



ITU Training on Conformance and Interoperability for AFR Regions



CERT, 28 October – 1st November 2013, Tunis

EMC fundamentals

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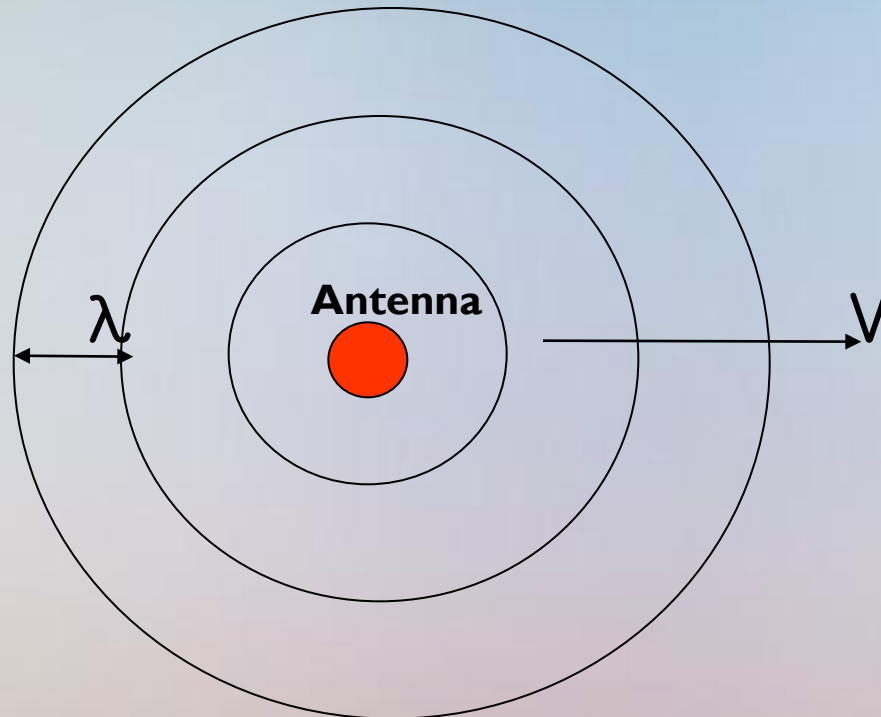
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Basics of electromagnetics

A wave is a moving vibration



$$\lambda \text{ (m)} = c \text{ (m/s)} / F \text{ (Hz)}$$

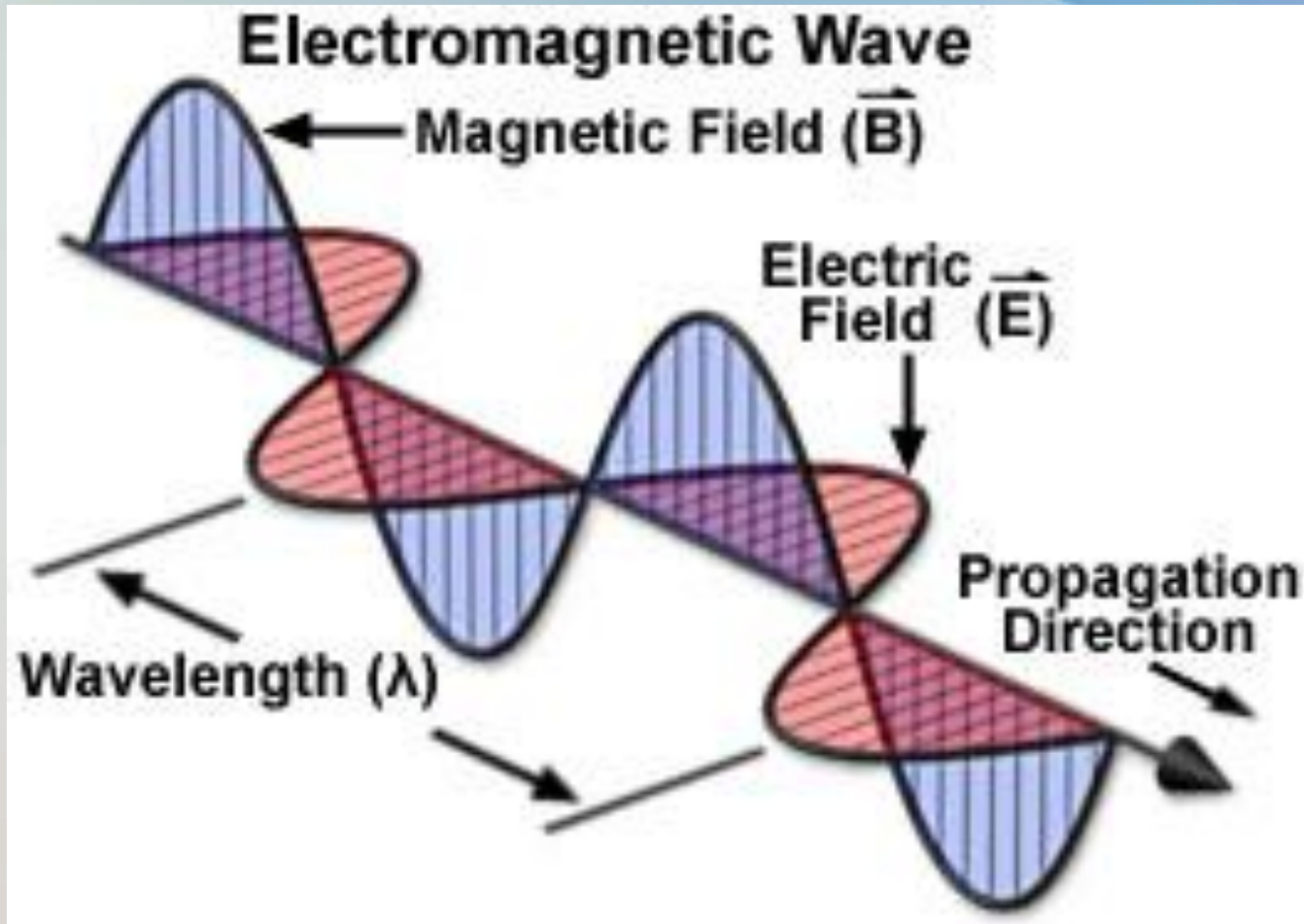


Definitions



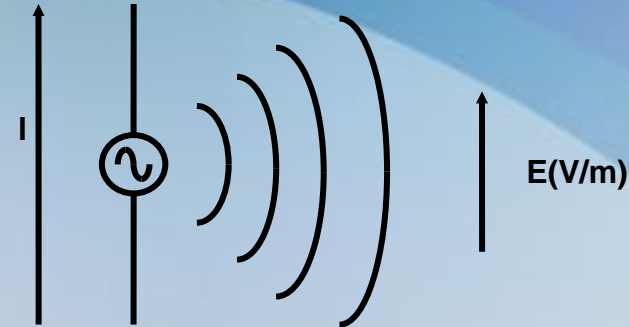
- The wavelength is the distance traveled by a wave in an oscillation cycle
- Frequency is measured by the number of cycles per second and the unit is Hz . One cycle per second is one Hertz.

- An electromagnetic wave consists of:
 - ✓ an electric field E (produced by the force of electric charges)
 - ✓ a magnetic field H (produced by the movement of electric charges)
- The fields E and H are orthogonal and are moving at the speed of light
 $c = 3 \cdot 10^8 \text{ m/s}$



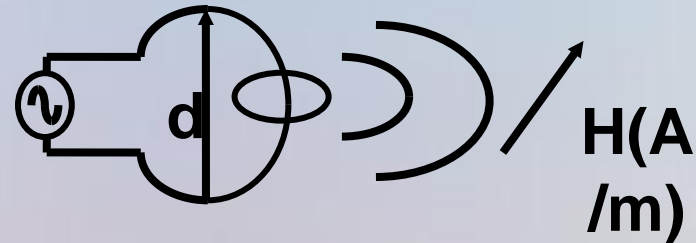
Electric field

The field amplitude is expressed in (V/m).



Magnetic field

The field amplitude is expressed in (A/m).

