Technical Information

R&S®NRP-Z81 Wideband Power Sensor

The sensor of choice for the analysis of radar and digital communications signals

The new R&S®NRP-Z81 power sensor represents latest power measurement technology. It offers all the functionality of a conventional peak power meter, and even more, in a compact unit. It can be operated on the R&S®NRP power meter or any Windows PC, e.g. as a cost-effective solution in production systems. No compromise was made in terms of accuracy and versatility. Therefore, this new member of the R&S®NRP family is particularly suitable for nearly every task in the field of power measurement:

- Analysis of radar and communications signals up to 30 MHz RF bandwidth (sensor rise time <13 ns)
- Accurate continuous average power measurements on modulated and unmodulated signals from –60 dBm to +20 dBm
- Ultrafast statistical analysis (1 million point CCDF in 25 ms)
- Frequency range from 50 MHz to 18 GHz (from 500 MHz with full video bandwidth)

ROHDE & SCHWARZ

Preliminary

R&S®NRP-Z81 Wideband Power Sensor

Specifications

Bold: Parameter 100 % tested.

Italics: Limits of uncertainty, calculated from the test assembly specifications and the modeled behavior of the sensor.

Normal: Compliance with specifications is ensured by the design or derived from the measurement of related parameters.

Sensor type		wideband diode power sensor
Measurand		envelope power
Frequency range		50 MHz to 18 GHz
Matching (SWR) values in ( ) for temperature range 15 °C to 35 °C	50 MHz to 2.4 GHz >2.4 GHz to 8.0 GHz >8.0 GHz to 18.0 GHz	**<1.16 (1.11)** **<1.20 (1.18)** **<1.25 (1.23)** Even lower values can be achieved by Γ correction (see top of page 6)
RF connector		N (male)
Power measurement range	measurement function Continuous Average Burst Average ('Full' video bandwidth) (300 kHz) Trace, Timeslot/Gate Average Statistics	 1 nW to 100 mW (–60 dBm to +20 dBm) 20 µW[1] to 100 mW (–17 dBm[1] to +20 dBm) 4 µW to 100 mW (–24 dBm to +20 dBm) 20 nW to 100 mW (–47 dBm to +20 dBm) 3 µW[1] to 100 mW (–25 dBm[1] to +20 dBm)
Max. power	average power peak envelope power	0.2 W (+23 dBm) continuous 1.0 W (+30 dBm) for max. 1 µs
Dynamic response	video bandwidth single-shot bandwidth video bandwidth settings rise time 10 %/90 % f ≥ 500 MHz < 500 MHz minimum burst width (f ≥ 500 MHz) overshoot	≥30 MHz [18] ≥30 MHz [18] full | 5 MHz | 1.5 MHz | 0.3 MHz **≤13 ns** [18] | <75 ns | <250 ns | <1.2 µs <40 ns [18] 50 ns ≤5 %
Acquisition	sampling rate (continuous) capture length time base accuracy time base jitter	80×10^{6} s^{-1} (full video bandwidth) 40×10^{6} s^{-1} (5 MHz) 10×10^{6} s^{-1} (1.5 MHz) 2.5×10^{6} s^{-1} (0.3 MHz) 50 ns to 1 s (depending on meas. function) ±50 ppm <1 ns
Trigger	internal trigger range level accuracy jitter external trigger input trigger delay delay range delay resolution source slope (external, internal) trigger hold-off trigger dropout resolution (hold-off, dropout) trigger level threshold hysteresis	 –30 dBm to +20 dBm (usable from –22 dBm at full video bandwidth) identical to uncertainty for absolute power measurements ≤6.3 ns see specs of R&S®NRP and R&S®NRP-Z3 USB adapter –51.2 µs to +10 s 12.5 ns bus, external, hold, immediate, internal pos./neg. 0 to 10 s 0 to 10 s 12.5 ns ±10 dB
Zero offset [3,5] Typical values in ( )	measurement function Continuous Average Burst/Timeslot/Gate Average Trace, Statistics	 10 µs sampling window | other lengths <400 (220) pW | <5 (2) nW with averaging | w/o averaging <10 (2) nW | <200 (100) nW

