepted for testing any mobile radio standard.

In most cases this is the better solution than RF fading simulators because signals are not degraded by the effects of the necessary multiple conversions. Additionally, baseband fading is more economic.

However, there are applications where there is no alternative to RF fading because the baseband signal is not available.

For example fading tests on actual transmissions from mobile radio base stations including signaling require a simulator for RF fading, or on military radio links with frequency hopping, on actual TV signals, or even on simple FM-signals.

A simulator for RF Fading can easily be built using a Signal Analyzer R&S[®]FSQ, R&S[®]FSG or R&S[®]FSV with Digital Base Band Interface (which is used as a downconverter) and a Signal Generator R&S[®]SMU with Digital Baseband Inputs and Fading option. If a R&S[®]FSV is used, additionally the option: "40 MHz Analysis Bandwidth" R&S[®]FSV-B70 is necessary.

The universal fading possibilities of the R&S[®]SMU, including superimposing AWGN, can be applied to an RF signal.

Compared to a standalone fading simulator, the R&S RF Fading Simulator is a cost effective solution. Particularly if an R&S[®]FSQ, R&S[®]FSG or an R&S[®]FSV signal analyzer and an R&S[®]SMU vector signal generator are already available

The following abbreviations are used in this Application Note:

R&S[®]SMU Vector Signal Generator: SMU

R&S[®]FSQ Signal Analyzer: FSQ

R&S[®]FSV Signal Analyzer: FSV

In the following only the FSQ and FSV is mentioned. An FSG can equally well be used instead of the FSQ.

2 What is fading?

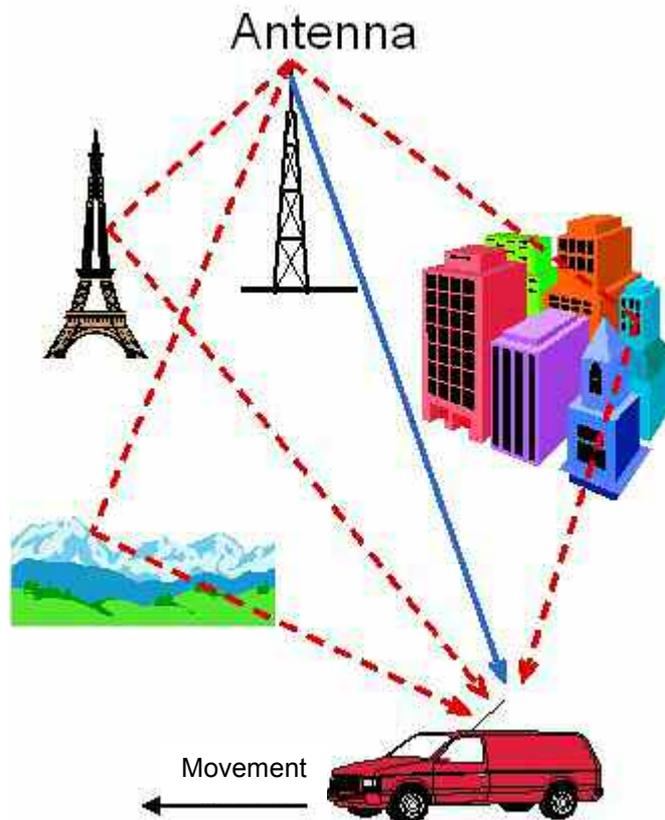


Figure 1: Different signal paths from the transmitter antenna to the receiver

The reception of any RF signal transmitted over the air is subject to a range of fading effects. Multiple propagation paths may be superimposed on each other either constructively or destructively. The distance from transmitter to receiver creates a delay; the movement of the receiver relative to the transmitter creates a frequency shift.

When testing receivers, it is important to be able to simulate fading conditions in the lab.

3 The R&S Baseband Fading solution

The only efficient way to optimize receiver performance is with fading.

The fading simulator option of the SMU makes it easy to simulate fading conditions in the lab.

A total of 40 fading paths with 40 MHz bandwidth and 10 ns time resolution are available for simulating multi-path propagation. If higher time resolution is needed (10 ps), the bandwidth (30 MHz or 50 MHz) and the number of fading paths (24 or 16) can be modified.

A precondition is that either the SMU generates the baseband signal itself or the baseband signal is fed to the SMU via analog or digital baseband input.

