Measurements & Tests

Véronique Beauvois, Ir.

2021-2022

Measurements & Tests

- Radio frequency emission
  - radiated emission f > 30MHz
  - conducted emission f < 30MHz
- Low frequency emission

- Radio frequency susceptibility
  - radiated susceptibility f > 80MHz
  - conducted susceptibility f < 80MHz
- Susceptibility to transients
- Low frequency susceptibility

→ Equipment and measurement & test methods?

Measurements & Tests
Emission

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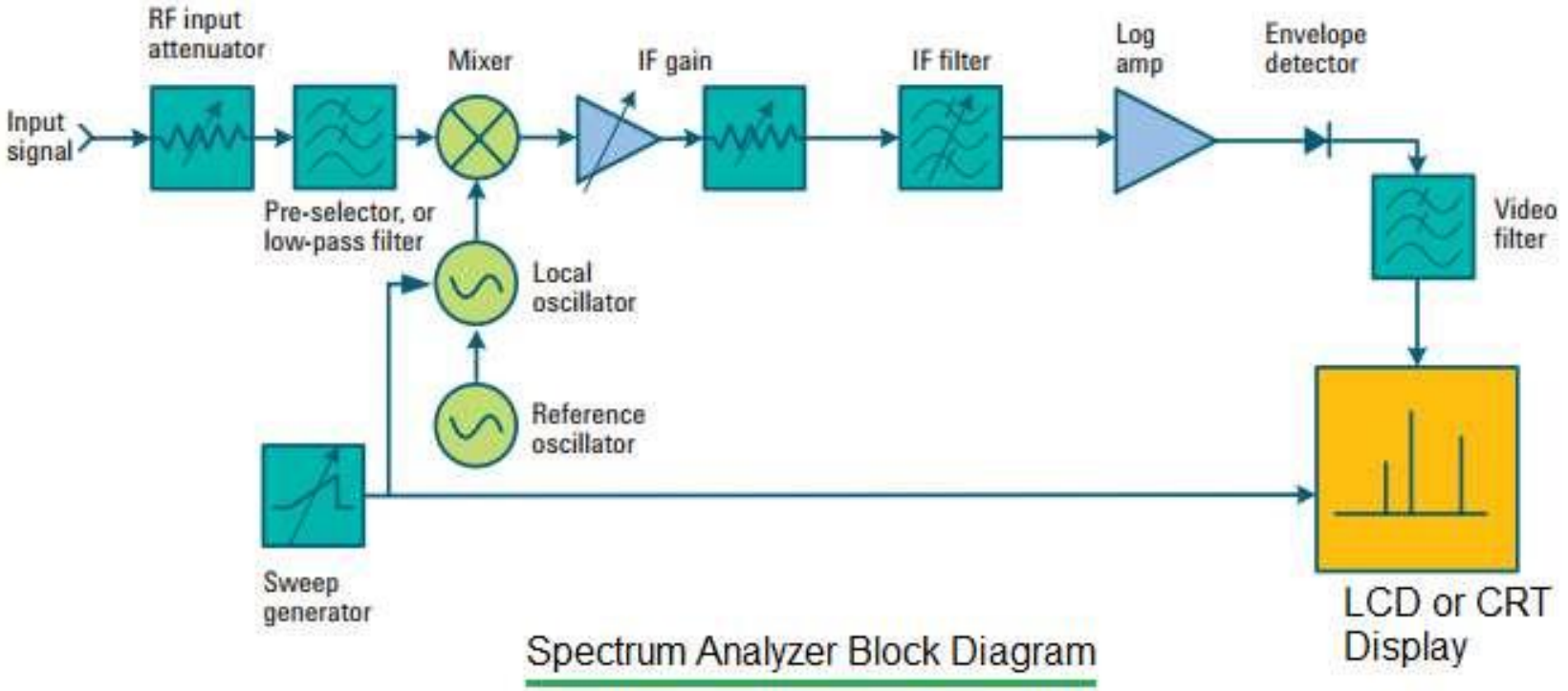
2021-2022

Radio frequency emission

1. Spectrum analyser

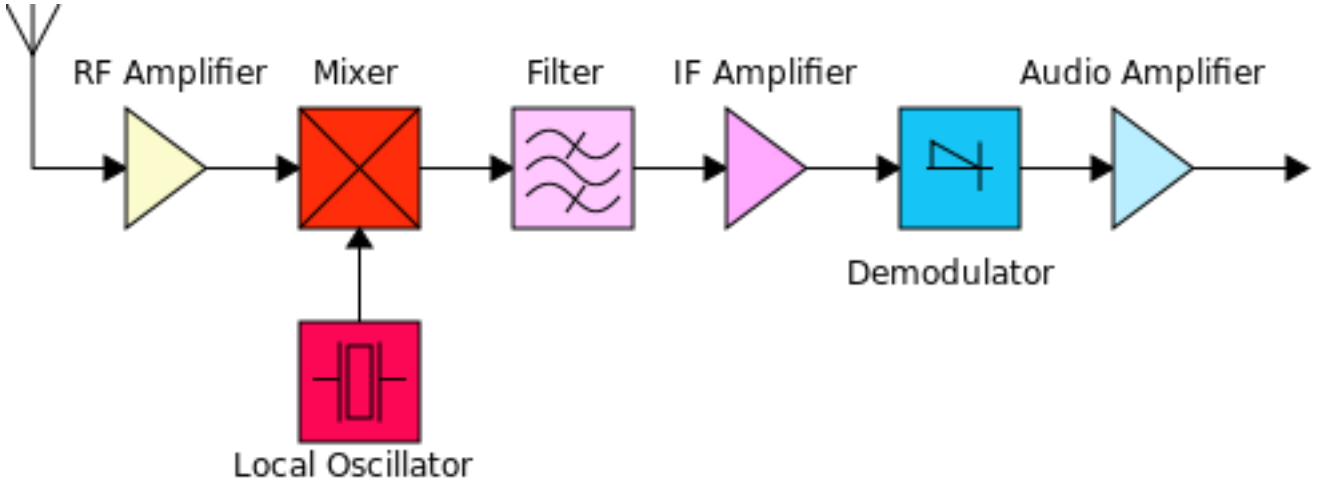


Spectrum Analyzer Block Diagram

Radio frequency emission

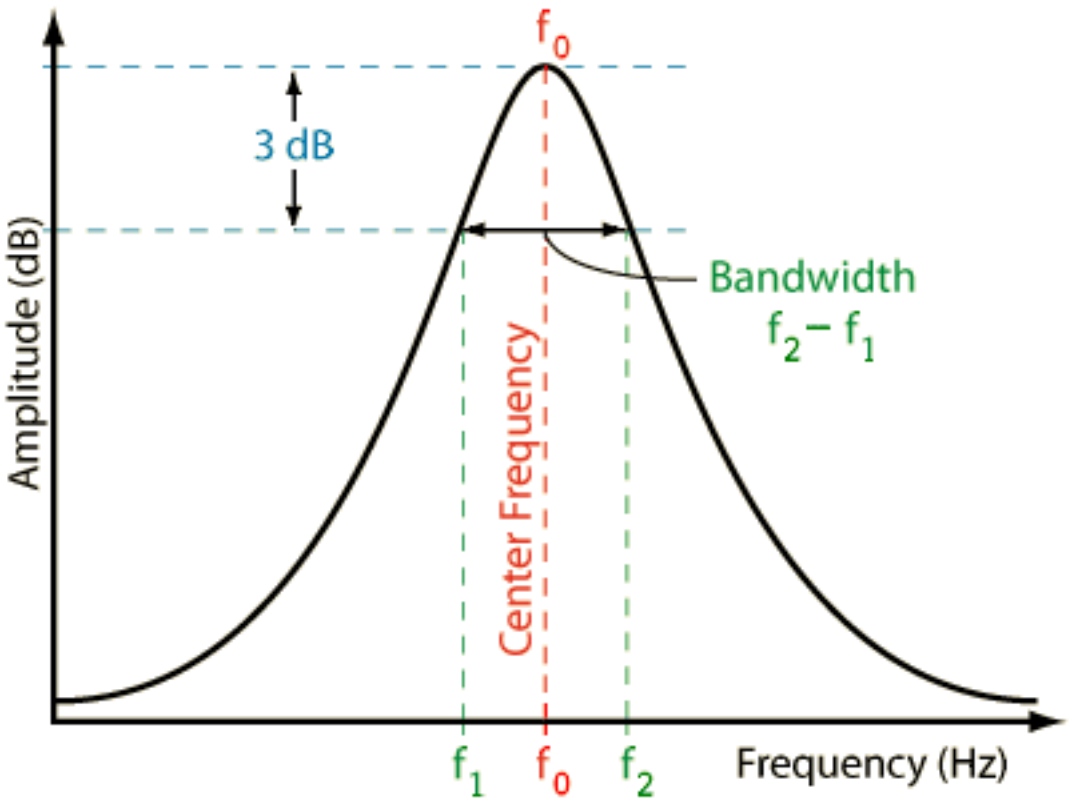
1. EMI receiver

Super-heterodyne receiver



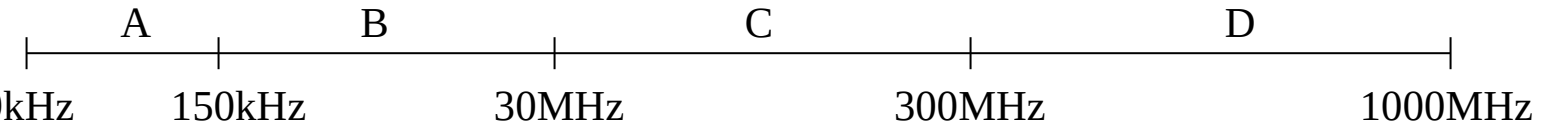
Radio frequency emission

Bandwidth



Radio frequency emission

Bandwidth



B.W. @ 6dB	**200Hz**	**9kHz**	**120kHz**	**120kHz**

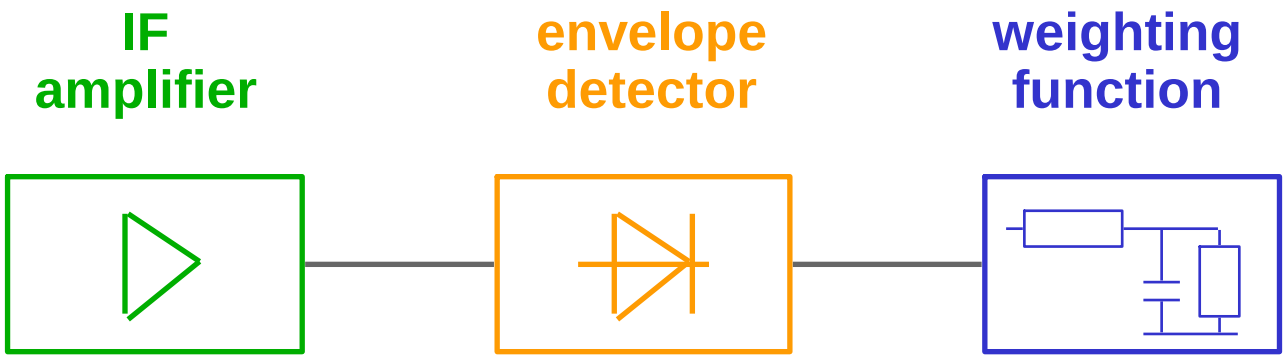
Broadband = signal width > B.W.
e.g. 30kHz = Broadband for band B and Narrowband for band C

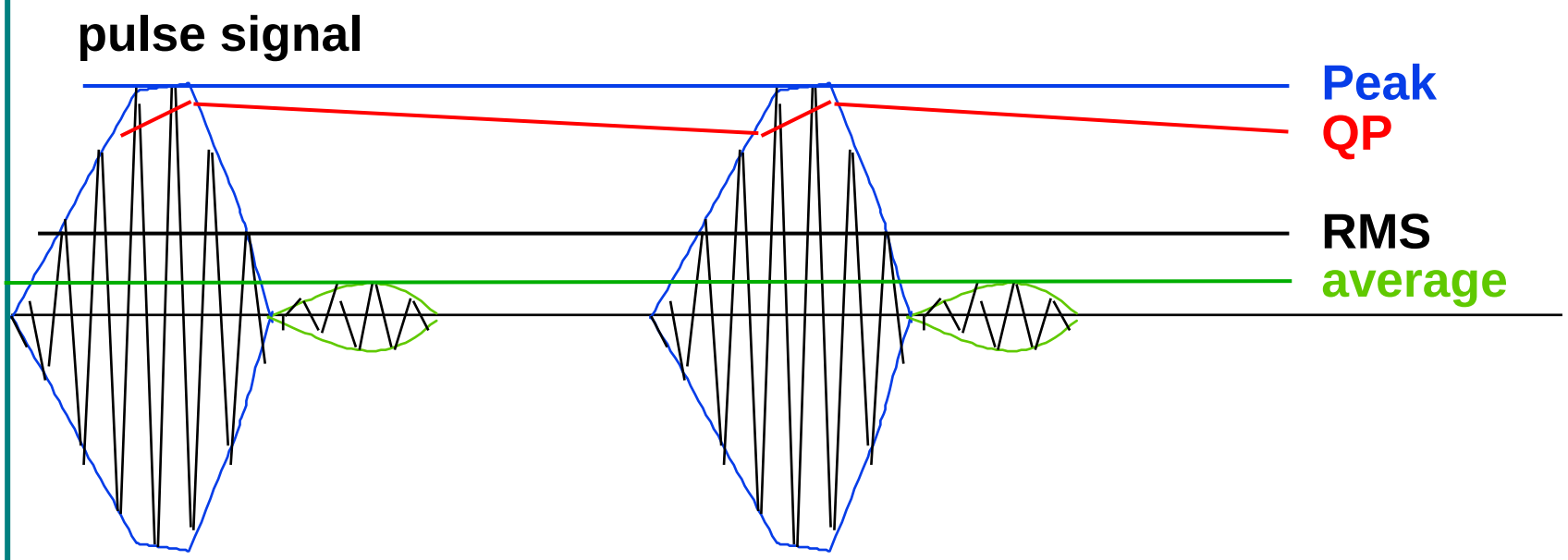
Noise level (dB) = $10 \times \log_{10} (BW_1/BW_2)$

e.g. changing BW from 10 kHz to 120 kHz increases noise level of 10.8 dB.