Zero drift [3,6]	Continuous Average	10 µs sampling window <200 pW; other lengths <500 pW
	Burst/Timeslot/Gate Average Trace, Statistics	with averaging <2 nW; w/o averaging <150 nW
Noise [2,3] Typical values in ( )	measurement function	
	Continuous Average	<200 (110) pW sampling window set to 10 µs [4]
	Trace / Statistics noise per sample at video bandwidth	
	full	**< 3.0** (2.0) **µW**
	5 MHz	< 1.5 (1.0) µW
	1.5 MHz	< 0.9 (0.6) µW
	300 kHz	< 0.6 (0.4) µW
	effect of time-gating on noise of average value	multiply "noise per sample" specification for full video bandwidth by noise reduction factors from tables B and C (page 6) A minimum noise value of 5 nW or better can be achieved with adequate averaging, valid for gate lengths ≥2 µs.
	Burst/Timeslot (Gate) Average	see "effect of time-gating" above
Uncertainty for absolute power measurements [7] 0 °C to 50 °C	50 MHz to <100 MHz	*0.18 dB* (*4.0 %*)
	≥100 MHz to 700 MHz	*0.14 dB* (*3.3 %*)
	>700 MHz to 4.0 GHz	*0.13 dB* (*3.0 %*)
	>4.0 GHz to 8.0 GHz	*0.15 dB* (*3.5 %*)
	>8.0 GHz to 18.0 GHz	*0.18 dB* (*4.0 %*)

Additional characteristics of the R&S®NRP-Z81

Continuous Average function Measurement of average power of stationary signals	sampling window	1 µs to 0.1 s
	window shape	rectangular or von Hann [8]
	duty cycle correction [9]	0.001 % to 100.00 %
	capacity of measurement buffer	1 to 8192 results
Burst Average function Measurement of average burst power with automatic detection of burst	detectable burst width	50 ns to 0.1 s
	minimum gap between bursts	40 ns
	dropout length [10] for burst end detection	0 to 0.3 s
	exclusion periods [11]	
	start	0 to 0.1 s
	end	0 to 51.2 µs
	resolution (dropout, exclusion periods)	12.5 ns
Timeslot (Gate) function Measurement of average power in one gate or in several equidistant successive timeslots	number of timeslots	1 to 16
	timeslot (gate) nominal width	50 ns to 0.1 s
	delay of first timeslot (gate)	see "trigger delay"
	exclusion periods [11]	
	start	0 to 0.1 s
	fence	0 to 0.1 s
	end	0 to 51.2 µs
	resolution (width, exclusion periods)	12.5 ns
Trace function Measurement of envelope power versus time	trace length (Δ)	50 ns to 1 s
	pixels (M)	3 to 8192
	resolution (Δ/M) at video bandwidth	
	full	≥12.5 ns
	5 MHz	≥25 ns
	1.5 MHz	≥100 ns
	300 kHz	≥400 ns
	pixel representation	average, random, maximum, minimum over pixel length
	trace start (referenced to trigger)	$-4096\times\Delta/M$ to 10 s

Statistics functions Measurement of envelope power distribution	modes acquisition window length delay exclusion periods [11] start fence end resolution (length, delay, exclusion) number of classes (*C*) power span (*S*) class width (*S/C*)	CCDF and PDF histograms 10 µs to 0.3 s –51.2 µs to 10 s referenced to trigger 0 to 0.3 s 0 to 0.3 s 0 to 51.2 µs see *Δ/M* under "Trace function" 3 to 8192 0.01 dB to 100 dB ≥0.006 dB
Measurement times [12] *N*: averaging factor *T*: number of timeslots	Continuous Average buffered [13], without averaging Burst Average (burst period – burst width – burst dropout) > 6 µs all other cases Timeslot Average (frame length – *T* × nominal width) > 6 µs all other cases	*2* × *N* × (duration of sampling window + 13 µs) + t_z *2* × buffer size × (duration of sampling window + 13 µs) + t_z ≤ t_z + (*N* + 1) × burst period ≤ t_z + *N* × (burst width + burst dropout + 6 µs + burst period) ≤ t_z + (*N* + 1) × frame length ≤ t_z + *N* × (*T* × nominal width + frame length + 6 µs) t_z : typ. 1.6 ms
Zeroing (duration)	for all functions and frequencies restricted to <500 MHz, all functions restricted to ≥500 MHz, all functions restricted to Trace and Statistics, entire frequency range	8 s 4 s 4 s 20 ms
Averaging	modes AUTO OFF supported measurement functions averaging factor N Trace, Statistics other AUTO ON/ONCE supported measurement functions Normal [14] operating mode Fixed Noise operating mode result output moving rate repeat	AUTO OFF (fixed averaging factor) AUTO ON (continuously auto-adapted) AUTO ONCE (automatically fixed once) all 2 to 2^{16} 2 to 2^{20} Continuous Average, Burst Average, Time-slot (Gate) Average averaging factor adapted to resolution setting and power to be measured averaging factor adapted to specified noise content continuously, independent of averaging factor can be limited from 0.1 s^{-1} to 1000 s^{-1} only final result
Measurement error due to harmonics at $n \times f_0$ **of carrier frequency** [15]	 *N* = 2 –60 dBc –40 dBc –20 dBc *N* = 3 –60 dBc –40 dBc –20 dBc	≤4 GHz / 4 GHz to 8 GHz / >8 GHz <0.001 dB / <0.002 dB / <0.003 dB <0.010 dB / <0.017 dB / <0.025 dB <0.100 dB / <0.170 dB / <0.250 dB <0.004 dB / <0.003 dB / <0.003 dB <0.035 dB / <0.030 dB / <0.025 dB <0.350 dB / <0.300 dB / <0.250 dB
Susceptibility of matching with respect to power	 –10 dBm to –60 dBm –10 dBm to 0 dBm –10 dBm to +10 dBm –10 dBm to +20 dBm	change of RCO <0.015 (0.005) <0.035 (0.025) <0.075 (0.050) <0.090 (0.060) values in ( ) for temperature range 15 °C to 35 °C and frequencies ≤ 4 GHz