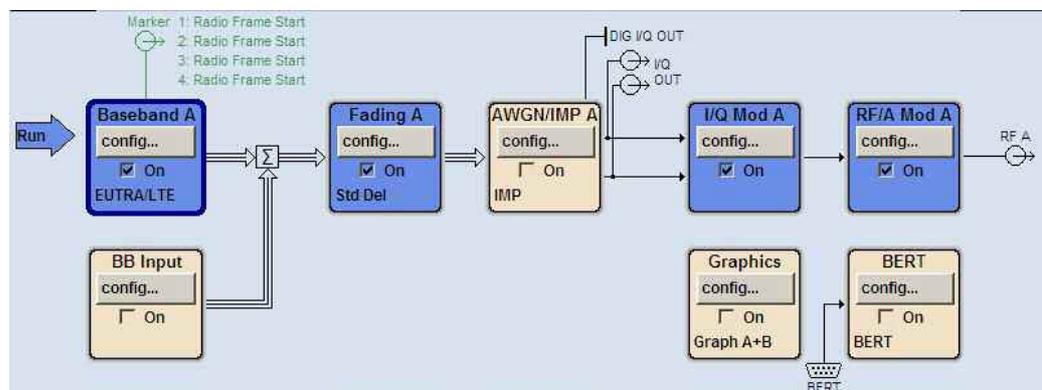


Figure 2: Fading an internally generated baseband signal in the SMU

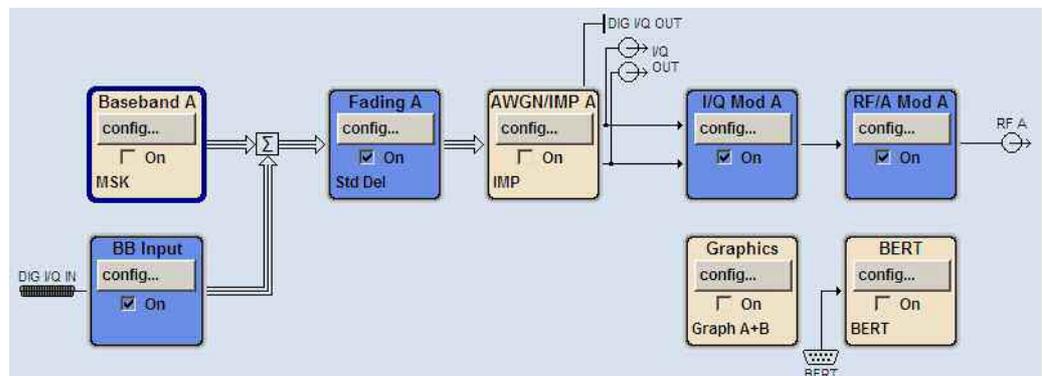


Figure 3: Fading of externally generated baseband signal fed in via the digital baseband input

In order to fade an RF signal, an RF Fading Simulator is necessary. An RF Fading Simulator can be arranged using the SMU together with a compatible RF to IQ-baseband converter, such as the FSQ with R&S®FSQ-B17 Digital Baseband Interface or the FSV with FSV®-B17 Digital Baseband Interface, as shown in the following section.

4 The new R&S RF Fading Solution

The R&S RF Fading solution requires an FSQ or FSV and SMU. The RF signal to be faded is fed into the FSQ's or FSV's RF input. The FSQ or FSV work as a down-converter and digitizes its IF.

The (optional) R&S®FSQ-B17 Digital Baseband Interface in the FSQ (or R&S®FSV-B17 in the FSV) outputs a digital baseband signal which is compatible to the SMU digital I/Q input. The FSQ's or FSV's digital baseband output signal is fed via the SMU-Z6 LVDS cable to the SMU's digital I/Q input.

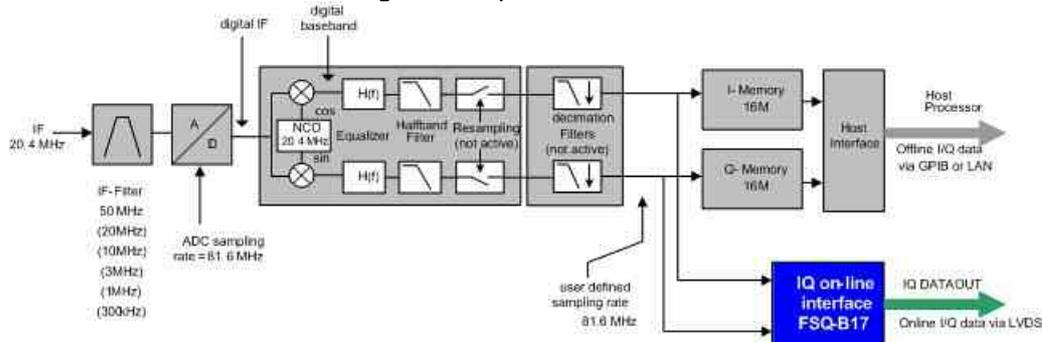


Figure 4: Block diagram of IQ down-converter within the FSQ in streaming mode

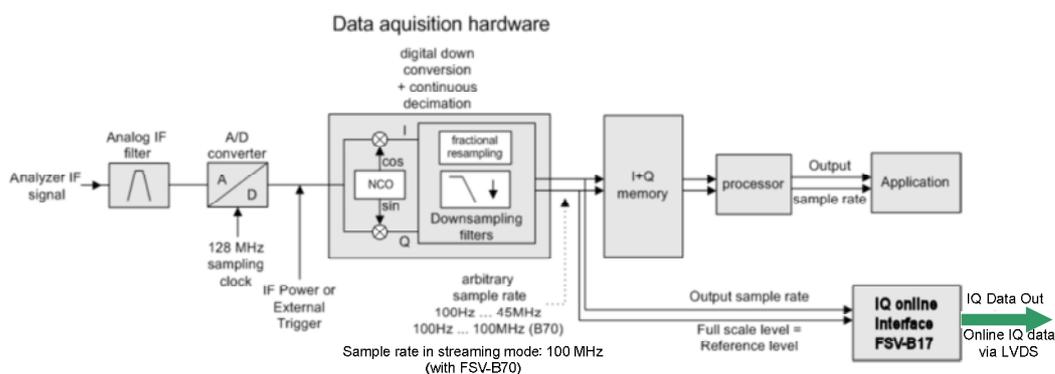


Figure 5: Block diagram of IQ down-converter within the FSV in streaming mode (FSV with FSV-B70)

If the SMU is set up correctly, it delivers an RF signal with the same level, modulation and frequency like the signal fed into the FSQ (or FSV) RF input. The universal baseband fading functions of the SMU, including superimposing Gaussian noise, can be applied to the SMU's baseband signal. The combination of the two instruments FSQ of FSV and SMU provides an RF Fading Simulator with a real-time bandwidth of 28 MHz. If an FSV is used instead of a FSQ, a fading simulator with a real-time bandwidth of 40 MHz is provided (option "40 MHz Analysis Bandwidth FSV-B70" is necessary for the FSV).