EMI receiver

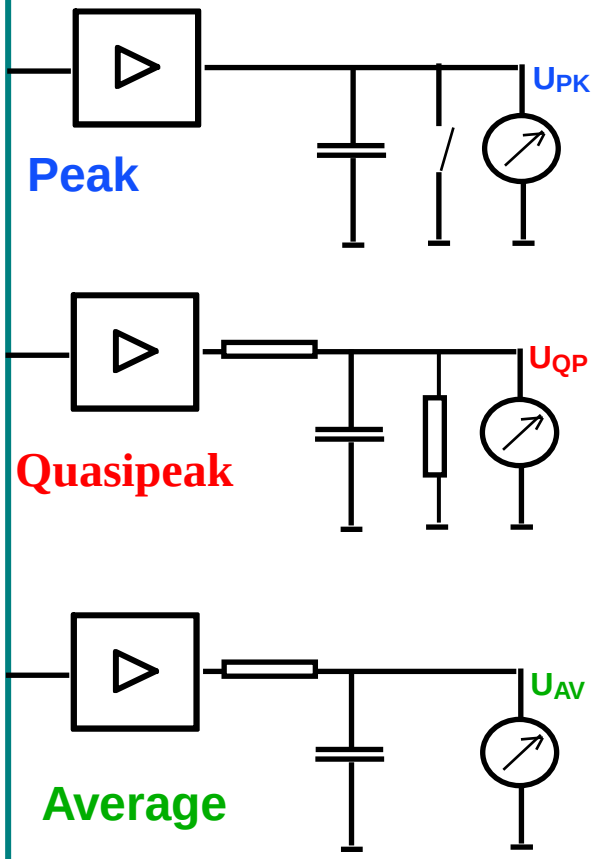
Detectors

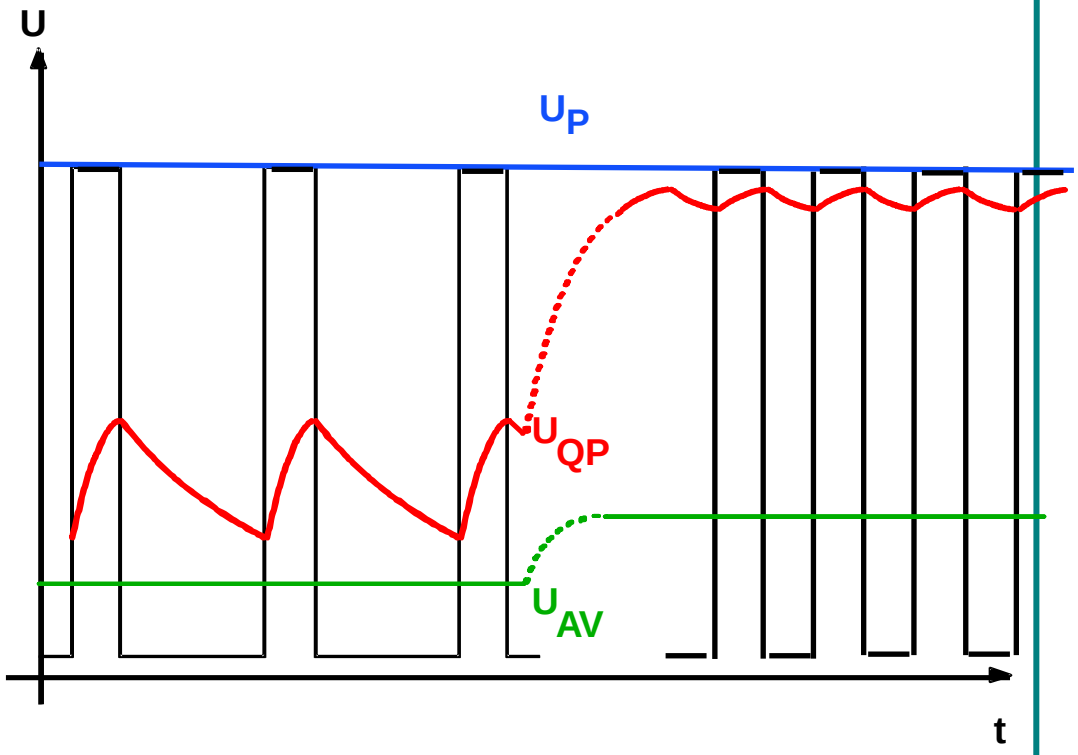




EMI receiver

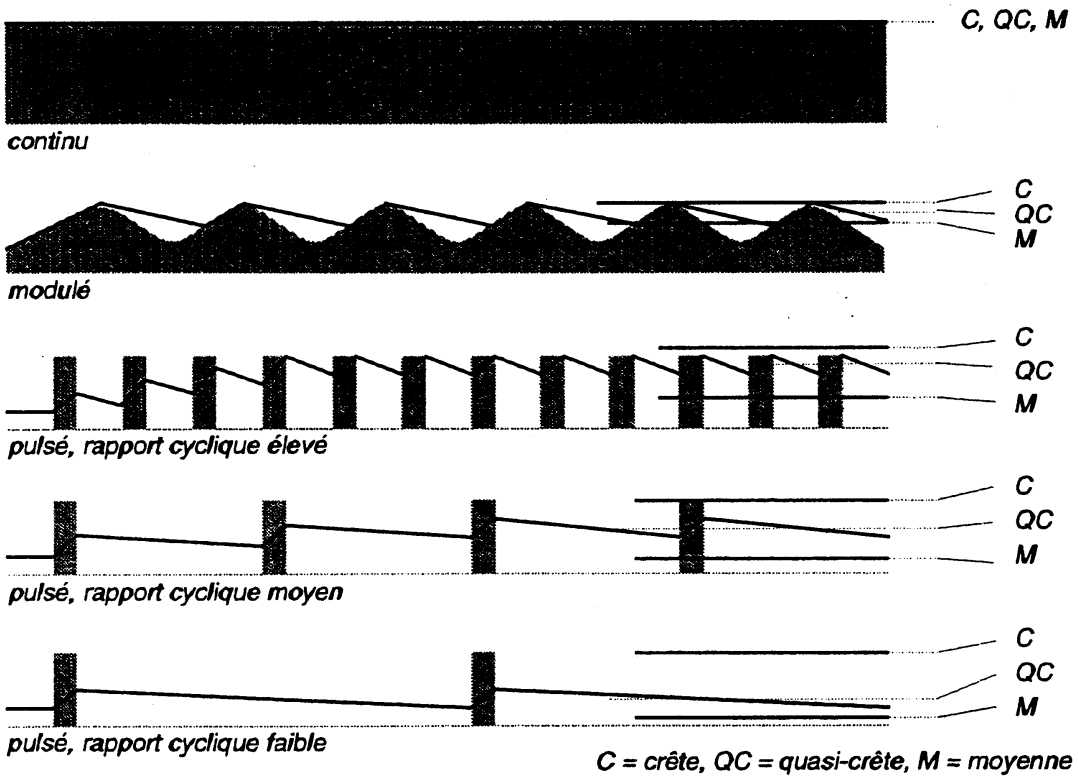
Detectors





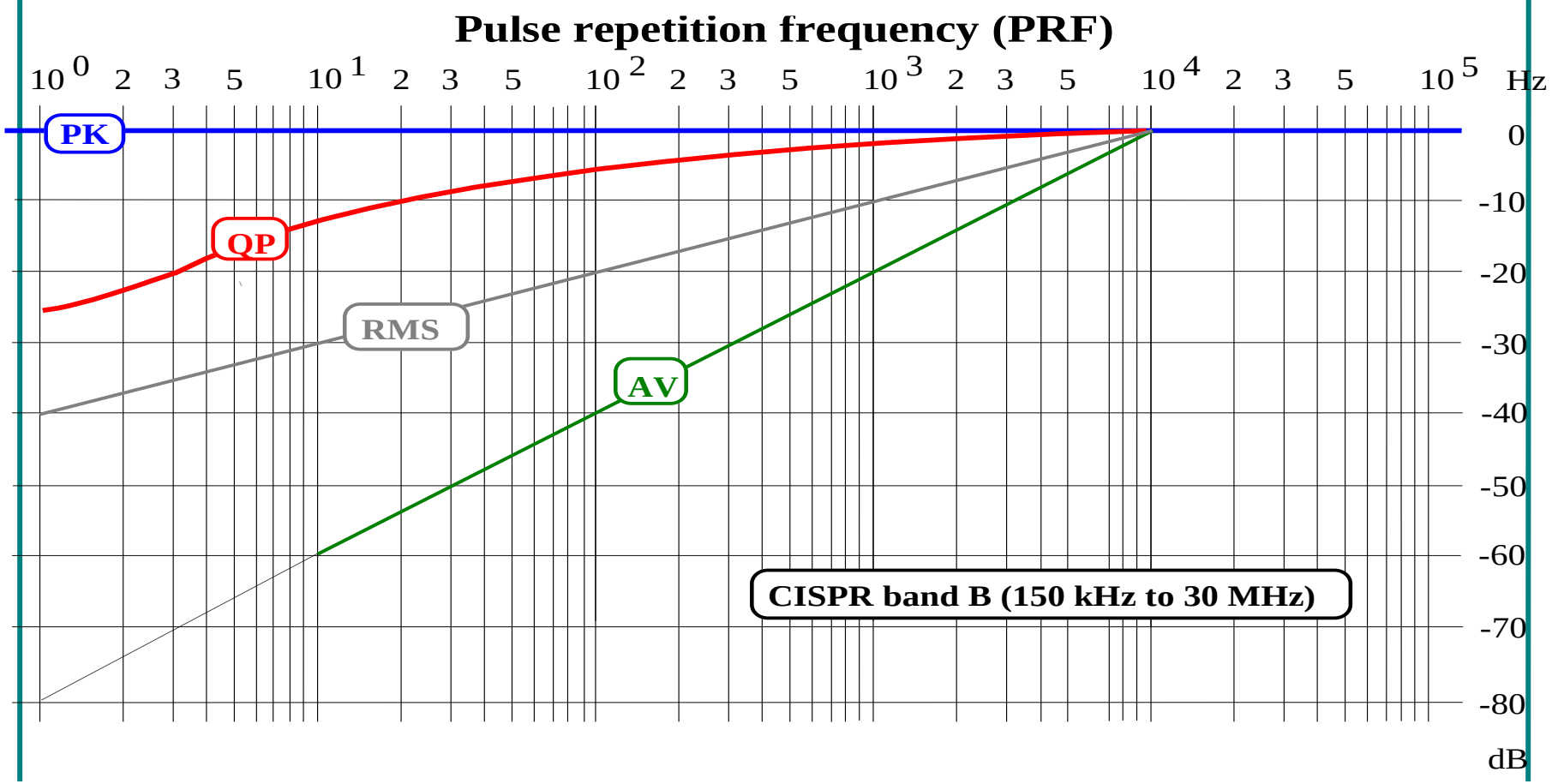
EMI receiver

Detectors



EMI receiver

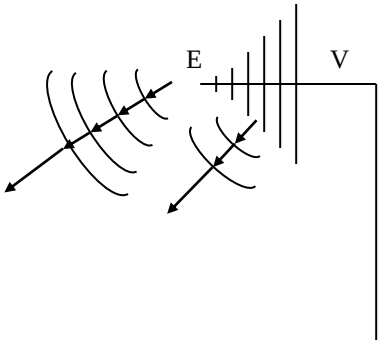
Detectors



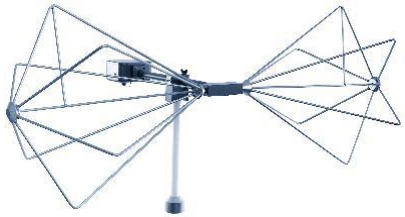
Radio frequency emission

2. Antenna

- Bandwidth
- Linear Polarisation
- Antenna factor



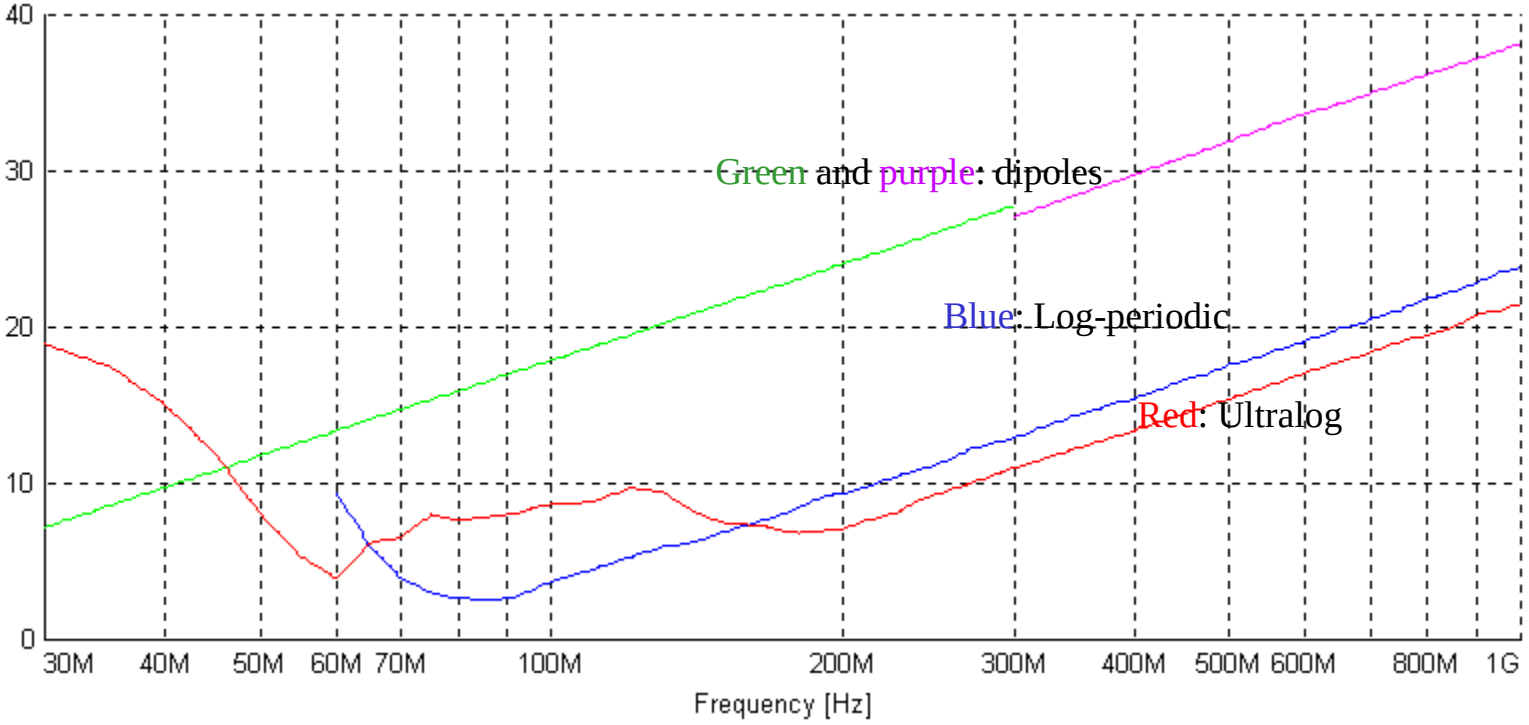
AF = E / V (linear) or E - V (log)



