

Path Compensation for MS Fading Tests

Application Note

Products:

| R&S[®]CMU200 | R&S[®]SMU200A
| R&S[®]CMU-B17 | R&S[®]AMU200A

As well as static tests, modern mobile communication standards also stipulate measurements under fading conditions, sometimes with additional white gaussian noise AWGN.

Rohde & Schwarz supports these tests with the combination of the R&S[®]CMU200 Radio Communication Tester and the R&S[®]SMU200A or R&S[®]AMU200A Vector / Baseband Signal Generator and Fading Simulator.

Applying fading and noise always raises the crest factor of a signal considerably. Thus, automatic path attenuation inside the R&S[®] baseband fader prevents the new signal peaks from being clipped at I/Q full scale. Any additional attenuation in the baseband, however, makes the RF output fall below its intended level.

This application note shows how to achieve an accurate RF output level by compensating for the I/Q attenuation - without modifying the test setup or using additional instruments.

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1 Overview

As well as static receiver tests, modern mobile communication standards also stipulate receiver sensitivity tests under multipath (fading) conditions, for example [1]. Depending on the standard, additional white gaussian noise (AWGN) may also be superimposed. Rohde & Schwarz supports these tests with the combination of the R&S[®]CMU200 Radio Communication Tester and the R&S[®]SMU200A Vector Signal Generator or the R&S[®]AMU200A Baseband Fading Simulator.

Fading and AWGN is best generated in the baseband, to make possible the highest signal quality and optimum dynamic range. Therefore the baseband part with fading and AWGN function of the Vector Signal Generator R&S[®]SMU200A or the Baseband Signal Generator and Fading Simulator R&S[®]AMU200A is inserted into the baseband chain of the R&S[®]CMU200.

Applying fading and noise, always raises the crest factor of a signal considerably.

Thus, automatic path attenuation inside the R&S[®] baseband fader prevents the new signal peaks from being clipped at I/Q full scale. Any additional attenuation in the baseband, however, makes the RF output fall below its intended level.

This application note shows how to achieve an accurate RF level by compensating for the I/Q insertion loss - without modifying the test setup or using additional instruments.

Several applications dealing with fading have already been implemented by Rohde & Schwarz [4]. You find pre-programmed test cases which run on the free test software R&S[®]CMUgo and compensate for the insertion loss automatically.

This application note is for those who operate tests manually or who want to write their own test programs. It explains which losses occur and describes the necessary steps to compensate for them. The procedure presented is the same for all supported mobile standards.

To help with writing test software the corresponding remote commands are also cited.

Notes: Non-hopping tests can be done with either an R&S[®]SMU200A or an R&S[®]AMU200A. For the hopping tests (GSM) use an R&S[®]SMU200A only.

Benefits of the Rohde&Schwarz solution:

- Optimum signal quality is achieved by applying baseband fading.
- Stable repeatable results are ensured by DSP baseband processing.
- No modification of the test setup is needed for the adjustment.
- No external measurements or instruments are required.
- One adjustment is valid for all frequencies.

The following abbreviations are used in this application note for R&S[®] test equipment:

- The R&S[®]CMU200 Universal Radio Communication Tester is referred to as CMU.
- The R&S[®]SMU200A Vector Signal Generator is referred to as SMU.
- The R&S[®]AMU200A Baseband Signal Generator and Fading Simulator is referred to as AMU.

To improve the readability, only the SMU200A is mentioned in the following text. For the remainder of this application note, a reference to the SMU could equally apply to an AMU.

2 Basics about Fading

Mobile tests under multipath fading conditions show how well a mobile station under test demodulates a realistic radio channel. Unlike tests using static signals, the RF input at the mobile antenna changes over time as if the mobile station were moving and received the forward signal at different times and with varying quality via different reflections.

Fig. 2_1 shows a car in a typical urban situation. Just some of the many routes a base station transmitter signal takes to reach the antenna of the car are drawn. Since the car is moving, the routes may be completely different an instant later.



Figure 2_1: Typical multipath conditions in the city

Reflected signals differ in attenuation and phase (propagation delay). We will call a set of routes with almost the same delay one "path". The yellow lines in Fig. 2_1 belong to one path, the white lines to another. If there is no direct line of sight between the base and the mobile station, the sum of the reflected signals of one path represents a "Rayleigh" fading profile. Other profiles are Rice, Gauss, Pure Doppler, and so on. Each mobile standard defines several fading profiles with appropriate parameters. During a test, the stipulated profile is calculated inside a fading simulator in real time. Measurements can be repeated at any time, providing the same results.

As an example Fig. 2_2 shows the details of the GSM standard profile TU 50 (typical urban, speed of 50 km/h):

	1	2	3	4	5	2
	1	2	3	4	5	1
State	On	On	On	On	On	On
Profile	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh
Path Loss /dB	3.00	0.00	2.00	6.00	8.00	10.00
Basic Delay / μ s	0.00	0.00	0.00	0.00	0.00	0.00
Additional Delay / μ s	0.000 00	0.200 00	0.500 00	1.600 00	2.300 00	5.000 00
Resulting Delay / μ s	0.00	0.20	0.50	1.60	2.30	5.00
Power Ratio /dB						
Const Phase /Deg	0.0	0.0	0.0	0.0	0.0	0.0
Speed /km/h	50.00	50.00	50.00	50.00	50.00	50.00
Freq. Ratio	0.00	0.00	0.00	0.00	0.00	0.00
Res. Doppler Shift /Hz	46.33	46.33	46.33	46.33	46.33	46.33
Correlation Path	Off	Off	Off	Off	Off	Off
Coefficient /%	100	100	100	100	100	100
Phase /Deg	0.00	0.00	0.00	0.00	0.00	0.00
Lognorm State	Off	Off	Off	Off	Off	Off
Local Constant /m	100.0	100.0	100.0	100.0	100.0	100.0
Standard Dev. /dB	0	0	0	0	0	0