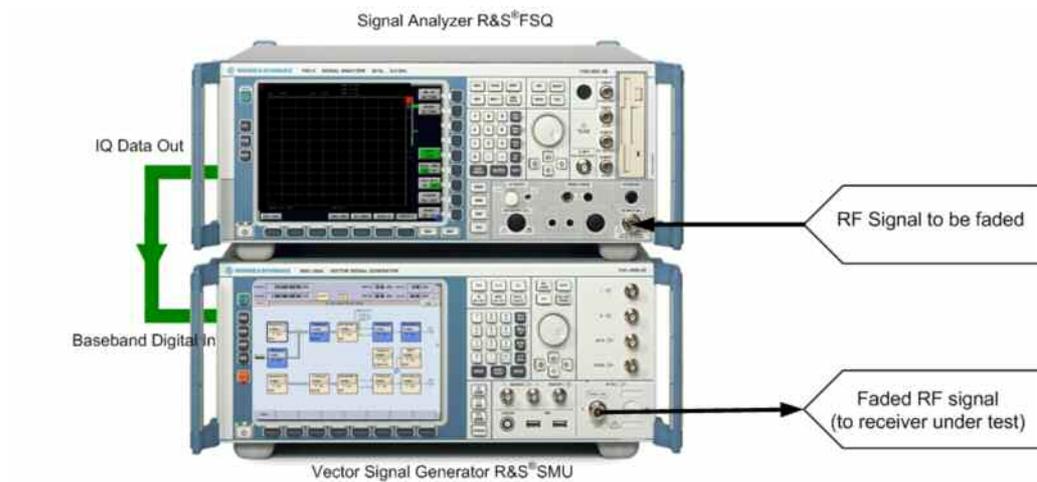


Figure 6: The R&S RF Fading Simulator with an FSQ and an SMU. It provides a real-time bandwidth of 28 MHz.

With a frequency range limit up to 6 GHz and a real-time bandwidth of 28 MHz (even 40 MHz with the FSV), the R&S RF Fading simulator covers all current digital radio standards for both uplink and downlink signals.

4.1 Application examples and according test setups

4.1.1 Example 1: Fading tests on Mobile Radio Receivers

Figure 7 shows a test setup for fading tests on a mobile radio receiver. Feed the base station's RF signal via a power attenuator into the RF input of the FSQ. Setup the FSQ and the SMU as fading simulator, and feed the SMU's output signal at the required level to the mobile radio receiver input. Apply a fading scenario according to your Mobile Radio Standard (GSM, 3GPP, LTE etc.) within the SMU.

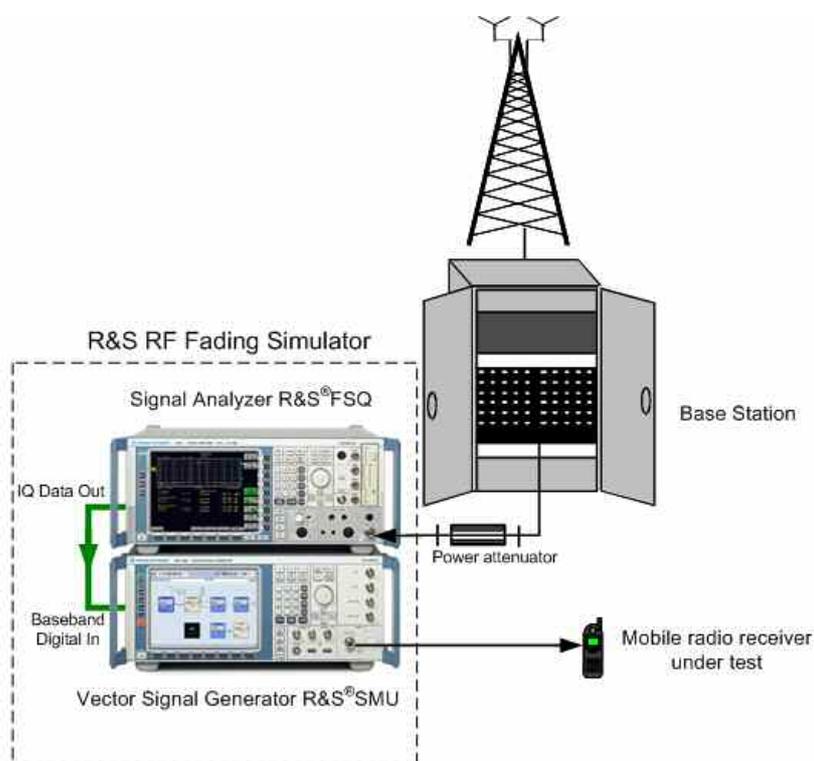


Figure 7: Fading tests on a mobile radio receiver with an actual base station signal.