Radio frequency emission

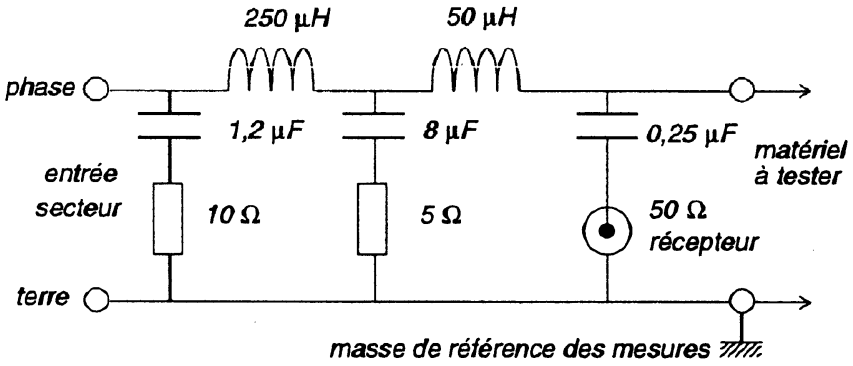
2. Antenna

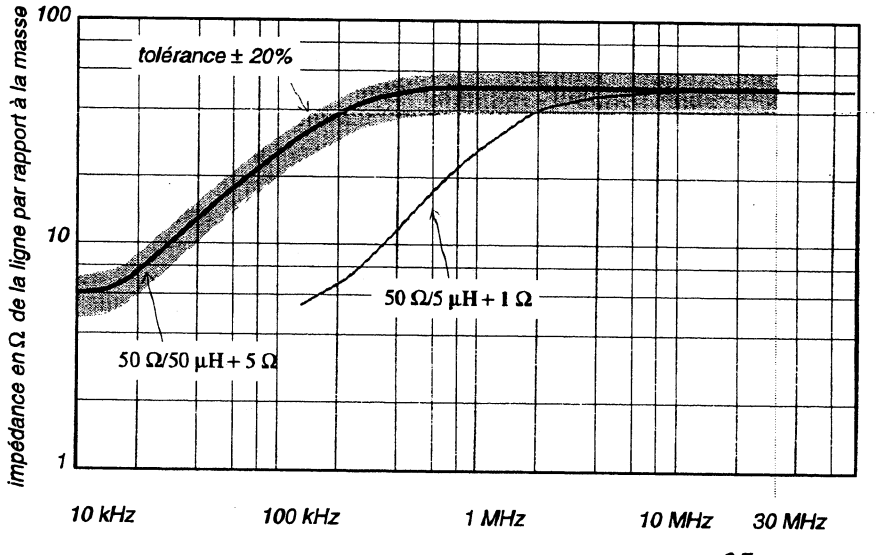
Typical antenna factors



Radio frequency emission

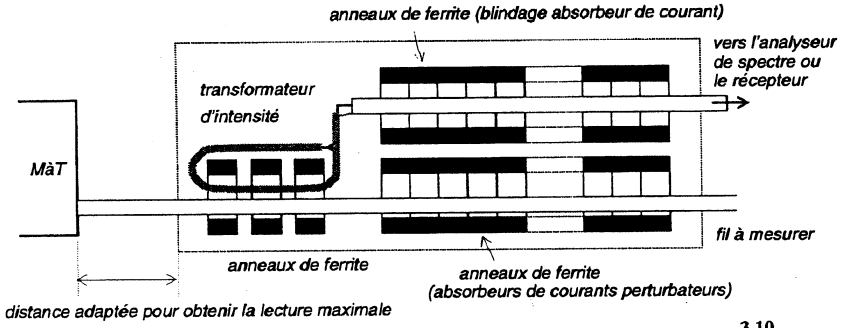
2. Artificial network

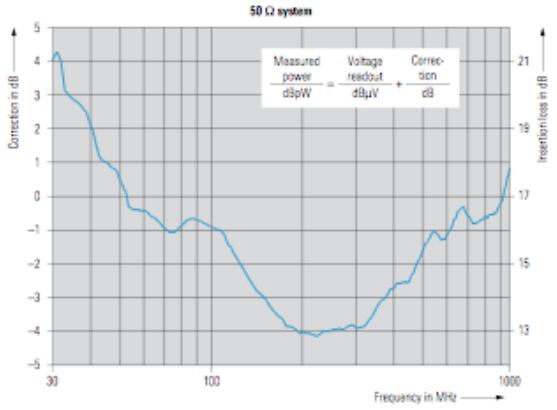


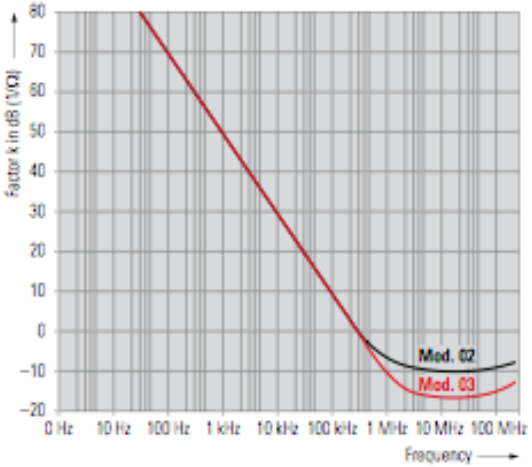


Radio frequency emission

2. Absorbing clamp and current probe

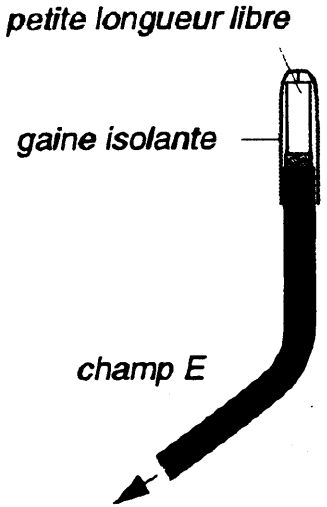


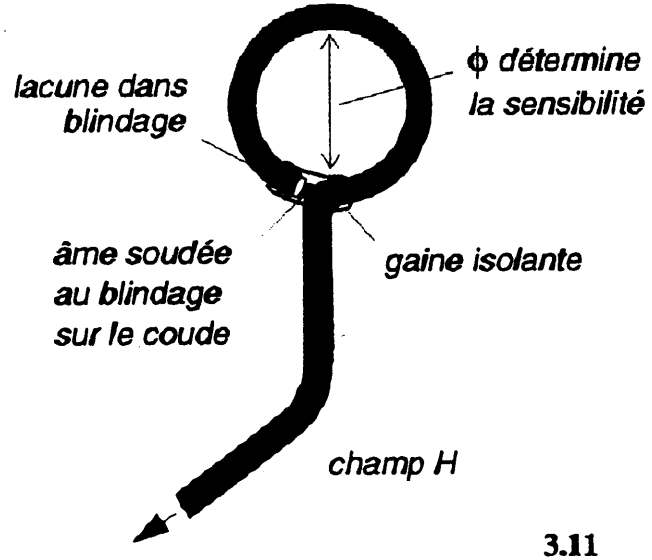




Radio frequency emission

2. Near-field probes





Radio frequency emission

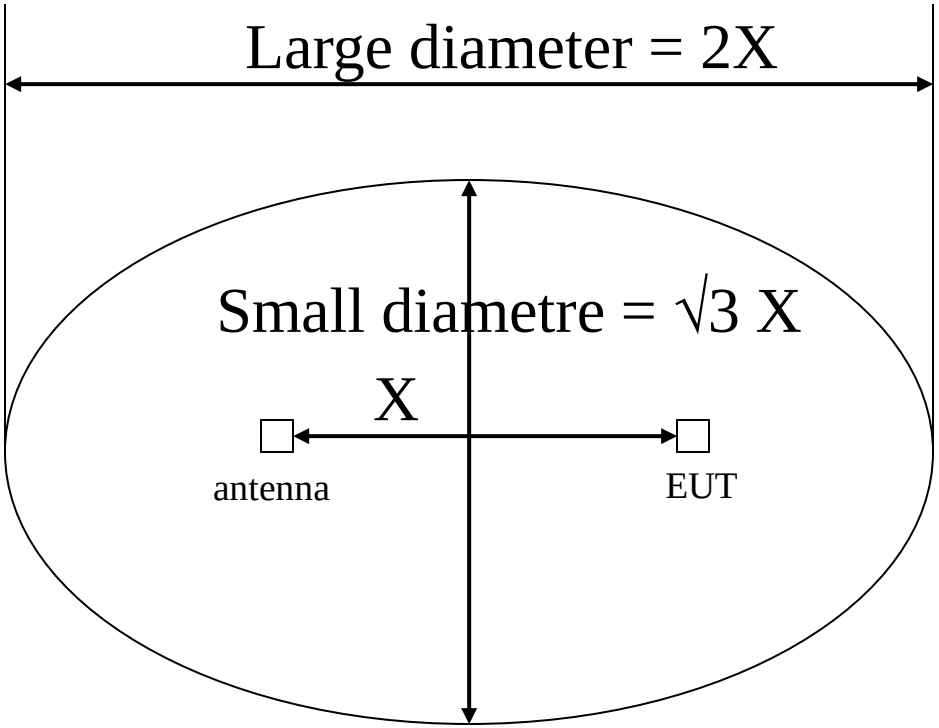
3. Measurement sites – Open Site (OATS)

- Site in conformity with CISPR16-1
  (SA @ +/-4dB of NSA 30-1000MHz)
- No reflecting object in the CISPR ellipse
- Metallic ground plane
- Measurements @X 3, 10 or 30 m (10 m preferably)
- EUT @ 1 m height
- Antenna scanning between 1 and 4 m

Radio frequency emission

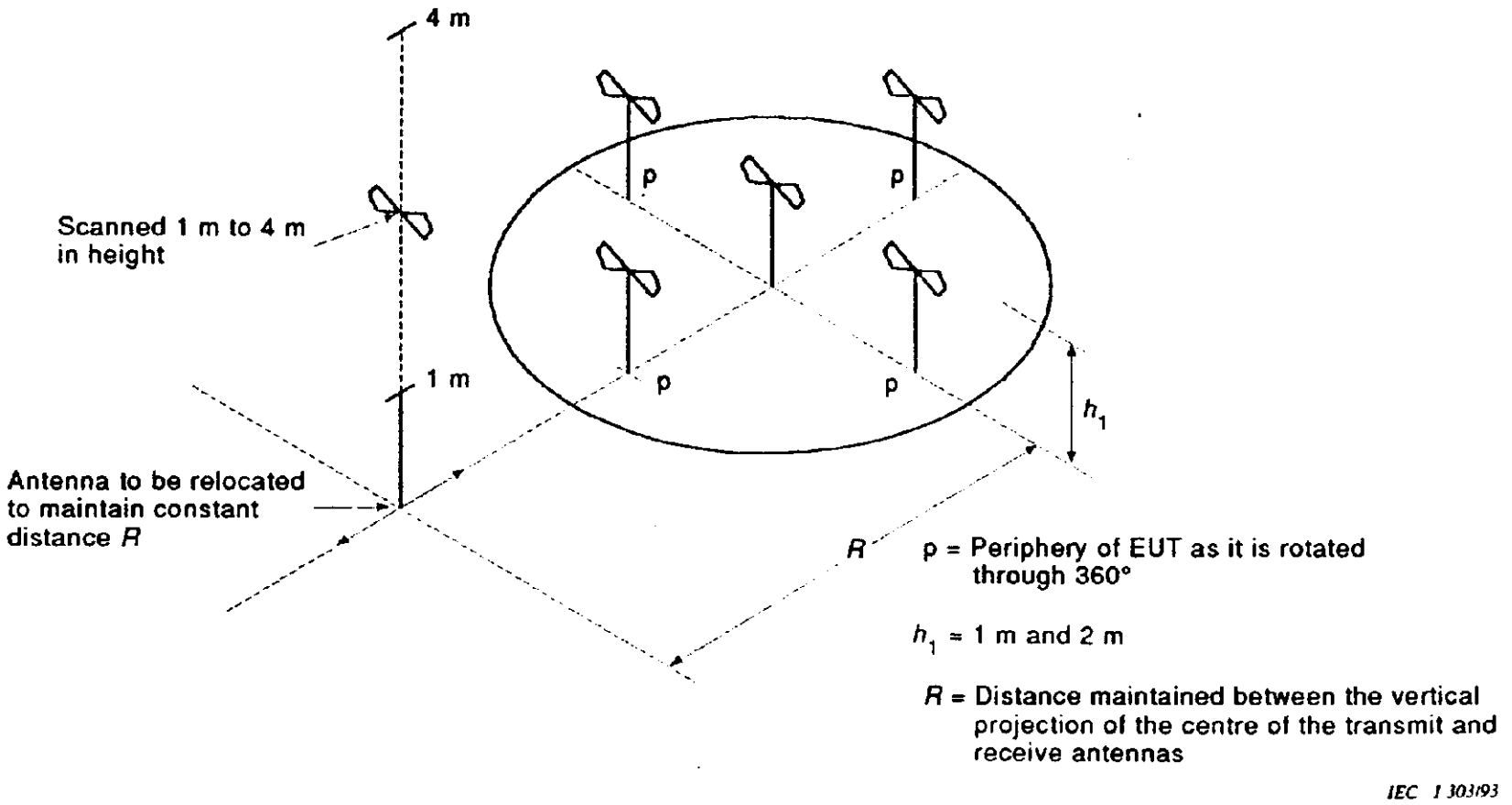
3. Measurement sites – Open Site (OATS)

CISPR ellipse



Radio frequency emission

3. Measurement sites – Open Site (OATS)



Radio frequency emission

3. Measurement sites – Open Site (OATS)

OATS Belcomlab, Oudenburg (B)

Radio frequency emission

3. Measurement sites – Open Site (OATS)

Problems

- climate & weather forecast
- electromagnetic noise

(e.g. communications, mobile, TV…)

Radio frequency emission

3. Faraday room

According to Gauss theorem

Weak points Door, honeycomb, cables…

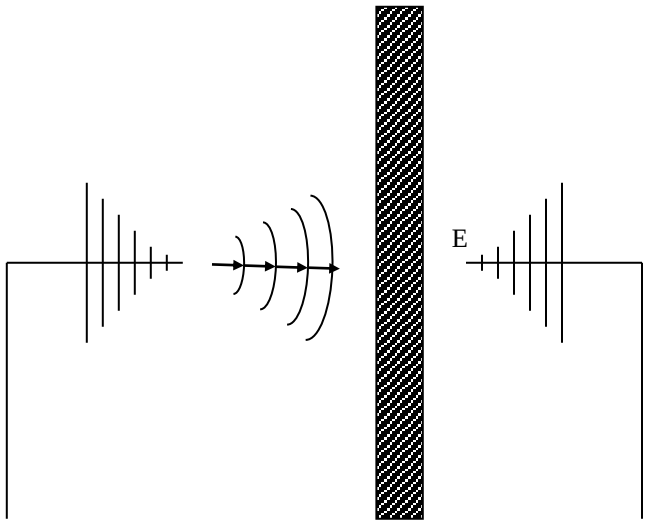
Resonant cavity (Q quality factor)

Radio frequency emission

3. Faraday room

Shielding attenuation: 20 log (E_{sans} / E_{avec})

10kHz	60 dB	1000
100kHz	83 dB	14.125
1MHz	112 dB	398.107
30MHz	122 dB	1.258.925
200MHz	141 dB	11.220.184
1GHz	130 dB	3.162.277
10GHz	103 dB	141.253
18GHz	82 dB	12.589



