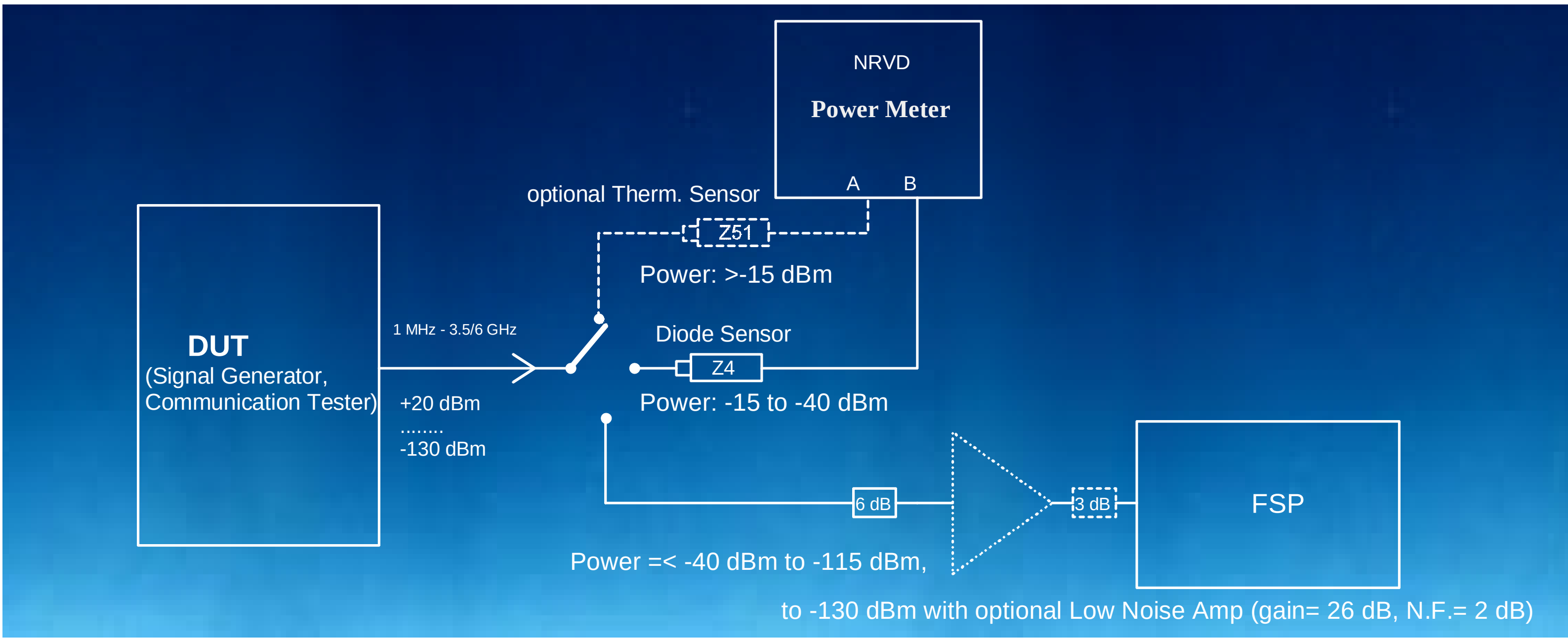


Products: FSP, NRVD

RF Level Test System
+20 dBm to –130 dBm

Application Note

The purpose of the test setup described is to ensure or to enhance the level accuracy of signal generators or the generator part of communication testers. The level accuracy of test signals is particularly important at low levels when measuring BER level sensitivity at digital communication receivers. The highly linear FSP spectrum analyzer is used in combination with a power meter to get the best possible accuracy with high measurement speed over a very wide level range.

ROHDE&SCHWARZ

Subject to change – Minihold 11.99 – 1MA21_1E

Contents

1 Overview

The purpose of this test setup is to ensure or to enhance the level accuracy of signal generators or the generator part of communication testers. The level accuracy of test signal is very important, especially at low levels when measuring the BER level sensitivity of digital communication receivers.