4.1.2 Example 2: Fading tests on military airborne transceivers

Figure 8 shows a test setup for military fast frequency hopping airborne transceivers. The synchronization of the receiver (lower device) to the transmitter (upper device) is tested introducing signal delays of several milliseconds to the transmitted signal set by the fading option of the SMU. These delays occur in real world conditions when two aircraft communicating are separated by several 100 km. High aircraft speed differences can be simulated by applying Doppler shift to the transmitted signal. Correct synchronization is checked by comparing the synchronization signals from the transceivers with an oscilloscope.

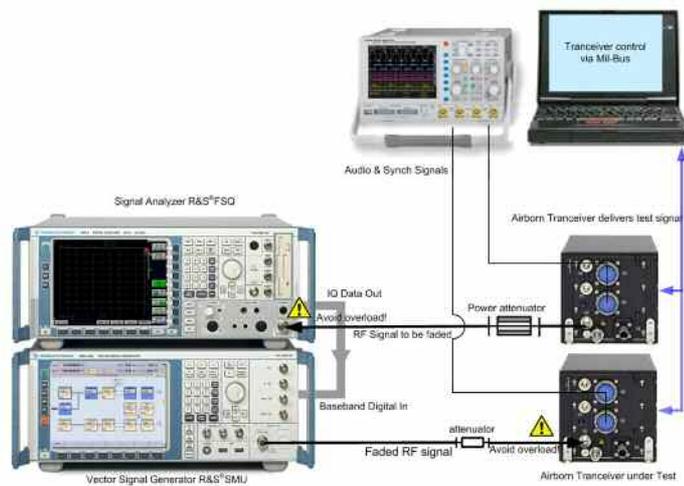


Figure 8: Application example: Fading tests on airborne radio transceivers. The synchronization of the transceivers can be tested simulating distances of several hundred kilometers and high speed differences.

A distance of for example 400 km causes a delay of:
 $(400 \text{ km}) / (\text{Speed of light}) = (400 \text{ km}) / (3 \cdot 10^5 \text{ km/s}) = 1335 \mu\text{s}$ which is set as the Basic Delay in the fading path table of the SMU. Speed difference can be directly set as Speed (e.g. 4000 km/h in Figure 9 below).

Freq A		310.000 000 00	MHz	PEP A	0.00	dBm	Lev A	0.00		
Freq B		1.000 000 000 00	GHz	RF OFF	MOD OFF	PEP B	-30.00	dBm	Lev B	-30.00
REMOTE		A: ALC:Auto B: ALC:Auto								
Fading A: Path Table Standard/Fine Delay										
		1	2	3	4	5	6	7	8	
State		Off	Off	Off	Off	Off	Off	Off	On	
Profile		Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Pure Doppler	
Path Loss dB		0.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00	
Basic Delay us		0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.335.00	
Additional Delay us		0.000 00	0.000 00	0.000 00	0.000 00	0.000 00	0.000 00	0.000 00	0.000 00	
Resulting Delay us		0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.335.00	
Power Ratio dB										
Const Phase dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Speed km/h		4 000.00	4 000.00	4 000.00	4 000.00	4 000.00	4 000.00	4 000.00	4 000.00	
Freq. Ratio		0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	
Res. Doppler Shift Hz		1 148.94	1 148.94	1 148.94	1 148.94	1 148.94	1 148.94	1 148.94	1 148.94	

Figure 9: Example: Setting fading on an SMU for simulating a distance of 400 km between transmitter and receiver and a speed difference of 4000 km/h. A direct receive path is assumed.

4.2 Setting up the instruments

Setting up the instruments for RF-fading can be either manually or remotely controlled which is even more convenient.

The following firmware versions are necessary for correct function of the R&S RF-Fading Simulator:

For FSQ: 4.55 SP1 or later

For FSV: 1.50 or later

For SMU: 2.05.269.101 or later

4.2.1 Setting up the instruments manually

To set up the instruments manually,

- ▶ Connect the signal to be faded to the RF input of the FSQ or FSV
Caution: If the signal's peak level changes to higher values after the SMU's setup procedure (step: *MENU:BB Input:Baseband Input Settings:Auto Level Set*) severe signal distortion will occur)

Setting up an FSQ or FSV is slightly different, use corresponding instructions:

FSQ

- ⇒ Press the *PRESET* button to set the basic operating mode
- ⇒ Set *Center Frequency* equal to input frequency (or with hopping signals to center of frequency range). In the following example we use 310 MHz
- ⇒ Set Reference Level at least 1 dB higher than the anticipated peak level of the input signal (Any peak input levels higher than the reference level set will cause severe signal distortion!)
- ⇒ Set Input Attenuation to 0 dB for Reference Levels < 0dB and to + 5 dB above Reference Level (in 5 dB steps) for Reference Levels ≥ 0dBm
(Examples:
Reference Level = 9dBm ⇒ Attenuation = 10 dB,
Reference Level = 10 dBm ⇒ Attenuation = 15 dB)
- ⇒ Press *MEAS:NEXT:IQ MODE:IQ MODE ON:*
DIQ IQ OUT DEFAULT:
DIQ IQOUT STREAM
to provide a digital baseband data stream at the IQ output of the FSQ

