Standards

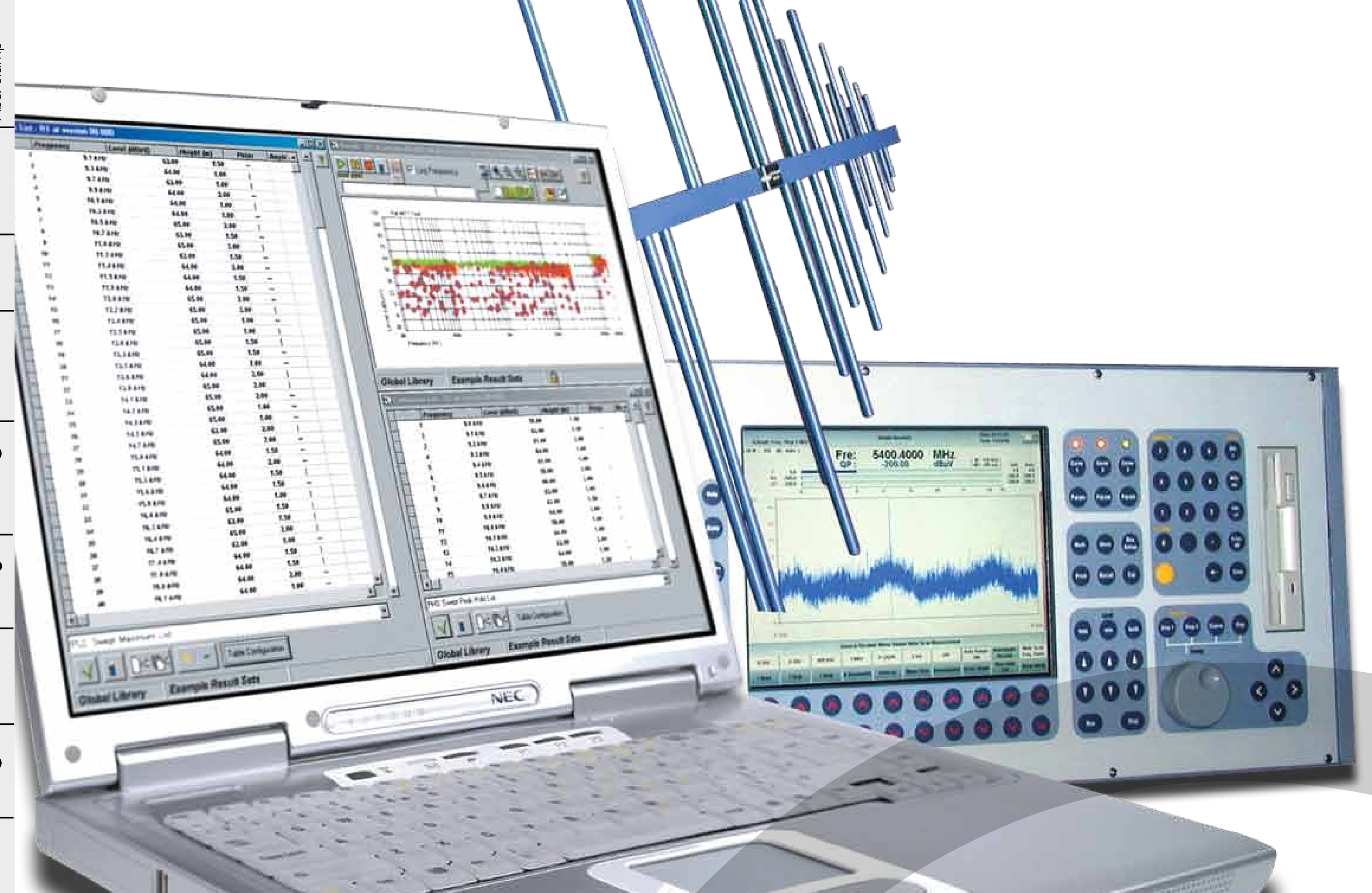
Scope and required tests and equipment for the common commercial standards