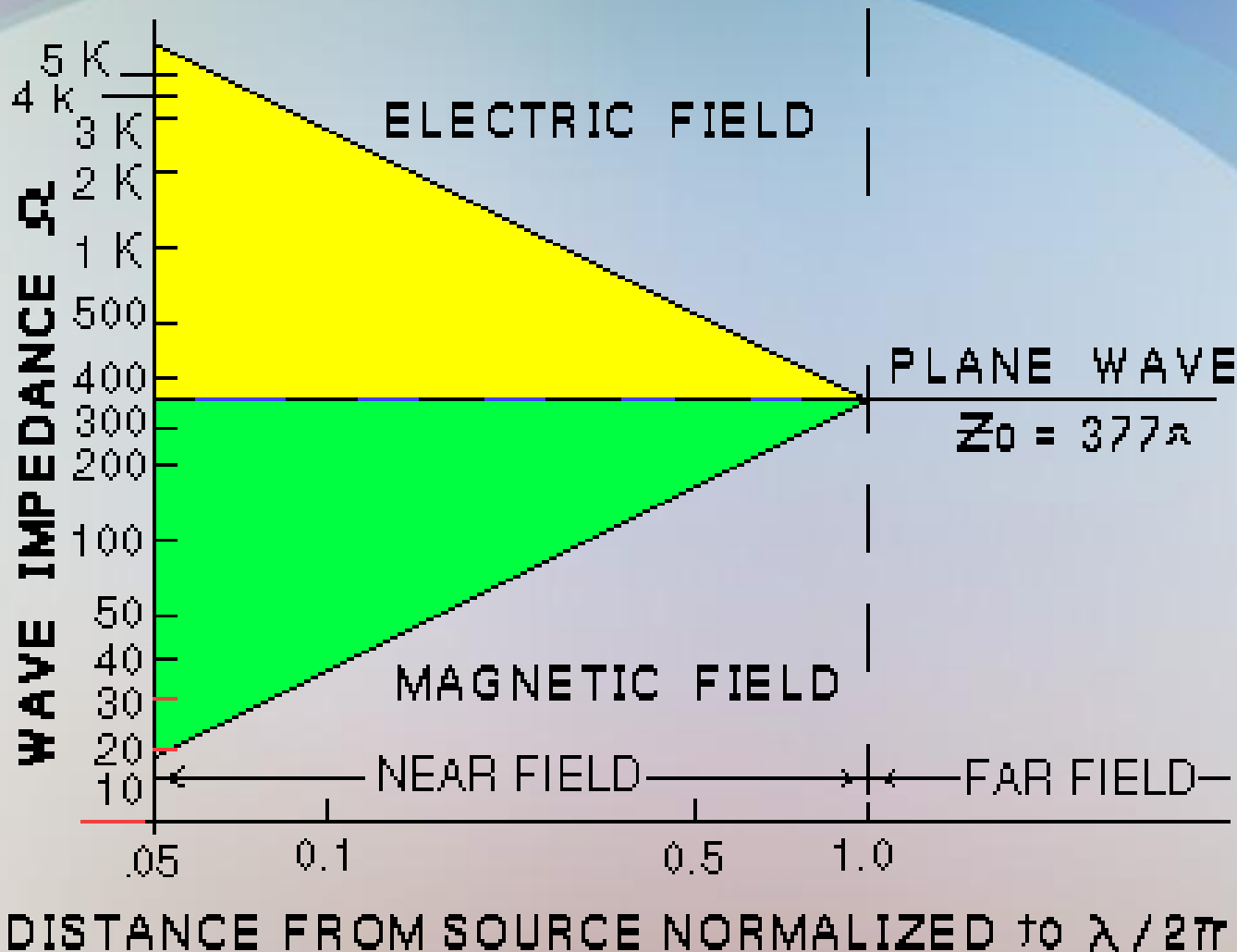


Power density

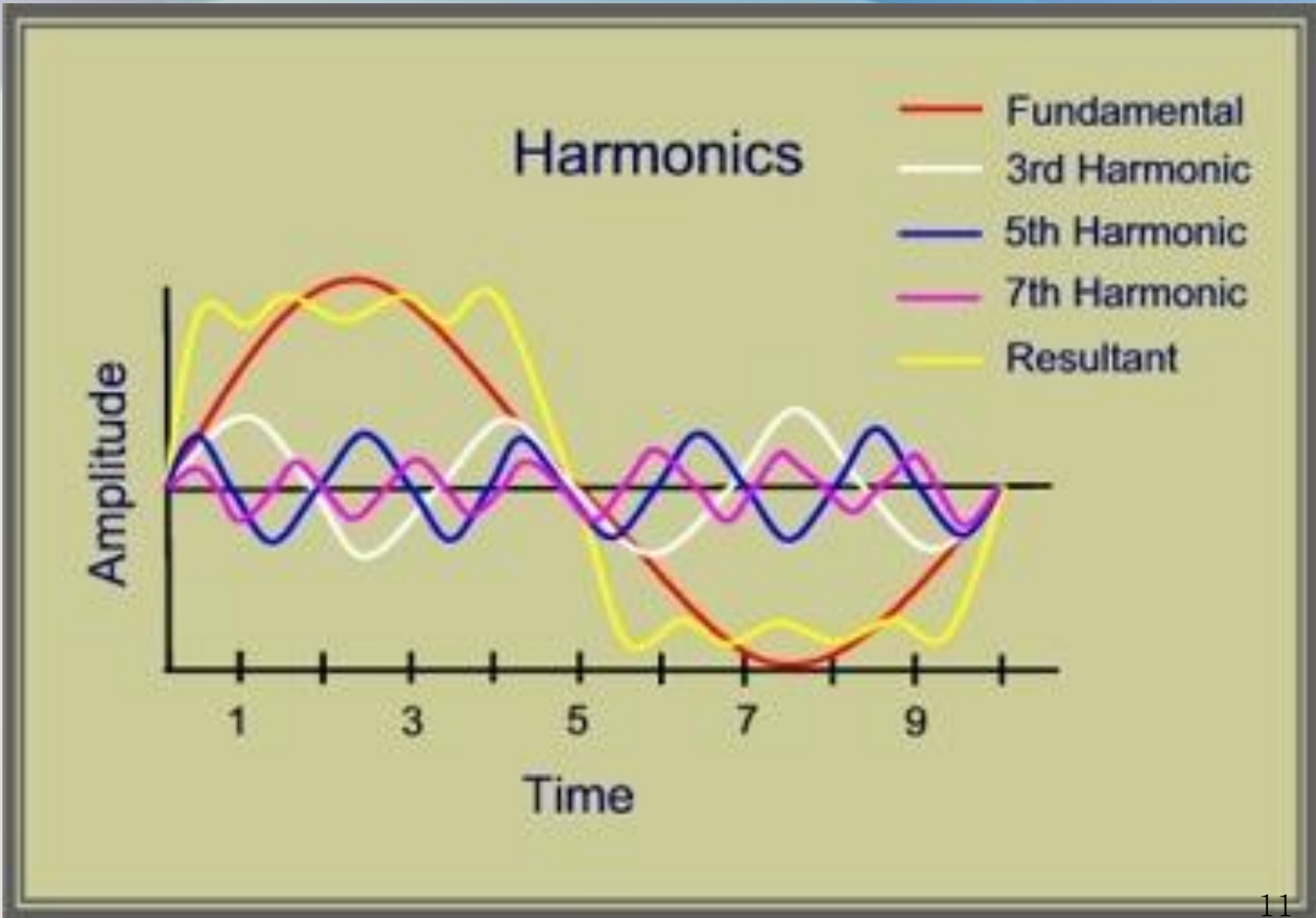
Radiated power is perpendicular to a surface, divided by the area of the surface. The power density is expressed as S (W / m^2), or (mW / cm^2), or ($\mu W / cm^2$).

