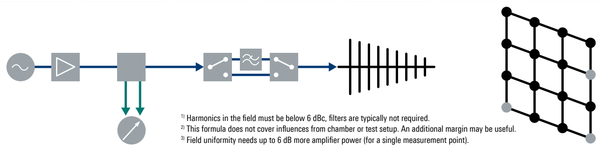
RF FUNDAMENTALS IN COMMERCIAL EMS TESTING

How to select the correct RF amplifier

Example estimation of the required power for a requested field strength of 10 V/m in the desired frequency range

0 dBm	43 dBm	=	–0.3 dB	–1.5 dB [1]	+9 dB	$E = \sqrt{\frac{30 \times P}{d}}$ [2]	–6 dB [3]
Signal generators	P–1dB – power		Directional coupler	Cables, connector, filter, switches	Antenna gain	3 m test distance	Field uniformity

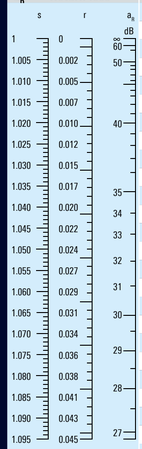


[1] Harmonics in the field must be below 6 dBc, filters are typically not required.
[2] This formula does not cover influences from chamber or test setup. An additional margin may be useful.
[3] Field uniformity needs up to 6 dB more amplifier power (for a single measurement point).

- The test distance between antenna and uniform field area has to include the distance to the antenna phase center.
- According to IEC/EN 61000-4-3 the amplifier must be operated below its 2 dB compression point. Due to amplifier variation the 1 dB compression point should be selected for the estimation.

Formulas

s VSWR
r Reflection coefficient
a_R Return loss



s (VSWR) $\frac{V_{max}}{V_{min}}$	r $\frac{V\leftarrow}{V\rightarrow}$	P_{refl} in %	a_R in dB $20 \lg \left(\frac{V\leftarrow}{V\rightarrow}\right)$
1.01	0.005		46.1
1.02	0.010	0.01	40.1
1.03	0.015	0.02	36.6
1.04	0.020	0.04	34.2
1.05	0.024	0.06	32.3
1.06	0.029	0.08	30.7
1.07	0.034	0.11	29.4
1.08	0.038	0.15	28.3
1.09	0.043	0.19	27.3
1.10	0.048	0.23	26.4
1.11	0.052	0.27	25.6
1.12	0.057	0.32	24.9
1.13	0.061	0.37	24.3
1.14	0.065	0.43	23.7
1.15	0.070	0.49	23.1
1.16	0.074	0.55	22.6
1.17	0.078	0.61	22.1
1.18	0.083	0.68	21.7
1.19	0.087	0.75	21.2
1.20	0.091	0.83	20.8
1.30	0.130	1.70	17.7
1.40	0.167	2.78	15.6
1.50	0.200	4.00	14.0
1.60	0.231	5.33	12.7
1.70	0.259	6.72	11.7
1.80	0.286	8.16	10.9
1.90	0.310	9.63	10.2
2.00	0.333	11.10	9.5
2.20	0.375	14.1	8.5
2.40	0.412	17.0	7.7
2.60	0.444	19.8	7.0
2.80	0.474	22.4	6.5
3.00	0.500	25.0	6.0
3.50	0.556	30.9	5.1
4.00	0.600	36.0	4.4
5.00	0.667	44.4	3.5
6.00	0.714	51.0	2.9
7.00	0.750	56.2	2.5
8.00	0.778	60.5	2.2
10.0	0.818	66.9	1.7
20.0	0.905	81.9	0.9
50.0	0.961	92.3	0.3

dB to ratio conversion

dB	Amplitude ratio	Power ratio
–100 dB	10^{-5}	10^{-10}
–50 dB	0.00316	0.00001
–40 dB	0.010	0.0001
–30 dB	0.032	0.001
–20 dB	0.100	0.010
–10 dB	0.316	0.100
–6 dB	0.501	0.251
–3 dB	0.708	0.501
–2 dB	0.794	0.631
–1 dB	0.891	0.794
0 dB	1.000	1.000
1 dB	1.122	1.259
2 dB	1.259	1.585
3 dB	1.413	2 ≈ 1.995
6 dB	2 ≈ 1.995	3.981
10 dB	3.162	10.000
20 dB	10.000	100.000
30 dB	31.623	1000.000
40 dB	100.000	10000.000
50 dB	316.228	100000.000
100 dB	10^5	10^{10}

$$s = \frac{1 + |r|}{1 - |r|} \qquad r = \left(\frac{s-1}{s+1}\right) \qquad a_R = 20 \lg \left(\frac{s+1}{s-1}\right)$$

$$s = \frac{10^{0.05 a_R} + 1}{10^{0.05 a_R} - 1} \qquad r = \frac{1}{10^{0.05 a_R}} \qquad a_R = 20 \lg \left(\frac{1}{|r|}\right)$$