● All EUTs ■ All mains powered EUTs
○ Some EUTs ◆ All EUTs with Telecom Ports

Standard	Scope	Required tests for EN emissions	LISN	ISNs	Current probe	H-field loop	BiLog	Abs. clamp
EN 61000-6-3:2001 + 11:2004 (Equivalent to IEC 61000-6-3: 1996)	Electrical and electronic apparatus intended for use in residential, commercial and light-industrial environments for which no dedicated product or product-family standard exists	Refers to EN 55022 and EN 55014-1 for tests. Radiated emissions on the enclosure; conducted RF including emissions on the AC mains port; conducted RF emissions on a current power port, DC power ports and other ports	■				●	
EN 61000-6-4:2001 (Equivalent to IEC 61000-6-4: 1997)	As above for industrial environments	Refers to EN 55011 for enclosure radiated and AC mains conducted tests; discontinuous conducted emissions on the AC mains port occurring more than 5 times a minute are subject to modified limits	■				●	
EN 55011: 1998 + A1: 1999 + A2: 2002 (Equivalent to CISPR 11: 1997 with modifications)	Equipment designed to generate RF energy for industrial, scientific and medical (ISM) purposes, including spark erosion	Mains terminal voltage 150 kHz – 30 MHz using CISPR-16 LISN; radiated field 30 – 1000 MHz on test site or in situ (Class A only). Group 2 Class A limits apply down to 150 kHz; A1: 1999 introduces emissions limits between 1 and 18 GHz from Group 2 Class B > 400 MHz	■			○	●	
EN 55013: 2001 + A1: 2003 (Equivalent to CISPR 13: 2001 with modifications)	Broadcast sound and television receivers and associated equipment intended to be connected directly to these or to generate or reproduce audio or video information	Mains terminal voltage 150 kHz – 30 MHz using CISPR-16 LISN; antenna terminal voltage 30 – 1000 MHz and Class B limits for others, disturbance power for associated equipment 30 – 300 MHz on leads > 25 cm; A1: 2003 adds methods for digital receivers	■				○	○
EN 55014-1: 2000 + A1: 2001 + A2: 2002 (Equivalent to CISPR 14-1: 2000)	Appliances whose main functions are performed by motors and switching or regulating devices, e.g. household appliances, electric tools etc.	Mains terminal voltage 150 kHz – 30 MHz using CISPR-16 LISN; discontinuous interference over this frequency range where appropriate; disturbance power 30 – 300 MHz on all leads; A1: 2001 adds an extra EN 55022 radiated test only for toys	■				○	●
EN 55015: 2000 + A1: 2001 + A2: 2002 (Equivalent to CISPR 15: 2000)	All lighting equipment and auxiliaries with a primary function of generating and/or distributing light for illumination, and lighting part of multi-function equipment	Fluorescent lamp luminaire insertion loss 150 – 1605 kHz; all other lighting equipment, mains terminal voltage 9 kHz – 30 MHz using CISPR-16 LISN; HF lamps, radiated magnetic field 9 kHz – 30 MHz using Van Veen loop, relaxed levels between 2.2 and 3 MHz	■			○		
EN 55022: 1998 + A1: 2000 + A2: 2003 (Equivalent to CISPR 22: 1997)	Information Technology Equipment (ITE), whose primary function is data entry, storage, display, retrieval, transmission, processing, switching or control	Mains terminal voltage 150 kHz – 30 MHz using CISPR-16 LISN; radiated field 30 – 1000 MHz on test site; conducted current or voltage from 150 kHz to 30 MHz at telecommunication ports; further tests are being introduced in a later edition from 1 to 6 GHz	■	◆	○		●	○
EN 61326: 1997 + A1: 1998, A2: 2001 + A3: 2003 (Equivalent to IEC 61326: 1997)	Electrical equipment intended for professional, industrial process and educational use, for measurement and test, control or laboratory	Mains port CISPR 22 150 kHz – 30 MHz; radiated RF 30 – 1000 MHz. The reference standard for the test methods quoted is CISPR 16-1 and CISPR 16-2	■				●	

Note: Most product standards reference one or other of the above to define the measurement methods for emissions. Those which define their own emissions test methods are

EN 50091- 2: 1995: Uninterruptible power systems **EN 60945: 2002:** Marine navigation and radio-communication equipment and systems



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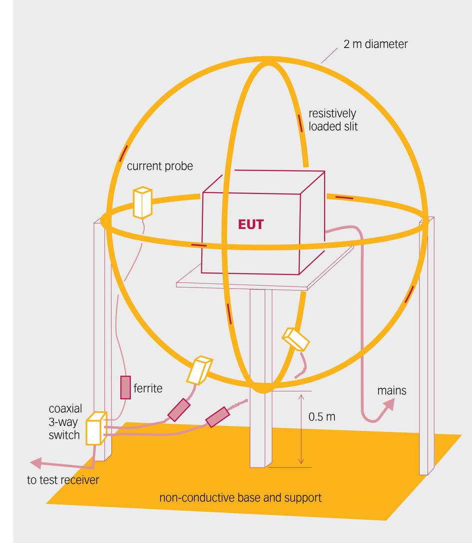
Magnetic field test