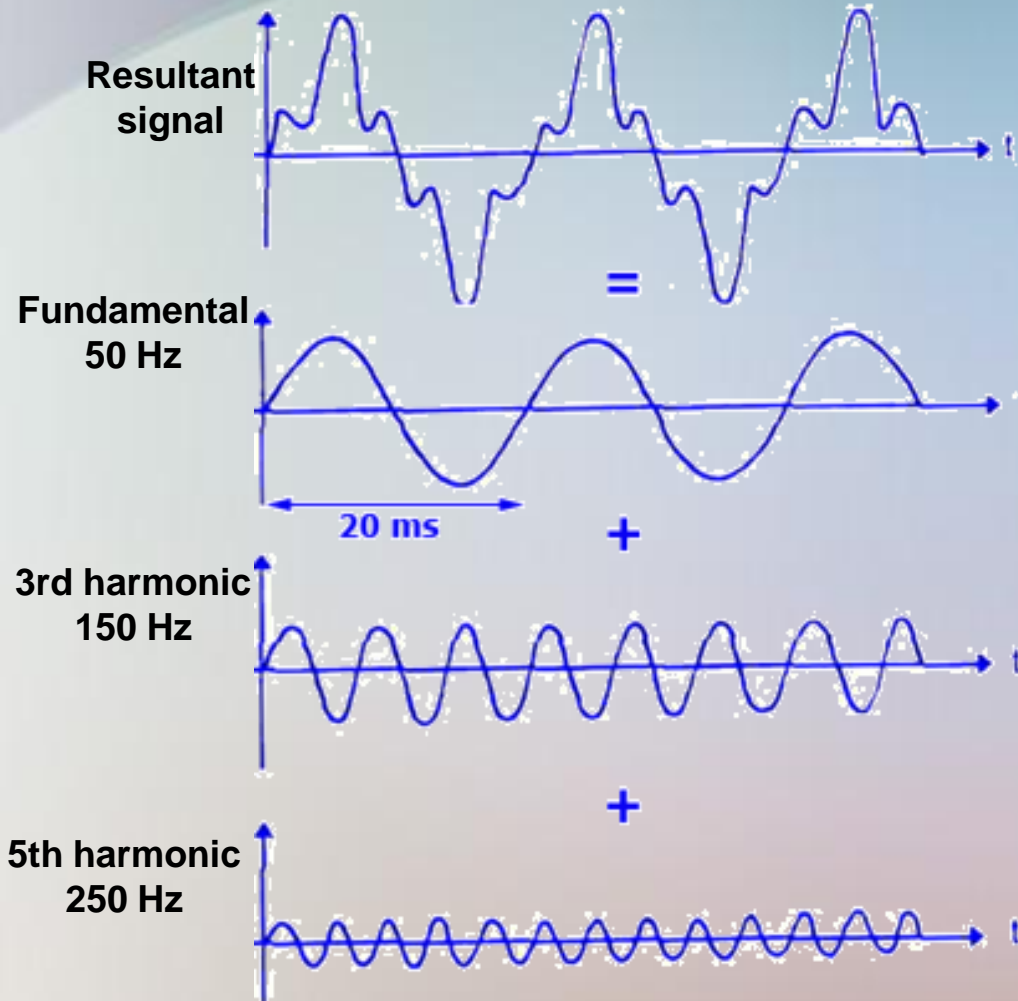
- Near a whip, the dominant field is the E field. The impedance in this area is $Z_c > 377$ ohms.
- Near a loop, the dominant field is the H field. The impedance in this area is $Z_c < 377$ ohms.

Plane wave

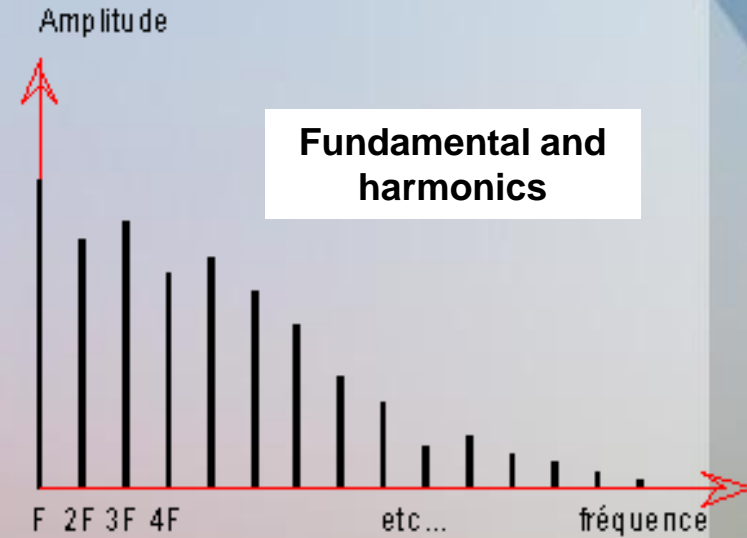


<i>Electrical domain</i>	<i>Electromagnetic domain</i>
Voltage V (Volt)	Electric Field E (V/m)
Current I (Amp)	Magnetic field H (A/m)
Impedance Z (Ohm)	Characteristic impedance Z ₀ (Ohm)
$Z=V/I$	$Z=E/H$
$P=I^2 \times R$ (watts)	$P=H^2 \times 377$ (watts/m ²) <i>far field conditions</i>





Time domain



Frequency domain

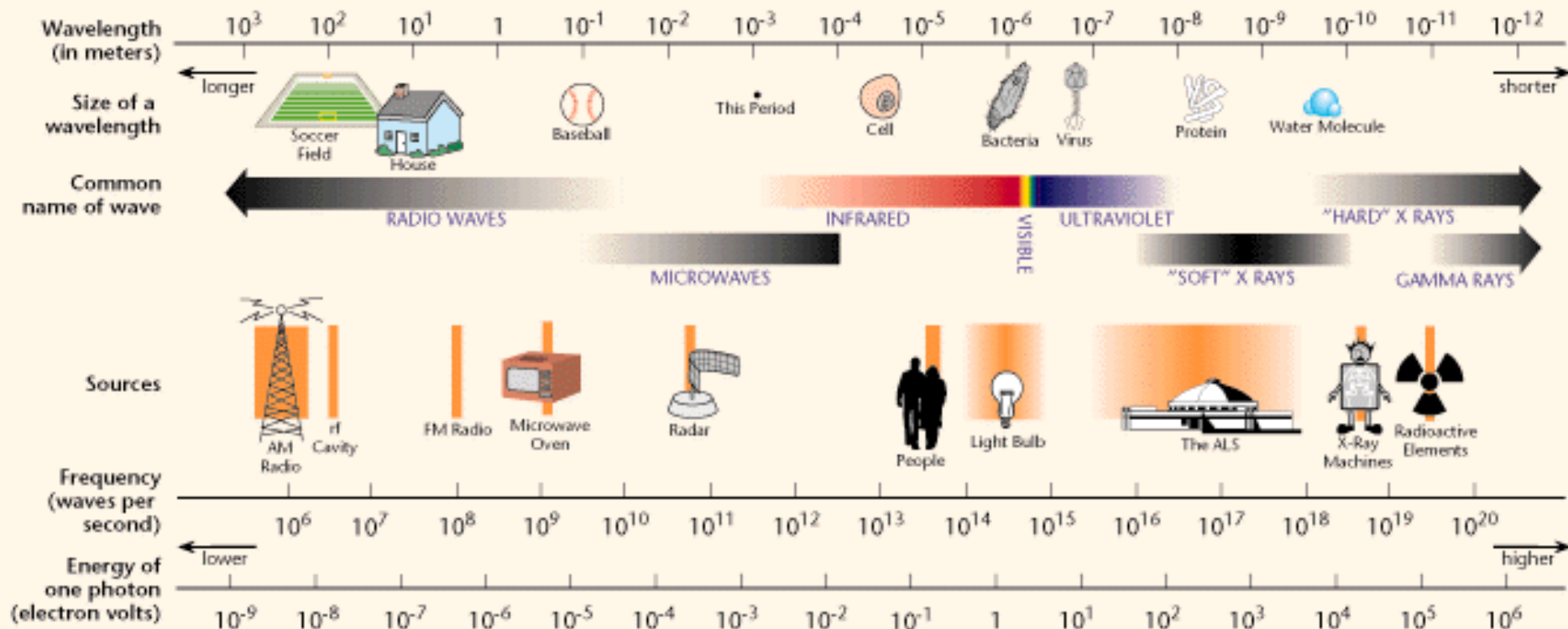
Why in frequency domain (Hz) ?

- Time domain aspect is dominated by the major frequency harmonics
- Distinguish contributions of each harmonics, even small ones

Why in logarithm scale (dB) ?

- Signals are composed of high and low amplitude harmonics
- Very large dynamic (from μV to several mV)
- Logarithm scale is requested

THE ELECTROMAGNETIC SPECTRUM



Frequency	Wavelength	Metric designation	Current designation	Abbreviations	
3 kHz à 30 kHz	100 km à 10 km	myriamétric waves	Very Low Frequencies	VLF	O.Mm
30 kHz à 300 kHz	10 km à 1 km	kilometric waves	Low Frequencies	LF	O.km
300 kHz à 3 MHz	1 km à 100 m	Hectometric waves	Mid Frequencies	MF	O.hm
3 MHz à 30 MHz	100 m à 10 m	Decamétric waves	High Frequencies	HF	O.dam
30 MHz à 300 MHz	10 m à 1 m	metric waves	Very High Frequencies	VHF	O.m
300 MHz à 3 GHz	1 m à 10 cm	décimetric waves	Ultra High Frequencies	UHF	O.dm
3 GHz à 30 GHz	10 cm à 1 cm	Centimetric waves	HyperFrequencies	SHF	O.cm
30 GHz à 300 GHz	1 cm à 1 mm	Millimetric waves		EHF	O.mm

- In an isotropic and homogenous area, wave propagation is modeled by Maxwell equations:

$$\text{rot } H = E(\sigma - j\omega_0\varepsilon)$$

$$\text{div } \varepsilon E = \rho$$

$$\text{rot } E = j\omega_0\mu H$$

$$\text{div } \mu H = 0$$

H (A/m), Magnetic field

E (V/m), electric field

ε (F/m), Dielectric constant (permittivity)