FSV

- ⇒ Press the *PRESET* button to set the basic operating mode
- ⇒ Set *Center Frequency* equal to input frequency (or with hopping signals to center of frequency range). In the following example we use 310 MHz
- ⇒ Set Reference Level at least 1 dB higher than the anticipated peak level of the input signal (Any peak input levels higher than the reference level set will cause severe signal distortion!)
- ⇒ Set Input Attenuation to 0 dB for Reference Levels < -10dB and to + 15 dB above Reference Level (in 5 dB steps) for Reference Levels ≥0dBm
(Examples:
Reference Level = 9dBm ⇒ Attenuation = 20 dB,
Reference Level = 10 dBm ⇒ Attenuation = 25 dB)
- ⇒ Press **MODE**: *IQ Analyzer: Data Acquisition: Sample Rate 100 MHz: Close Digital Output: Enable Digital Output: Close* to provide a digital baseband data stream at the IQ output of the FSV

SMU

- ⇒ Press the *PRESET* button to set the basic operating mode
- ⇒ Set RF Frequency (normally equal to the Center Frequency of the FSQ; 310 MHz in this example)
- ⇒ Set RF level (normally equal to input level of the FSQ, so that the RF Fader has 0 dB attenuation)
- ⇒ Press *RF ON*
- ⇒ Press *MENU:BB Input:Baseband Input Settings:Mode:Digital Input* to select the Digital Baseband input
- ⇒ Press *MENU:BB Input:Baseband Input Settings:Sample Rate: Digital IQ In* to estimate the digital IQ input sample rate
- ⇒ Press *MENU:BB Input: Baseband Input Settings:State ON* to switch the Digital Baseband input on
- ⇒ Press *MENU:BB Input:Baseband Input Settings:Auto Level Set* to initiate an auto leveling procedure
- ⇒ Press *MENU:Setup:Internal Adjustments:Adjust IQ Modulator:Current Frequency* to adjust the IQ modulator at the current frequency for max. spurious suppression

- ⇒ Set up fading parameters according to your needs, as set below for Example 2 in section 4.1.2:
Press *MENU: Fading A:Fading Settings: Path Table 1 1: Stat Off*
- ⇒ Press *Path Table 2 1: Stat On* (*Path table 2 offers a wider range of signal delays*)
- ⇒ Press *Profile Pure Doppler*
- ⇒ Set *Path Loss/dB: 0*
- ⇒ Set *Basic Delay/μs: 1335*
- ⇒ Set *Freq Ratio: 1* (*head on approach of both airplanes assumed*)

- ⇒ Set Speed/km/h: 4000 (speed difference 4000 km/h)
- ⇒ Press State: ON

At the RF output of the signal generator the faded input signal from the signal analyzer is available and can be fed to a second spectrum analyzer to check the signal.

4.2.2 Setting up the instruments remotely

Remote control is either via GPIB or LAN.

Remote control can be setup easily adapting the small computer program "GDE" (Generic Demonstration Engine) with project "RF-Fader" which comes with this Application Note. It sets up the instruments for RF fading and sets the fading scenario from Example 2 in section 4.1.2. The script file can be easily modified for your needs. The GDE software is free of charge and offers a straightforward user interface, benchmarking, and IEEE command sequence export functions for integrating the programming commands into any user-specific test environment.

PC requirements

Recommended system configuration:

- Operating system:
 - Windows 98 / 2000 / Me / XP
 - Microsoft Internet Explorer 5.0 or later
 - VISA (e.g. National Instruments)
- General PC requirements:
 - Pentium II 450 MHz or later
 - 128 MByte RAM
 - 50 MByte free hard disk space
 - XGA monitor (1024x768)
- Either IEC/IEEE bus interface: GPIB card, driver software version 1.7 or later or
- LAN interface

Installation

The file GDE_1.4.17.exe which comes with this Application Note is required in order to install the GDE-software on the controlling PC

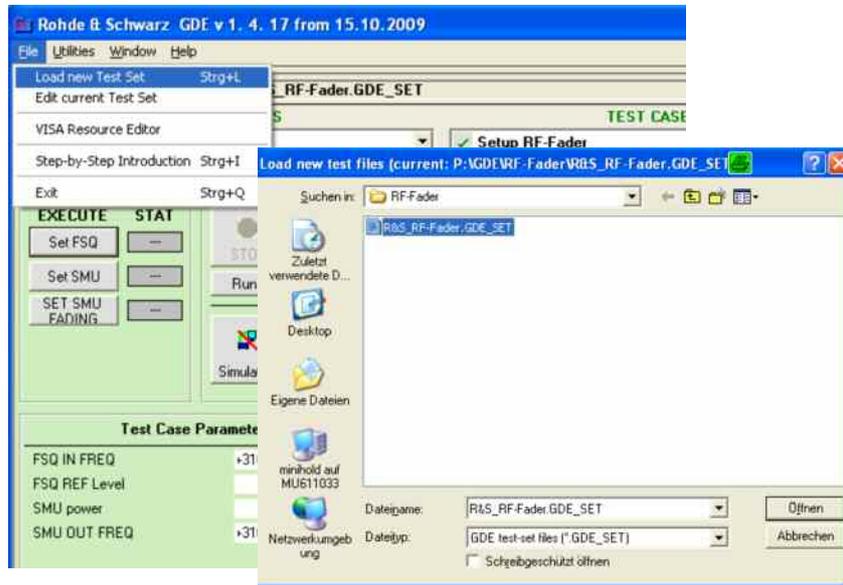
1. Execute the installation program and select the directory of your choice
2. During installation, program files are copied to the directory e.g. \Rohde-Schwarz\GDE\.
3. Unzip GDE-project:RF-Fader_01.ZIP" which comes with this Application Note to a subdirectory e.g. \Rohde-Schwarz\GDE\RF_Fader\