For the sensitivity measurement of receivers at base station and mobiles in different digital standards, the following levels have to be applied and are therefore effectively the lowest levels (minus some extra dB's) which have to be calibrated:

Table 1 Static BER Levels in different Digital Communication Standards

Communication Standard	**BER Sensitivity Level**
GSM 900/1800/1900	-104 dBm
IS 136	-110 dBm
IS 95	-104 dBm

2 General measurement principle

By far the most accurate instrument for level measurement is a power meter with a thermocouple power sensor.

However the sensitivity of a thermocouple sensor is limited to about -20 dBm to -30 dBm. A power meter with a diode sensor is more sensitive and provides accurate level measurement down to about -50 dBm. Levels far below –50 dBm can only be measured by a selective device like a spectrum analyzer (or a receiver). However, the absolute level accuracy of these instruments is quite low compared to that of a power meter. So the idea of the level tester is to calibrate the spectrum analyzer readings for each test frequency at a level which can be measured well by a power meter, such as -40 dBm. When the level is lowered further, only the linearity error of the analyzer contributes to the overall level uncertainty. The R&S FSP spectrum analyzer shows a very low linearity error at bandwidths ≤30 kHz (digital IF filter), so that the measurement accuracy remains high. Thus levels down to -130 dBm and even below can be measured with high precision. If the range setting of the FSP has to be changed, renormalize the FSP at the same level in the new range. Thus the FSP's range setting uncertainty does not contribute to the overall measurement uncertainty either.

Measuring the power of CW signals will in general give the most accurate results and can be done down to the lowest level because very small measurement bandwidths can be used. However the signal power of a DUT may change when switching from CW to a digitally modulated signal. If the purpose of the test is to ensure the level accuracy of the modulated signal, the modulations's influence to the output level should be tested first at a reference point and taken into account for all following CW measurements.

3 Suggested test setup

The suggested test system contains an FSP spectrum analyzer, an NRVD power meter with one (or two) power sensors, optionally an NRV-Z51 thermocouple sensor and an NRV-Z4 sensitive diode power sensor. To switch between the different paths, a low VSWR switch is required (see appendix 2). If signal levels below approximately –115 dBm have to be measured, a low noise amplifier is also necessary.

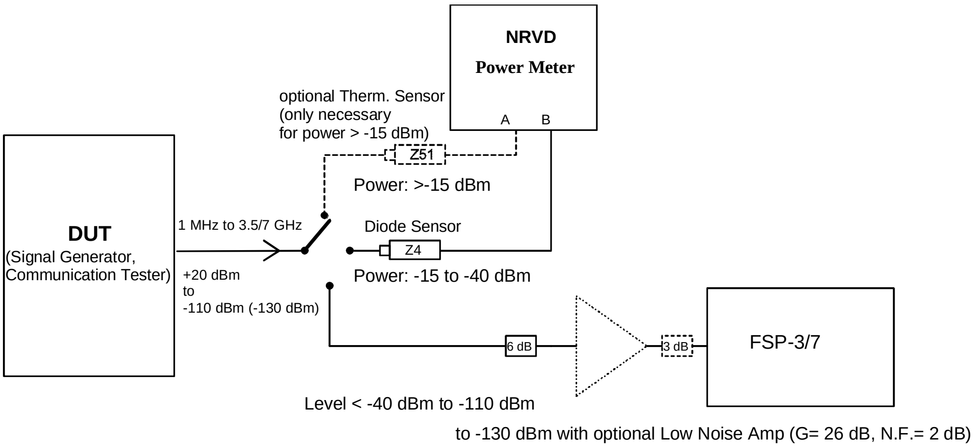


Fig. 1 Schematic diagram of test setup

4 Description of level measurement

If digitally modulated signals are to be measured, the influence of digital modulation on the output power of a device (compared to a CW signal) should be tested in advance. Switching on digital modulation in a signal generator or communication tester usually changes the internal signal path by switching in or out various components (like an I-Q modulator). This may have some influence to the output level.