Radio frequency emission

3. Anechoic room

Absorbing materials

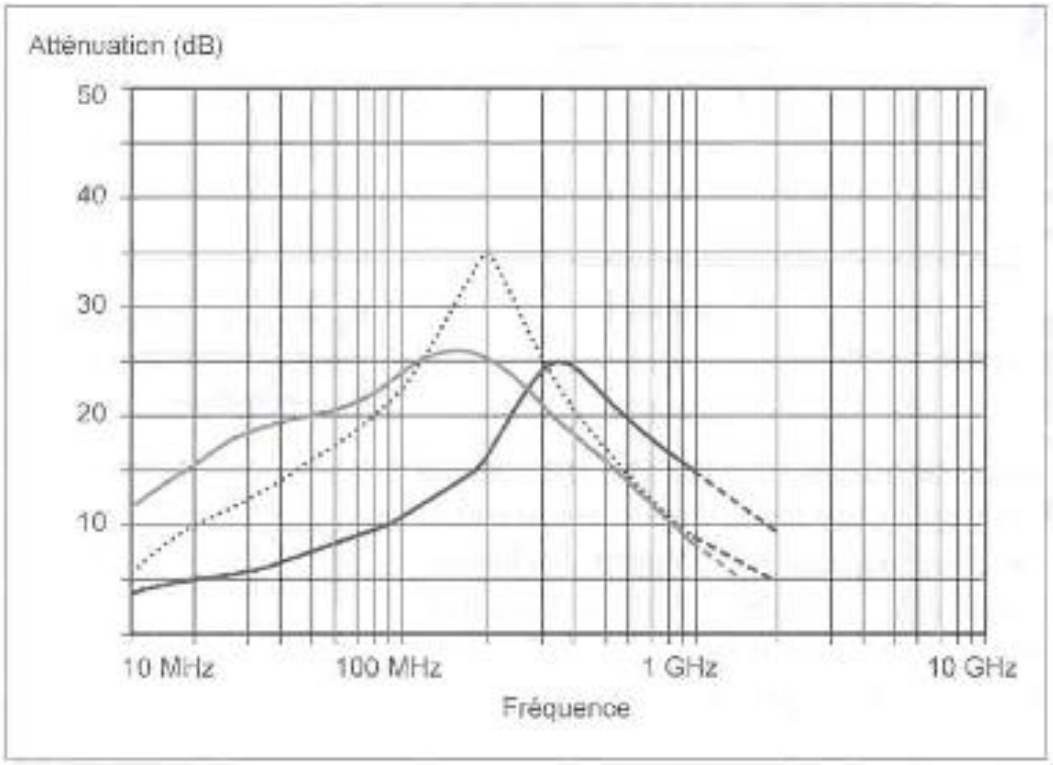
Magnetic effect --> ferrite tiles

Resistive load --> foam (polyurethane) loaded with carbon
+
Geometric effect

Radio frequency emission

3. Anechoic room

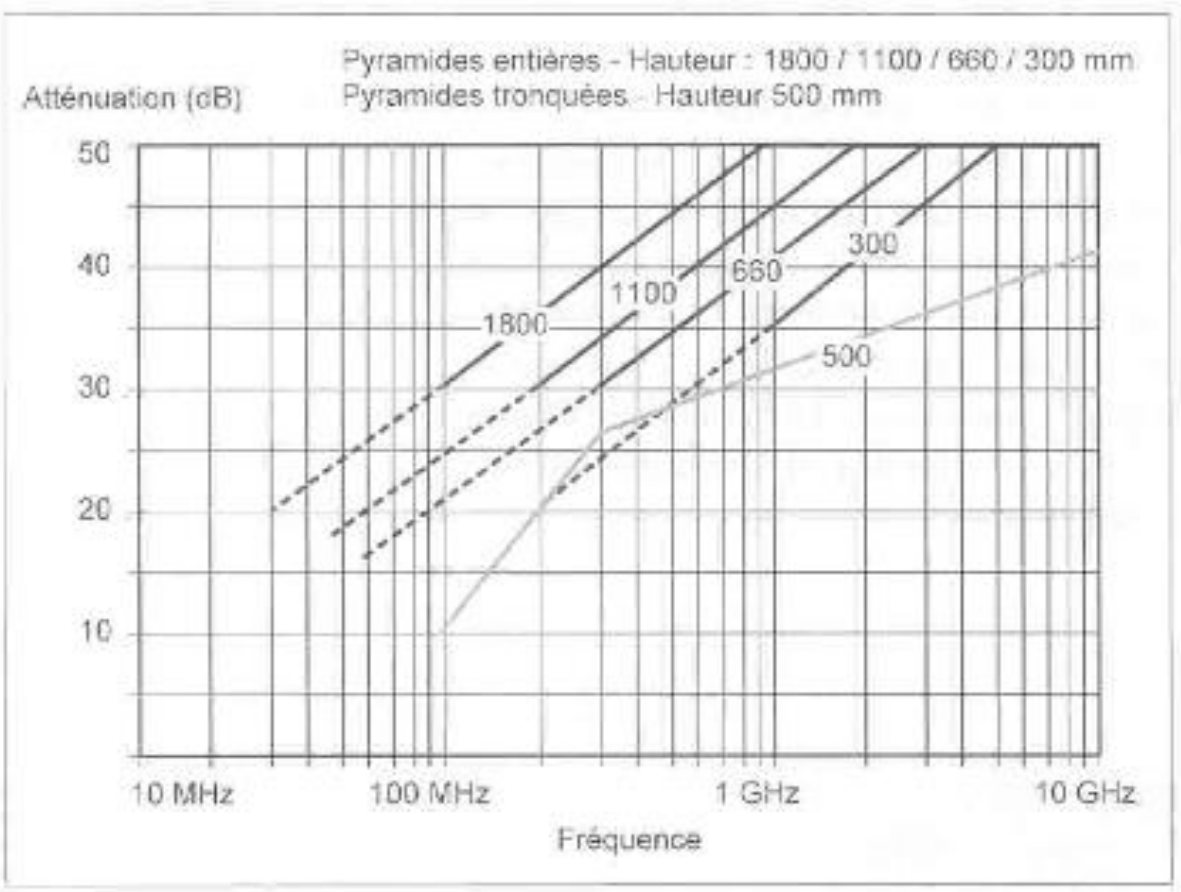
Typical performance of ferrite tiles



Radio frequency emission

3. Anechoic room

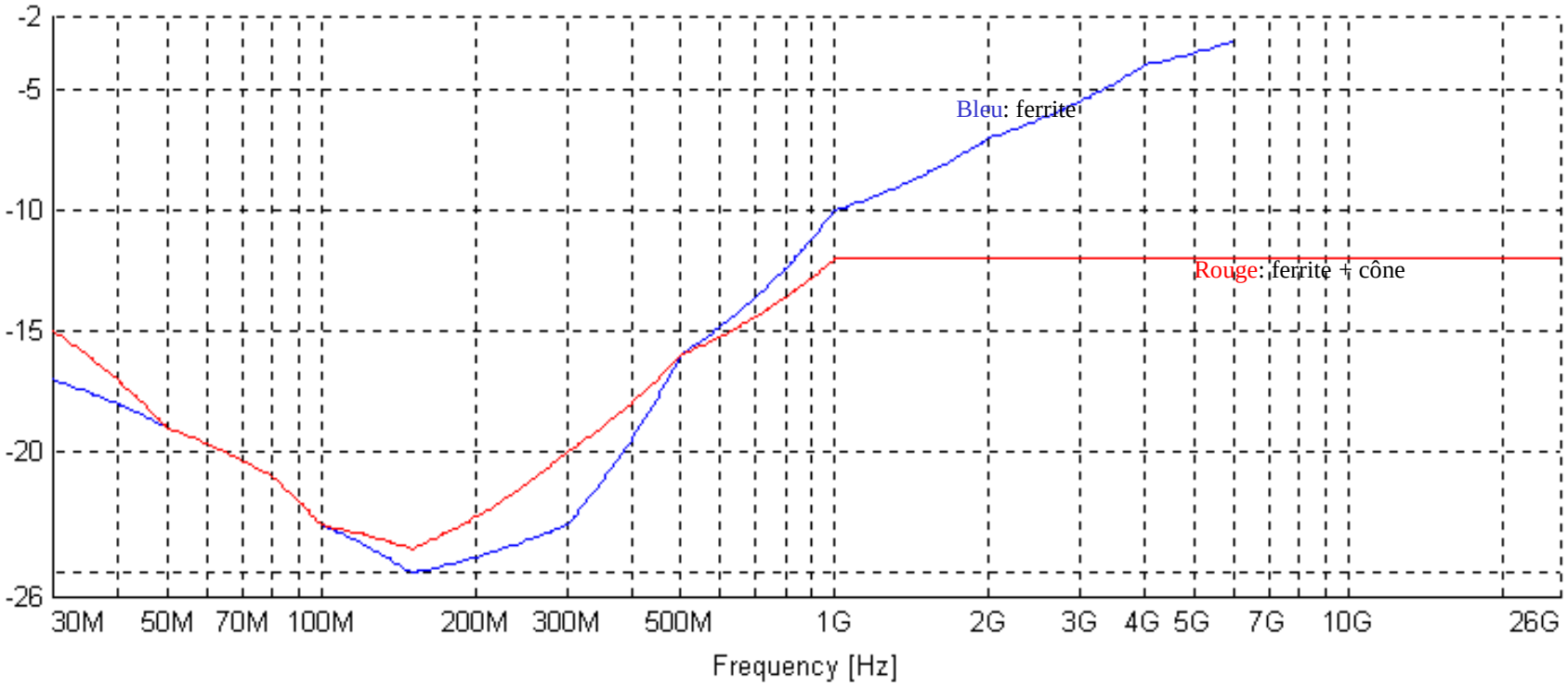
Typical performance of foam pyramids



Radio frequency emission

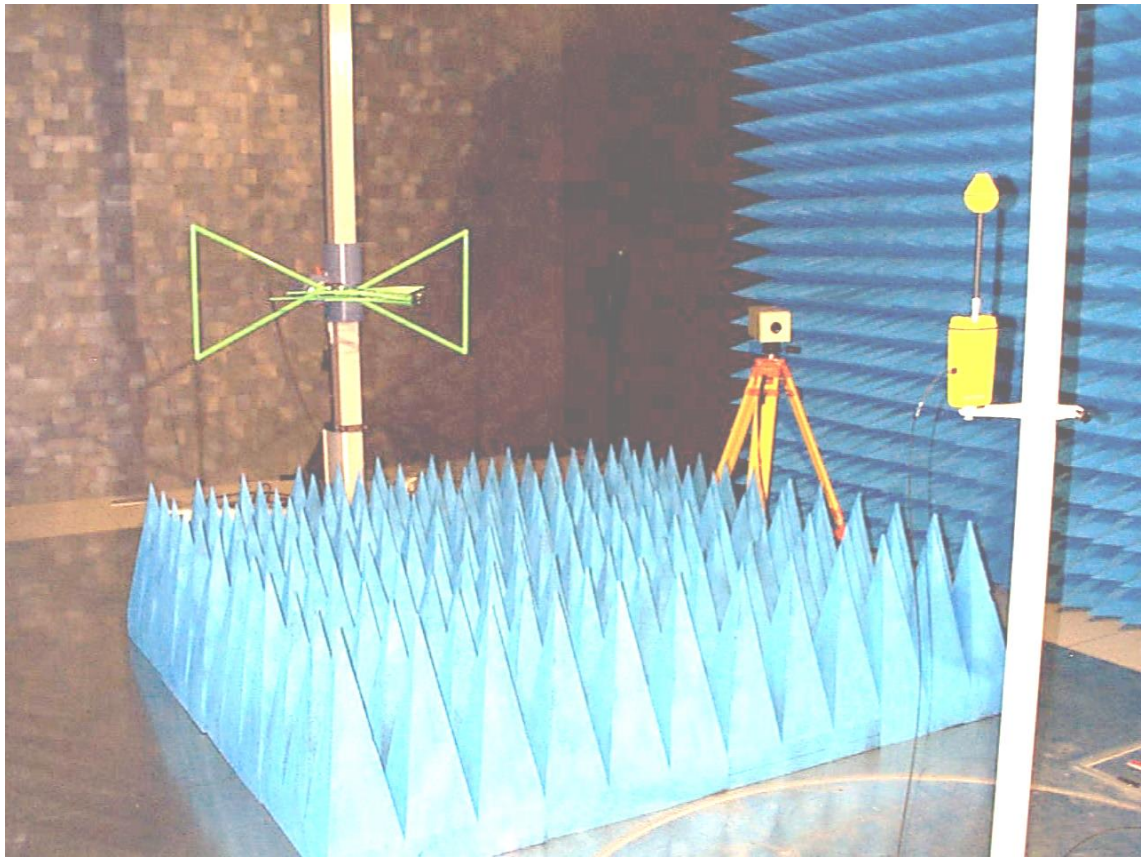
3. Anechoic room

Reflectivity (@ULg EMC Laboratory)



Radio frequency emission

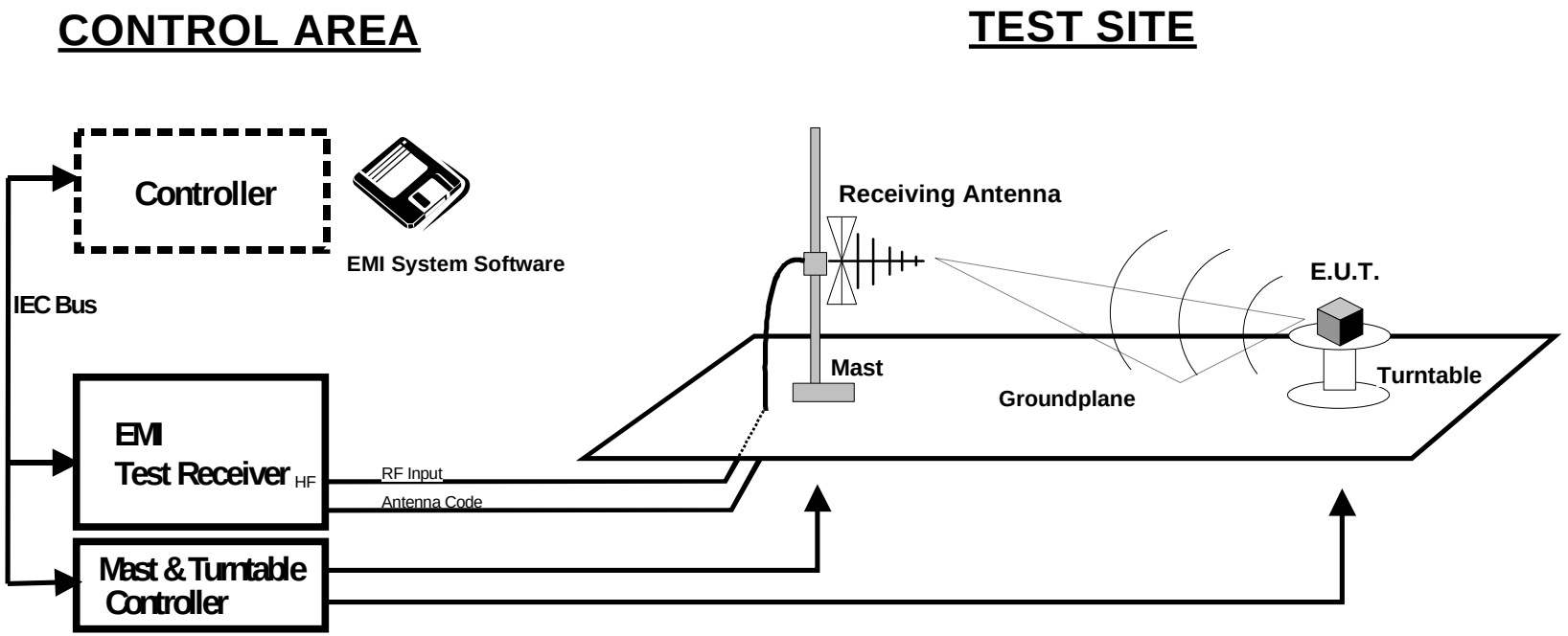
3. Anechoic room



SAC ULG, Liège (B)

Radio frequency emission

4. Radiated emission



Radio frequency emission

4. Radiated emission

Limit (EN 55022 > EN 55032)

Table 5 – Limits for radiated disturbance of class A ITE at a measuring distance of 10 m

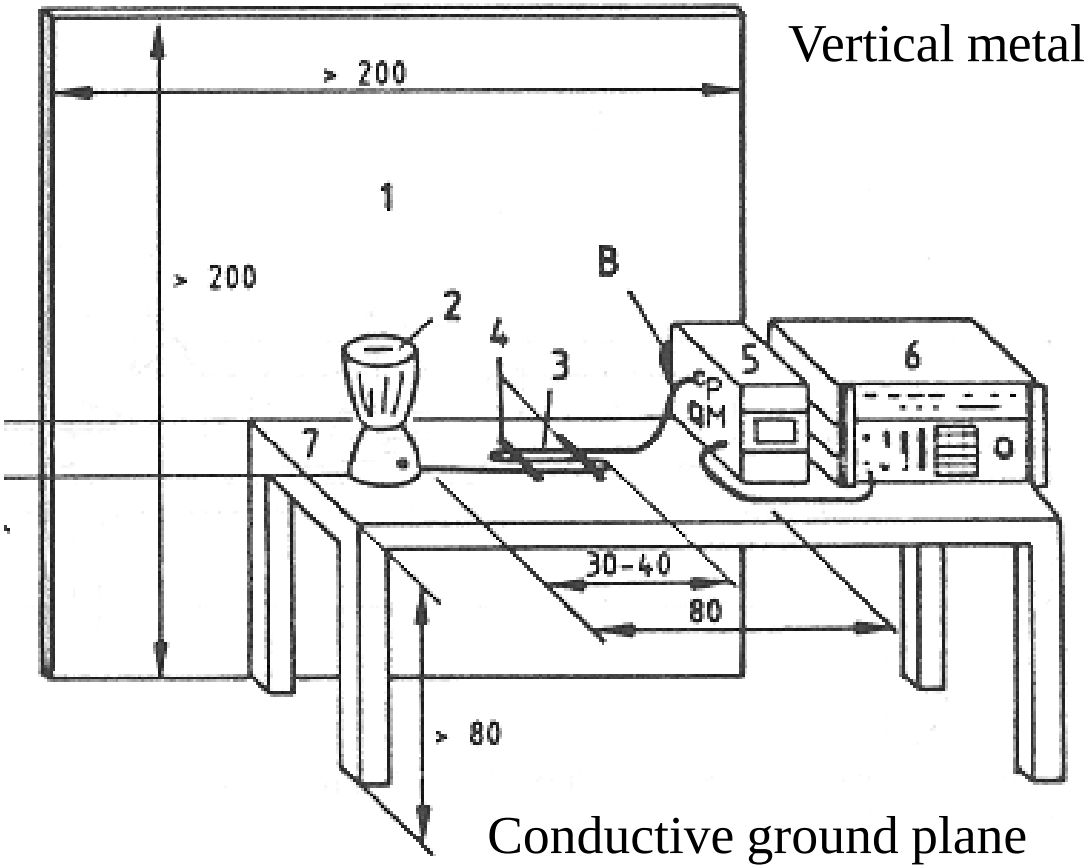
Frequency range MHz	**Quasi-peak limits** dB(µV/m)
30 to 230	40
230 to 1 000	47
NOTE 1 The lower limit shall apply at the transition frequency. NOTE 2 Additional provisions may be required for cases where interference occurs.	

Table 6 – Limits for radiated disturbance of class B ITE at a measuring distance of 10 m

Frequency range MHz	**Quasi-peak limits** dB(µV/m)
30 to 230	30
230 to 1 000	37
NOTE 1 The lower limit shall apply at the transition frequency. NOTE 2 Additional provisions may be required for cases where interference occurs.	