μ (H/m), magnetic permeability

σ (ohms⁻¹/m), conductivity

Grandeur	Symbol	Unit	Symbol
Frequency	f	Hertz	Hz
Wavelength	λ	Metre	m
Electric field	E	Volt per metre	V/m
Magnetic field	H	Ampere per metre	A/m
Magnetic flow density	B	Tesla	T
Power density	S	Watt per square metre	W/m ²
intrinsic impedance	Z	Ohm	Ω
Antenna's highest dimension	D	Metre	m

- At several wavelengths from the antenna, wave impedance is expressed as:

$$Z_0 = \frac{E}{H} = \sqrt{\frac{\mu}{\epsilon}}$$

Intrinsic impedance of the propagation environment (in ohms)

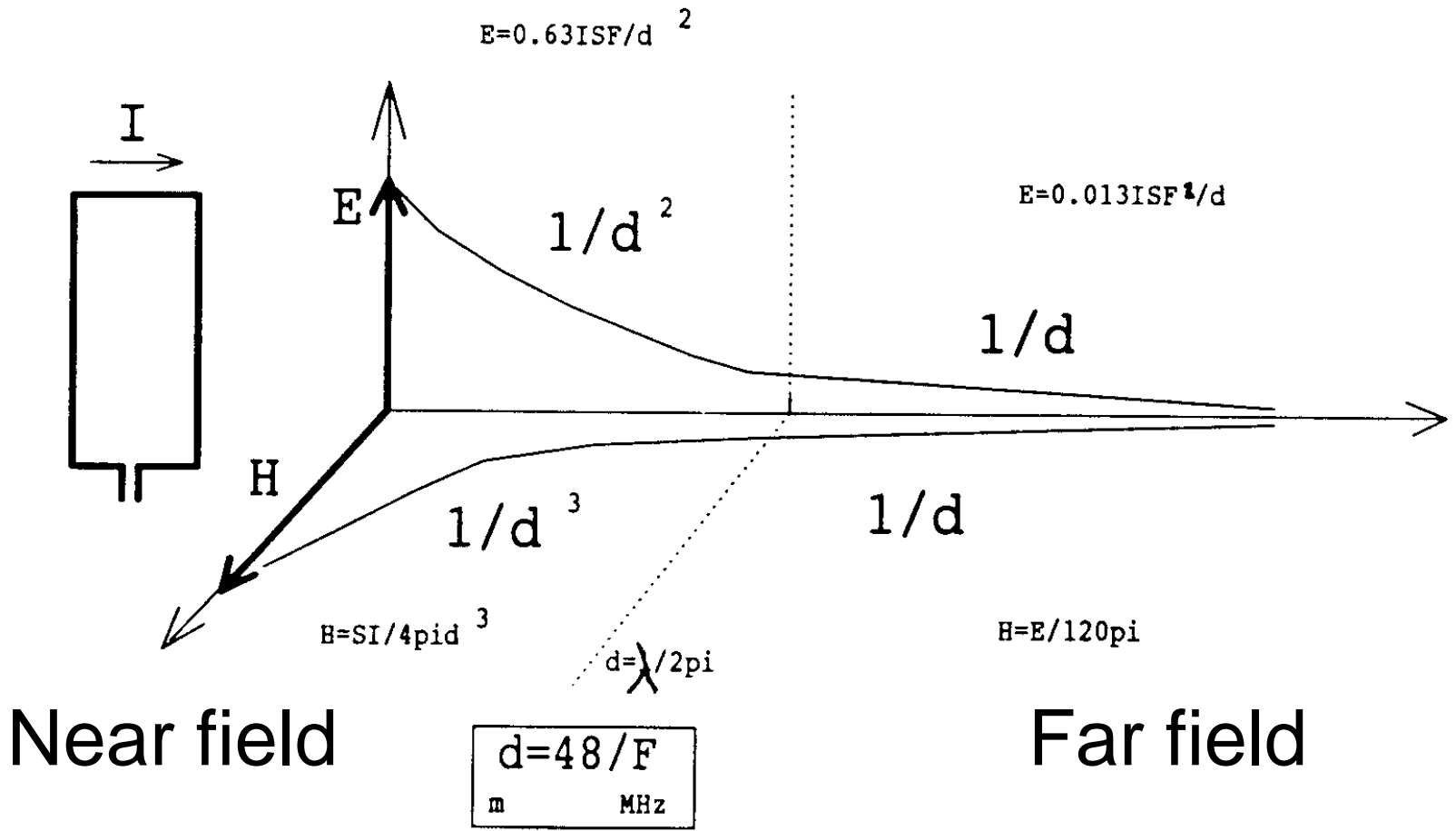
- For distances to the source below $\lambda / 2\pi$ we consider that we are in near field conditions.
Electric dipole: E varies as $1/r^3$, H varies as $1/r^2$, So Z varies as $1/r$.

At short distance from the dipole radiates mainly in E field .

- Magnetic dipole: E varies as $1/r^2$, $1/r^3$ H, Z varies as r

At short distance loop radiates mainly in H field .

- E and H decrease as $1/r$, $Z=Cte=377\Omega$
(empty environment impedance)
- The EM field has the characteristics of a plane wave
- For the majority of radio tests, only electric component is measured as the tests are carried out in far field conditions



- Radiated field (in V/m)

$$E = \frac{1}{d} \sqrt{30.P.G}$$

d: distance from the transmitter (in m)

P: power of the output transmitter in W

G: Antenna gain (in dB)

Voltage Units

Wide dynamic range of signals in EMC → use of dB (decibel)

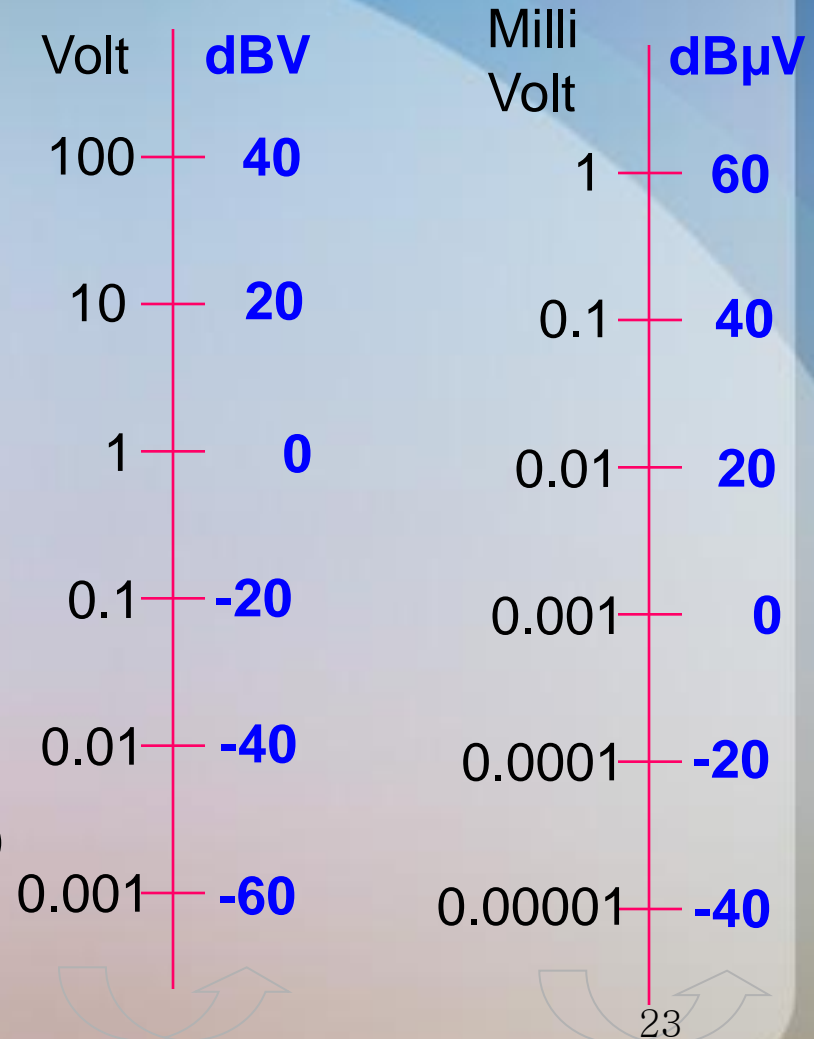
For example dBV, dBA :

$$dBV = 20 \times \log(V)$$

$$dBA = 20 \times \log(A)$$

Extensive use of **dB μ V**

$$V_{dB\mu V} = 20 \times \log\left(\frac{V}{1\mu V}\right) = 20 \times \log(V) + 120$$