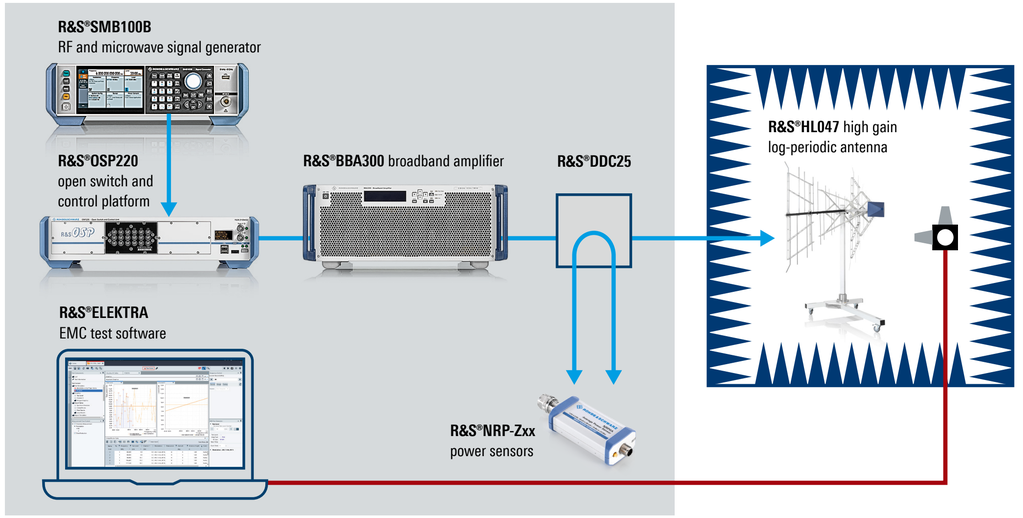
$$Ratio_{dB} = 10 \lg \left(\frac{P_1}{P_0}\right) \qquad \frac{P_1}{P_0} = 10^{\frac{Ratio_{dB}}{10}}$$

$$Ratio_{dB} = 20 \lg \left(\frac{V_1}{V_0}\right) \qquad \frac{V_1}{V_0} = 10^{\frac{Ratio_{dB}}{20}}$$

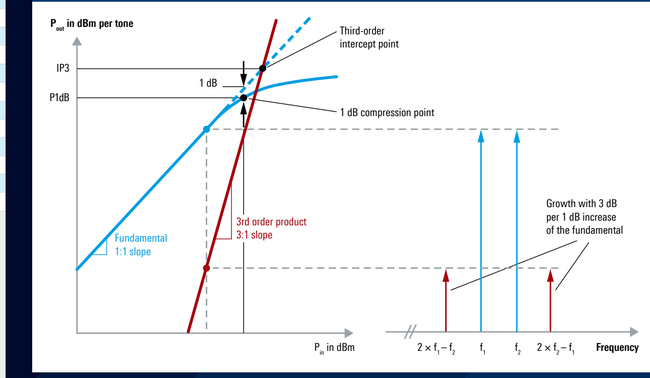
Wavelength to frequency conversion

$$\frac{\lambda}{m} \approx \frac{300\ m/s}{\left(\frac{f}{MHz}\right)}$$

EMS radiated test setup



Amplifier compression (P1dB) and two-tone intermodulation characteristics (IM3)



Antennas for EMS applications

Antenna type	Frequency range	Gain	Permissible input power	Half-power beamwidth (E plane)
R&S®HL562E ULTRALOG	30 MHz to 6 GHz	8.5 dBi (typ.) above 200 MHz	225 W CW at 30 MHz 900 W CW at 80 MHz 150 W CW at 6 GHz	80° to 30°
R&S®HL223 log-periodic antenna	200 MHz to 1.3 GHz	≥ 6 dBi	1500 W CW at 200 MHz 600 W CW at 1.3 GHz	approx. 60°
R&S®HL047 high gain log-periodic antenna	80 MHz to 3 GHz	9 dBi (typ.)	1400 W CW at 80 MHz 500 W CW at 1 GHz 300 W CW at 3 GHz 200 W CW at 6 GHz	65° to 45°
R&S®HK116E biconical antenna	20 MHz to 300 MHz	2 dBi (typ.) (100 MHz to 250 MHz)	75 W CW	110° to 55°
R&S®HF907 double-ridged horn antenna	800 MHz to 18 GHz	5 dBi to 14 dBi (typ.)	300 W CW at 0.8 GHz to 4.5 GHz 200 W CW at 10 GHz 150 W CW at 18 GHz	90° to 35° (typ.)