Radio frequency emission

4. Conducted emission



Vertical metal plate (or Faraday room)

Non conductive table

Conductive ground plane

Radio frequency emission

4. Conducted emission

Limit (EN 55022 > EN 55032)

Table 1 – Limits for conducted disturbance at the mains ports of class A ITE

Frequency range MHz	Limits dB(µV)	
	Quasi-peak	Average
0,15 to 0,50	79	66
0,50 to 30	73	60
NOTE The lower limit shall apply at the transition frequency.		

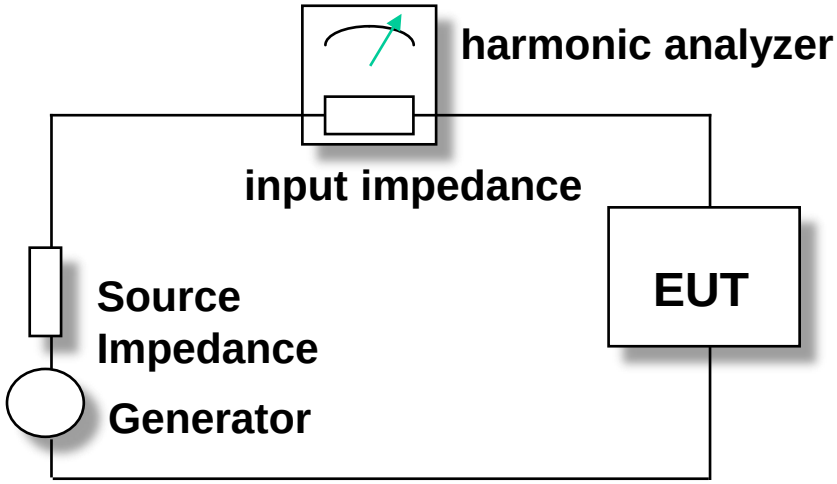
Table 2 – Limits for conducted disturbance at the mains ports of class B ITE

Frequency range MHz	Limits dB(µV)	
	Quasi-peak	Average
0,15 to 0,50	66 to 56	56 to 46
0,50 to 5	56	46
5 to 30	60	50
NOTE 1 The lower limit shall apply at the transition frequencies. NOTE 2 The limit decreases linearly with the logarithm of the frequency in the range 0,15 MHz to 0,50 MHz.		

Harmonics Emission

EN 61000-3-2 (<16A)

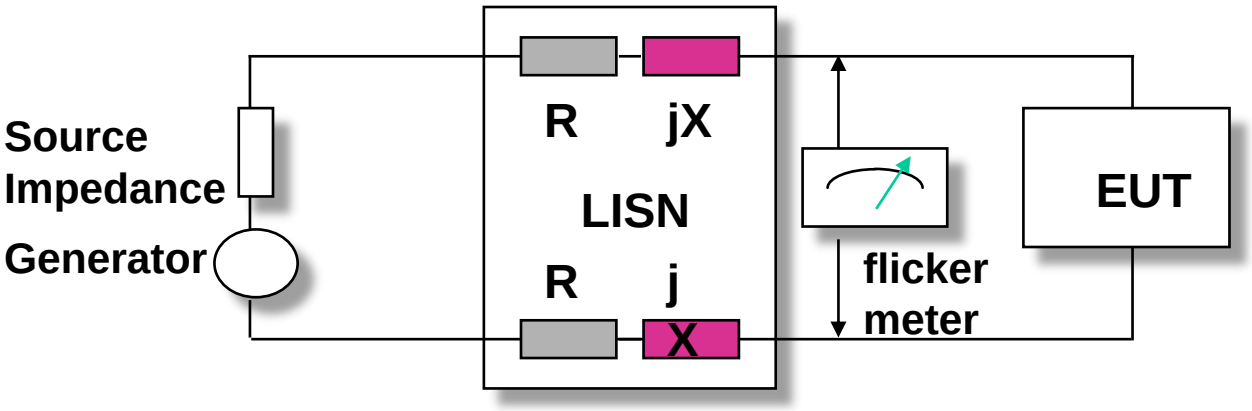
- Classification of EUTs
  (classes A, B, C, D)
- Limits only for 40 first harmonics (2kHz)
- Quality of source (harmonic content)
- Measuring equipment based on TFD



Flicker Emission

EN 61000-3-3 (<16A)

- Quality of the source
- Measuring equipment
- Reference impedance



Measurements & Tests Susceptibility

Véronique Beauvois, Ir.
2021-2022

Radio-frequency Susceptibility
1. Equipment

- Frequency generator (150 kHz – 3 GHz - minimum)
  with modulation (AM (pulse))

- Broadband Power Amplifiers

According to the required level and the characteristics of the transducers.

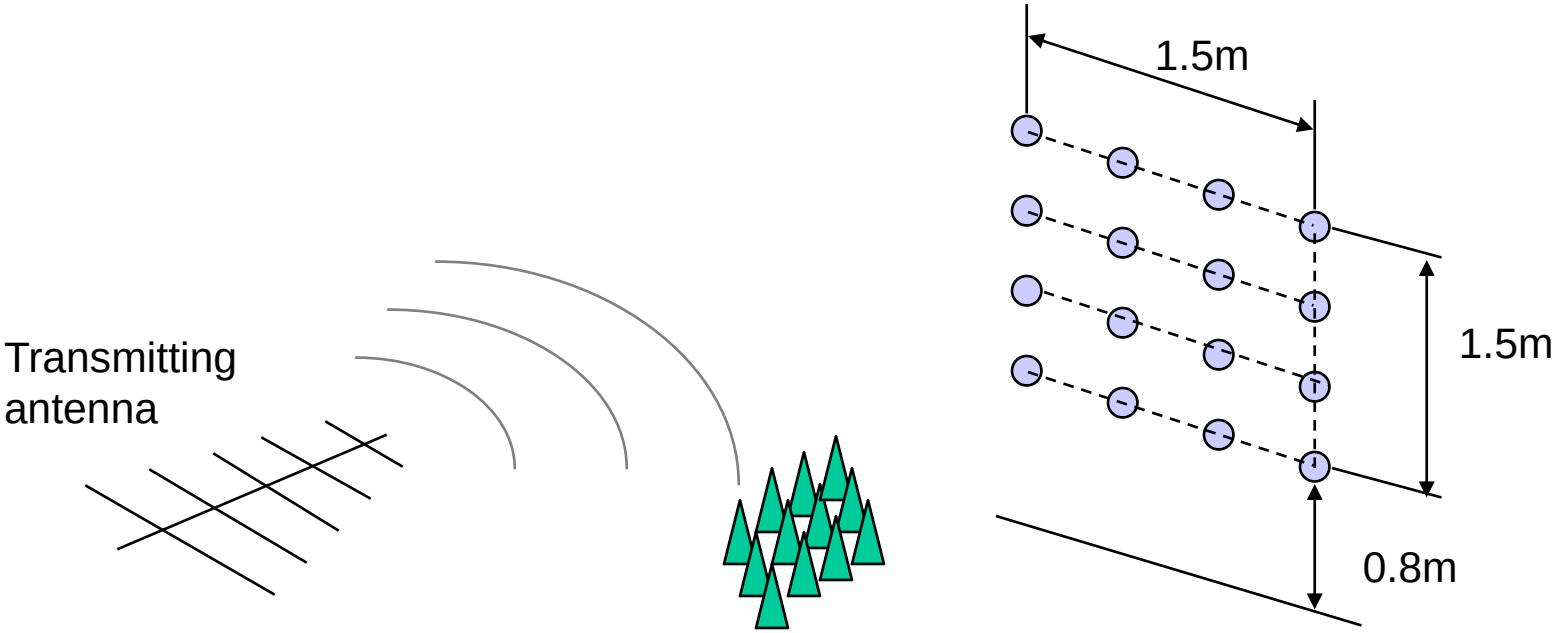
- Transducers : antennas (VSWR, Gain), couplers (CDN, clamp)...

- Field probe

Radio-frequency Susceptibility

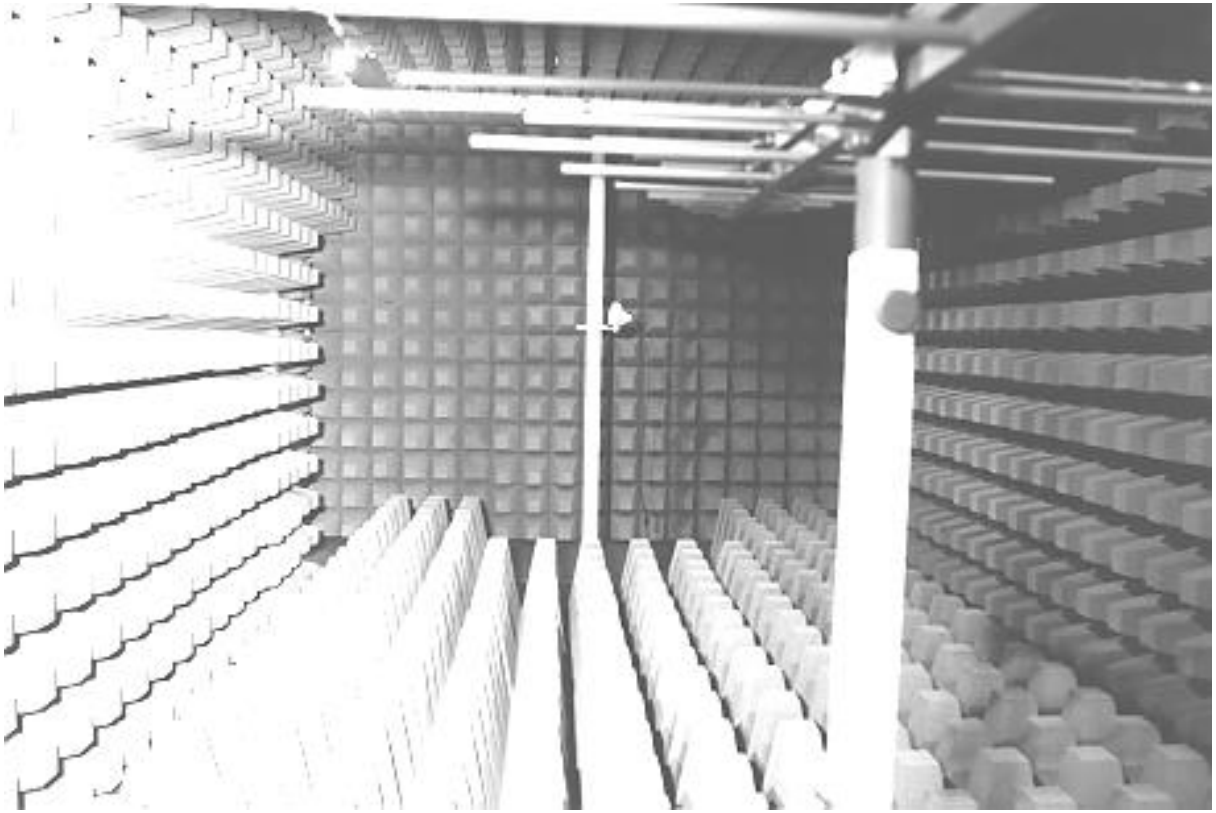
2. Anechoic room

Electric field uniformity



Radio-frequency Susceptibility

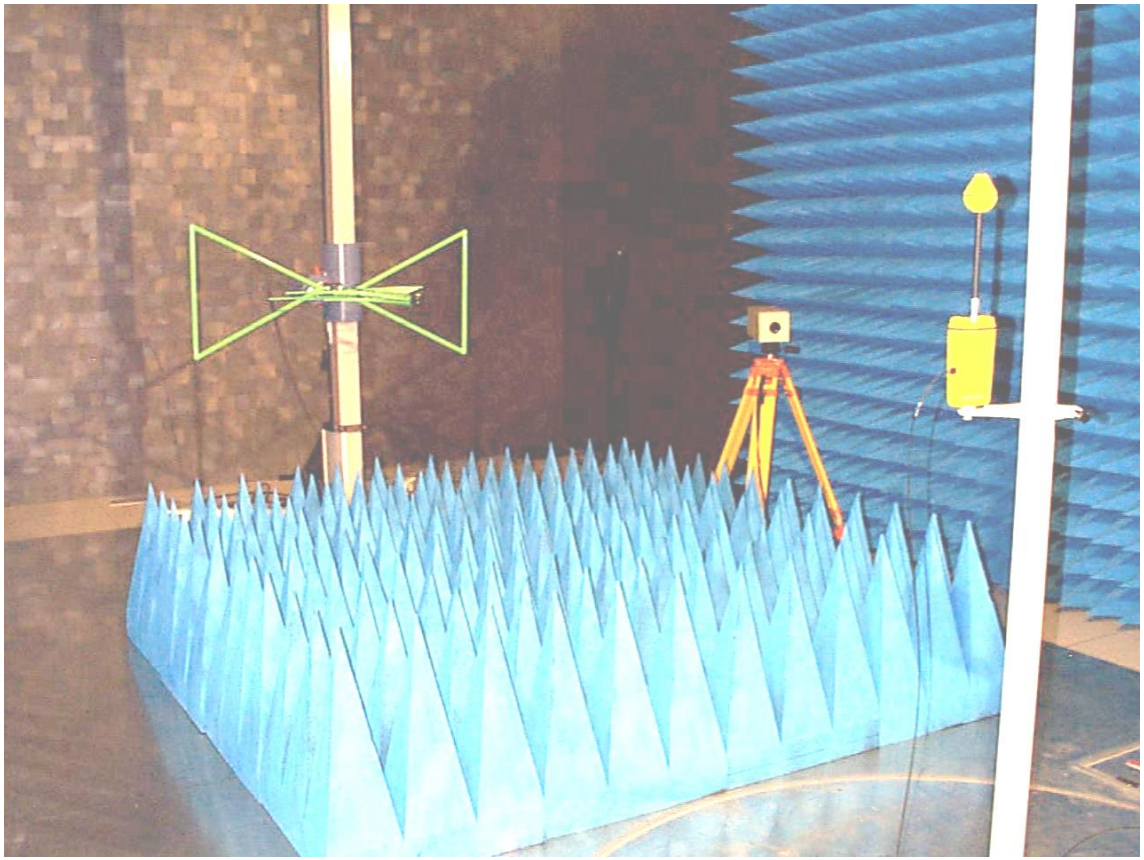
2. Anechoic room



FAC Belcomlab, Oostende (B)

Radio-frequency Susceptibility

2. Anechoic room



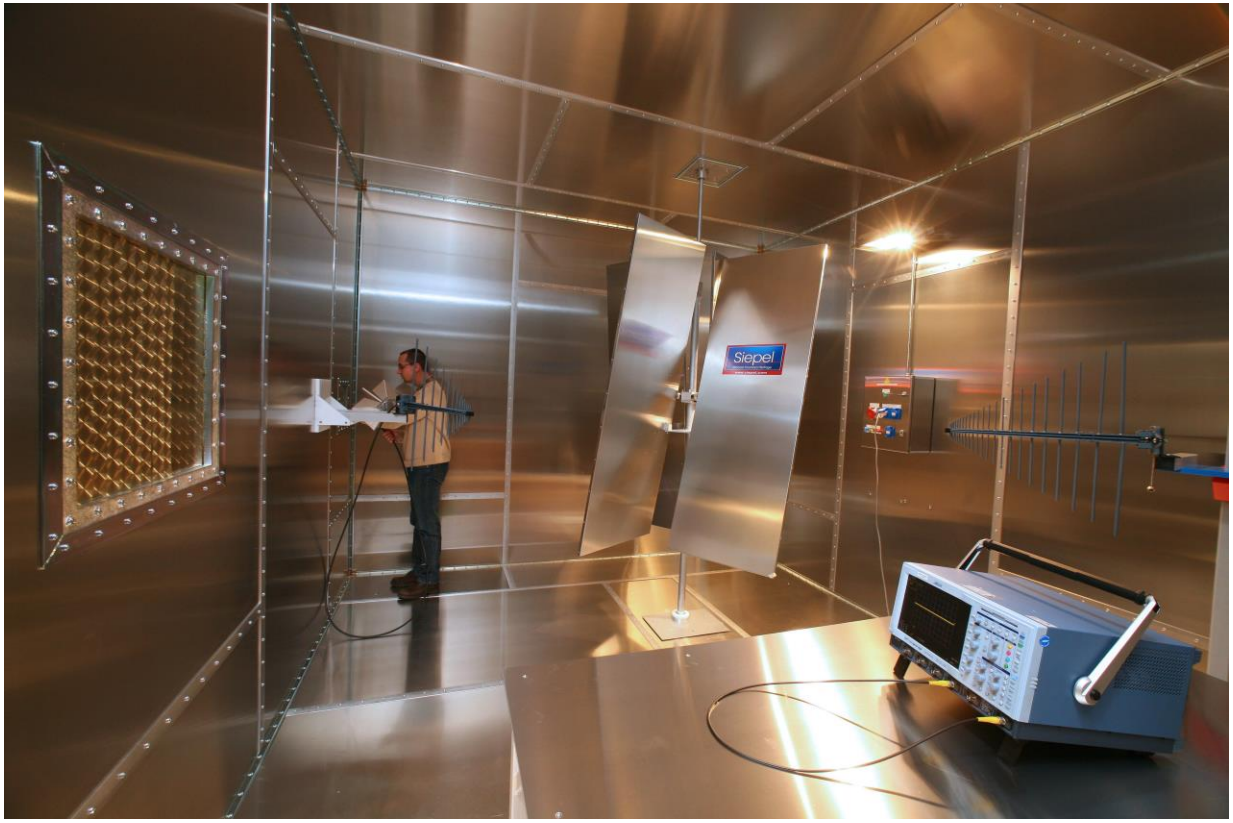
AC ULG, Liège (B)

2. Alternate solutions – Reverberating Chamber

- A reverberating chamber (R.C.) is a metallic enclosure with high conductivity walls (Faraday room) completely isolated from external EM world (except by the connections).
- This enclosure is equipped with a rotating structure, panels, called a stirrer.
- No absorbing material (anechoic room), to maximise reverberations.
- Properties:
  - Statistical E field uniformity in a defined volume,
  - E field level is high, even with a low injected power (reverberations).