Getting started

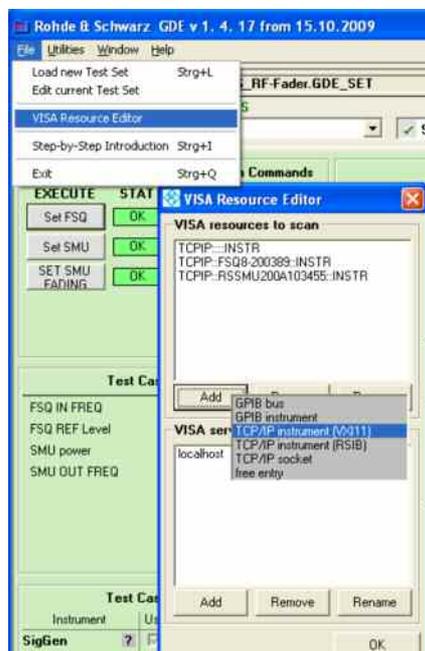
1. When the program starts for the first time, you are requested to register.¹

¹ We kindly ask you to register GDE. Registration is free of charge and is without obligations for you or your company. The unregistered version has full functionality and no expiration date but is a little slower to start.

2. Please follow the instructions on the screen to register GDE. After clicking "Continue" or entering Name and Key, the user interface will come up:
3. Load the new test set "R&S_RF-Fader.GDE_SET" into a subdirectory of the GDE installation (e.g. \Rohde-Schwarz\GDE\RF-Fader)



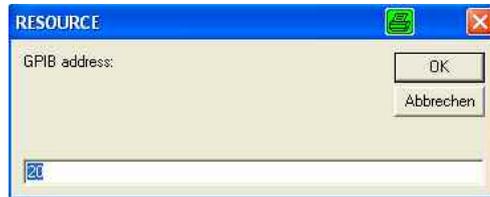
4. Connect the SMU and the FSQ or FSV to the controller via the VISA Resource Editor:



GPIO: select:

File: Visa Resource Editor: Add: GPIO instrument

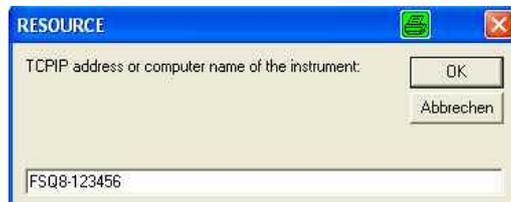
and enter the instrument's GPIO address into the Resource input box:



LAN (TCP/IP): select:

File: Visa Resource Editor: Add: TCP/IP instrument (VXI11)

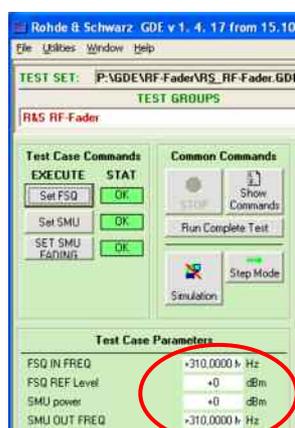
and enter the instrument's TCP/IP address or computer name:



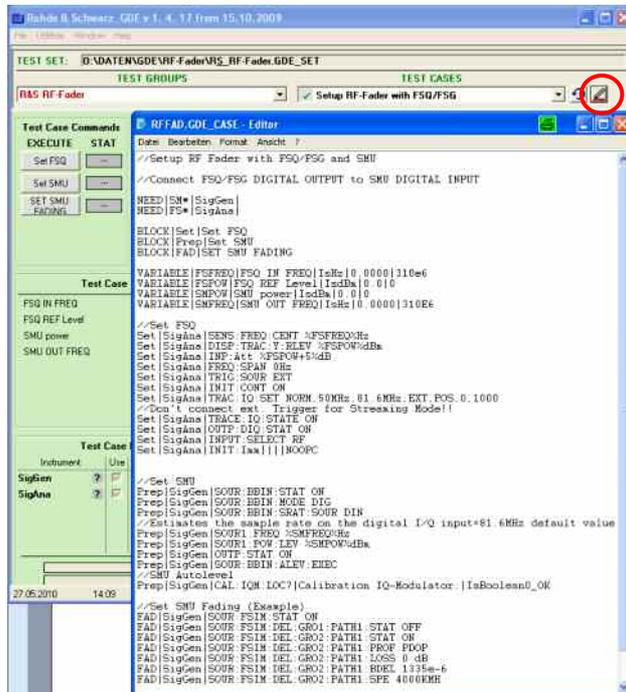
5. Choose FSQ or FSV Test Case depending on the used signal analyzer:



6. Modify Test Case parameters such as the frequency and level via the user interface. Default values are 310 MHz for FSQ/FSV center frequency and SMU output frequency, a FSQ/FSV reference level of 0 dBm and a SMU Level of 0 dBm.