Power Units

The most common power unit is the “**dBm**” (dB milli-Watt)

$$P_{dBmW} = 10 \times \log \left(\frac{P_W}{1mW} \right) = 10 \times \log(P_W) + 30$$

Exercise: Specific units

$$1 \text{ mV} = \text{ ____ } \text{ dB}\mu\text{V}$$

$$1 \text{ W} = \text{ ____ } \text{ dBm}$$

Power (Watt)	Power (dBm)
1 MW	90
1 KW	60
1 W	30
1 mW	0
1 μ W	-30
1 nW	-60



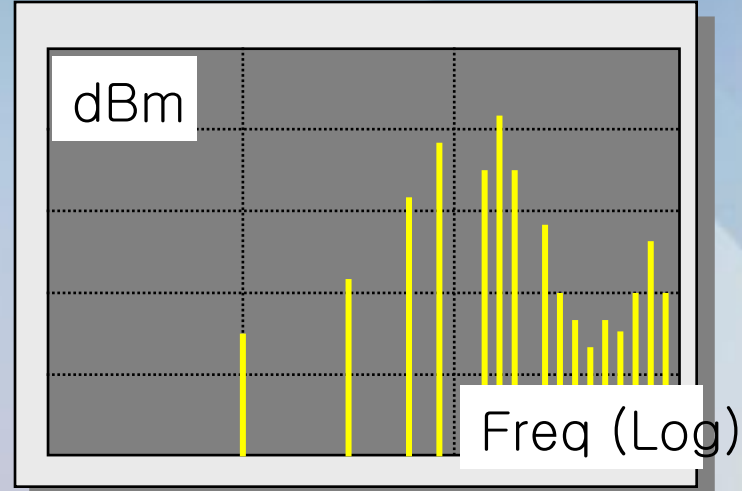
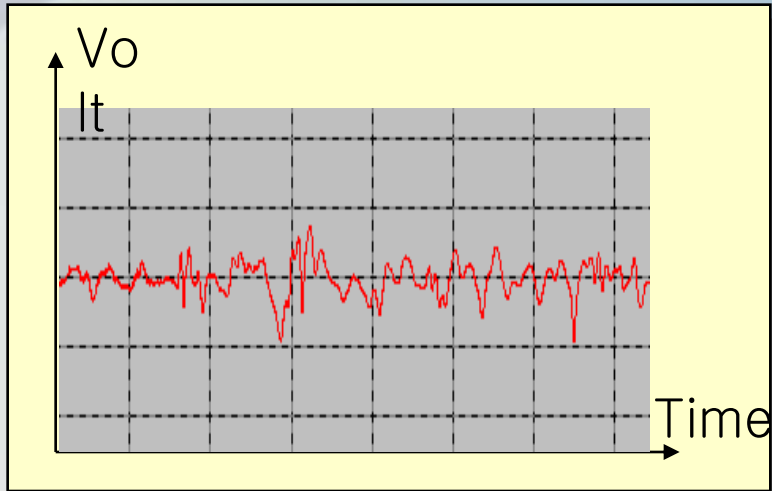


dB	Voltage or current ratio	Power ratio	dBm (50Ω, column 1 in dBμV)
-20	0.1	0.01	-127
-10	0.3162	0.1	-117
-6	0.501	0.251	-113
-3	0.708	0.501	-110
0	1.000	1.000	-107
0.5	1.059	1.122	-106.5
1	1.122	1.259	-106
2	1.259	1.585	-105
3	1.413	1.995	-104
4	1.585	2.512	-103
5	1.778	3.162	-102
6	1.995	3.981	-101
7	2.239	5.012	-100
8	2.512	6.310	-99
9	2.818	7.943	-98
10	3.162	10.000	-97
12	3.981	15.849	-95
14	5.012	25.120	-93
16	6.310	39.811	-91
18	7.943	63.096	-89
20	10.000	100.00	-87
25	17.783	316.2	-82
30	31.62	1000	-77
35	56.23	3162	-72
40	100	10,000	-67
45	177.8	31,623	-62
50	316.2	10 ⁵	-57
55	562.3	3.162 · 10 ⁵	-52
60	1000	10 ⁶	-47
65	1778	3.162 · 10 ⁶	-42
70	3162	10 ⁷	-37
75	5623	3.162 · 10 ⁷	-32
80	10,000	10 ⁸	-27
85	17,783	3.162 · 10 ⁸	-22
90	31,623	10 ⁹	-17
95	56,234	3.162 · 10 ⁹	-12
100	10 ⁵	10 ¹⁰	-7
110	3.162 · 10 ⁵	10 ¹¹	3
120	10 ⁶	10 ¹²	13

	Amplitude	Power
3 dB	x 1,41	x 2
6 dB	x 2	x 4
10 dB	x 3,16	x 10
20 dB	x 10	x 100

Example:

$$\begin{aligned}
 46 \text{ dB}\mu\text{V} &= 20 + 20 + 6 \text{ dB}\mu\text{V} \\
 (\text{eqvlt in } \mu\text{V}) &= 10 \times 10 \times 2 \mu\text{V} \\
 &= 200 \mu\text{V}
 \end{aligned}$$

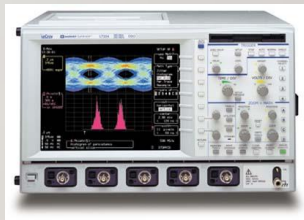


Fourier transform

Time domain measurement

Frequency measurement

Invert Fourier transform



Oscilloscope



Spectrum analyser

Electromagnetic compatibility

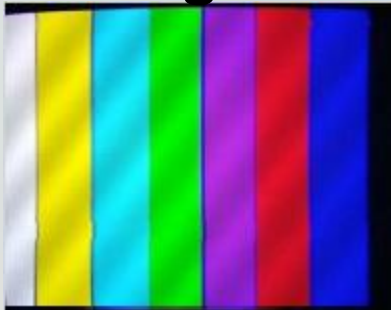


Electromagnetic interference



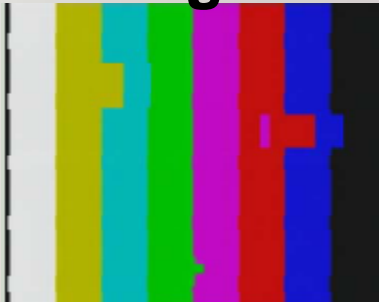
- Electric and electronic systems are not isolated from their environment.
- Electromagnetic energy can unintentionally cross their borders:
 - ✓ to enter,
 - ✓ or to escape.
- This energy is called stray electromagnetic interference.

Analogue video signal



- ✓ Moire
- ✓ loss of luminance, contrast
- ✓ loss of color
- ✓ loss of synchronization