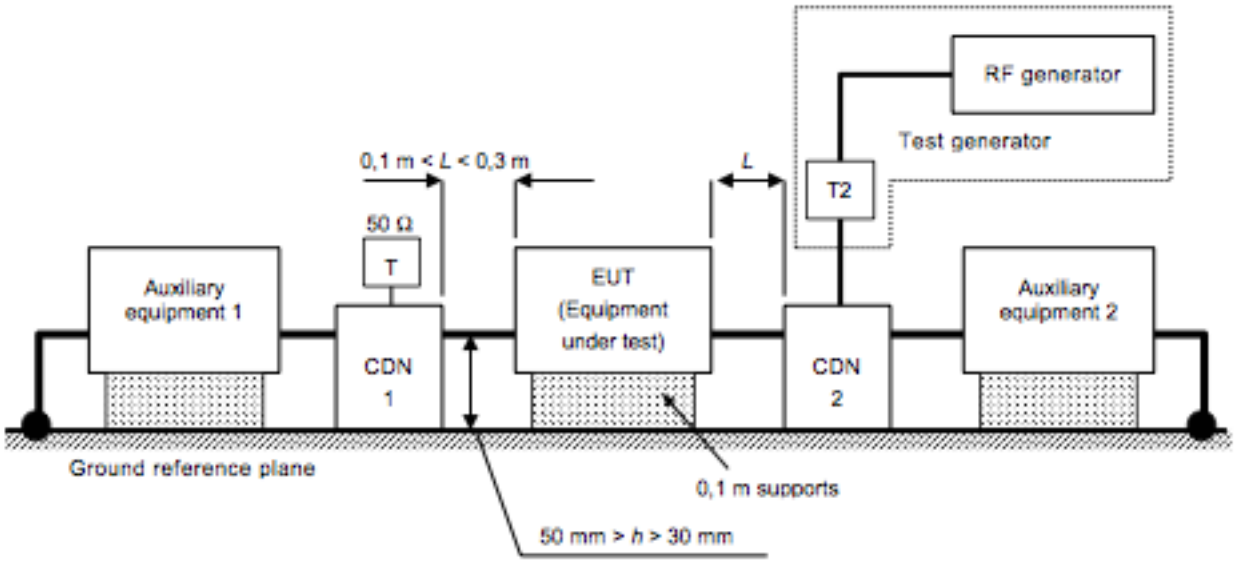
Radio-frequency Susceptibility

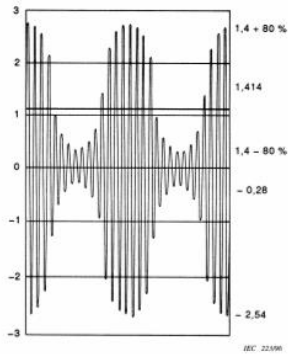
2. Alternate solutions – Reverberating Chamber



Radio-frequency Susceptibility

3. Test methods – RF conducted susceptibility

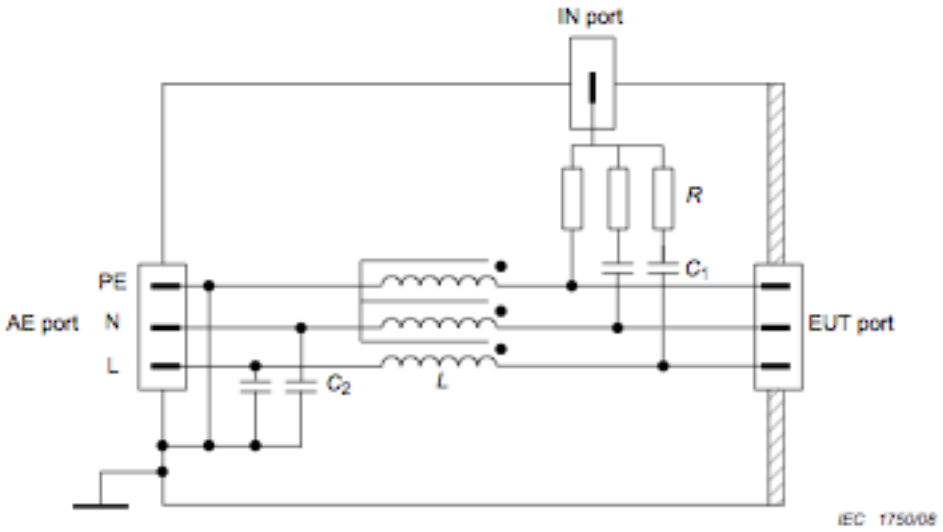




CEI / EN 61000-4-6
3 or 10V
150k-80MHz (230MHz)
80% AM 1kHz

Radio-frequency Susceptibility

3. Test methods – RF conducted susceptibility



CDN-M3, C_1 (typ) = 10 nF, C_2 (typ) = 47 nF, R = 300 Ω, L ≥ 280 µH at 150 kHz
CDN-M2, C_1 (typ) = 10 nF, C_2 (typ) = 47 nF, R = 200 Ω, L ≥ 280 µH at 150 kHz
CDN-M1, C_1 (typ) = 22 nF, C_2 (typ) = 47 nF, R = 100 Ω, L ≥ 280 µH at 150 kHz

Figure D.2 – Example of simplified diagram for the circuit of CDN-M1/-M2/-M3 used with unscreened supply (mains) lines (see 6.2.1.1)

3. Test methods – RF conducted susceptibility

Radio-frequency Susceptibility

3. Test methods – RF radiated susceptibility - AC

CEI/EN 61000-4-3
3 or 10V/m
80M-2.7GHz (step 1%)
80% AM 1kHz

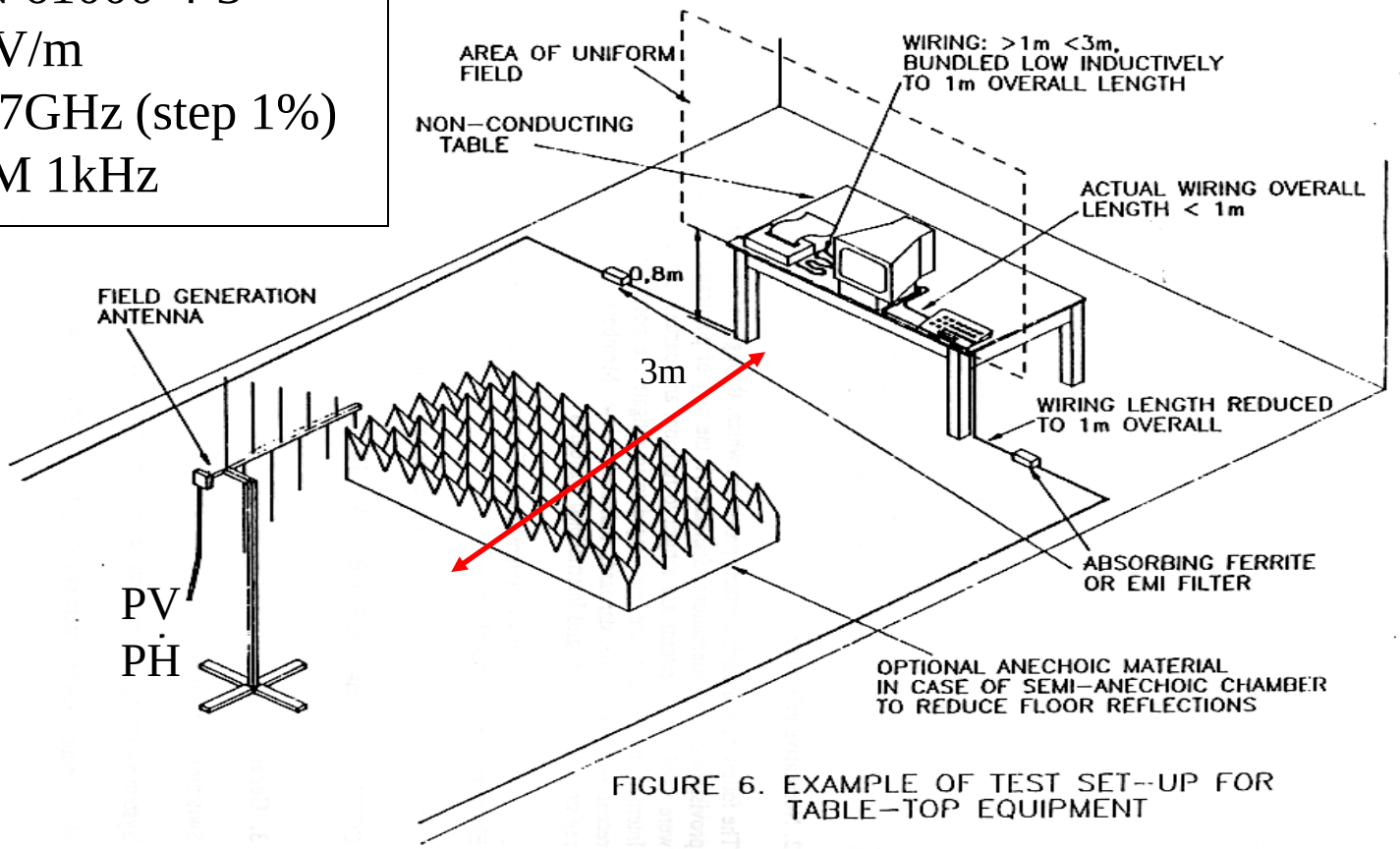


FIGURE 6. EXAMPLE OF TEST SET–UP FOR TABLE–TOP EQUIPMENT

3. Test methods – Electrostatic discharges

- Electrostatic discharges with ESD gun, generator, and different tips according CEI/EN 61000-4-2
- Levels 1 to 4 and X according the environment
- By contact @ **2, 4, 6 or 8 kV**
- In air @ **2, 4, 8 and 15 kV**

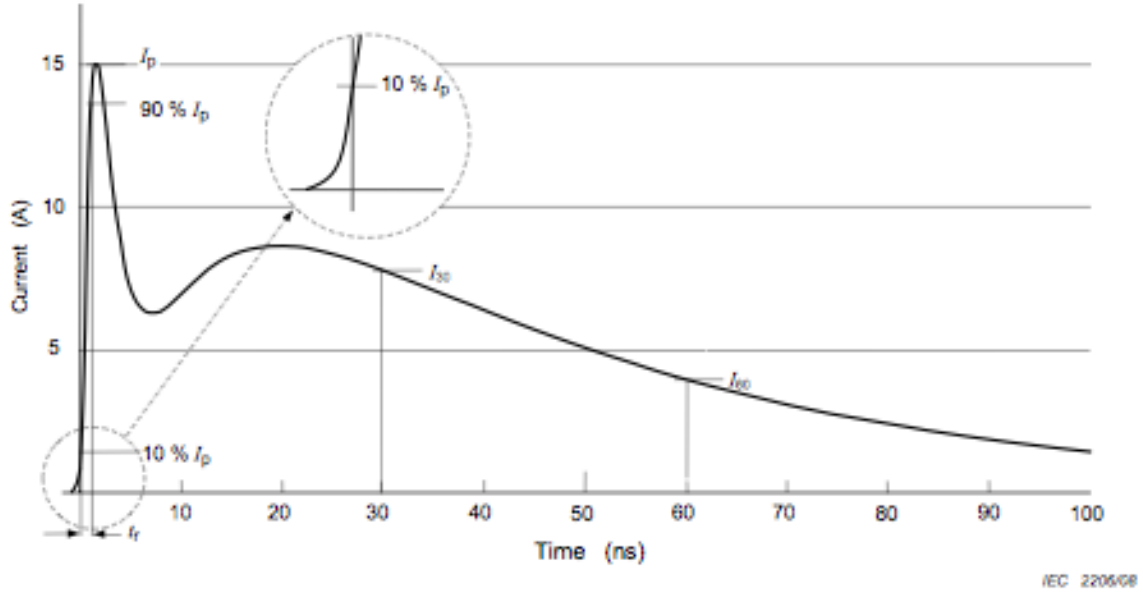
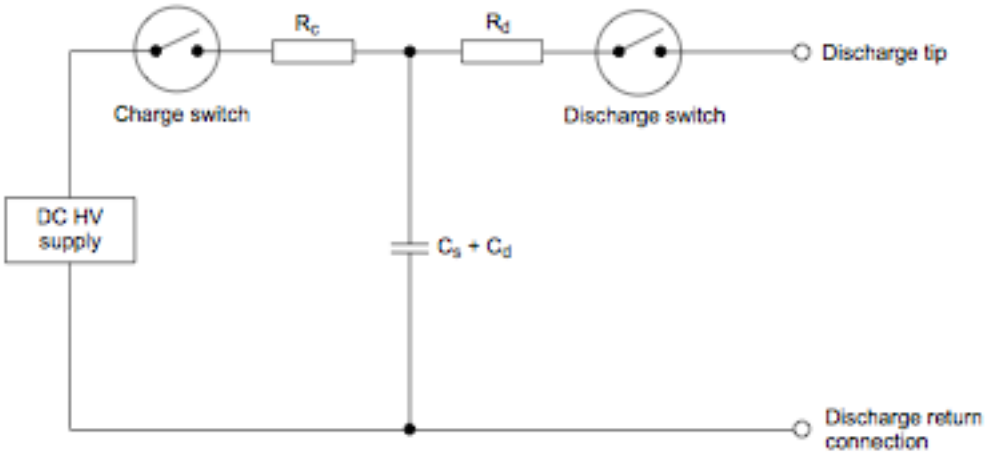


Figure 2 – Ideal contact discharge current waveform at 4 kV

Radio-frequency Susceptibility

3. Test methods – Electrostatic discharges



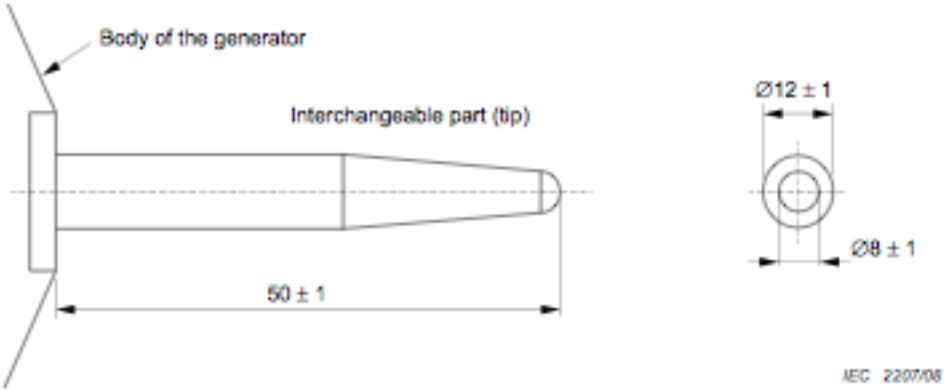
NOTE 1 C_d is a distributed capacitance which exists between the generator and its surroundings.