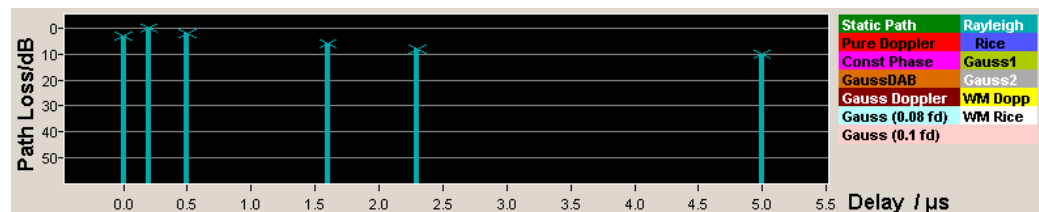


Figure 2_2: GSM fading profile TU 50

The TU 50 profile consists of six paths, each with Rayleigh characteristics. The paths have different losses and delays. The moving speed (50 km/h) is the same for all paths, causing the same Doppler shift.

Fig. 2_2 shows screen-copies taken from the SMU. The instrument supports all modern standards; TU 50 is one of the many pre-programmed fading profiles, see Fig. 2_3:

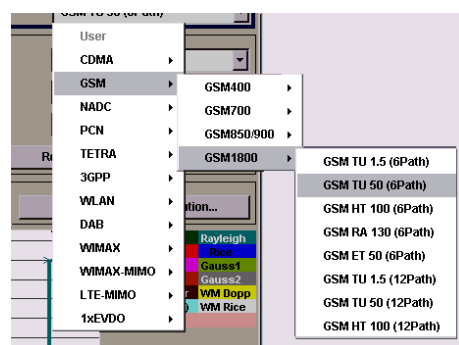


Figure 2_3: Preprogrammed fading profiles

You can select your profile out of the pre-programmed models or define a new one as a user profile.

3 Path Losses in the Hardware Setup

Fig. 3_1 shows schematically how the baseband part of the SMU is inserted into the I/Q path of the CMU. To connect the instruments in your test setup use the I/Q cable included in the CMU-B17 option *IQ/IF analogue Interface*.

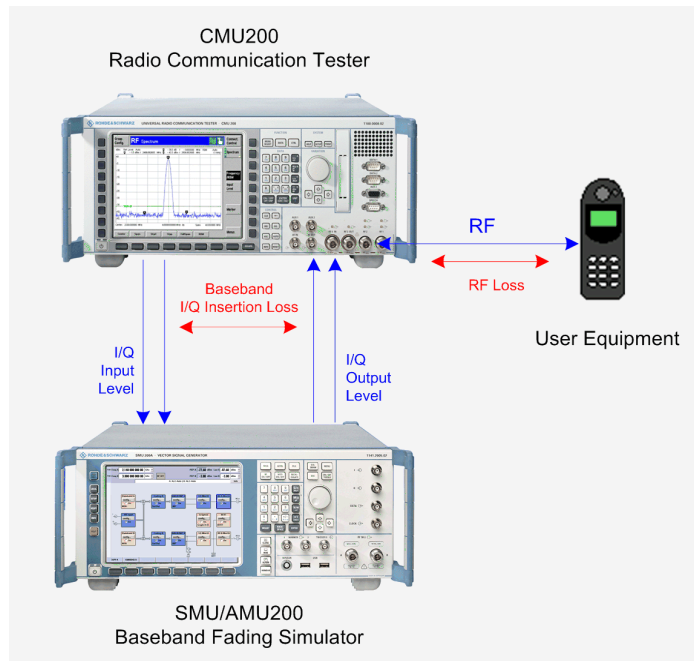


Figure 3_1: I/Q and RF paths in the hardware test setup

The TX RF output of the CMU would be the same as without SMU inserted - if the SMU baseband section could be adjusted to 0 dB insertion loss. However, the CMU I/Q output (SMU I/Q level input) already uses full scale (0 dBFS equals 7 dBm at 50 ohms) and applying fading and noise raises the crest factor of the signal considerably:

- The crest factor of a multipath signal is greater than the crest factor of an unfaded signal.
- The total power of all faded channels is greater than the power of one unfaded signal. You see in Fig. 3_2, which is a section of Fig. 2_2, that in the GSM profile TU 50 the second path alone provides 100% (0 dB path loss). All other paths make an additional contribution.

	1	2	3	4	5	1
State	On	On	On	On	On	On
Profile	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh	Rayleigh
Path Loss /dB	3.00	0.00	2.00	6.00	8.00	10.00
Basic Delay /µs	0.00	0.00	0.00	0.00	0.00	0.00
Additional Delay /µs	0.000.00	0.200.00	0.500.00	1.600.00	2.300.00	5.000.00

Figure 3_2: Path losses in the GSM profile TU 50

Inside the SMU each fading path is created as an independent signal, see Fig. 3_3.