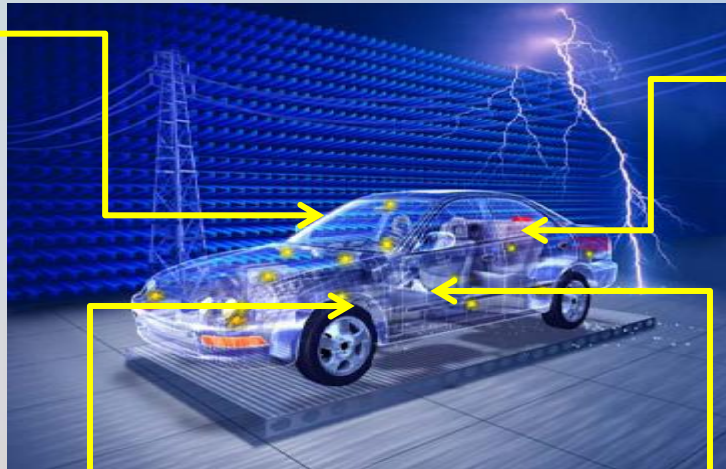
Digital video signal



- ✓ block effect
- ✓ cessation of movement
- ✓ black screen



RF transmitters



Mobile phone



ESD

- External Impacts
- Internal Impacts
- Human Impacts



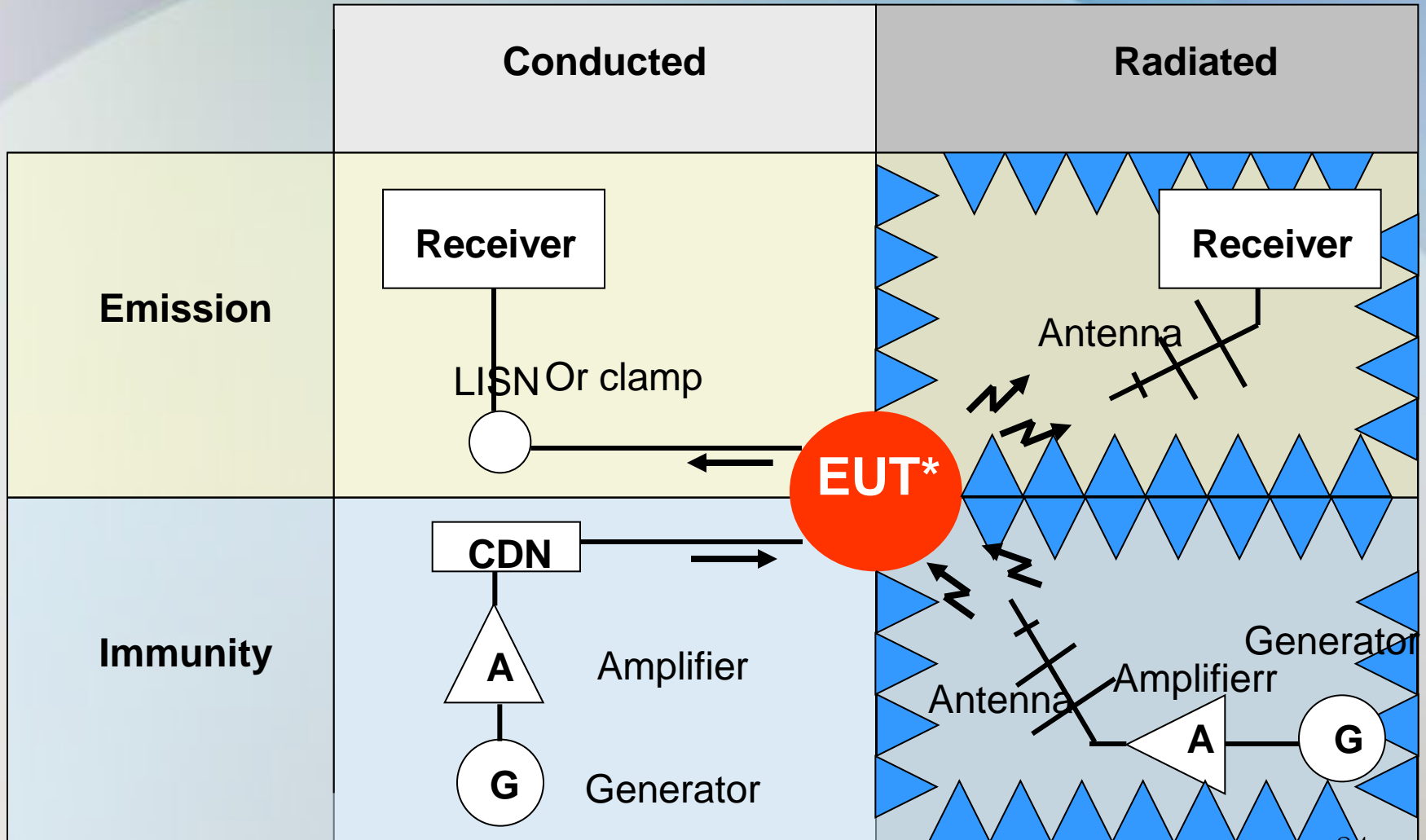
Oragons

Electric equipment:

1. Victim of its environment:
 - ✓ Malfunction
 - ✓ Temporary malfunction or permanent
2. Source of disturbance in its environment

According to the european directive 2004/108/CEE, EMC refers to:

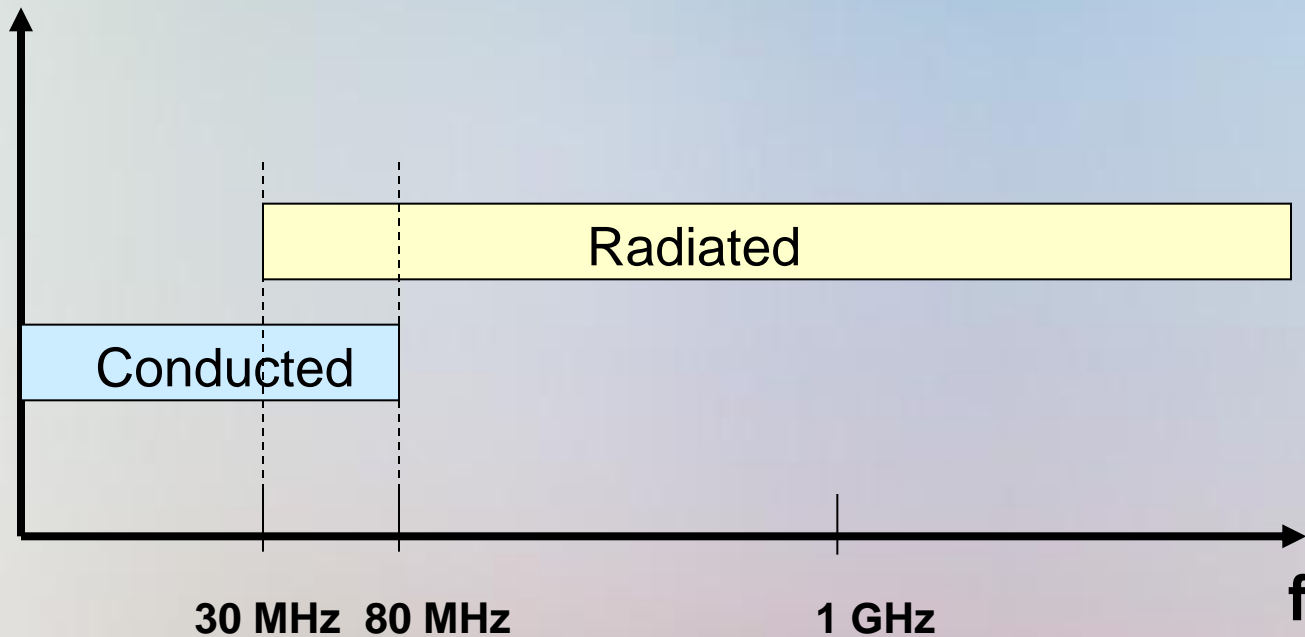
- the ability of an equipment or a system to perform satisfactorily in its electromagnetic environment
- without introducing intolerable interference into any thing in that environment.



*EUT = Equipement Under Test

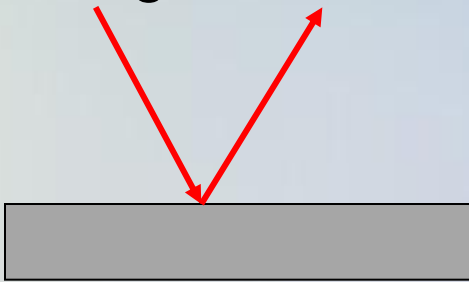
- The parasites circulating currents and voltages in cables or equipments will radiate.
 - The radiated power will also induce currents and stray voltages in the different interconnections.
- => The conducted and radiated disturbances are closely coupled.**

Conducted/radiated (2)