NOTE 2 $C_d + C_s$ has a typical value of 150 pF.

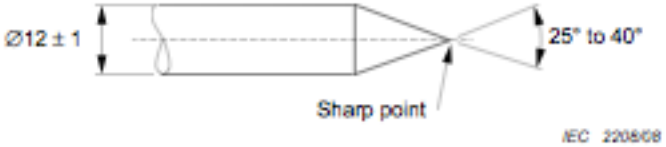
NOTE 3 R_d has a typical value of 330 Ω.

Figure 1 – Simplified diagram of the ESD generator

3. Test methods – Electrostatic discharges



3a) – Discharge electrode for air discharges

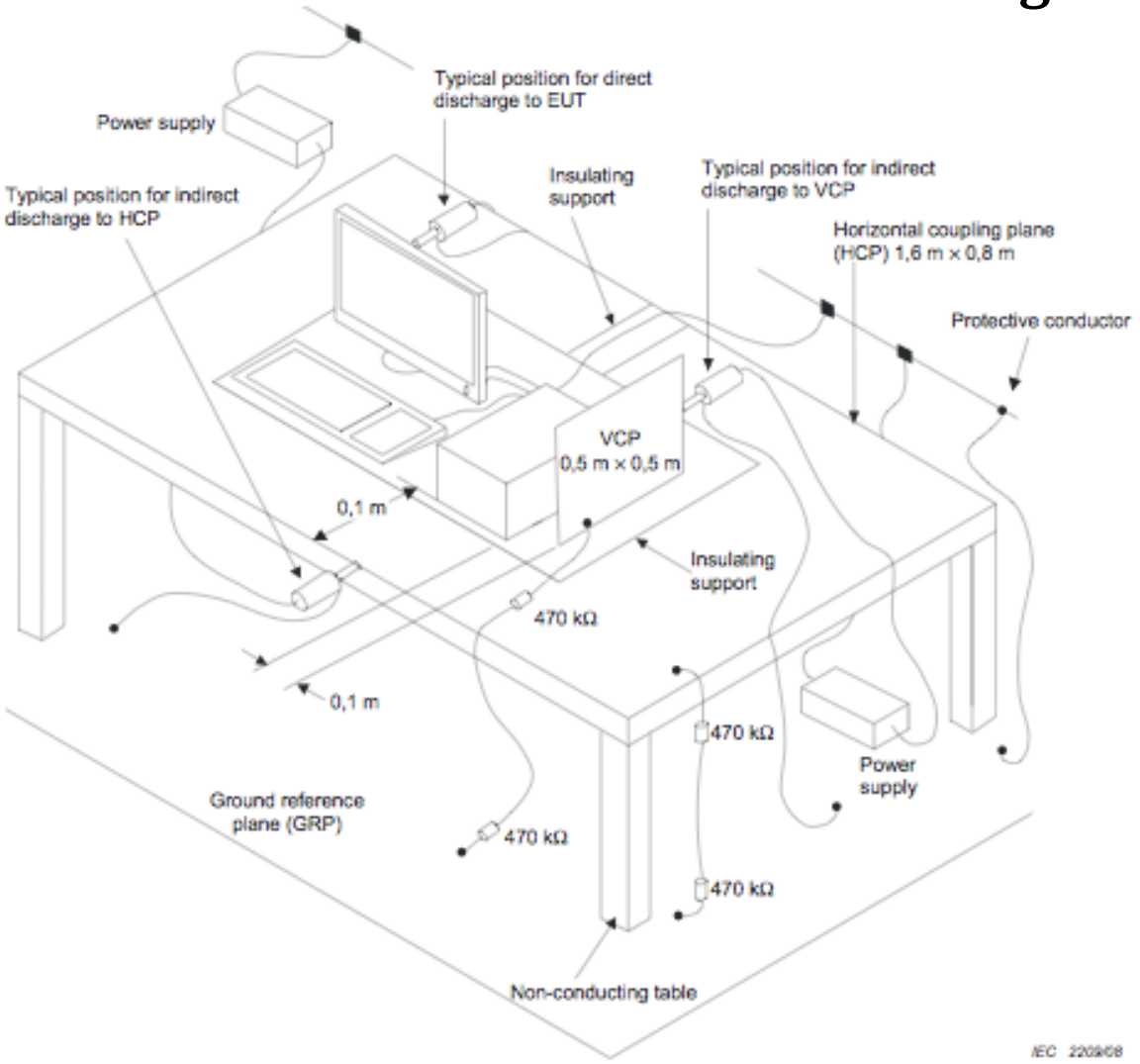


3b) – Discharge electrode for contact discharges

Figure 3 – Discharge electrodes of the ESD generator

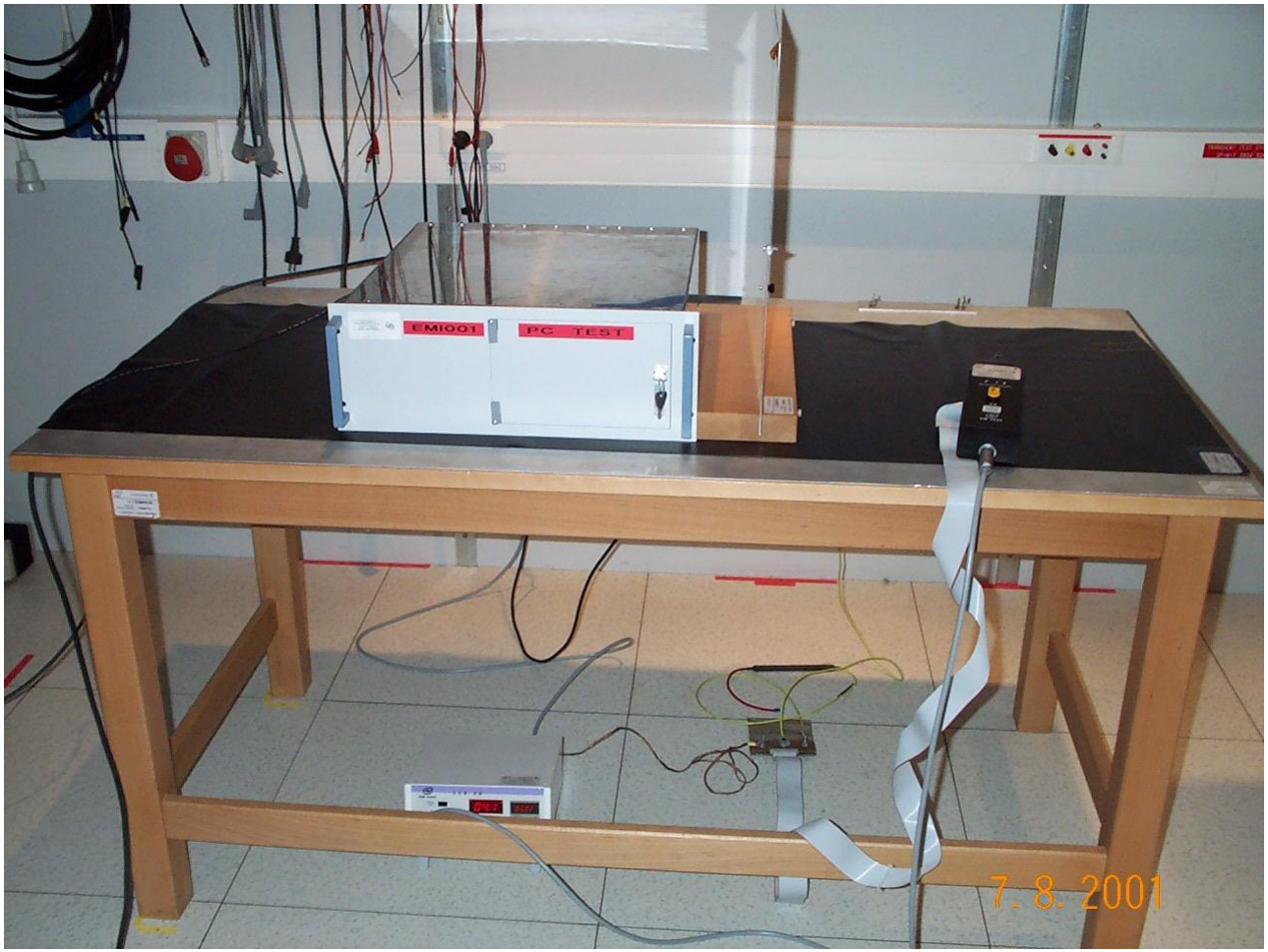
Radio-frequency Susceptibility

3. Test methods – Electrostatic discharges



Radio-frequency Susceptibility

3. Test methods – Electrostatic discharges

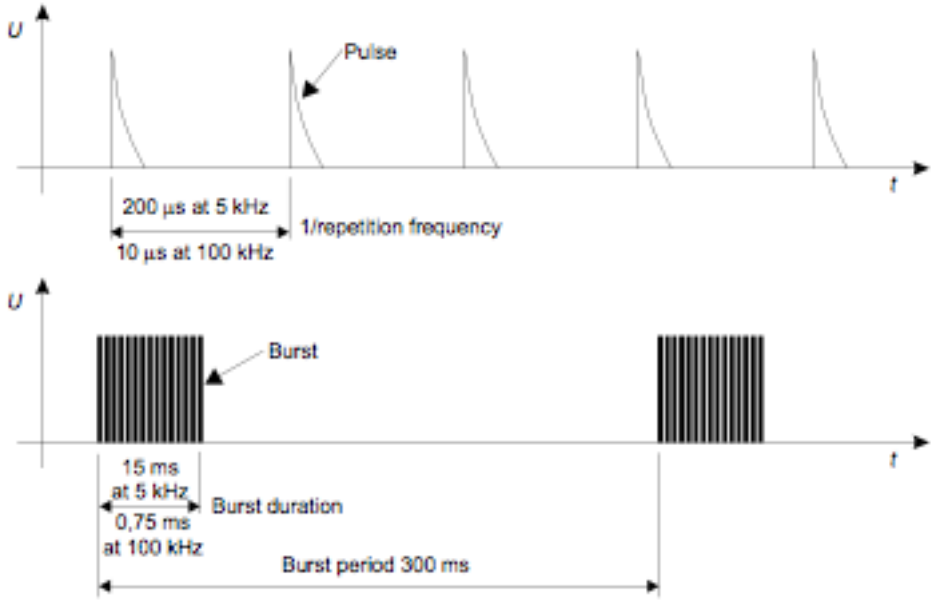


Susceptibility to Transients

3. Test methods – Burst

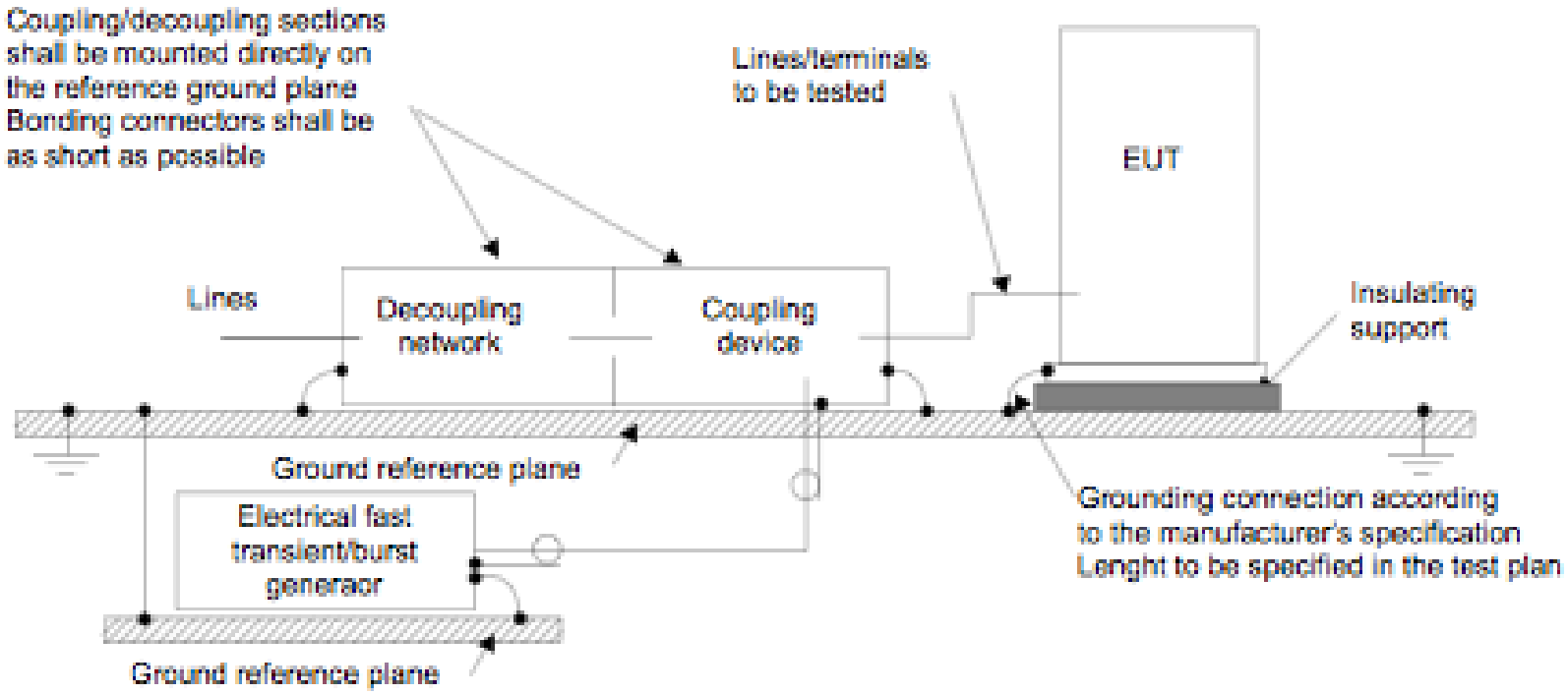
CEI/EN 61000-4-4

- Electrical Fast Transient (disconnection of inductive loads)
- Applicable to all ports (AC & DC power ports, signals and control ports – length > 3 m)
- Positive and negative polarities
- Voltage from 250 V to 4 kV with a repetition frequency @5/100kHz



