Electromagnetic Compatibility

Véronique Beauvois

2021-2022

Electromagnetic Compatibility
Introduction

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0. Introduction - ULiège

- EMC activities are included in research unit ACE (Applied and Computational Electromagnetics)

- Prof. Christophe Geuzaine

- Véronique Beauvois, Ir.

- 1 PostDoc, 2 technicians

- EMC laboratories

0. Introduction - ULiège

1996

- Directive 89/336/CEE
- Walloon companies (especially SMEs) are searching for an EMC laboratory (competent, nearby, independent, accredited)
- Funding: Europe & Walloon Region

0. Introduction - ULiège

July 1997

- Building of a semi-anechoic chamber 9 x 6 x 6 m
- Equipment
- Budget ~ 1.500.000 €

March 1998

Official opening

2003

Initial BELAC Accreditation ISO 17025

0. Introduction - ULiège

In 20 years, more than 150 companies

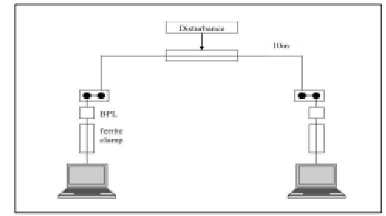
BEA Gillam DELTATEC EVS SGS EURESYS ALSTOM

0. Introduction - ULiège

2009

- New needs for military & spatial applications
- Reverberating Chamber
- High electric fields and larger frequency band
- Budget ~ 1.600.000 € (SPW)

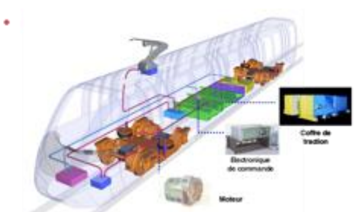
0. Introduction - ULiège

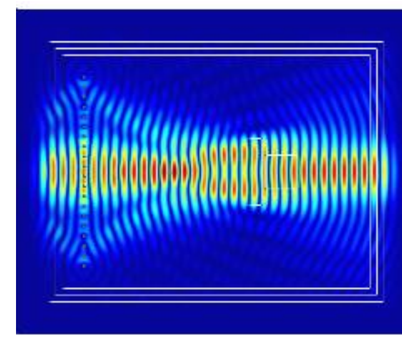


Research activities

Previously

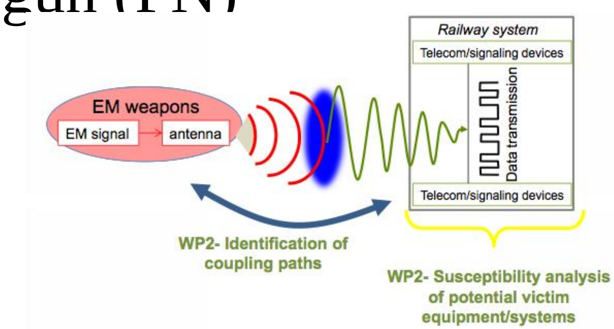
- On site measurements
- PLC
- Near-field measurements
- Railway applications
- Smart-Pod (FN)
- EM field control





Currently

- Railway applications
- Electric tommy gun (FN)



1. Introduction

A little bit of history (1)

- 19th century: lightning strikes on ships, buildings and power supplies, short-circuit failures lead to the development of output circuit breakers on power stations and input fuses in buildings and appliances

- Beginning of the 20th century: advent of radio communications, with first radio interference problems (especially related to electrical motors sparks)

- Electrostatic discharge (ESD) problems in hazardous environments lead to development of safe working practice

- Germany 1924: high-frequency committee from VDE (*Verband der Elektrotechnik*)

- Netherlands 1931: *Radiostoringscommissie*

- England 1933: Institution of Electrical Engineers (IEE) creates a Radio Frequency Interference (RFI) committee

- 1933: International Electrotechnical Commission (IEC) creates CISPR (International Special Committee on Radio Interference) to develop standards to limit interferences

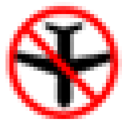
1. Introduction

A little bit of history (2)