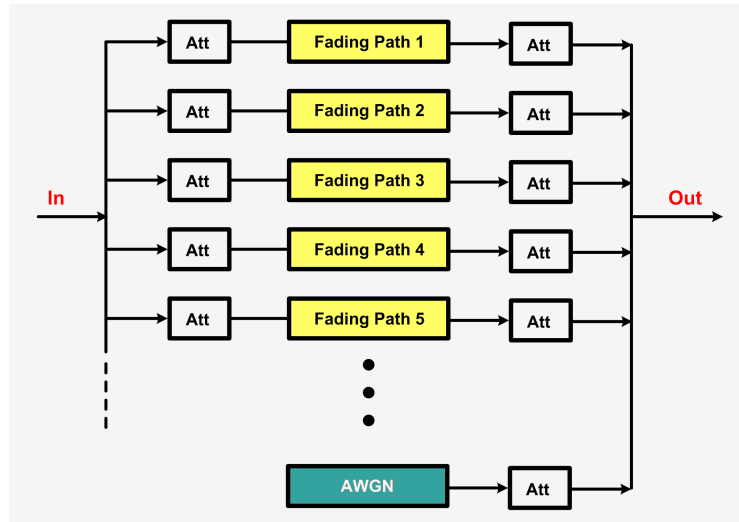


Figure 3_3: Functional blocks for the baseband processing inside SMU

The many attenuators in this figure are required to set up relationship between the fading channels, and optimize the internal levels automatically to achieve the best dynamic swing. (Please keep in mind that Fig. 3_3 is only a functional diagram. The baseband processing is done completely by digital signal processors.)

- Some mobile standards such as 3GPP WCDMA stipulate additional AWGN with a power level even above the "wanted" signal. This also raises the summary level.

Baseband levels greater than 0 dBFS overdrive the CMU I/Q input. To avoid clipping and distortion, the baseband level is thus decreased inside the SMU during the fading processing. This is done automatically, depending on the kind of fading profile and, if required, the carrier to interferer ratio of the AWGN.

Decreasing the baseband level decreases the RF output by the same amount. Without level correction the CMU output signal would be too low. We have to compensate for exactly the *Insertion Loss* in Fig. 3_1, namely the difference between the RMS levels of SMU I/Q Input and SMU I/Q Output.

- ▶ Both levels can be measured inside the SMU.

To raise the CMU RF output accordingly, we add the insertion loss to the actual RF cable loss and enter a higher CMU external RF output attenuation than really exists.

CMU External RF Output Attenuation =

$$\text{actual RF Loss} + (\text{SMU I/Q Input} - \text{SMU I/Q Output})$$

This simply shifts the baseband attenuation virtually to the RF path. The RMS level displayed on the CMU indicating the power (of the wanted signal) at the device under test is correct now.

4 Path Compensation

Fig. 4_1 shows the typical program flow for mobile station signaling tests.

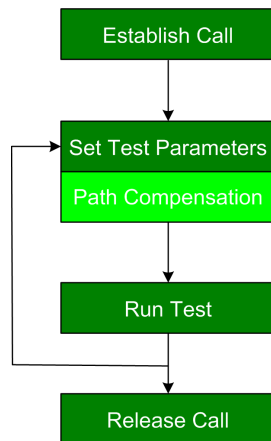


Figure 4_1: Path compensation in the test loop

While establishing the call, you set all general test parameters, e.g. the mobile standard or the configuration of the downlink control channels. These are CMU settings. Then - in the test loop - you set the individual parameters for the current test, e.g. the downlink level. First enter the CMU settings. Then, for tests with fading (and AWGN), you set the fading profile and the AWGN parameters. These are SMU settings.

Now the signal level has to be adjusted to compensate for the insertion loss in the baseband path. This is necessary only:

- ▶ if you change the fading profile
- ▶ if you add or vary the AWGN signal.

No action is necessary if you only change the downlink level or the frequency. Adjust the extra path compensation as follows:

- | | |
|--|-----|
| 1. Feed the SMU I/Q input | CMU |
| 2. Measure the SMU I/Q input signal | SMU |
| 3. Set the parameters for fading & AWGN | SMU |
| 4. Measure the SMU I/Q output signal | SMU |
| 5. Adjust the CMU Ext. RF output attenuation | CMU |
| 6. Insert the SMU in the CMU baseband path | CMU |

These steps are covered in detail in the following sections 4.1 to 4.6.

The *Call Release* concludes the test sequence.

The path compensation described here is embedded in the (fading) test. This is best for R&D. For production you could save test time if you measure the insertion loss of each test only once in the first sequence run, and store the results in a table. From there you can fetch them quickly when repeating the test sequence many times.

Because the baseband processing is completely done by signal processor calculations the insertion loss of a given fading profile and AWGN parameter set is constant. The loss is independent of your test frequency. It does not depend on the current Doppler Shift. However the RF loss could change over the frequency which results in different values of the external CMU output attenuation at different frequencies.

4.1 Feed the SMU I/Q Input

Connect the CMU, the SMU, and the DUT as shown in Fig. 3_1. For the baseband wiring use the CMU-B17 cable.

On the CMU

1. Reset the CMU, establish a call connection with the DUT.
After Reset both TX and RX I/Q paths are bypassed.
2. Set the TX path to *Bypass with I/Q IF OUT*, see Fig. 4.1_1:

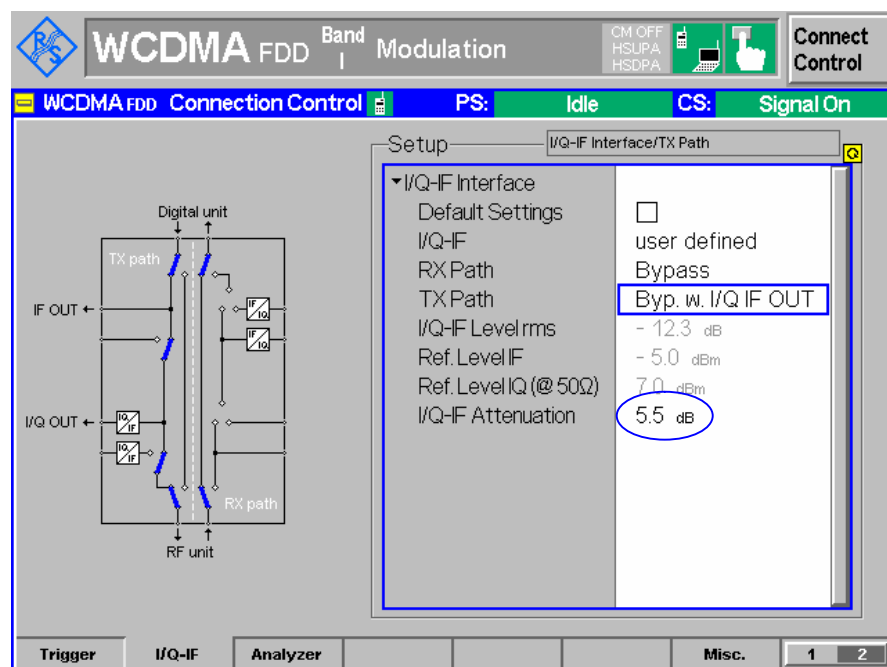


Figure 4.1_1: I/Q path setting on the CMU for WCDMA

This feeds the SMU IQ input (connected to CMU I/Q OUT) without any impact on the call connection.

Note: The four items *I/Q-IF Level rms*, *Ref. Level IF*, *Ref. Level I/Q*, and *I/Q-IF Attenuation* in Fig. 5_1 appear only for WCDMA. For this standard a higher baseband output is possible. To avoid overdriving the SMU input set the *I/Q-IF Attenuation* to 5.5 dB.

4.2 Measure the SMU I/Q Input Signal

On the SMU

1. Select and enter the *BB Input* block, see Fig. 4.2_1.
2. Select *route to path A*.
(In the following text we always use path A of the SMU. Path B of a two channel instrument could be used as well; it works identically.)
3. Click Baseband Input Settings.

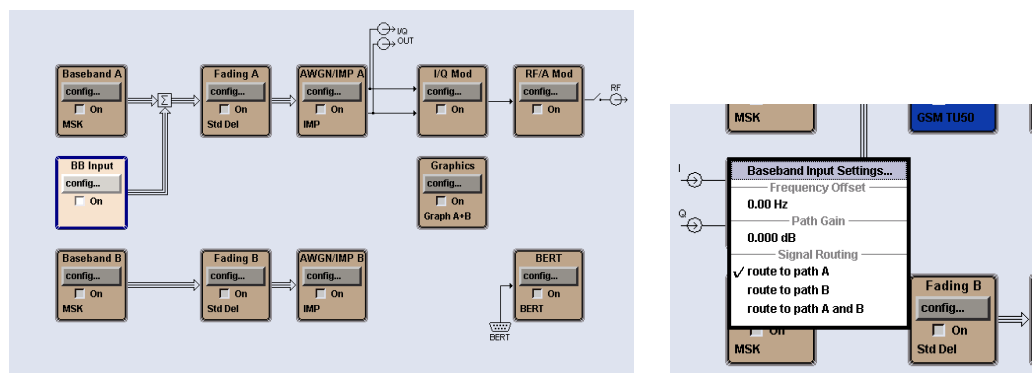


Figure 4.2_1: How to find the input settings

The *Input Setting* window opens, see Fig. 4.2_2. Here you can measure the input level.

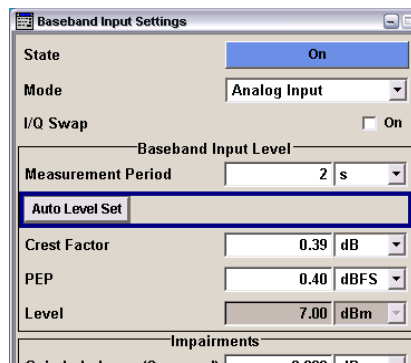


Figure 4.2_2: Baseband input menu to measure the I/Q input level

4. Switch State On.
(On the SMU this automatically activates the *I/Q Mod* block too. You can leave it activated or cancel it.)
5. Set the *Measurement Period* to 2 seconds. This guarantees a stable result.
6. Click *Auto Level Set*.

The action you triggered by this is called *Auto Level Set* because - after measuring the input level - the SMU adjusts several attenuators in the baseband chain for best dynamic behaviour, see Fig. 3_3.

As results of the measurement you get the *Crest Factor*, the *PEP*, and the *RMS Level*. In this example the *SMU I/Q Input is 7.0 dBm or 0 dBFS* (full scale).

GSM signals from the CMU (with an ideal crest factor of zero) use that full scale baseband level. Signals with a high crest factor (e.g. WCDMA signals with 12 dB crest factor) have an RMS level of about -5 dBm in the baseband.

4.3 Set the Parameters for Fading & AWGN

1. Select and enter the *Fading A* block. Click on *Fading Settings*.

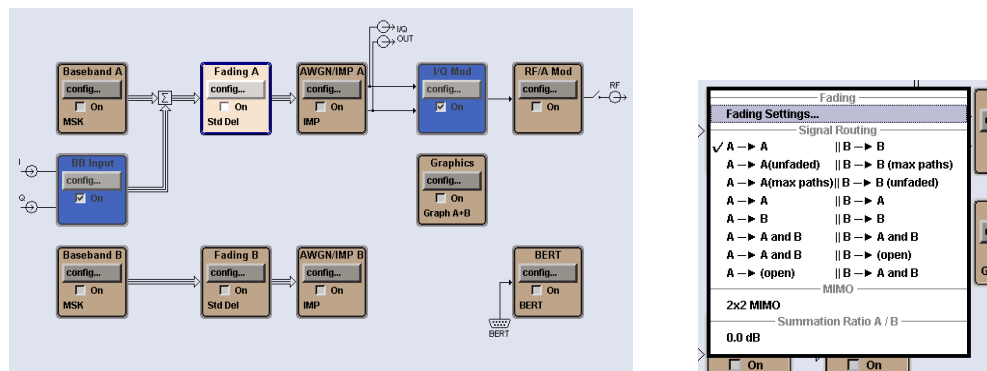


Figure 4.3_1: How to find the fading settings

The fading main menu opens.