Therefore the difference in indication between modulated and unmodulated signal should be noted as a correction factor. It can be measured either with the thermocouple power sensor at a level **> -15 dBm** or – if it is not available - with the diode sensor as well at a level of **-40 dBm**. At -40 dBm the diode sensor remains in the square law region even for signals with high crest factors such as IS95 signals. Thus the error due to the crest factor is negligible. For TDMA signals the power ramping has to be switched off . Use the FSP in zero span mode to test also if there is any change in level dependant on power ramping.

After getting the correction factor, set the device to CW. All the following measurements are done in CW taking this correction factor into account. This technique is applicable for lower levels, because they are achieved by switching in additional attenuation before the output, so that the relative difference between modulated and non-modulated signal remains the same.

The power of the DUT is measured then in up to four ranges :

Table 2: Level ranges, measuring devices and VSWR of measurement paths

No.	**Level range**	**Measuring device**	**Description/Setting**	**VSWR of measuring path**
1 (optional)	> - 15 dBm	power meter + thermocouple sensor	NRVD + NRV-Z51	1.1 for f<= 2 GHz
2	- 15 dBm to - 40 dBm	power meter + diode sensor	NRVD + NRV-Z4	1.1 for f <= 2 GHz
3	- 40 dBm to - 80 dBm	Spectrum analyzer (FSP)	Ref - 40 dBm, Atten.: 10 dB (with amp: Ref -20 dBm, Atten.: 10 dB)	1.15 for f<= 2 GHz
4	< -80 dBm	Spectrum analyzer (FSP)	Ref - 60 dBm, Atten.: 0 dB (with amp: Ref –40 dBm, Atten.: 0 dB	1.3 for f <= 2 GHz

The upper two ranges are measured using two power sensors. If level range < -15 dBm is sufficient, only one range and one detector are required. Levels above about -15 dBm (if necessary) are measured by the NRV-Z51 thermocouple power sensor which is insensitive to harmonics of the DUT. Signal generators and the generator part of a communication tester typically show harmonics of -30 dBc which may cause significant measurement errors when measuring with a power meter with diode sensor beyond the square law region.

Levels below -15 dBm down to –40 dBm are measured by the more sensitive NRV-Z4 diode sensor which is in the square law region at these levels for CW signals and therefore also insensitive to harmonics.

Both detectors show a very low VSWR (1.1 for f < 2 GHz), so that the level measurement uncertainty contribution due to source mismatch is low.

The lower two ranges are measured using the FSP. At a level of about –40 dBm a reference point is set at each measurement frequency: the measurement is done first by the power meter and then by the FSP with a small resolution bandwidth, and its reading is normalized to the power meter indication. The absolute level measurement uncertainty of the FSP is therefore eliminated along with the level uncertainty caused by the mismatch of the FSP path. For lower power levels than -40 dBm, only the very low linearity error of the FSP (Linearity error < 0.2 dB in the range 0 dB to -70 dB , Standard uncertainty: 0.07 dB) and the uncertainty due to S/N at very low levels contribute to the overall level uncertainty. If levels below –80 dBm have to be measured, the FSP has to be set to a more sensitive range to keep inside the high linearity region (see table 2). To avoid additional error contributions due to range switching, normalise at –80 dBm, correct the indication from more sensitive range to previously recorded reading.