Power sensors and accessories

Thermal power sensors

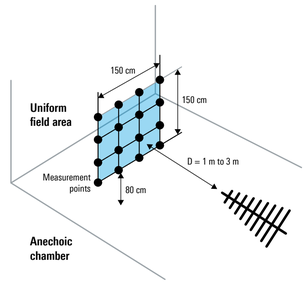
- Outstanding linearity and maximum accuracy
- Outstanding performance for reference applications
- Excellent impedance matching
- Sophisticated connector concept
- Internal calibration test
- Frequency range from DC to 110 GHz
- Level range from –35 dBm to +20 dBm
- Excellent impedance matching
- Innovative connector design for improved ease of use
- Outstanding performance for reference applications and calibration labs

Average power sensors

- Specially designed for EMC applications
- 90 dB dynamic range thanks to innovative three-path concept
- Power measurements independent of the modulation type
- Frequency range from 9 kHz to 6 GHz
- Level range from –67 dBm to +33 dBm
- Support of low frequencies down to 9 kHz

The uniform field area (UFA)

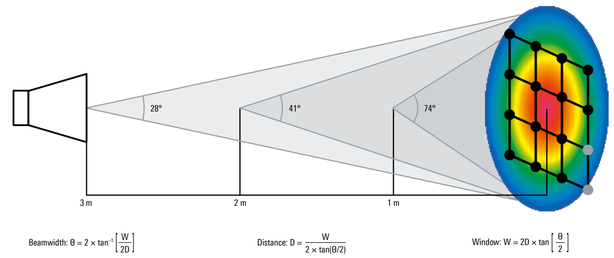
IEC/EN 61000-4-3 field calibration



Uniform field area (UFA) criteria

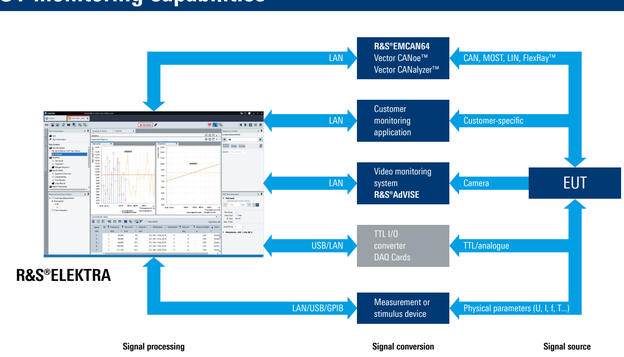
- Size: 1.5 m × 1.5 m
- –0 dB/+6 dB variation over UFA plane
- More than 75 % of points have to be within tolerance
- Larger sizes and partial illumination allowed for larger EUT
- Smaller sizes allowed for smaller EUT (including cabling)
- Located 0.8 m above floor
- Distance from antenna tip: minimum 1 m, preferred 3 m

Uniform field area criteria versus beamwidths and distance



Beamwidth: $\theta = 2 \times \tan^{-1}\left[\frac{W}{2D}\right]$ Distance: $D = \frac{W}{2 \times \tan(\theta/2)}$ Window: $W = 2D \times \tan\left[\frac{\theta}{2}\right]$

EUT monitoring capabilities



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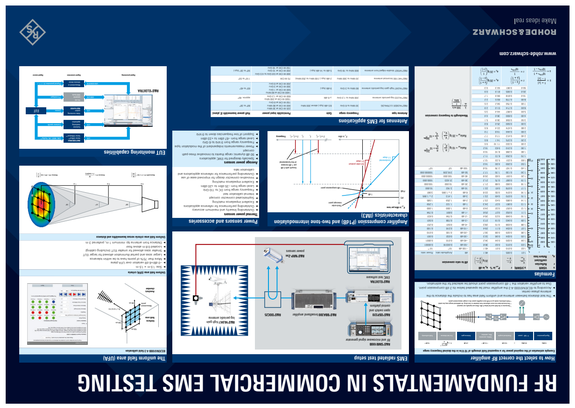

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