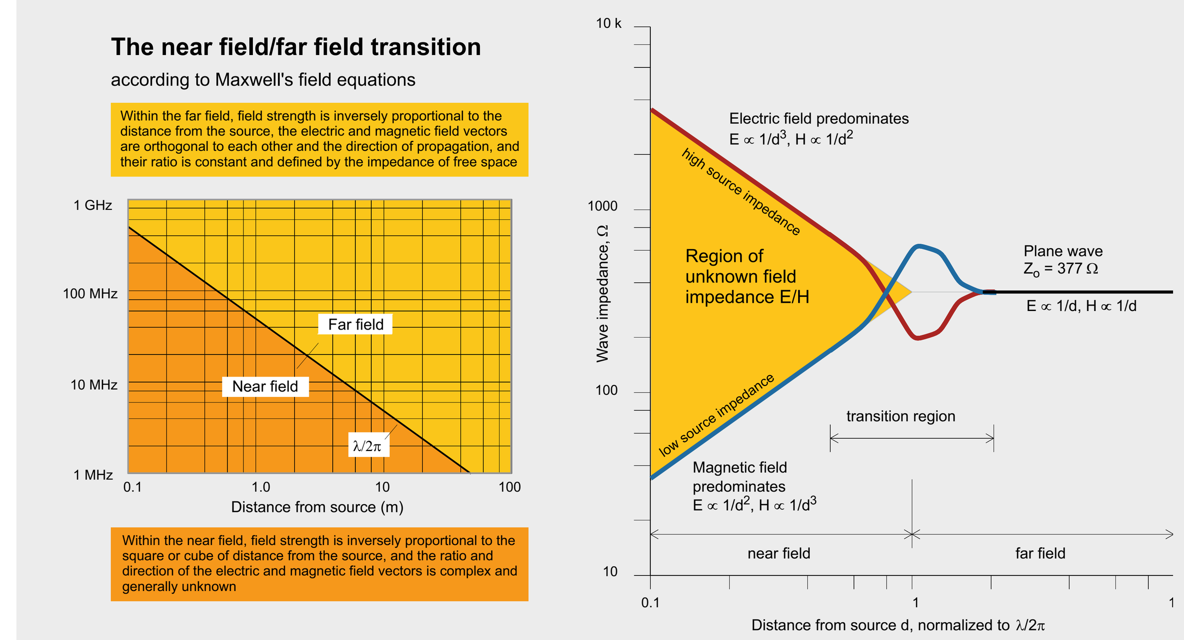


Large loop antenna (LLA or Van Veen loop) for magnetic field measurements 9 kHz - 30 MHz from CISPR 15 annex B

Electromagnetic field

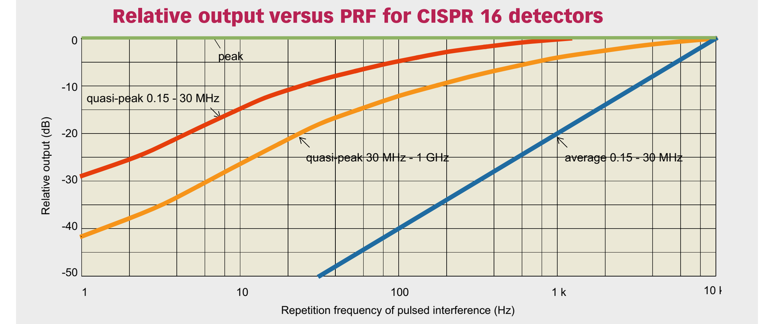
The near field/far field transition

according to Maxwell's field equations

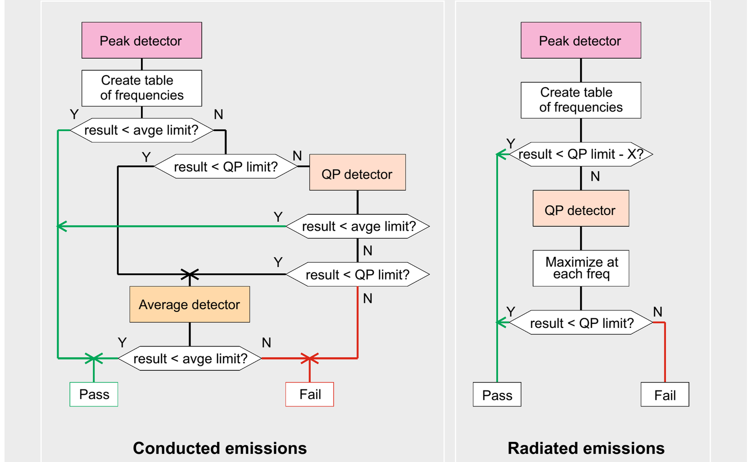


CISPR 16-1 Instrumentation

Relative output versus PRF for CISPR 16 detectors



The peak detector will always give the highest reading on all types of disturbance. The QP detector will give a lower reading for low pulse rate impulsive signals, while the average detector will give a lower reading still. Continuous signals will show the same value with all types of detector.



X is a margin to allow for expected difference due to maximization procedure; a fully compliant measurement requires that all radiated emissions are maximized

Flowchart for use of detectors

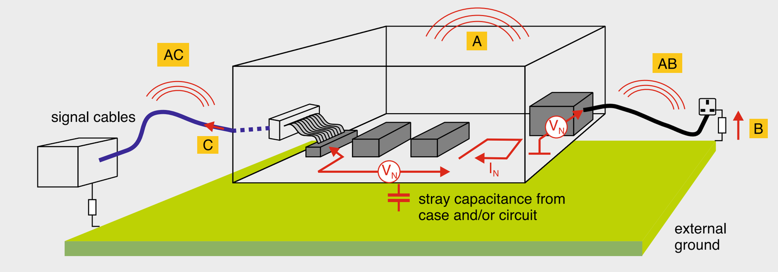
CISPR 16-1 Instrumentation characteristics

Parameter	Frequency range		
	9 to 150 kHz	0.15 to 30 MHz	30 to 1000 MHz
Quasi - Peak			
Bandwidth	200 Hz	9 kHz	120 kHz
Charge time	45 ms	1 ms	1 ms
Discharge time	500 ms	160 ms	550 ms
Overload factor	24 dB	30 dB	43.5 dB
Sweep duration[1]	64 mins	89 mins	74 mins
Peak			
Bandwidth	200 Hz	9 kHz	300 kHz
τ_D/τ_C	$1.89 \cdot 10^4$	$1.25 \cdot 10^6$	$1.67 \cdot 10^7$

[1] For dwell time of 5 time constants, half-bandwidth frequency spacing

IEC/CISPR 16-1-1, "Specification for radio disturbance and immunity measuring apparatus and methods – measuring apparatus", specifies the characteristics and performance of equipment for measuring EMI in the frequency range 9 kHz to 1 GHz. All commercial standards refer to CISPR 16 measuring receivers.