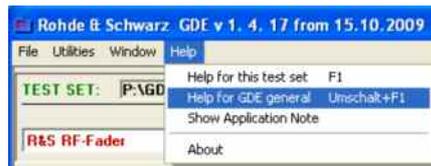


- Setup the connected instruments for RF Fading by successively clicking the buttons *Set FSQ(Set FSV)*, *Set SMU*, *Set SMU Fading* (Fading parameters are as shown in Example 2 in section 4.1.2. These parameters and all other parameters can be modified by editing the test scripts (RFFAD.GDE_Case or RFFAD1.GDE_Case):



To update the test case using the modified test script click to .

For detailed information on the GDE-software use the Help Key:



5 Spectral Performance of the R&S RF Fader

The R&S RF Fading solution has an excellent spectral performance in terms of phase noise, dynamic range and spurious suppression. This ensures that the performance of the receiver under test is not disguised by the RF fader's spectral characteristic and is a result of the applied fading profiles.

- Figure 10 shows the spectral performance of the output signal by applying a full range CW signal with 310 MHz at the FSQ's center frequency 310 MHz. The noise of the output signal is typically -137 dBc/Hz.

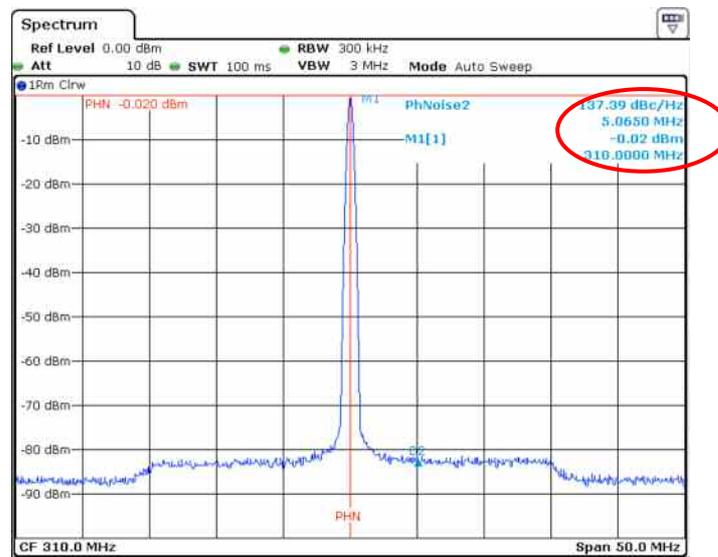


Figure 10: Output spectrum of the R&S RF Fader. A CW signal with 0 dBm at 310 MHz is input at the FSQ RF input. The SMU is set also to a frequency of 310 MHz and 0dBm output level.

- Figure 11 shows the spectral performance of the RF fader's output signal using an FSQ by applying a full range clean CW signal with 5 MHz offset from the FSQ's center frequency 310 MHz. Spurious emissions (carrier feedthrough and 2nd sideband) are typically < -65 dB.
- Figure 12 shows the spectral performance of the RF fader's output signal using an FSV by applying a full range clean CW signal with 5 MHz offset from the FSV's center frequency 310 MHz. Spurious emissions (carrier feedthrough and 2nd sideband) are typically again < -65 dB. Phase noise in 5 MHz offset is about 3 dB higher compared to using an FSQ as down converter.
- Figure 13 shows the RF fader's output spectrum with a 3 GPP Downlink signal with 11 dB crest factor, 0 dBm and 4 MHz offset at the FSQ' RF input. The Reference level of the FSQ is set to +12 dB (1 dB above expected peak power). Some small carrier feedthrough is the only visible spurious.

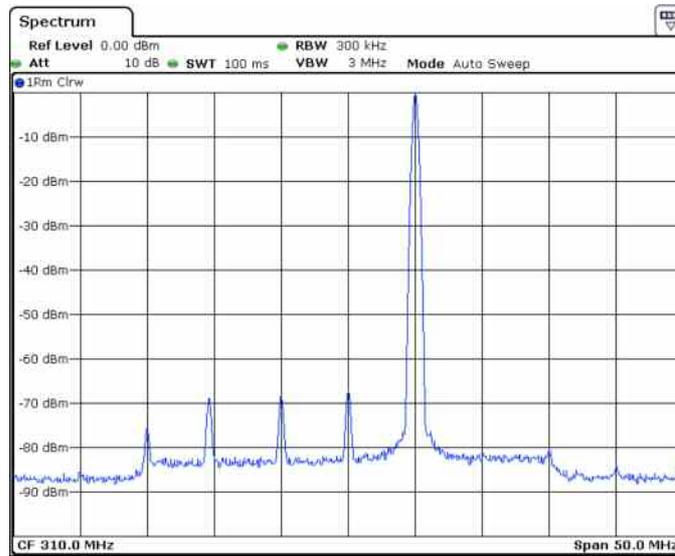


Figure 11: Output spectrum of the R&S Fader with input signal at 320 MHz (FSQ used as RF to baseband converter, 10 MHz offset to FSQ Center frequency). Carrier feedthrough and spurious are typically < -65 dB.