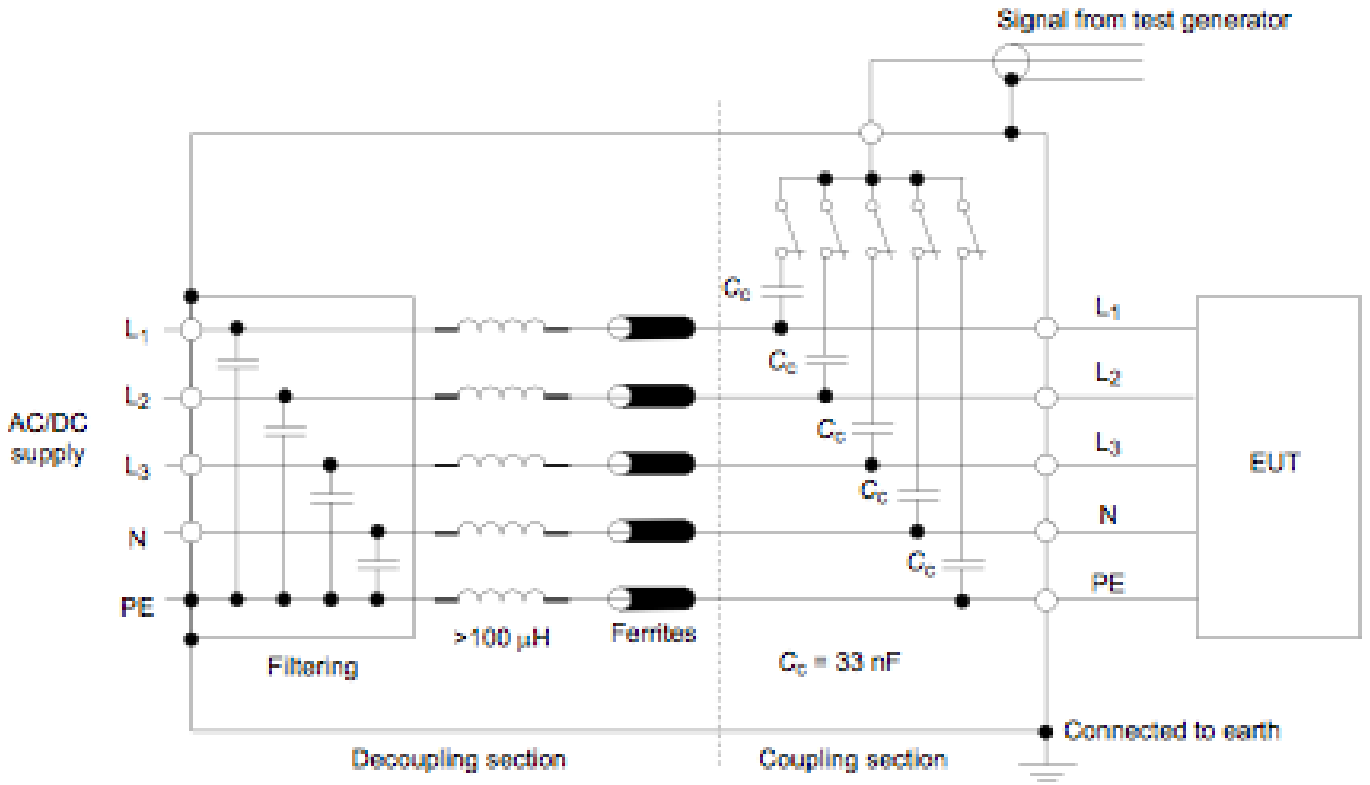
Susceptibility to Transients

3. Test methods – Burst

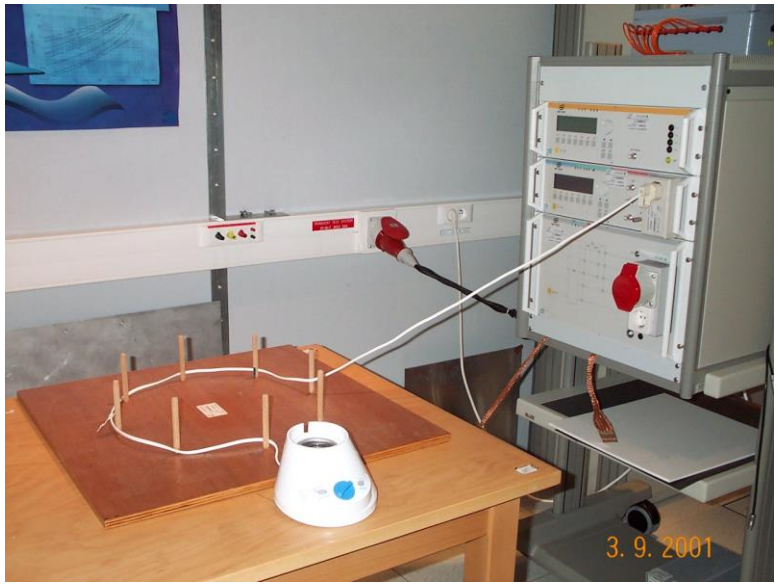


Susceptibility to Transients

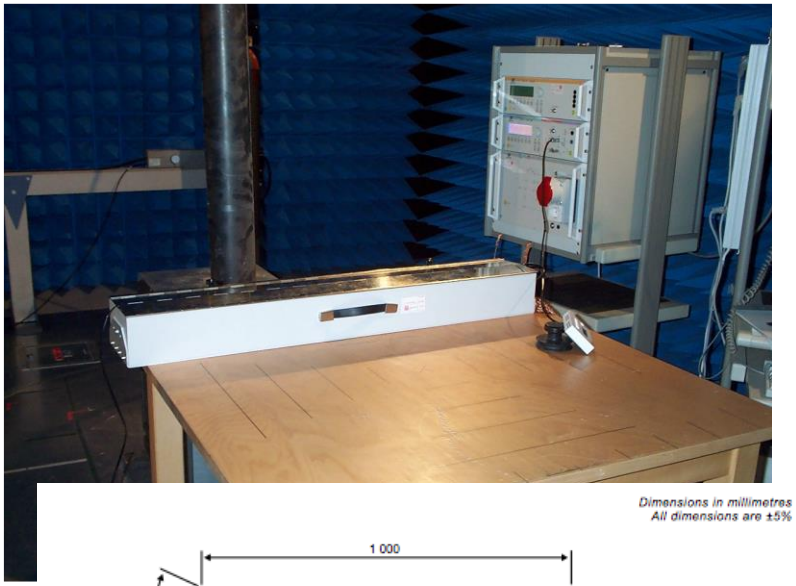
3. Test methods – Burst

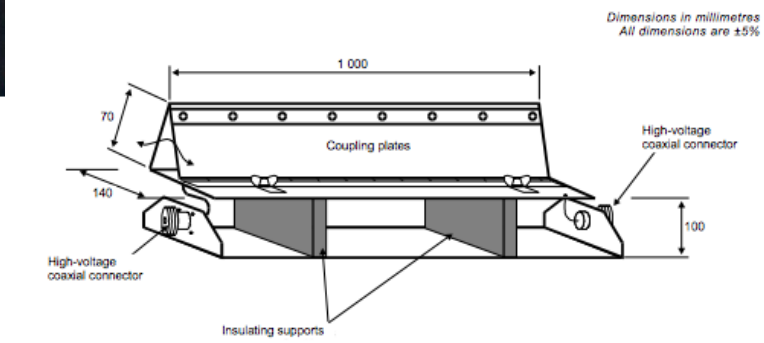


Coupling with a Coupling-Decoupling Network CDN (33nF)



Coupling with a capacitive clamp



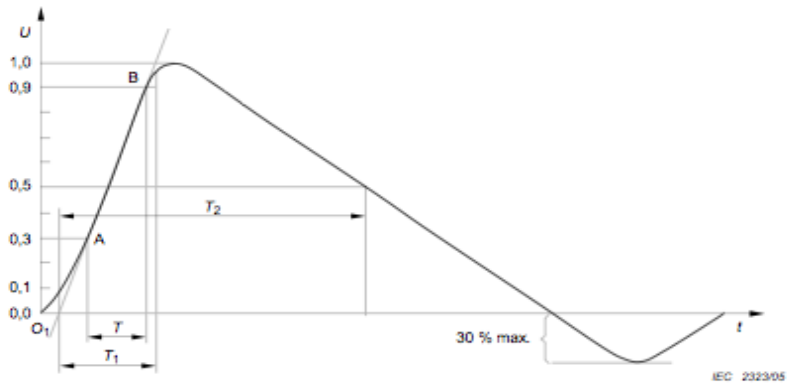


Susceptibility to Transients

3. Test methods – Surge

CEI / EN 61000-4-5

- Surge wave
- Common and differential modes
- Positive and negative polarities, once per minute
- Open circuit 1.2/50µs @ 0.5 to 4 kV (0.5 – 1 - 2 – 4)
- Short circuit 8/20µs @ 0.25 to 2kA (0.25 – 0.5 – 1 - 2)
- Coupling with coupling-decoupling networks, capacitors…



Durée du front: $T_1 = 1{,}67 \times T = 1{,}2\ \mu s \pm 30\ \%$

Durée jusqu'à la mi-valeur: $T_2 = 50\ \mu s \pm 20\ \%$

Susceptibility to Transients
3. Test methods – Surge
CEI/EN 61000-4-5 (differential mode)

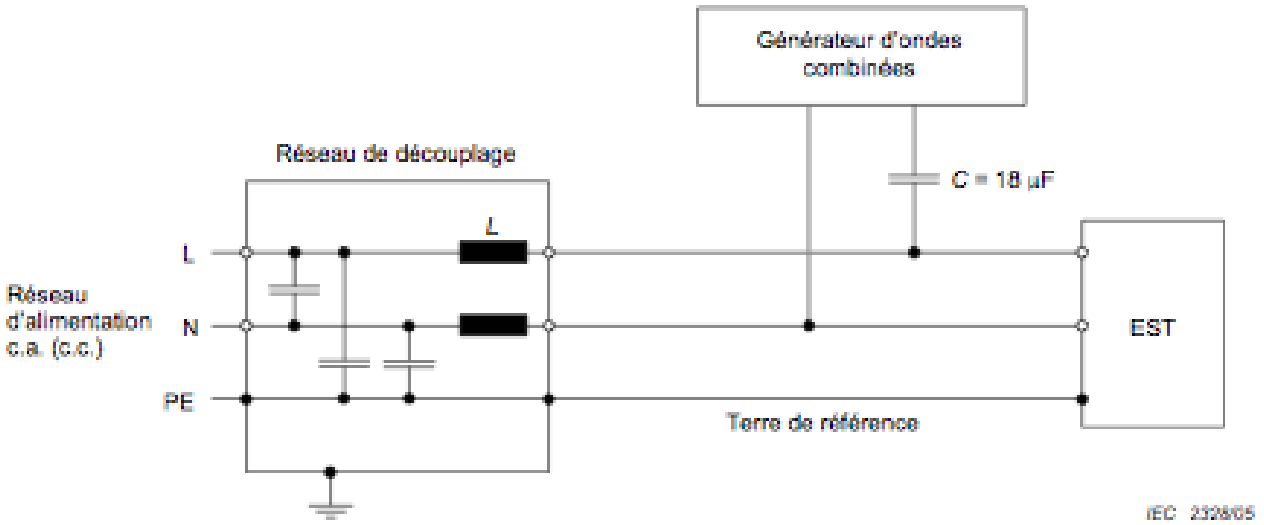


Figure 7 – Exemple de montage d'essai de ligne à couplage capacitif sur lignes à c.a./c.c.; couplage entre fils (conformément à 7.2)

Susceptibility to Transients
3. Test methods – Surge
CEI/EN 61000-4-5 (common mode)

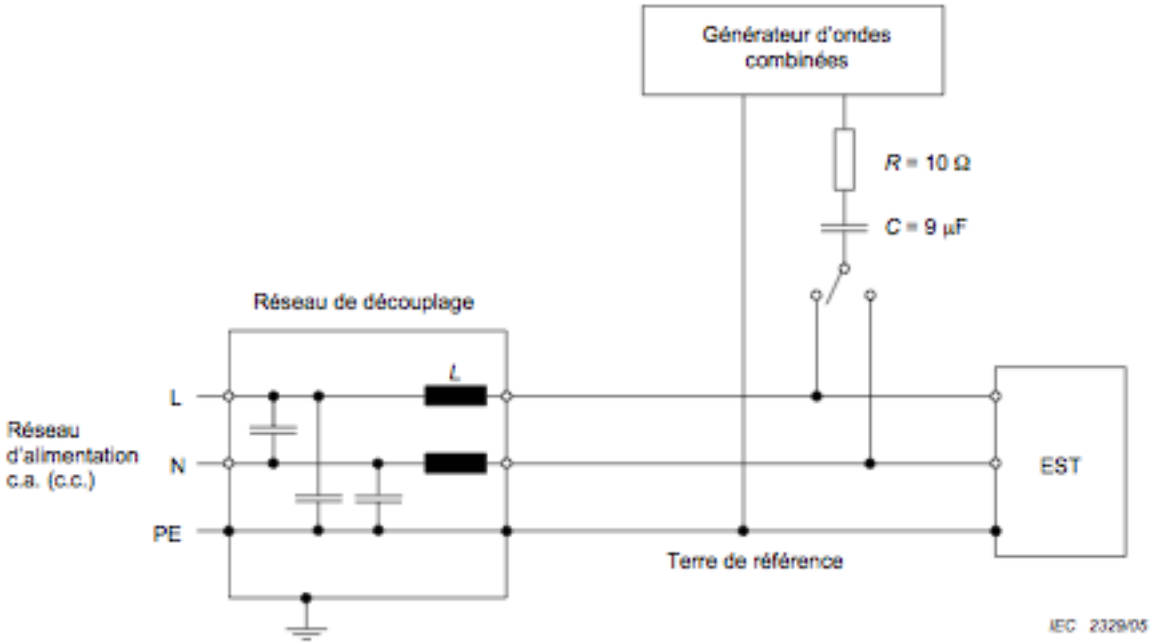


Figure 8 – Exemple de montage d'essai de ligne à couplage capacitif sur lignes à c.a./c.c.; couplage entre un fil et la terre (conformément à 7.2)

Low Frequency Susceptibility
3. Test methods – 50 Hz magnetic field

- CEI/EN 61000-4-8

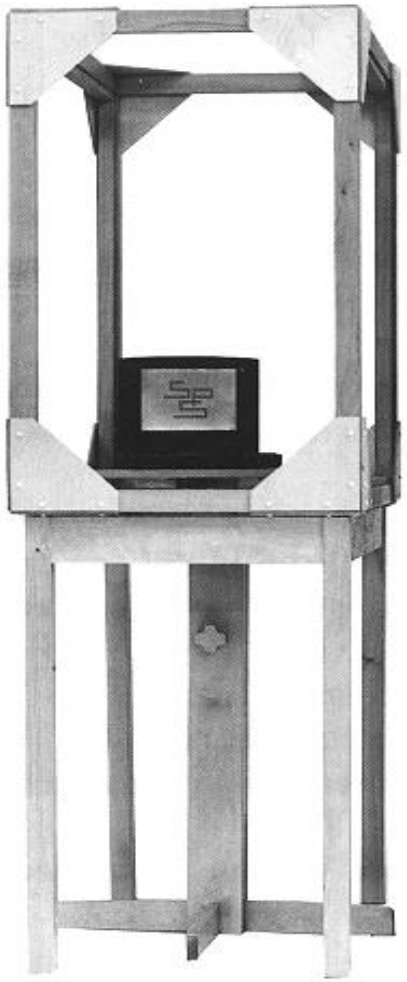
-Environments:

  - Residential and commercial
  - Industrial and Power plants

- 50 / 60 Hz magnetic field – permanent - Levels: 1 to 100 A/m (1A/m = 1.26µT)

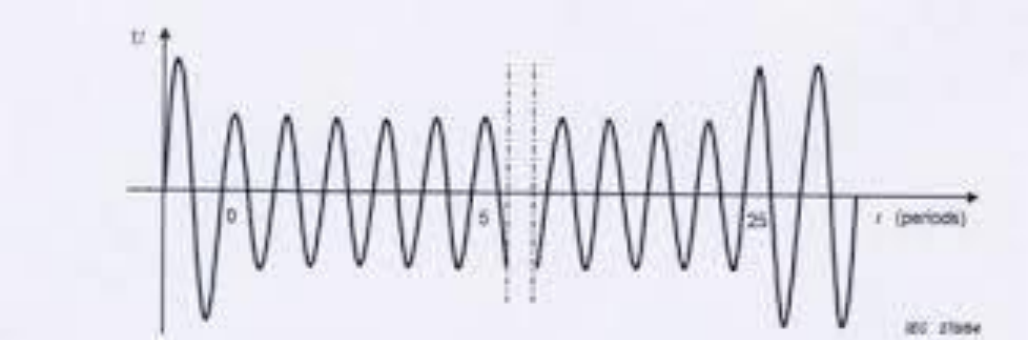
-50 / 60 Hz magnetic field – short duration (1 to 3s) – Levels: 300 to 1000 A/m

-Method: 50 / 60 Hz current circulating in a coil (or 3 – 3 axis). Immersion or influence methods.



Low Frequency Susceptibility
3. Test methods – Dips/Interruption/Variation
CEI/EN 61000-4-11

- Dips, short interruptions and variations: applicable to all equipment connected to the low voltage power mains (up to 16A/phase)
- Dips (40 or 70% of Un during a half period or some periods)
- Short interruptions (0% of Un during a period less than 1 minute)
- Voltage variations



NOTE The voltage decreases to 70 % for 25 periods. Step at zero crossing

Figure 1a) – Voltage dip – 70 % voltage dip sine wave graph

Susceptibility – EUT monitoring

- It is required to monitor the EUT behaviour during the susceptibility tests.
- Performance criteria (A, B, C, D)
- Parameters monitoring:
  - BER
  - Voltage - Voltmeter
  - Scope
  - Luxmetre
  - Observing (camera)
  - …