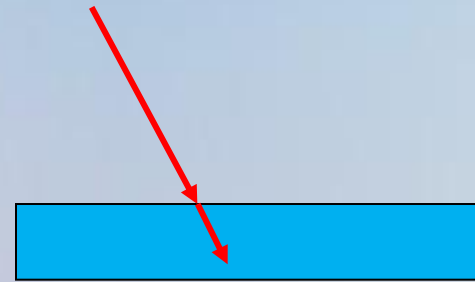


Test sites

Electromagnetic wave



Metal

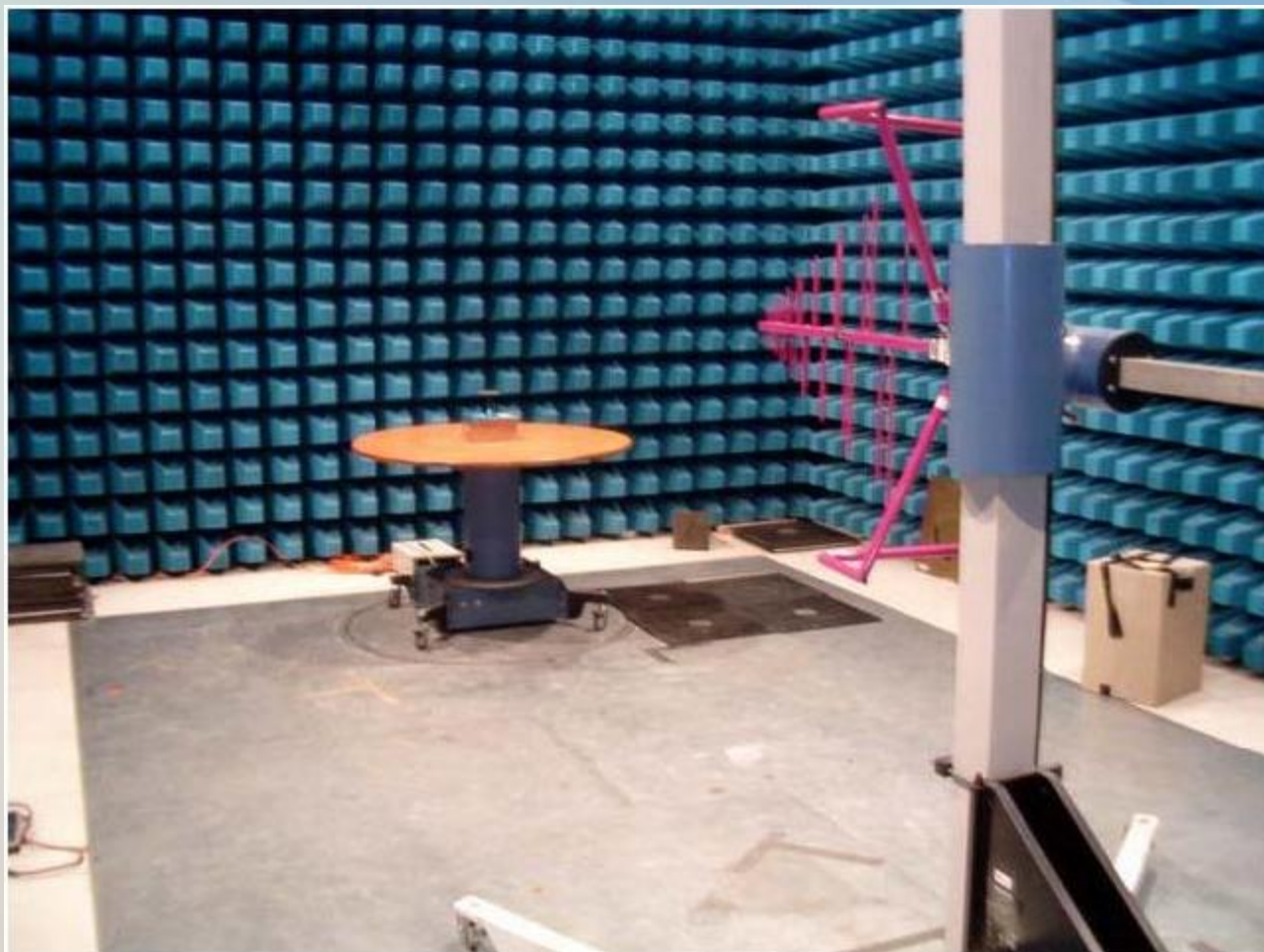


Absorber

Semi anechoic chamber SAC (1)

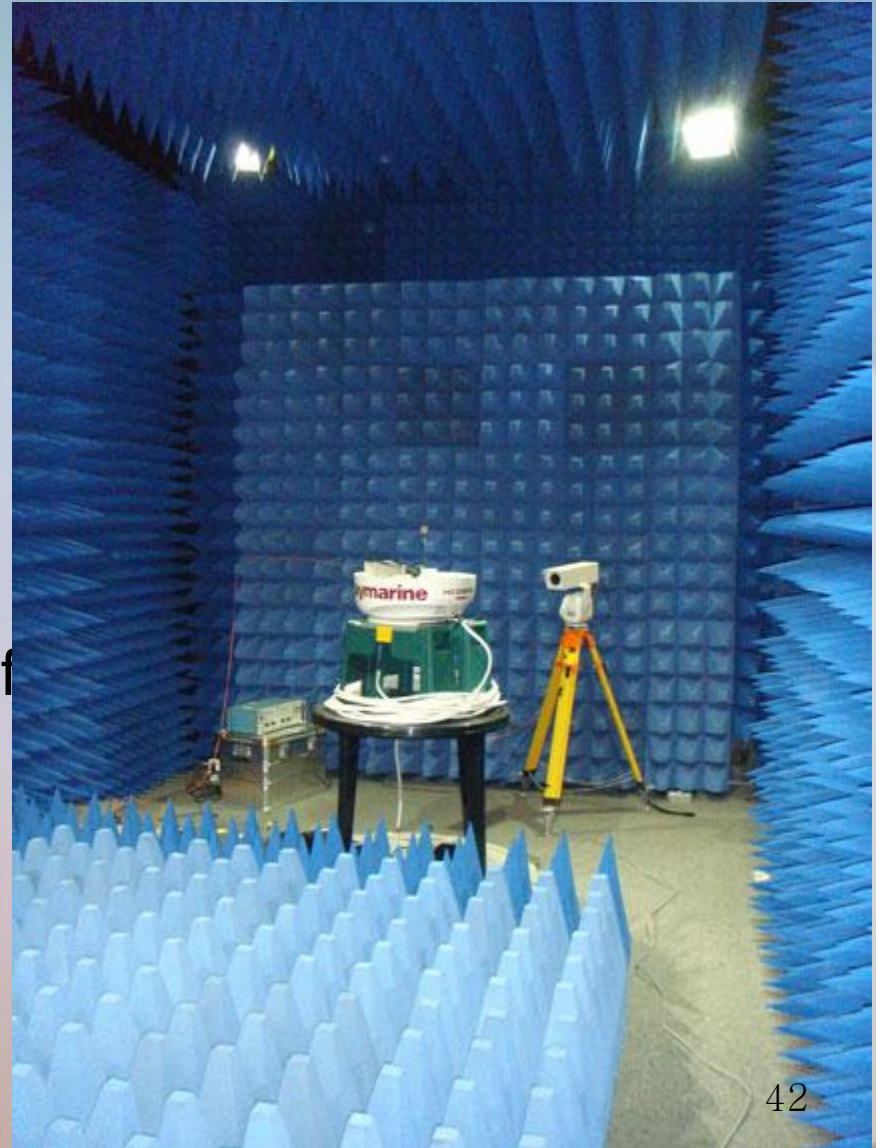


Semi anechoic chamber SAC (2)



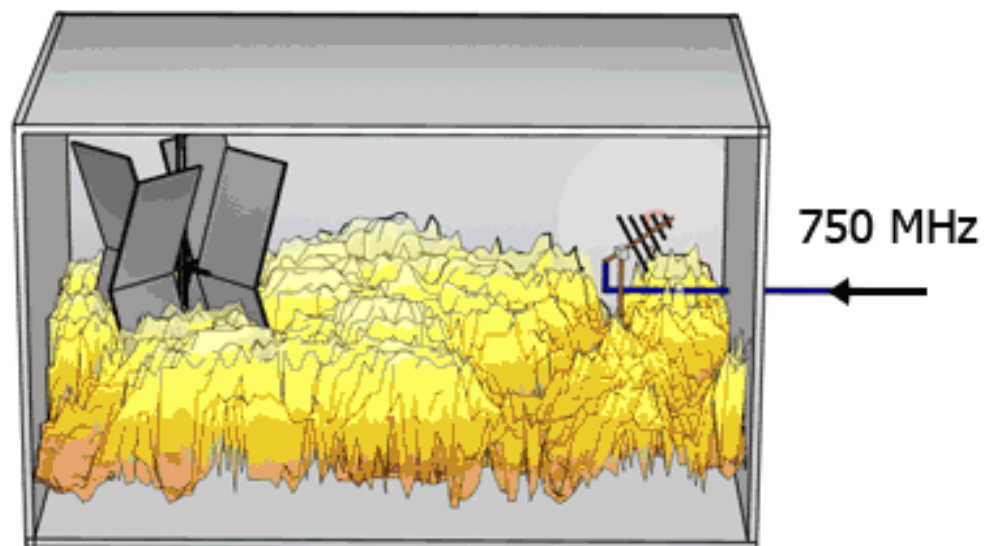
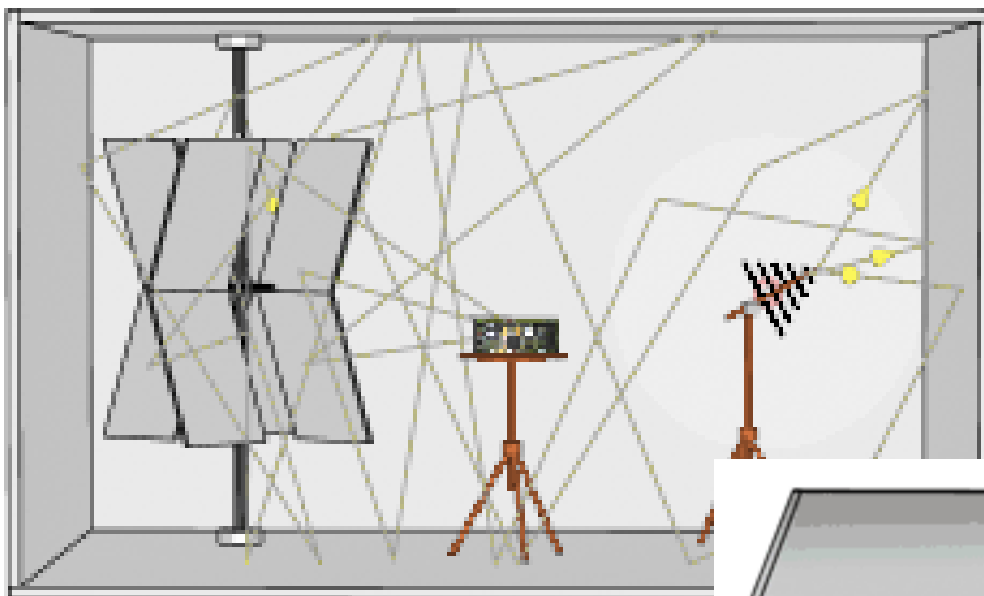