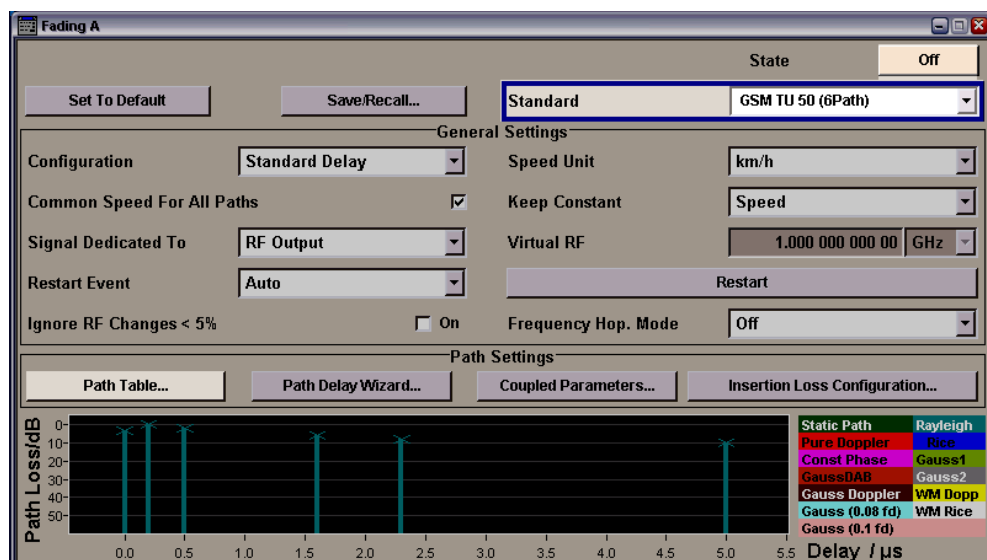


Figure 4.3_2: Fading main menu

2. Select the stipulated fading *Standard* e.g. GSM TU 50 or define a user profile.
3. In the *Path Table* set the (Moving) *Speed* to the maximum possible value (entering 10000 km/h for example, sets it automatically to maximum), see Fig. 4.3_3.

Remaining Delay (ns)		0.00	0.20	0.40	1.00	2.00	3.00
F A S T	Power Ratio (dB)						
	Const Phase (Deg)	0.0	0.0	0.0	0.0	0.0	0.0
	Speed (km/h)	1726.81	1726.81	1726.81	1726.81	1726.81	1726.81
	Freq. Ratio	0.00	0.00	0.00	0.00	0.00	0.00
	Doc. Number Shift (Hz)	1.600 04	1.600 04	1.600 04	1.600 04	1.600 04	1.600 04

Figure 4.3_3: Fading-speed set to maximum

Now the fading cycles are passed through as fast as possible. By this the later measurement of the I/Q output level which has to integrate over a certain amount of cycles takes minimum time. (The moving speed does not affect the levels.)

4. Switch Fading on.

Note: For the measurement of the I/Q output signal you may leave *Signal Dedicated to RF Output*; it has no influence on the measurement result.

If **AWGN** is required:

5. Select and enter the *AWGN/IMP A* block.

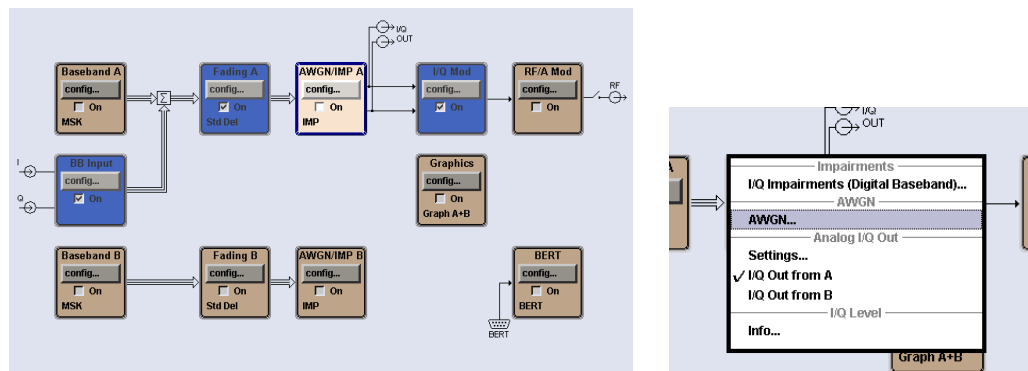


Figure 4.3_4: How to find the AWGN settings

6. Select *I/Q Out from A* (not applicable at the AMU, see below)
7. Click on *AWGN...*

The AWGN Settings menu opens.

8. Enter the parameters stipulated by your test.
(These parameters vary greatly from standard to standard as well as from test case to test case. This is why a typical example cannot be given here.)
9. Switch AWGN on.

Configure the AMU Output Stage

Unlike the SMU the AMU includes an additional I/Q-output stage which has to be configured as well.