How does a product emit RF?



- Internal circuit operation creates noise voltages V_N and currents I_N within the circuit and chassis structure: sources include SMPS, HF clocks and digital operation, video signals, electro-mechanical switching
- V_N and I_N create radiated E and H fields which travel away from their source (A)
- Noise voltages also appear on mains and signal cable ports and cause common-mode currents (on all wires together) which radiate directly from the cables (AB), (AC)
- At lower frequencies these currents radiate more effectively from long cables, and so measurement of voltage (B) or current (C) on the cable is easier
- All conducting parts (PCB, wires and chassis) of the product contribute to the process, and common mode paths are usually the most important
- Good shielding, filtering, layout and grounding help, but can never be perfect, so testing is always needed

Measurement uncertainty CISPR 16-4-2

CISPR 16-4-2: 2003, Uncertainty in EMC measurements, specifies how to calculate the uncertainty budget for an emissions test and how to use it. If the laboratory's calculated uncertainty U_{lab} is less than or equal to U_{CISPR} as given below, then:

- The product complies if no measurement exceeds the limit;
- The product does not comply if any measurement exceeds the limit.

If U_{lab} is greater than U_{CISPR}, then the measurements are increased by a factor ($U_{lab} - U_{CISPR}$) and compared to the limit as before.

The table to the right gives U_{CISPR} and that below indicates how this was derived as an example for radiated test with a vertically polarised log periodic antenna at 3 m. See CISPR 16-4-1 and 16-4-2 for more detail and UKAS publication LAB 34 for more guidance on EMC measurement uncertainty.

Measurement		U_{CISPR}
Conducted disturbance (mains port)	9 - 150 kHz	4.0 dB
	0.15 - 30 MHz	3.6 dB
Disturbance power	30 - 300 MHz	4.5 dB
Radiated disturbance	30 - 1000 MHz	5.2 dB

Measurement uncertainty budget for radiated measurement

Example: 200 MHz to 1 GHz, log periodic antenna, vertical polarisation, distance = 3 m

Contribution	Value (±dB)	Prob. dist.	Divisor	u(y)	u(y)²
Receiver contributions					
Receiver sinewave accuracy	1.00	Normal	2.000	0.500	0.250
Receiver pulse amplitude	1.50	Rectangular	1.732	0.866	0.750
Receiver pulse repetition rate	1.50	Rectangular	1.732	0.866	0.750
Receiver indication	0.10	Normal (1)	1.000	0.100	0.010
Noise floor proximity	0.50	Normal	2.000	0.250	0.063
Antenna contributions					
Antenna factor calibration	2.00	Normal	2.000	1.000	1.000
AF frequency interpolation	0.30	Rectangular	1.732	0.173	0.030
Antenna directivity	0.50	Rectangular	1.732	0.289	0.083
Antenna phase centre variation	1.00	Rectangular	1.732	0.577	0.333
AF height deviation	0.10	Rectangular	1.732	0.058	0.003
Cross-polarisation	0.90	Rectangular	1.732	0.520	0.270
Balance	0.00	Rectangular	1.732	0.000	0.000
Other contributions					
Cable loss calibration	0.10	Normal	2.000	0.050	0.003
Site imperfections	4.00	Triangular	2.449	1.633	2.668
Measurement distance variation	0.30	Rectangular	1.732	0.173	0.030
Table height variation	0.10	Normal	2.000	0.050	0.003
Mismatch	-1.001	U-shaped	1.414	-0.708	0.501
Receiver VRC	0.33				
Antenna VRC	0.33				
Combined standard uncertainty		Normal		2.597	6.747
Expanded uncertainty		Normal, k = 2.0		5.19	

To be entered
Calculated

The deciBel

dB	Voltage or current ratio	Power ratio
-20	0.1	0.01
-10	0.3162	0.1
-6	0.501	0.251
-3	0.708	0.501
0	1.000	1.000
0.5	1.059	1.122
1	1.122	1.259
2	1.259	1.585
3	1.413	1.995
4	1.585	2.512
5	1.778	3.162
6	1.995	3.981
7	2.239	5.012
8	2.512	6.310
9	2.818	7.943
10	3.162	10.000
12	3.981	15.849
14	5.012	25.120
16	6.310	39.811
18	7.943	63.096
20	10.000	100.00
25	17.783	316.2
30	31.62	1000
35	56.23	3162
40	100	10,000
45	177.8	31,623
50	316.2	10^5
55	562.3	$3.162 \cdot 10^5$
60	1000	10^6
65	1778	$3.162 \cdot 10^6$
70	3162	10^7
75	5623	$3.162 \cdot 10^7$
80	10,000	10^8
85	17,783	$3.162 \cdot 10^8$
90	31,623	10^9
95	56,234	$3.162 \cdot 10^9$
100	10^5	10^{10}
110	$3.162 \cdot 10^5$	10^{11}
120	10^6	10^{12}

The deciBel (dB) represents a logarithmic ratio (base ten) between two quantities and is unitless. If the ratio is referred to a specific quantity this is indicated by a suffix, e.g. dBµV is referred to 1 µV, dBm is referred to 1 mW.