Γ correction	function parameters residual SWR	reducing the influence of mismatched sources magnitude and phase of reflection coefficient of source <1.06 in temperature range 15 °C to 35 °C
Attenuation correction	function range	correcting the measurement result by means of a fixed factor (dB offset) –100.000 dB to +100.000 dB
S-parameter correction	function parameters number of independently addressable data sets total number of frequencies (sum of all data sets)	taking into account a component connected to the sensor input by loading its s-parameter data set into the sensor s_{11}, s_{21}, s_{12}, s_{22} (in s2p format) freely definable 32000
Calibration uncertainty [16] 20 °C to 25 °C	50 MHz to <100 MHz ≥ 100 MHz to 700 MHz > 700 MHz to 2.0 GHz > 2.0 GHz to 4.0 GHz > 4.0 GHz to 8.0 GHz > 8.0 GHz to 12.5 GHz >12.5 GHz to 18.0 GHz	*0.120 dB (2.8 %)* *0.075 dB (1.8 %)* *0.065 dB (1.5 %)* *0.070 dB (1.6 %)* *0.085 dB (2.0 %)* *0.090 dB (2.1 %)* *0.120 dB (2.8 %)*

General data

Interface to host	power supply remote control trigger input	+5 V / typ. 500 mA (USB high-power device) as a USB device (function) in full-speed mode, compatible with USB 1.0/1.1/2.0 specifications differential (0 V/+3.3 V)
Dimensions	W × H × L length incl. connecting cable	48 mm × 31 mm × 170 mm approx. 1.6 m
Weight		<0.3 kg
Temperature loading		
Operating range and permissible range [17]	permissible range in [ ]	0 °C [–10 °C] to +50 °C [+55 °C] in line with IEC 60068
Storage range		–40 °C to +70 °C
Climatic resistance		in line with IEC 60068
Damp heat		+25 °C/+40 °C cyclic at 95 % relative humidity without condensation
Mechanical resistance		
Vibration, sinusoidal		in line with IEC 60068 5 Hz to 55 Hz, max. 2 g 55 Hz to 150 Hz, 0.5 g constant
Vibration, random		in line with IEC 60068 10 Hz to 500 Hz, 1.9 g (rms)
Shock		in line with IEC 60068; 40 g shock spectrum
Air pressure	operation transport	795 hPa (2000 m) to 1060 hPa 566 hPa (4500 m) to 1060 hPa
Electromagnetic compatibility		in line with EN 61326, EN 55011
Safety		in line with EN 61010-1
Calibration interval		2 years

Table A **Multipliers for noise, zero offset, and zero drift specifications**

Use these multipliers for the calculation of noise, zero offset, and zero drift when operating the sensor outside the square law region, at frequencies below 500 MHz, or at temperatures different from 23°C.