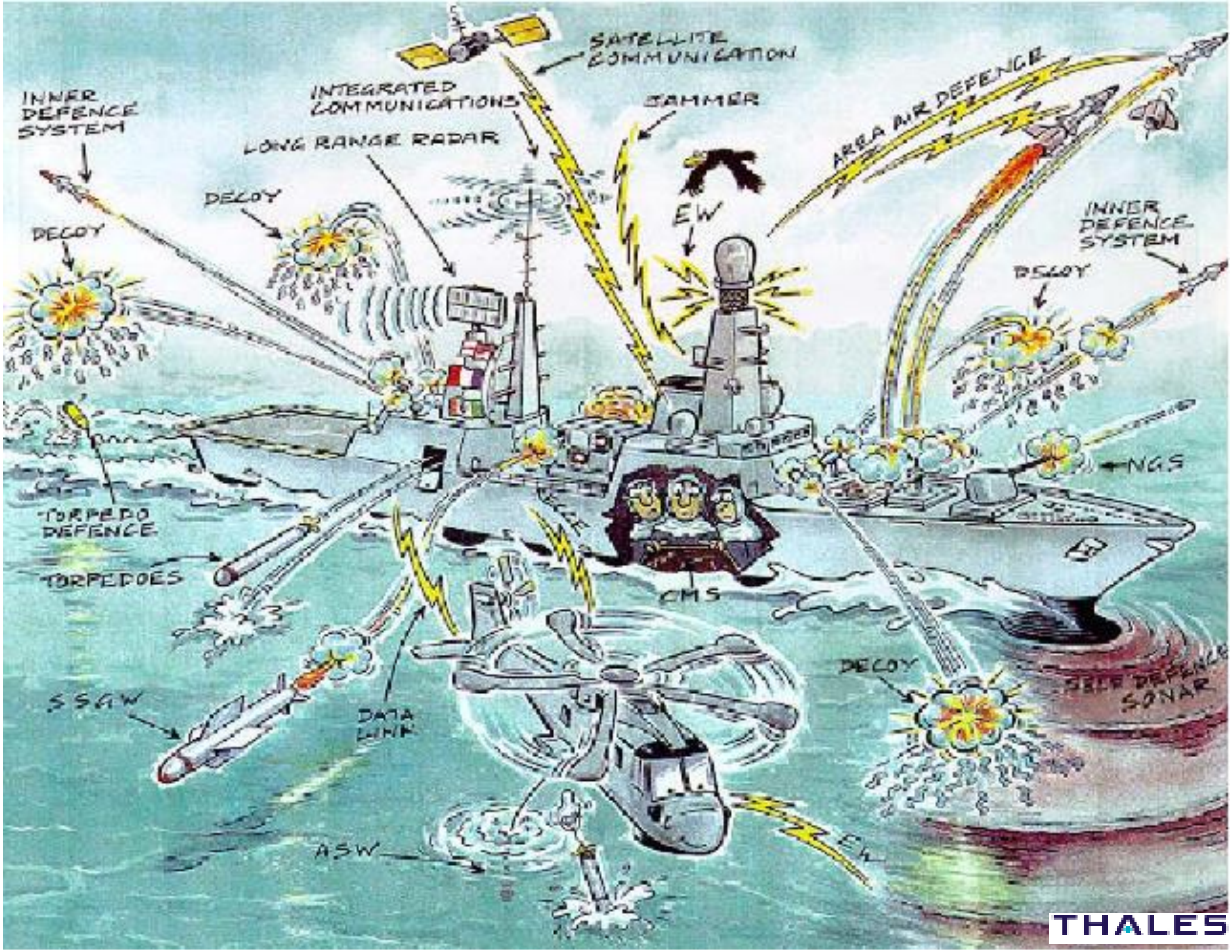
- 2nd World War: Electronic and radio communication equipment (radio, navigation, radar) developments increase and the number of reported interference problems also (e.g. air navigation)
- From then on increasingly rapid evolution of electronics: transistors, integrated circuits, high density components, microprocessors, ... combined with enlarged frequency spectrum to increase information transfer capacity
- 1967: aircraft carrier Forrestal was destroyed during Vietnam war. An on-board radar disturbed the firing system of rockets under a plane, the rocket was launched accidently, hit a plane which exploded and set the deck on fire
- 1982: HMS Sheffield missile destroyer was destroyed by an Exocet missile because the antimissile detection system was off, related to interference with the satellite communication system (Falklands war – Argentina vs United Kingdom)
- 1996: All products to be put on the European market should be in conformity with emission and susceptibility requirements, in order to protect communication systems

1. Introduction

Numerous modern technological developments highlight the importance of correctly dealing with electromagnetic interferences: ABS and electronics on board of automotive vehicles, mobile phones and electronic equipment on airplanes or in hospitals, medical implants such as pacemakers and hearing aids, etc.