Originally the dB was conceived as a **power** ratio, given by

$$dB = 10 \log (P_1/P_2)$$

Power is proportional to voltage squared, hence the ratio of voltages or currents across a constant impedance is given by

$$dB = 20 \log (V_1/V_2) \quad \text{or} \quad 20 \log (I_1/I_2)$$

Conversion between voltage in dBµV and power in dBm for a given impedance Z ohms is

$$V(dB\mu V) = 90 + 10 \log (Z) + P(dBm)$$

Actual voltage, current or power can be derived from the antilog of the dB value:

$$V = \log^{-1}(dBV/20) \text{ volts}$$
$$I = \log^{-1}(dBA/20) \text{ amps}$$
$$P = \log^{-1}(dBW/10) \text{ watts}$$

Expressing values in dB means that multiplicative operations (such as attenuation and gain) are transformed into simple additions. For example, a signal of 42 µV (32.5 dBµV) fed via a transducer with conversion factor 0.67 (-3.5 dB) and a cable with attenuation loss 0.75 (-2.5 dB) into an amplifier of gain 200 (46 dB) will result in an output of:

$$V_{out} = 32.5 - 3.5 - 2.5 + 46.0 = 72.5 \text{ dB}\mu V = 12.5 \text{ dBmV} = 4.2 \text{ mV}$$

A simple rule of thumb:
When working with power, 3 dB is twice, 10 dB is ten times;
When working with voltage or current, 6 dB is twice, 20 dB is ten times.

dBµV vs dBm

dBµV	Power in dBm for impedance Z Ω: 50	75	150	600
-20	-127	-129	-132	-138
-10	-117	-119	-122	-128
0	-107	-109	-112	-118
10	-97	-99	-102	-108
20	-87	-89	-92	-98
30	-77	-79	-82	-88
40	-67	-69	-72	-78
50	-57	-59	-62	-68
60	-47	-49	-52	-58
70	-37	-39	-42	-48
80	-27	-29	-32	-38
90	-17	-19	-22	-28
100	-7	-9	-12	-18
110	3	1	-2	-8
120	13	11	8	2
Power in dBW				
0	-17	-19	-22	-28
10	-7	-9	-12	-18
20	3	1	-2	-8
30	13	11	8	2

Common suffixes

suffix	refers to
dBV	1 volt
dBmV	1 millivolt
dBµV	1 microvolt
dBV/m	1 volt per metre
dBµV/m	1 microvolt per metre
dBµA	1 microampere
dBW	1 watt
dBm	1 milliwatt
dBµW	1 microwatt