<table>
<tr><th></th><th>≤–20 dBm</th><th>–10 dBm</th><th>–5 dBm</th><th>0 dBm</th><th>5 dBm</th><th>10 dBm</th><th>15 dBm</th><th>20 dBm</th></tr>
<tr><td>0 °C</td><td>0.8 [0.9]</td><td>0.9 [1.0]</td><td>1.4 [1.5]</td><td>3.2 [3.5]</td><td>7.5 [8.5]</td><td rowspan="5">17 [18]</td><td rowspan="5">35 [37]</td><td rowspan="5">65 [70]</td></tr>
<tr><td>15 °C</td><td>0.9 [1.0]</td><td>1.1 [1.2]</td><td>1.6 [1.8]</td><td>3.4 [3.6]</td><td>7.5 [8.5]</td></tr>
<tr><td>23 °C</td><td>1.0 [1.2]</td><td>1.3 [1.5]</td><td>1.8 [2.0]</td><td>3.5 [3.8]</td><td>7.6 [8.7]</td></tr>
<tr><td>35 °C</td><td>1.4 [1.7]</td><td>1.7 [2.1]</td><td>2.3 [2.6]</td><td>3.9 [4.3]</td><td>7.8 [9.0]</td></tr>
<tr><td>50 °C</td><td>2.5 [3.0]</td><td>2.7 [3.3]</td><td>3.3 [4.0]</td><td>5.2 [5.4]</td><td>8.7 [9.5]</td></tr>
</table>

[ ] at frequencies <500 MHz

Table B **Noise reduction factors for gating and smoothing**

The noise reduction factors in this table describe how noise is reduced if adjacent samples are averaged for the measurement of mean power over a time interval. The time interval can be the length of a gate, timeslot, or pixel in trace mode. Without averaging or for single events, use the leftmost column. With averaging activated, use the columns for the individual repetition rates, and additionally apply reduction factors from table B. The repetition rate is identical to the frequency of the measurement being carried out, i.e. the inverse of the trigger period.

<table>
<tr><th>Repetition rate → / Gate (point) width</th><th>0</th><th>10 s^{-1}</th><th>100 s^{-1}</th><th>10^{3} s^{-1}</th><th>10^{4} s^{-1}</th><th>5×10^{4} s^{-1}</th><th>10^{5} s^{-1}</th></tr>
<tr><td>25 ns</td><td colspan="7">0.7</td></tr>
<tr><td>50 ns</td><td colspan="7">0.5</td></tr>
<tr><td>100 ns</td><td colspan="7">0.4</td></tr>
<tr><td>200 ns</td><td colspan="7">0.3</td></tr>
<tr><td>500 ns</td><td colspan="7">0.2</td></tr>
<tr><td>1 µs</td><td>0.16</td><td colspan="2">0.15</td><td colspan="4">0.14</td></tr>
<tr><td>2 µs</td><td>0.14</td><td>0.13</td><td>0.12</td><td>0.11</td><td colspan="3">0.10</td></tr>
<tr><td>10 µs</td><td>0.11</td><td>0.1</td><td>0.09</td><td>0.08</td><td>0.07</td><td>0.06</td><td></td></tr>
<tr><td>100 µs</td><td>0.10</td><td>0.09</td><td>0.07</td><td>0.06</td><td>0.04</td><td></td><td></td></tr>
<tr><td>1 ms</td><td>0.10</td><td>0.07</td><td>0.06</td><td>0.035</td><td></td><td></td><td></td></tr>
<tr><td>10 ms</td><td>0.10</td><td>0.06</td><td>0.035</td><td></td><td></td><td></td><td></td></tr>
</table>

Table C **Noise reduction factors for averaging** (see footnote [4] for *Continuous Average* function)

Averaging no.	2	4	8	16	32	64	128	256	512	1 k	2 k	4 k	8 k
Reduction factor	**0.7**	**0.5**	**0.35**	**0.25**	**0.18**	**0.13**	**0.09**	**0.063**	**0.044**	**0.031**	**0.022**	**0.016**	**0.011**

Example: A power measurement on a radar pulse is carried out by means of the Timeslot (Gate) function. Nominal width is set to 1 µs, and the averaging factor to 32. The pulse repetition rate is 100 Hz, and the measurement is performed at 15°C ambient temperature. The measured value is about –10 dBm.

Sample noise (2σ) under reference conditions is max. 3 µW. Applying the multiplier of 1.1 specified in table A results in 3.3 µW sample noise under measurement conditions. Gating results in a noise reduction factor of 0.15 (table B), and averaging in a reduction factor of 0.18 (table C). Residual noise can then be calculated as follows: 3.3 µW × 0.15 × 0.18 = 89 nW (approximately 0.1% of measured value).