1. Select and enter the *I/Q Out A* block.

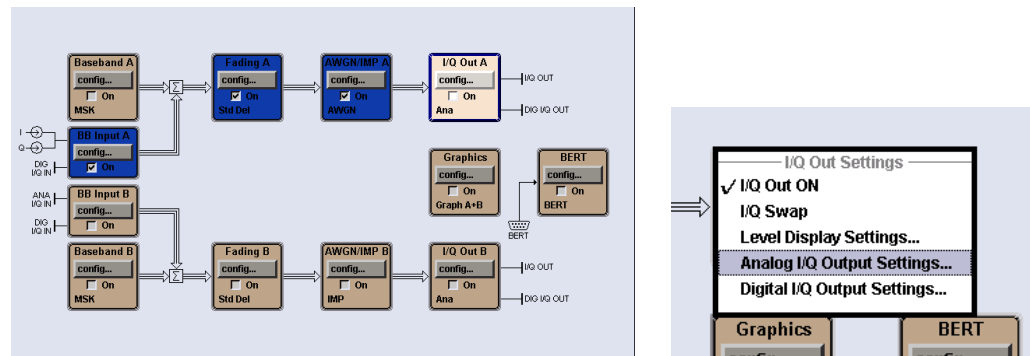


Figure 4.3_5: Additional output stage inside the AMU

2. Click *I/Q Out ON*.
3. Select *Analog I/Q Output Settings...*

The Output Settings window opens, see Fig. 4.3_6.

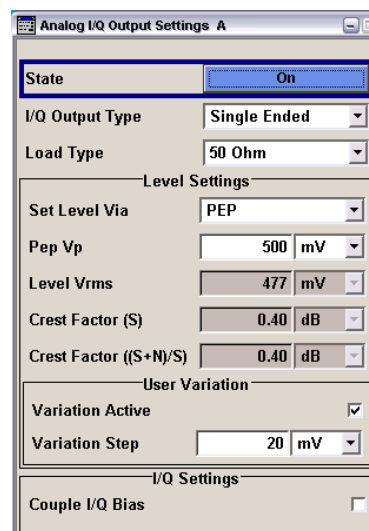


Figure 4.3_6: Output settings (AMU only)

4. Switch *State* on.
5. Set *Level Via* PEP.
6. Set *Pep Vp* to 500 mV (which is equal to full scale: 7.0 dBm).

This makes sure that the instrument always uses the full output range, no matter what insertion loss or current RMS level might occur.

4.4 Measure the SMU I/Q Output Signal

1. Select and enter the *AWGN/IMP A* block, select *Info*, see Fig. 4.4_1.

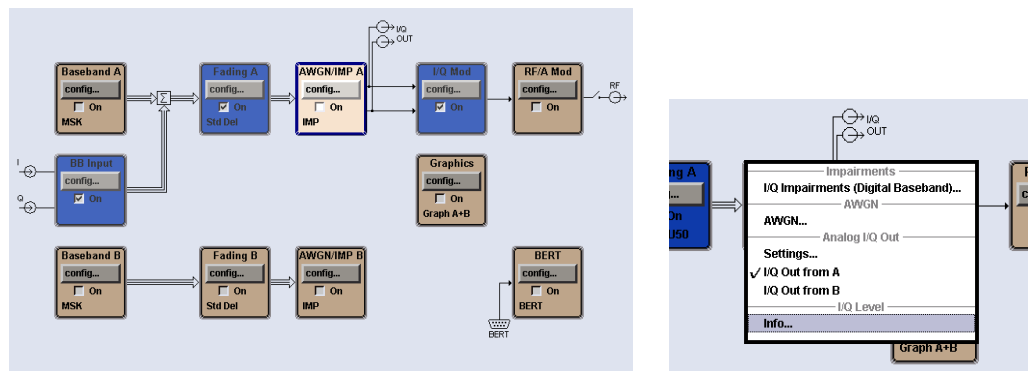


Figure 4.4_1: How to find the SMU baseband output level measurement

SMUs and AMUs with current hard- and firmware show a *Baseband Signal Level Measurement* window like Fig. 4.4_2. If your window looks different, see Fig. 4.4_3 below.

Baseband Signal Level Measurement	
State	Off
Signal Source	Baseband w/o AWGN
Duration [HH:MM:SS]	00:00:02
Remaining Time [HH:MM:SS]	00:00:00
Crest Factor	9.51 dB
Peak Level	-3.07 dBFS
Signal Level (RMS)	-12.57 dBFS
MIMO Fading Power Correction	0.00 dB

Figure 4.4_2: Measuring the SMU baseband output

2. Always select for the Signal Source *Baseband w/o AWGN*.

Even if your application works with AWGN the insertion loss for the "wanted" signal matters. The AWGN is relative to the level of the wanted signal.

3. Set the measurement *Duration* to 2 seconds. Together with the maximum fading speed (see section 4.3) this guarantees a stable result.
4. Click *State OFF* to start the measurement. *OFF* changes to *ON* for the measurement duration.

As results you get the *Crest Factor*, the *Peak Level*, and the *RMS Signal Level* of the SMU baseband output signal.

In this example the **SMU I/Q Output is -12.57 dBFS** which is equal to **-5.57 dBm** at 50 ohms.

Early SMUs calculated the output level. (The measurement hardware was not yet implemented.)

In this case switch AWGN off - if it was activated. Then open the *Info* window.

For early SMUs the *Info* window looks like Fig. 4.4_3. You don't need to start a measurement; simply read out the calculated *Signal Level*.