1. Introduction



1. Introduction

Interference Classification

Natural

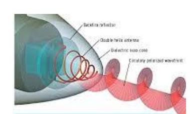
- thunderstorm/lightning
- solar activities
- cosmic noise
- electrostatic discharges

Artificial

non intentional

intentional



1. Introduction

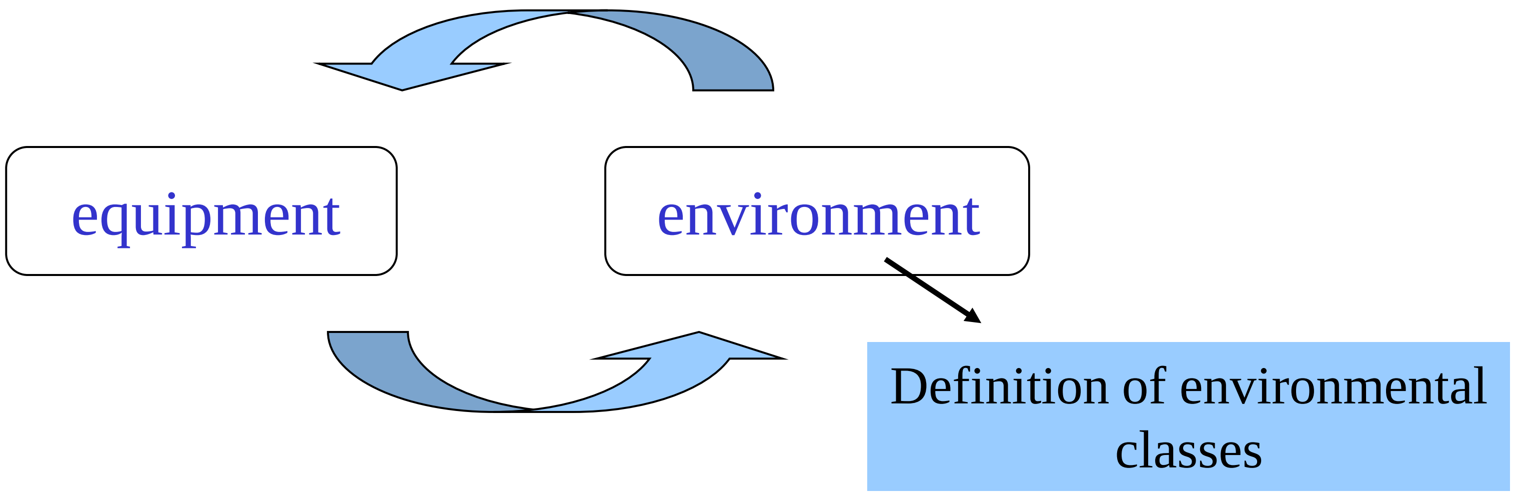
Electromagnetic interferences

→ Electromagnetic Compatibility (EMC)

→ What is EMC?

According to the European Directive (2014/30/EU)

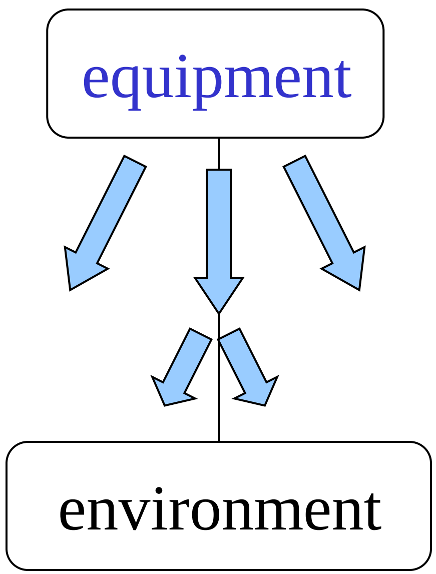
EMC (electromagnetic compatibility) means the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment.