1 With full video bandwidth. Reduce specified minimum levels in accordance with the reduction of sampling noise at lower bandwidths.

2 Measured over a one-minute interval, at constant temperature, two standard deviations.

3 Specifications are valid at 23 °C ambient temperature for power levels <–20 dBm and frequencies ≥500 MHz. For measurements at other temperatures, frequencies and/or levels, use the multipliers from table A.

4 512 k averages taken with the sampling window set to 10 µs (default). Noise with other averaging numbers can be calculated using the multipliers indicated below:

Averaging number	512 k	128 k	32 k	8 k	2 k	512	128	32	8
Integration time	10.5 s	3.9 s	1.0 s	0.25 s	60 ms	15 ms	3.8 ms	1.0 ms	0.24 ms
Noise multiplier	**1**	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**

A sampling window length of 10 µs is optimal with respect to noise for a specific total integration time. Increasing the length above 10 µs, e.g. for effectively suppressing modulation-induced fluctuations of the measurement result, only lowers the noise contribution of the sampling window itself, i.e. 50 % maximum for lengths >100 µs. Since the number of sampling windows is inversely proportional to their length for a specific integration time, total noise increases with lengths other than 10 µs.

5 Specification in terms of an expanded uncertainty with a confidence level of 95 % (two standard deviations). For calculating zero offsets at higher confidence levels, use the properties of the normal distribution (e.g. 99.7 % confidence level for three standard deviations).

6 Within 1 hour after zeroing, permissible temperature change ±1 °C, following a 2-hour warm-up of power sensor.

7 Expanded uncertainty (k=2) for absolute power measurements on CW signals.

8 Preferably used with determined modulation when the duration of the measurement window cannot be matched to the modulation period. Compared to a rectangular window, noise is about 22 % higher.

9 For calculating the pulse power of periodic bursts from an average power measurement.

10 This parameter enables power measurements on modulated bursts. The parameter must be longer in duration than modulation-induced power drops within the burst.

11 To exclude unwanted portions at the beginning, at the end or in the measurement window from the measurement result.

12 Valid for Repeat mode, extending from the beginning to the end of all transfers via the USB interface of the power sensor. Measurement times in the case of remote control of the R&S®NRP base unit via the IEC625/IEEE488 bus are approximately 2.5 ms longer, extending from the start of the measurement to the moment when the measurement result is supplied to the output buffer of the R&S®NRP.

13 To increase measurement speed, the power sensor can be operated in buffered mode. In this mode, measurement results are stored in a buffer of user-definable size and then output as a block of data when the buffer is full. To enhance measurement speed even further, the sensor can be set to record the entire series of measurements when triggered by a single event. In this case, the power sensor automatically starts a new measurement as soon as it completes the preceding one.

14 Characteristics like a conventional power meter. The averaging factor increases continuously as power decreases, but not to the extent that would be necessary to keep the relative noise content at the same level.

15 Magnitude of measurement error referenced to an ideal thermal power sensor that measures the sum power of carrier and harmonics. For power levels below –10 dBm, the specifications for $2\times f_0$ ($3\times f_0$) can be lowered by a factor of √10 (10) per 10 dB below –10 dBm. Example: At 12 GHz / –30 dBm, the influence of the second harmonic, suppressed by 30 dBc, will cause an error of max. 0.025 dB × √10 ÷ 10 = 0.008 dB. Standard uncertainties can be assumed to be half the values.

16 Expanded uncertainty (k=2) for absolute power measurements on CW signals at a calibration level of –10 dBm and at calibration frequencies (50/55/60/68/80/100/200/300/400/499.99/500/600/720/850 MHz; from 1 GHz to 18 GHz in steps of 0.5 GHz).

17 The operating temperature range defines the span of ambient temperature in which the instrument complies with specifications. In the permissible temperature range, the instrument functions but adherence to specifications is not warranted.

18 Specifications are valid from 15°C to 50°C ambient temperature. Below 15°C, video bandwidth and single shot bandwidth continuously decrease down to 20 MHz typically at 0°C. Accordingly, sensor rise time increases up to 50 ns for signals below 500 MHz and up to 20 ns for all other frequencies (at 0°C).

Accessories

See the R&S®NRP data sheet (PD 0757.7023.21)

Ordering information

Designation	Type	Order No.
Wideband Power Sensor 1 nW to 100 mW; 50 MHz to 18 GHz	R&S®NRP-Z81	1137.9009.02

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