- Fully anechoic shielded enclosure
- Provided with radio frequency absorbent on its entire inner surface
- Emission measurements of direct radiation of radio frequency transmitters.
- Complies with ETSI standards

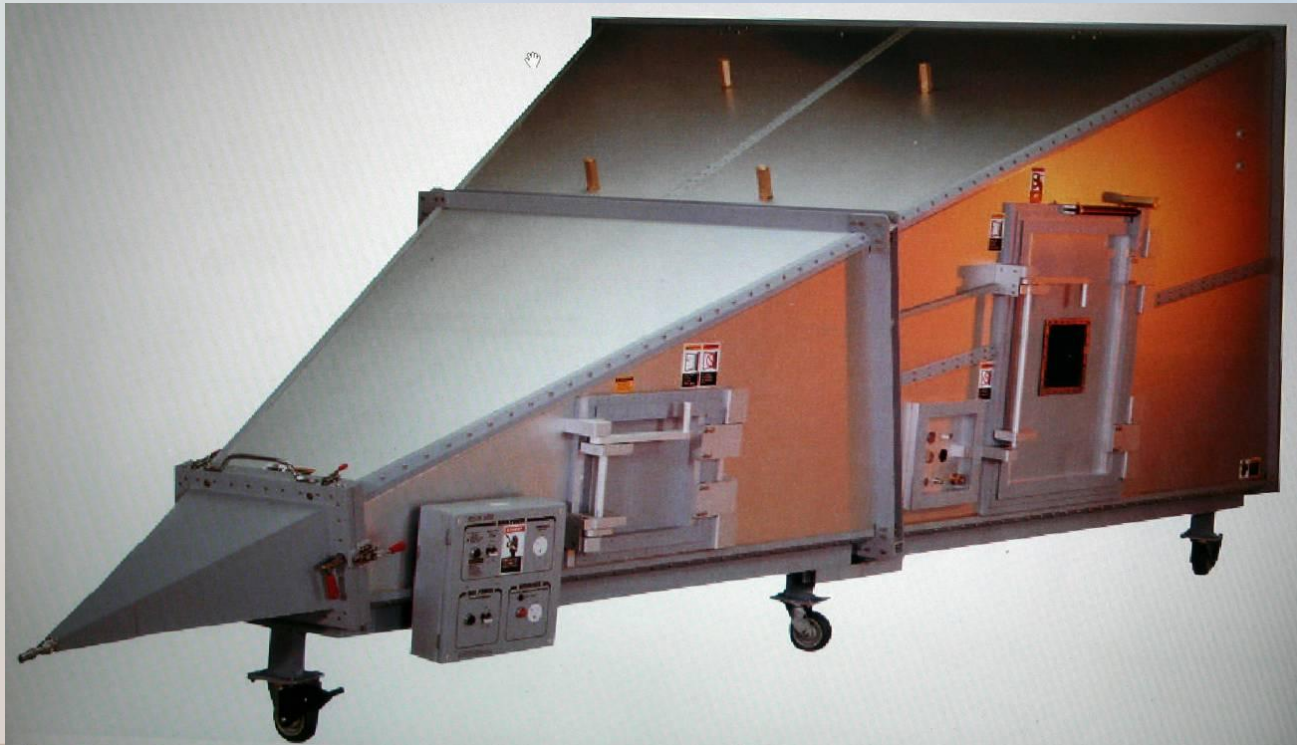


- Shielded enclosure, single or double wall, with metal stirrer
- Measures of radiated immunity and emission
- EN 61000-4-21.





- Closed cell loaded onto a characteristic impedance
- Measures radiated emission and immunity.
- EN61000-4-20



- The reference CISPR test site
- Radiated fields measures
- Great distance measures (10m – 30m).



Open Area test sites





Performance of measure sites



	Low distance faraday cage	Open area test site	Semi or fully anechoic chamber
Advantages	Isolating EUT from external EM noise	Correct field measurements	Correct field measurements
drawbacks	<ul style="list-style-type: none">•Walls reflexions•Near field measure	Electromagnetic noise	<ul style="list-style-type: none">•Degradation of absorbers performance•high cost



EMC standards

- These are standards or guidelines that define the general requirements for the "EMC" (phenomena, testing ...).
- They apply to all products and are used as references to develop specific standards.
- They include:
 - ✓ the description of electromagnetic phenomena
 - ✓ the characteristics of measuring instruments and of generation of test signals
 - ✓ the implementation of testing
 - ✓ the recommendations of severity levels
 - ✓ general criteria for proper operation.

EN 61000.4.2	Electrostatic discharge immunity test
EN 61000.4.3	Radiated, radio-frequency, electromagnetic field immunity test
EN 61000.4.4	Electrical fast transient/burst immunity test
EN 61000.4.5	Surge immunity test
EN 61000.4.6	Immunity to conducted disturbances, induced by radio-frequency fields
EN 61000.4.8	Power frequency magnetic field immunity test
EN 61000.4.9	Pulse magnetic field immunity test
EN 61000.4.11	Voltage dips, short interruptions and voltage variations immunity tests
EN 61000-3-2 et EN 61000-3-3	Limits for harmonic current / flicker emissions (equipment input current ≤ 16 A per phase)



Product standards



EN 55011	Industrial, scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics - Limits and methods of measurement
EN 55014	Requirements for household appliances, electric tools and similar apparatus Part 1: Emission. Part 2: Immunity
EN 55022	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement
EN 55024	Information technology equipment - Immunity characteristics - Limits and methods of measurement.
ETSI EN 300-330	Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz;

- These standards define, for products or product families , the special design, characteristics, methods and test levels.
- Where available, these standards take precedence over generic standards.
- They use the fundamental standards.
- They define:
 - ✓ tests to be performed
 - ✓ levels of severity of tests
 - ✓ the criteria for proper operation

- These standards define the essential requirements in terms of level to be maintained by type of test
- In the absence of product or family product standards, they apply to products installed in a defined environment (industrial, residential).
- They use the fundamental standards.
- They define:
 - ✓ the environment (residential, industrial ...)
 - ✓ tests to be performed
 - ✓ levels of severity of tests
 - ✓ the performance criteria

EN 61000-6-1: .	Immunity for residential, commercial and light-industrial environments
EN 61000-6-2	Immunity for industrial environments
EN 61000-6-3:	Emission standard for residential, commercial and light-industrial environments
EN 61000-6-4:	Emission standard for industrial environments

OLD CISPR 16

CISPR 16-1	Radio disturbance and immunity measuring apparatus
CISPR 16-2	Methods of measurement of disturbances and immunity
CISPR 16-3	Reports and recommendations of CISPR
CISPR 16-4	Uncertainty in EMC measurements

NEW CISPR 16

CISPR 16-1-1	Measuring apparatus
CISPR 16-1-2	Ancillary eqpt – conducted disturbances
CISPR 16-1-3	Ancillary eqpt – Disturbance power
CISPR 16-1-4	Ancillary eqpt – Radiated disturbances
CISPR 16-1-5	Antenna calibration test sites 30MHz - 1000MHz
CISPR 16-2-1	Conducted disturbance power
CISPR 16-2-2	Measurement of disturbance power
CISPR 16-2-3	Radiated disturbance measurements
CISPR 16-2-4	Immunity measurements
CISPR 16-3	CISPR technical reports
CISPR 16-4-1	Uncertainties in standardised EMC tests
CISPR 16-4-2	Measurement instrumentation uncertainty
CISPR 16-4-3	Statistical considerations in the determination of EMC compliance of mass –produce products
CISPR 16-4-4	Statistics of complaints and a model for the calculation of limits





ITU Training on Conformance and Interoperability for AFR Regions



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