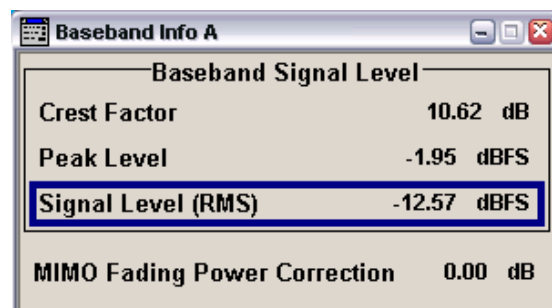


Figure 4.4_3: Calculated baseband output on early SMUs

Again the **SMU I/Q Output is -12.57 dBFS** which is equal to **-5.57 dBm**.

If necessary, switch AWGN on again.

Reset the Fading Profile

In section 4.3 the fading speed was set to maximum to achieve a quick I/Q output level measurement. This now has to be cancelled. The simplest way to do this is to reload the requested fading profile. Proceed as in section 4.3:

1. Select and enter the *Fading A* block. Click on *Fading Settings*.
The fading main menu opens.
2. Select the stipulated fading *Standard* e.g. GSM TU 50 or define a user profile.

In addition (only on SMU):

3. Set *Signal Dedicated To Baseband Output*.
4. Enter the CMU downlink frequency as *Virtual RF*, see Fig. 4.4_4. This value is used as the basis for computing the Doppler shift.

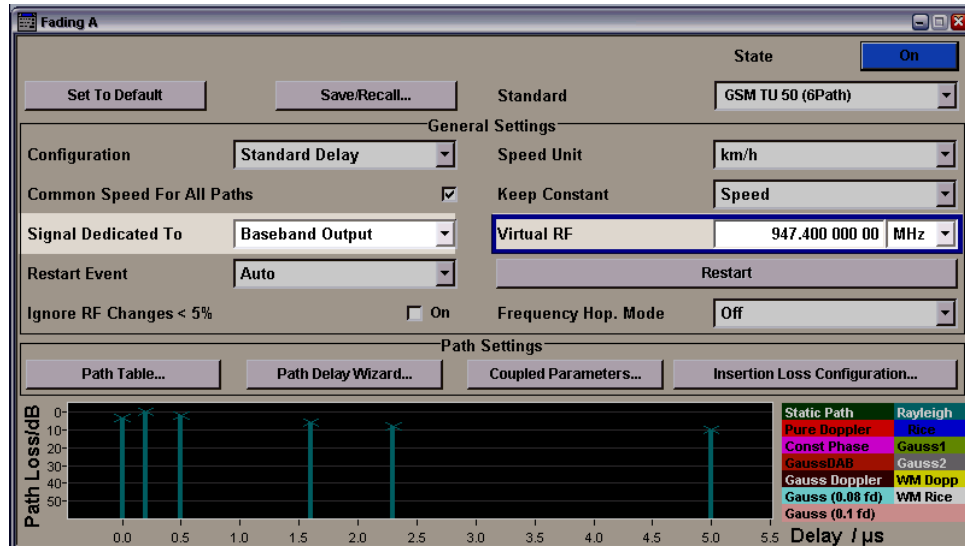


Figure 4.4_4: Virtual RF edit field

4.5 Adjust the CMU Ext. RF Output Attenuation

With the measured levels of sections 4.2 and 4.4 and an actual RF Loss of for example 1.2 dB we get:

CMU External RF Output Attenuation =

$$\text{actual RF Loss} + (\text{SMU I/Q Input} - \text{SMU I/Q Output})$$

$$\text{CMU External RF Output Attenuation} = 1.2 \text{ dB} + (7.0 - (-5.57)) \text{ dB} = 13.77 \text{ dB}$$

1. Enter this value as external attenuation for the CMU output.
2. Enter the actual RF loss as external attenuation for the CMU input, see Fig. 4.5_1.

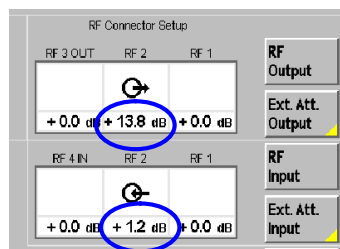


Figure 4.5_1: Setting the external attenuation at the CMU (using RF 2 for TX and RX)

4.6 Insert the SMU in the CMU Baseband Path

On the CMU

- Set I/Q-IF to *Fading* or the TX path to *I/Q IN/OUT*, see Fig. 4.6_1:

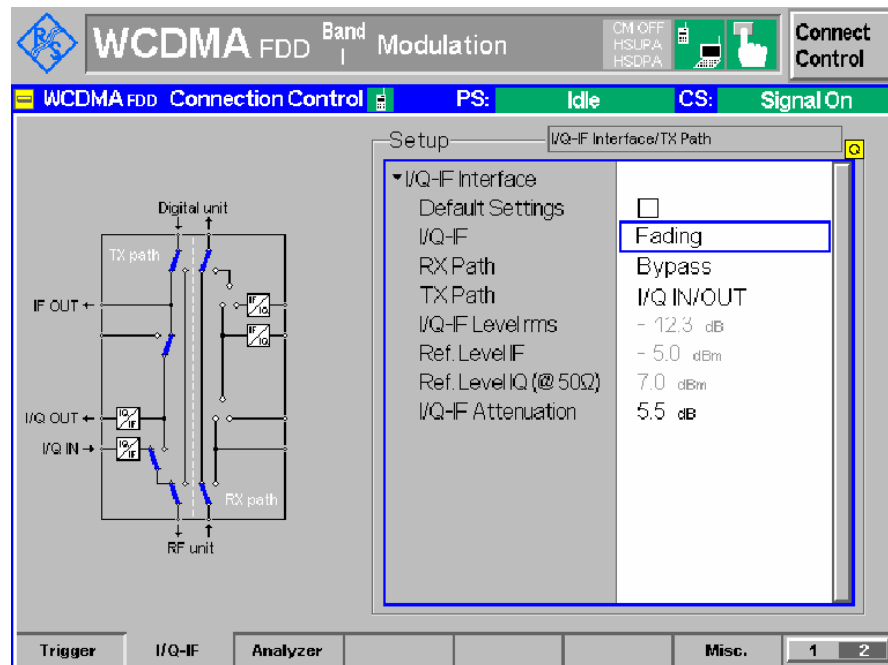


Figure 4.6_1: I/Q path setting on the CMU for fading

This applies fading and AWGN to the signal. Now you are ready to run the fading tests.