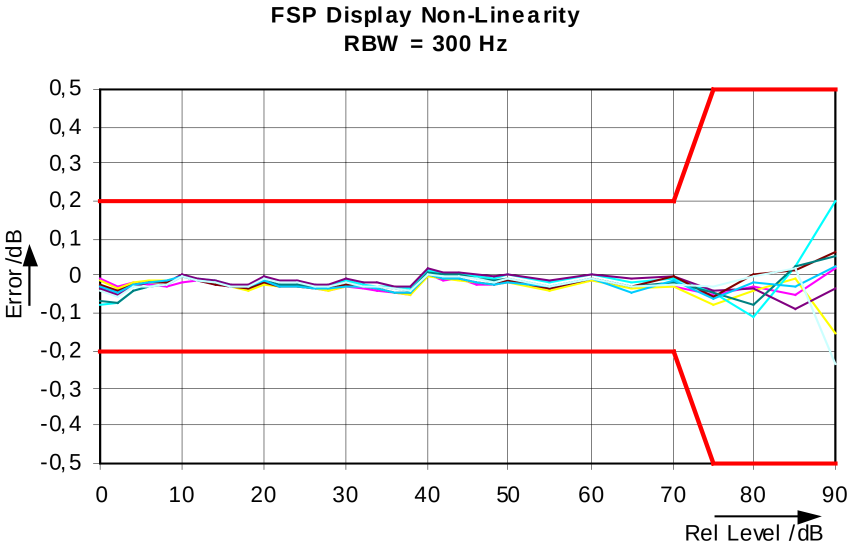


Fig. 2: Linearity of 10 different FSP samples

Note: *The FSP measures in digital bandwidths (preferably 10 Hz for optimum S/N) where the analog logamp which can cause unpredictable linearity error of up to 0.5 dB is avoided. The IF signal inside the FSP is then sampled directly by an 12 bit A/D converter which is extremely linear due to a special dither circuit.*

The measurement is done in Zero Span mode using the Summary Marker RMS. The Summary Marker RMS integrates the power over time to achieve the best possible stability per measurement time (sweep time). Therefore the sweep time can be set low even at moderate S/N. Increasing the sweep time of the FSP achieves better stability, especially at lower S/N at low levels. A sweep time of 3 s is adequate at -115 dBm without amplification and even at –130 dBm with amplification.

To achieve sufficient frequency accuracy when measuring with 10 Hz resolution bandwidth, synchronise the device under test to the FSP by using the same reference frequency.

Note: *The VSWR of the device under test must not change for levels < -80 dBm (optimally: for levels < -40 dBm) otherwise additional level uncertainty occuring due to variation in the source VSWR in combination with the VSWR of the FSP path take place. With all R&S signal generators (SMT, SME, SMIQ), before or at -40 dBm a 40 dB attenuator is switched in directly before the output connector so that any additional switching does not noticeably influence the output VSWR.*

With R&S CMD55/57 communication testers, fixed attenuators (e.g. 20 dB) are immediately before the output connectors (RF 1 IN/OUT, RF 2 Out) so that the output VSWR remains stable as well.

When calibrating other equipment than R&S generators and Communication testers, the behaviour of the VSWR when lowering the level beyond - 80 dBm has to be tested and taken into account. The signal generator HP ESG-D Series, for example, change output VSWR at or before -60 dBm.

An uncertainty calculation (Excel sheet) for level measurement at -110 dBm at 2 GHz (without amplifier) is added in the appendix. The calculation is done according to the ETR 028 ETSI recommendation.