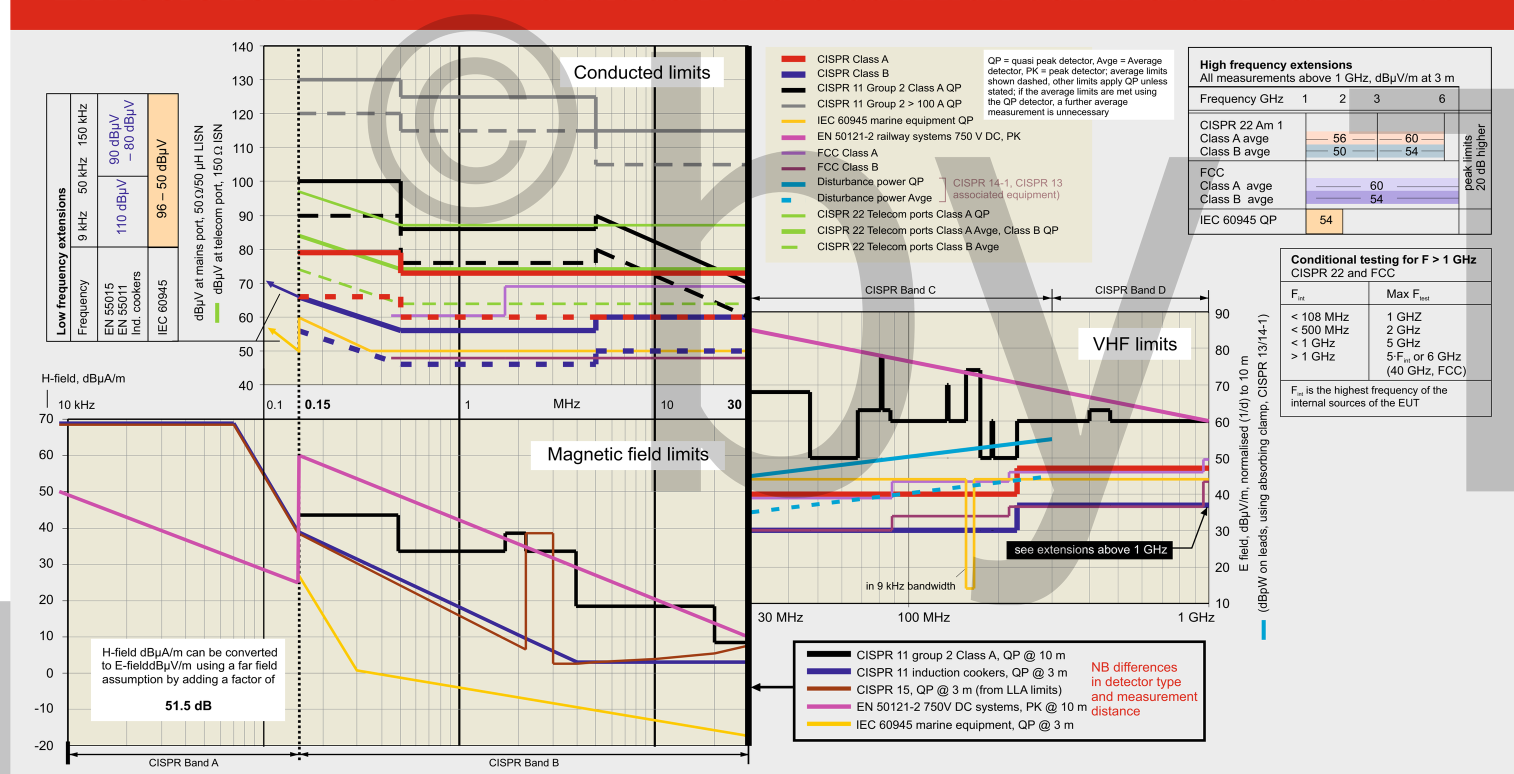
Field strength conversion table

In the far field, with $Z_0 = 377\ \Omega$

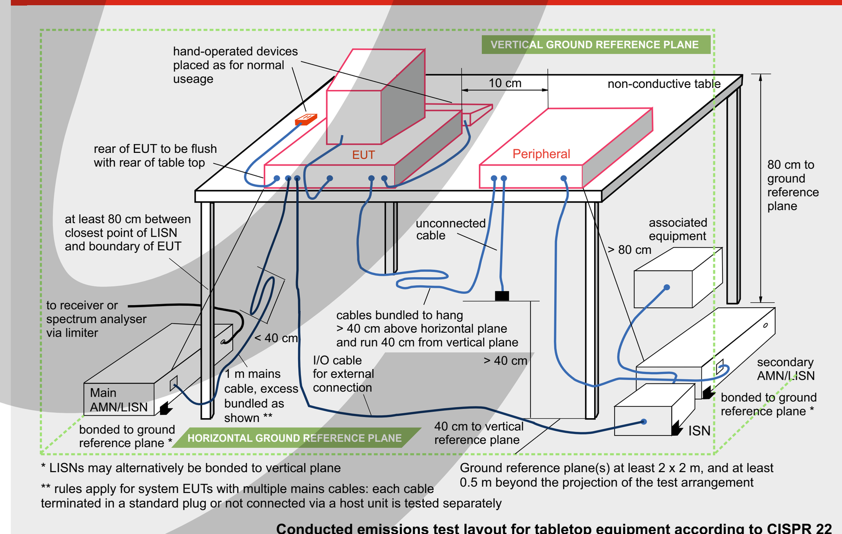
Electric field strength: dBµV/m	µV/m	Magnetic field strength: dBµA/m	µA/m	picogauss	picoTesla
0	1.0	-51.5	0.00265	33.1	0.0033
5	1.78	-46.5	0.0047	58.8	0.0059
10	3.162	-41.5	0.0084	105.0	0.0105
15	5.623	-36.5	0.0149	186.2	0.0186
20	10.000	-31.5	0.0265	331.5	0.0331
				nanogauss	
25	17.8	-26.5	0.0472	0.590	0.0590
30	31.62	-21.5	0.0839	1.048	0.1048
35	56.23	-16.5	0.1492	1.865	0.1865
37	70.79	-14.5	0.1878	2.347	0.2347
40	100.00	-11.5	0.2652	3.315	0.3315
	mV/m				
50	0.316	-1.5	0.839	10.48	1.048
60	1.000	8.5	2.652	33.15	3.315
70	3.162	18.5	8.388	104.8	10.485
80	10.000	28.5	26.525	331.5	33.156
			mA/m	µgauss	nanoTesla
90	31.6	38.5	0.0839	1.048	0.1048
100	100.0	48.5	0.2652	3.315	0.3315
110	316.2	58.5	0.8388	10.48	1.048
120	1000.0	68.5	2.652	33.15	3.315