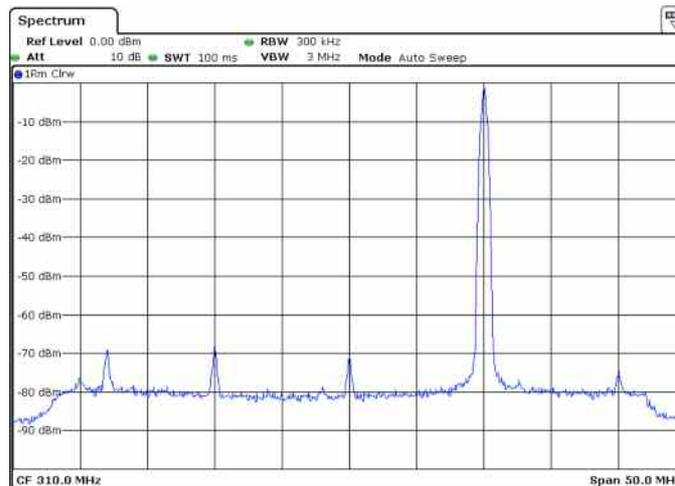


Figure 12: Output spectrum of the R&S Fader with input signal at 320 MHz (FSV used as RF to baseband converter, 10 MHz offset to FSV Center frequency). Carrier feed-through and spurious are again typically < -65 dB. Phase noise is slightly higher (about 3 dB compared to the FSQ).

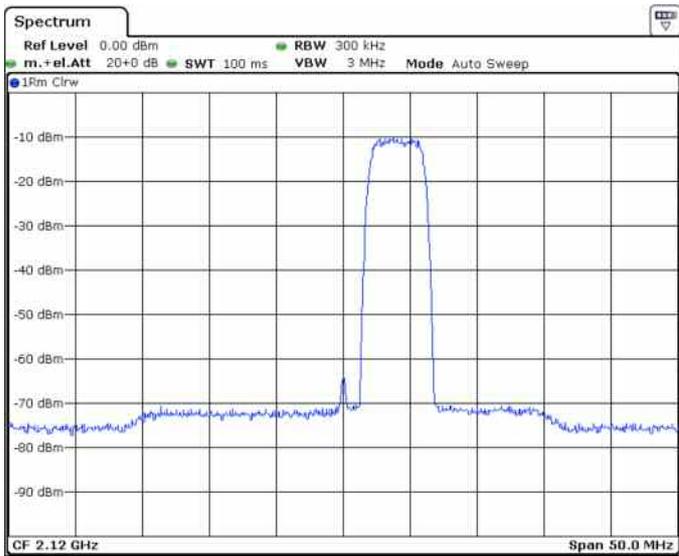


Figure 13: Output spectrum of the R&S Fader with a 3GPP Downlink Signal with 4 MHz offset at the FSQ input. The FSQ's Reference level is set to the peak level of the 0 dBm 3GPP signal (11 dBm).

6 Literature

- [1] Rohde & Schwarz: [Operating Manual: Vector Signal Generator R&S® SMU200A](#)
- [2] Rohde & Schwarz: [Operating Manual: Vector Signal Analyzer R&S® FSQ](#)
- [3] Rohde & Schwarz: [Operating Manual: Digital Baseband Interface R&S® FSQ-B17](#)
- [4] Rohde & Schwarz: [Operating Manual: Vector Signal Analyzer R&S® FSV](#)
- [5] Rohde & Schwarz: [Fading Simulation Options for R&S® Signal Generators Software Manual](#)
- [6] Rohde & Schwarz: At the R&S website there is a number of Application Notes available which highlight special [fading](#) topics.

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-B14	Fading Simulator	1160.1800.02
SMU-B10x	1 st RF path	
SMU-B15 (optional)	Fading Simulator Extension	1160.2288.02
SMU-K62 (optional)	AWGN	1159.8511.02
SMU-B17	Baseband Input (analog/digital)	1142.2880.02
SMU-Z6	LVDS Cable TVR290	1415.0201.02
Signal Analyzers		
FSQ	Up to 3, 8, 26, 31 or 40 GHz	1155.5001.xx
FSG	Up to 8 or 13.5 GHz	1309.0002.xx
FSQ-K17	Digital Baseband Interface	1163.0063.02
FSV	Up to 3.6, 7, 13.6, 30 or 40 GHz	1307.9002.xx
FSV-B17	Digital Baseband Interface	1310.9568.02
FSV-B70	40 MHz Analysis Bandwidth	1310.9645.02

Please contact your local Rohde & Schwarz sales office for further assistance.

About Rohde & Schwarz

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Regional contact

Europe, Africa, Middle East

+49 1805 12 42 42* or +49 89 4129 137 74

customersupport@rohde-schwarz.com

North America

1-888-TEST-RSA (1-888-837-8772)

customer.support@rsa.rohde-schwarz.com

Latin America

+1-410-910-7988

customersupport.la@rohde-schwarz.com

Asia/Pacific

+65 65 13 04 88

customersupport.asia@rohde-schwarz.com

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Rohde & Schwarz GmbH & Co. KG

Mühlendorfstraße 15 | D - 81671 München

Phone + 49 89 4129 - 0 | Fax + 49 89 4129 - 13777

www.rohde-schwarz.com