4.7 Remote Controlled Compensation

To write to and read from the SMU or the CMU, the VISA C functions `viPrintf()` and `viScanf()` are used in the following lines. Transform the example in your program language if necessary.

Measure the SMU Input Signal

```
MeasurementPeriod = 2; // 2 s
viPrintf (smu, "BBIN:MPER %d", MeasurementPeriod);

viScanf (smu, "BBIN:ALEV:EXEC;*OPC?", "%d", &RetState); // start measurement
if (!RetState) return -1;
viScanf (smu, "BBIN:POW:RMS?", "%lf", &BBIn); // read the BBIn value
```

Check for EarlySMU (DAC Version <= 8090)

```
EarlySMU = false;
viScanf (smu, "DIAG1:BGIN? 'DACB'", "%s", VString); // read board version
VString = strncpy (VString, VString+10, 4); // extract DAC Version

if (atoi(VString) <= 8090) EarlySMU = true;
```

Get the SMU Baseband Output Level

```
if (EarlySMU)
{
    viScanf (smu, "BB:POW:RMS?", "%lf", &BBOut); // read BBOut value
}
else

// CurrentSMU

{
    MeasurementDuration = 2; // 2 s
    viPrintf (smu, "BB:MEAS:DUR \"00:00:%2d\"", MeasurementDuration);

    viPrintf (smu, "BB:MEAS:STAT ON"); // start measurement
    do
        viScanf (smu, "BB:MEAS:RTIM?", "%s", szRTim); // sit it out
        while (strcmp ("\"00:00:00\"", szRTim)); // quit when 00:00:00

    viScanf (smu, "BB:MEAS:POW:RMS?", "%lf", &BBOut); // read BBOut value
}
```

Set the CMU Output Attenuation

```
viPrintf (cmu, "SOUR:CORR:LOSS:OUTP2 %lf", BBIn - BBOut + CableLoss);
```

5 Summary

For fading tests Rohde & Schwarz offers an advantageous baseband solution with all its benefits using the combination of the CMU radio communication tester and the SMU/AMU vector / baseband signal generators and fading simulators.

This application note showed the compensation for the baseband insertion loss in the combination of the CMU and the SMU. The necessary measurements are done in the unmodified test setup without additional instruments.

Compensation values can be determined during each single test or before running a test suite. Because the baseband processing is completely done by DSP calculations the insertion loss for each given fading profile and AWGN parameter set is constant.

Both SMU and AMU are best prepared for the future. Fitted with two independent channels they allow correlated as well as non-correlated 2-channel fading for next generation applications.

6 Literature

[1] 3GPP TS34.121; Terminal conformance specification; Radio transmission and reception (FDD) (Release 7.0.0)

[2] SMU200A Operating Manual, Rohde&Schwarz, 2008

[3] Supplement to SMU200A Operating Manual, B14 / Fading, Rohde&Schwarz, 2008

[4] Measurements on 3GPP UE's according to TS34.121 with CMUgo, Application Note 1MA130, Rohde&Schwarz, 2008

7 Additional Information

Please contact TM-APPLICATIONS@ROHDE-SCHWARZ.COM for comments and further suggestions.

8 Ordering Information

Vector Signal Generator

SMU200A	Vector Signal Generator	1141.2005.02
SMU-B13	Baseband Main Module	1141.8003.04
SMU-B14	Fading Simulator	1160.1800.02
SMU-B15	Fading Simulator ext. (optional)	1160.2288.02
SMU-B17	Analog Baseband Input	1142.2880.02
SMU-K62	Additive White Gaussian Noise (AWGN)	1159.8511.02
SMU-K71	Dynamic fading and enhanced resolution	1160.9201.02
SMU-K72	Enhanced Fading Models	1408.7062.02

Baseband Signal Generator and Fading Simulator

AMU200A	Baseband signal generator, base unit	1402.4090.02
AMU-B10	Baseband generator with dig. modulation	1402.5300.02
AMU-B13	Baseband Main Module	1402.5500.02
AMU-B14	Fading Simulator	1402.5600.02
AMU-B15	Fading Simulator ext. (optional)	1402.5700.02
AMU-B17	Analog Baseband Input	1402.5900.02
AMU-K62	Additive White Gaussian Noise (AWGN)	1402.7202.02
AMU-K71	Dynamic fading and enhanced resolution	1402.7302.02
AMU-K72	Enhanced Fading Models	1402.9605.02

Radio Communication Tester

CMU200	Univ. Radio Comm. Tester	1100.0008.02
CMU-B17	IQ/IF analogue Interface	
CMU-B21	Univ. Signalling Unit	1100.5200.54
CMU-K20	GSM400 SW-option and / or	1115.5900.02
CMU-K21	GSM900 SW-option and / or	1115.6007.02
CMU-K22	GSM1800 SW-option and / or	1115.6107.02
CMU-K23	GSM1900 SW-option and / or	1115.6207.02
CMU-K24	GSM850 SW-option	1115.6307.02

About Rohde & Schwarz

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

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