1 Gauss = 100 micro Tesla = 80 Amps/metre

Emissions limits: Limit values for the common commercial standards



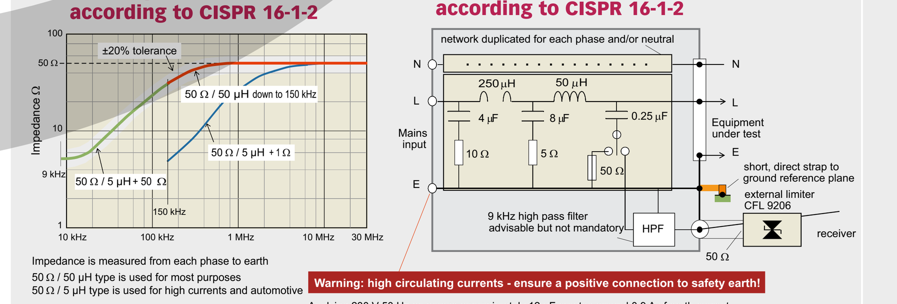
Conducted test setup and LISN



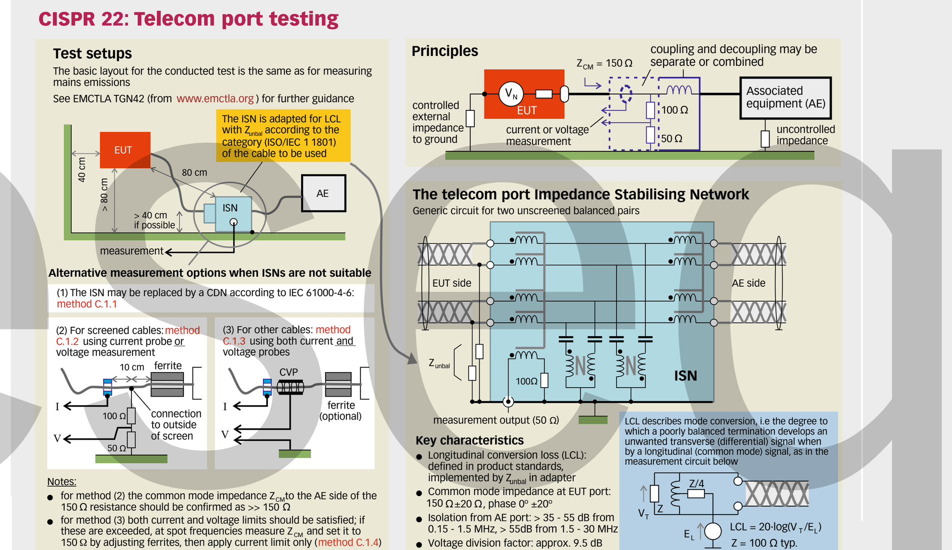
Conducted emissions test layout for tabletop equipment according to CISPR 22

LISN impedance according to CISPR 16-1-2

50 Ω/50 µH + 5 Ω LISN circuit according to CISPR 16-1-2



CISPR 22: Telecom port testing

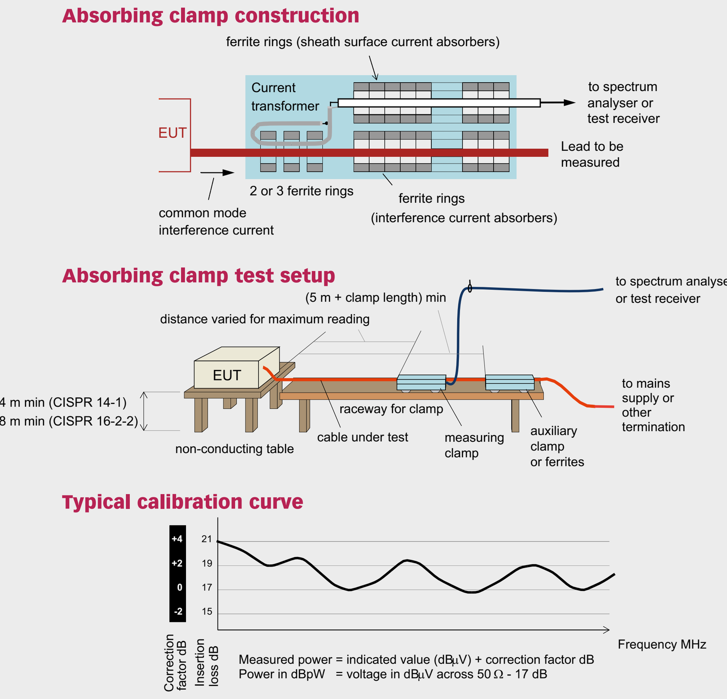


Absorbing clamp setup

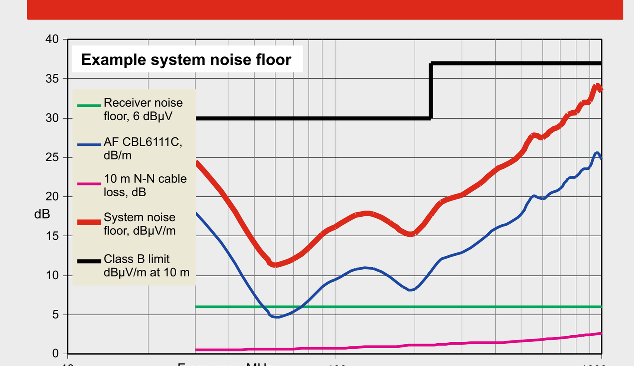
Absorbing clamp construction

Absorbing clamp test setup

Typical calibration curve



Antenna factors



Using the antenna factor

Emissions measuring antennas are characterised by their antenna factor AF. This gives the conversion between the field strength E they are measuring and their output voltage:

$$V_{MEAS}(dB\mu V) = E(dB\mu V/m) + AF(dB/m) + A(dB)$$

V_{MEAS} is the measured voltage at the test receiver, A is the cable and other losses between the antenna and receiver