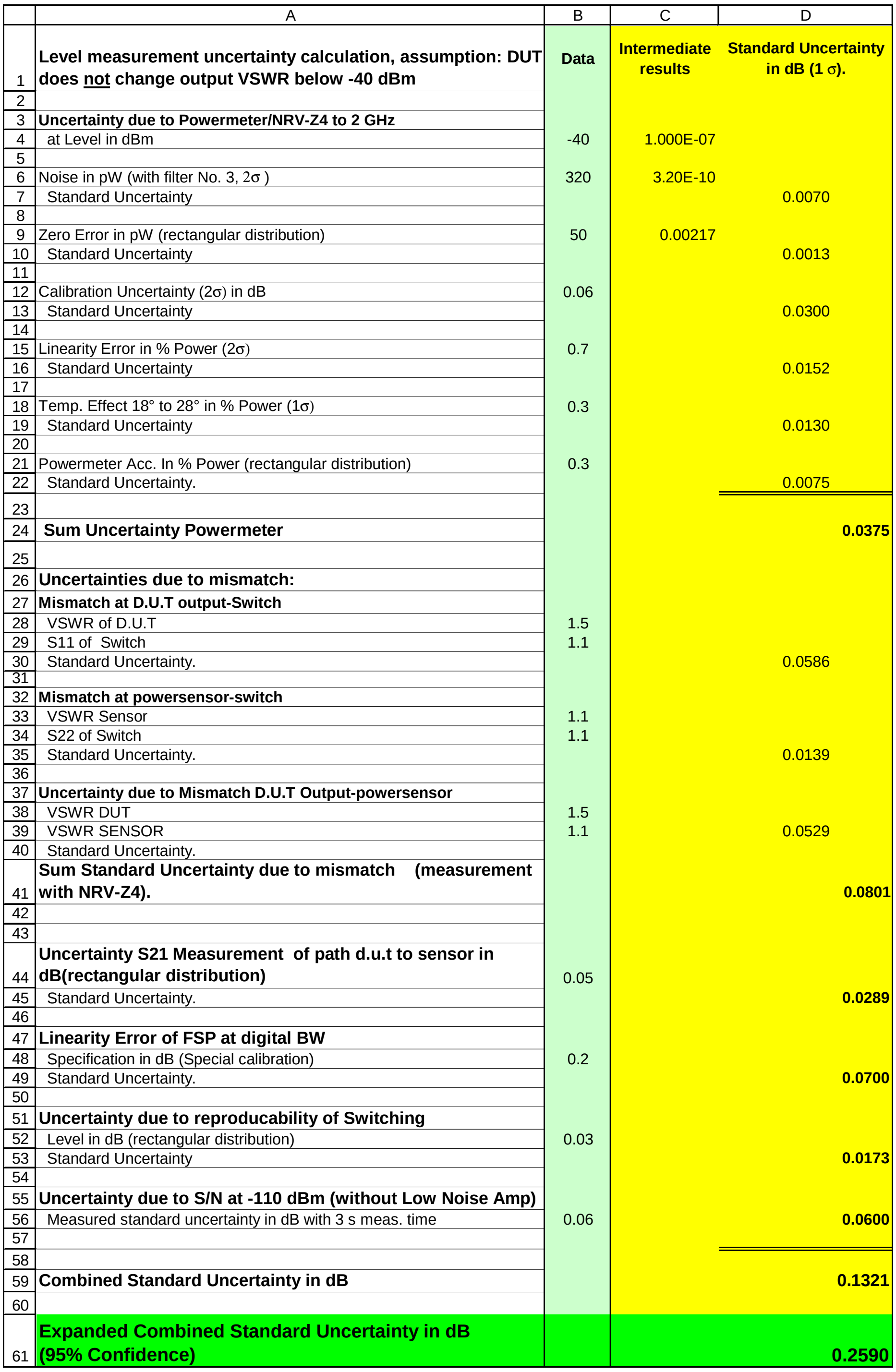
The following assumptions are made:

DUT does not change output VSWR for levels <= -40 dBm (at one frequency).
Output VSWR of DUT: 1.5, VSWR of measurement paths as in table 1 (VSWR of switch: 1.1 up to 2 GHz).

This leads to an expanded combined standard uncertainty (95 % confidence) of **0,26 dB**.