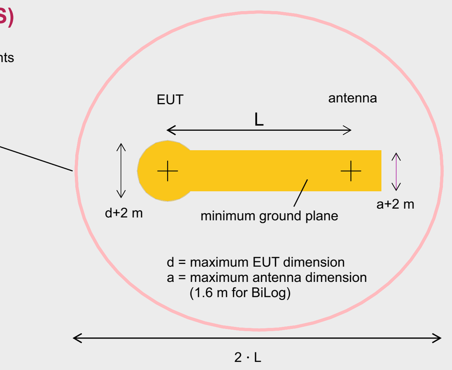
The system noise floor as shown above – the smallest signal that can be detected – is given by the receiver's own noise floor corrected by A and AF.

The antenna factor is initially provided by the manufacturer but can be re-calibrated at any time by a specialist calibration house, using a number of methods. CISPR has standardized on the free space calibration in which the antenna is assumed not to interact with its surroundings, e.g. the EUT and the ground plane. Actual antenna factors will vary with proximity to other objects and also between vertical and horizontal polarization; these variations should be accounted for in the measurement uncertainty budget.

Radiated test setup

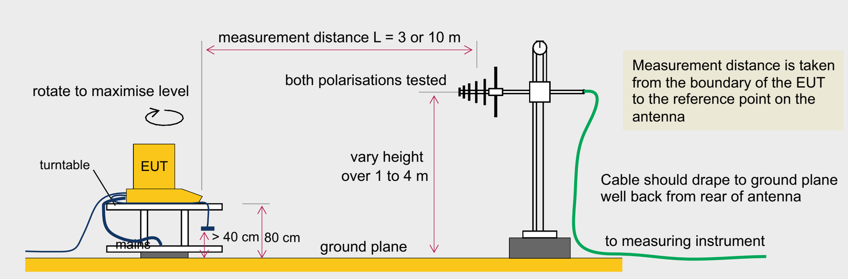
Standard open area test site (OATS)

Site must meet the normalised site attenuation requirements of CISPR 16-1-4 (see below).
Alternative test sites (e.g. semi-anechoic chambers) can be used if they meet the ±4 dB NSA requirement over five points.



Radiated emissions test setup according to CISPR 22

Method: select frequencies to be measured, at each frequency find maximum with respect to height scan, polarization and turntable rotation.
Record level, frequency and polarization of the six highest measurements of those disturbances greater than (Limit – 20 dB).

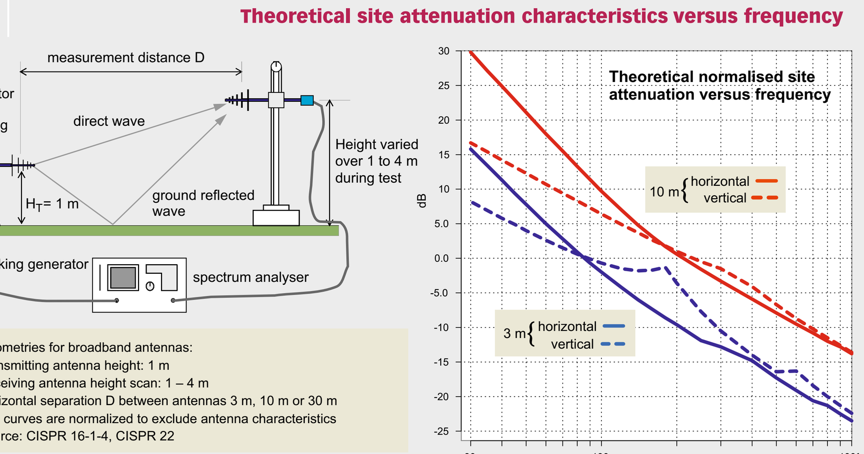


Normalised site attenuation

- Site attenuation is the overall loss between two antennas on a given open field test site, spaced at the measuring distance.
- According to CISPR 16-1-4 and CISPR 22, the measured site attenuation of a site used for compliance tests must be within ±4 dB of the theoretical for an open site.
- Site attenuation can be measured with a pair of broadband antennas, a spectrum analyser and tracking generator (see diagram).
- For test sites which do not conform to the open area requirements, a set of site attenuation measurements are needed with the transmit antenna placed at several points over the test volume (see CISPR 22 annex A and CISPR 16-1-4).
- The measured value V_{SITE} is the maximum recorded over the receiving antenna height scan at each frequency, and V_{DIRECT} is the value recorded when the antenna cables are connected to each other. AF_T and AF_R are the respective antenna factors. The NSA is then given by

$$A_N(dB) = V_{DIRECT} - V_{SITE} - AF_T - AF_R$$

Theoretical site attenuation characteristics versus frequency



Electromagnetic spectrum - RF emissions