5 Appendix:

Appendix 1: Uncertainty calculation (Excel Sheet)



	A	B	C	D
1	**Level measurement uncertainty calculation, assumption: DUT does not change output VSWR below -40 dBm**	**Data**	**Intermediate results**	**Standard Uncertainty in dB (1 σ).**
2				
3	**Uncertainty due to Powermeter/NRV-Z4 to 2 GHz**			
4	at Level in dBm	-40	1.000E-07	
5				
6	Noise in pW (with filter No. 3, 2σ)	320	3.20E-10	
7	Standard Uncertainty			0.0070
8				
9	Zero Error in pW (rectangular distribution)	50	0.00217	
10	Standard Uncertainty			0.0013
11				
12	Calibration Uncertainty (2σ) in dB	0.06		
13	Standard Uncertainty			0.0300
14				
15	Linearity Error in % Power (2σ)	0.7		
16	Standard Uncertainty			0.0152
17				
18	Temp. Effect 18° to 28° in % Power (1σ)	0.3		
19	Standard Uncertainty			0.0130
20				
21	Powermeter Acc. In % Power (rectangular distribution)	0.3		
22	Standard Uncertainty.			0.0075
23				
24	**Sum Uncertainty Powermeter**			**0.0375**
25				
26	**Uncertainties due to mismatch:**			
27	**Mismatch at D.U.T output-Switch**			
28	VSWR of D.U.T	1.5		
29	S11 of Switch	1.1		
30	Standard Uncertainty.			0.0586
31				
32	**Mismatch at powersensor-switch**			
33	VSWR Sensor	1.1		
34	S22 of Switch	1.1		
35	Standard Uncertainty.			0.0139
36				
37	**Uncertainty due to Mismatch D.U.T Output-powersensor**			
38	VSWR DUT	1.5		
39	VSWR SENSOR	1.1		0.0529
40	Standard Uncertainty.			
41	**Sum Standard Uncertainty due to mismatch (measurement with NRV-Z4).**			**0.0801**
42				
43				
44	**Uncertainty S21 Measurement of path d.u.t to sensor in dB(rectangular distribution)**	0.05		
45	Standard Uncertainty.			**0.0289**
46				
47	**Linearity Error of FSP at digital BW**			
48	Specification in dB (Special calibration)	0.2		
49	Standard Uncertainty.			**0.0700**
50				
51	**Uncertainty due to reproducability of Switching**			
52	Level in dB (rectangular distribution)	0.03		
53	Standard Uncertainty			**0.0173**
54				
55	**Uncertainty due to S/N at -110 dBm (without Low Noise Amp)**			
56	Measured standard uncertainty in dB with 3 s meas. time	0.06		**0.0600**
57				
58				
59	**Combined Standard Uncertainty in dB**			**0.1321**
60				
61	**Expanded Combined Standard Uncertainty in dB (95% Confidence)**			**0.2590**

Appendix 2: Hints to additional equipment of the level test system

a) Switch:

Dependant on the power levels which need to be tested (max.test level < -15 dBm or max. test level > -15 dBm) a SPDT-switch or a multiport switch is necessary. Choose a low VSWR type like:
HP 8762 B (SPDT) or HP 87104 B (SP4T).

b) For testing power levels below –115 dBm a low noise amplifier is needed to increase the S/N of the level measurement.

The low noise amplifier has to have the following features:

- Needed frequency range (e.g. 1 MHz to 2 GHz)
- High gain (> 20 dB)
- Medium output power (power at amplifier output should be at least 20 dB below 1-dB-compression point). The Pico Amps type PA2-0350-26 is a well proven amplifier used in R&S test systems (frequency range: 300 kHz –5 GHz, N.F.= 2.5 dB, gain = 21 dB). A combination of 2 of such amplifiers and three 6-dB attenuators (in front of the first amplifier, in between and after the second amplifier) to improve amplifier VSWR and thus enhance measurement accuracy is recommended.

6 Ordering information

Spectrum-/Signal Analyzer		
FSP-3	9 kHz ..... 3 GHz	1093.4495.03
FSP-7	9 kHz .... 7 GHz	1093.4495.07
Dual Channel Power Meter		
NRVD		857.8008.02
Power Sensor		
NRV-Z4	20 mW, 6 GHz	828.3618.02
NRVD-Z51	100 mW, 18 GHz	857.9004.02