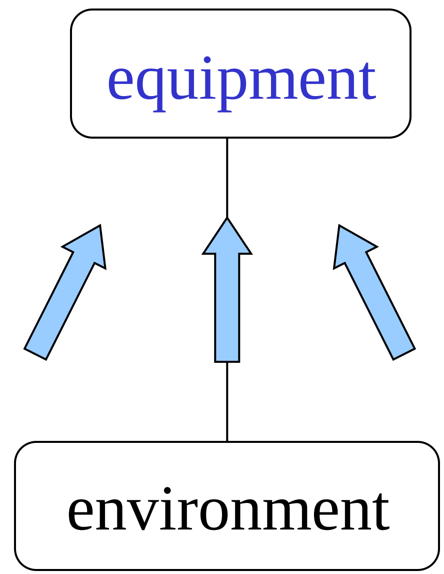
What is EMC?

Two-way phenomena

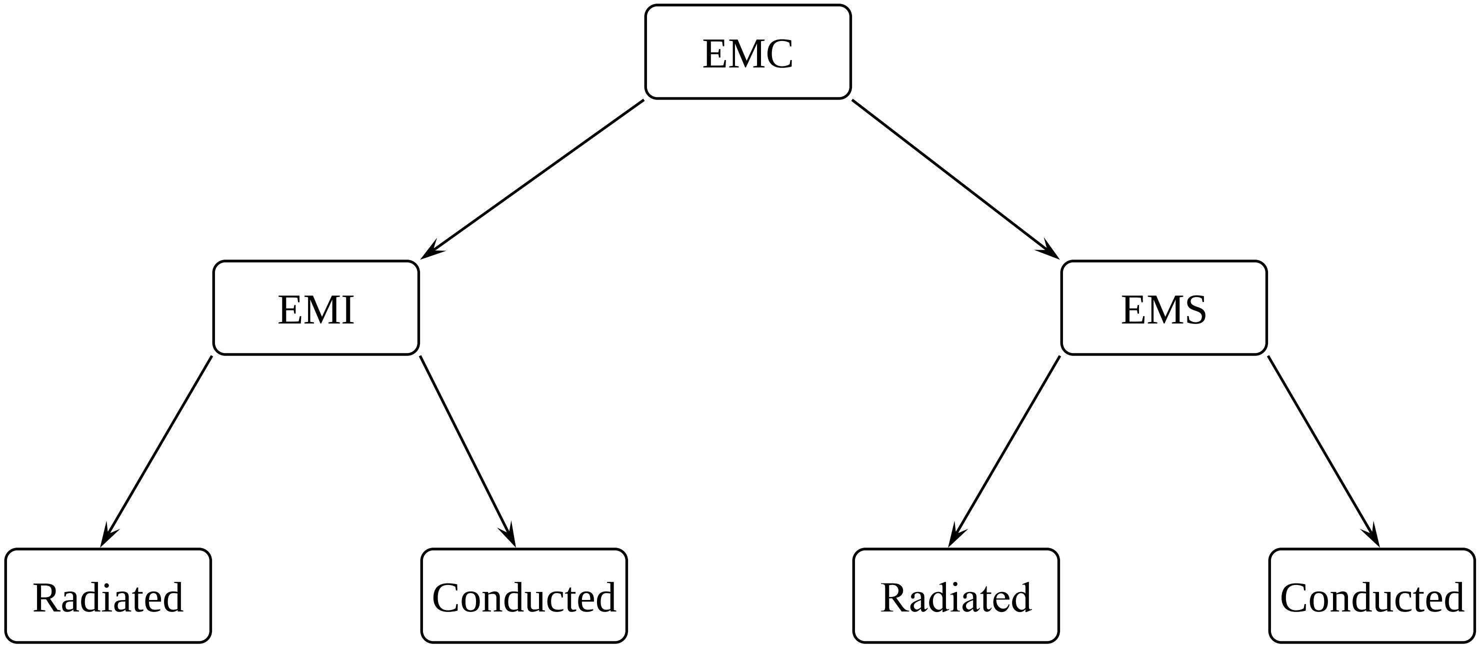
Emission



Susceptibility/Immunity



What is EMC?



EMI = ElectroMagnetic Interference
EMS = ElectroMagnetic Susceptibility

What is EMC?

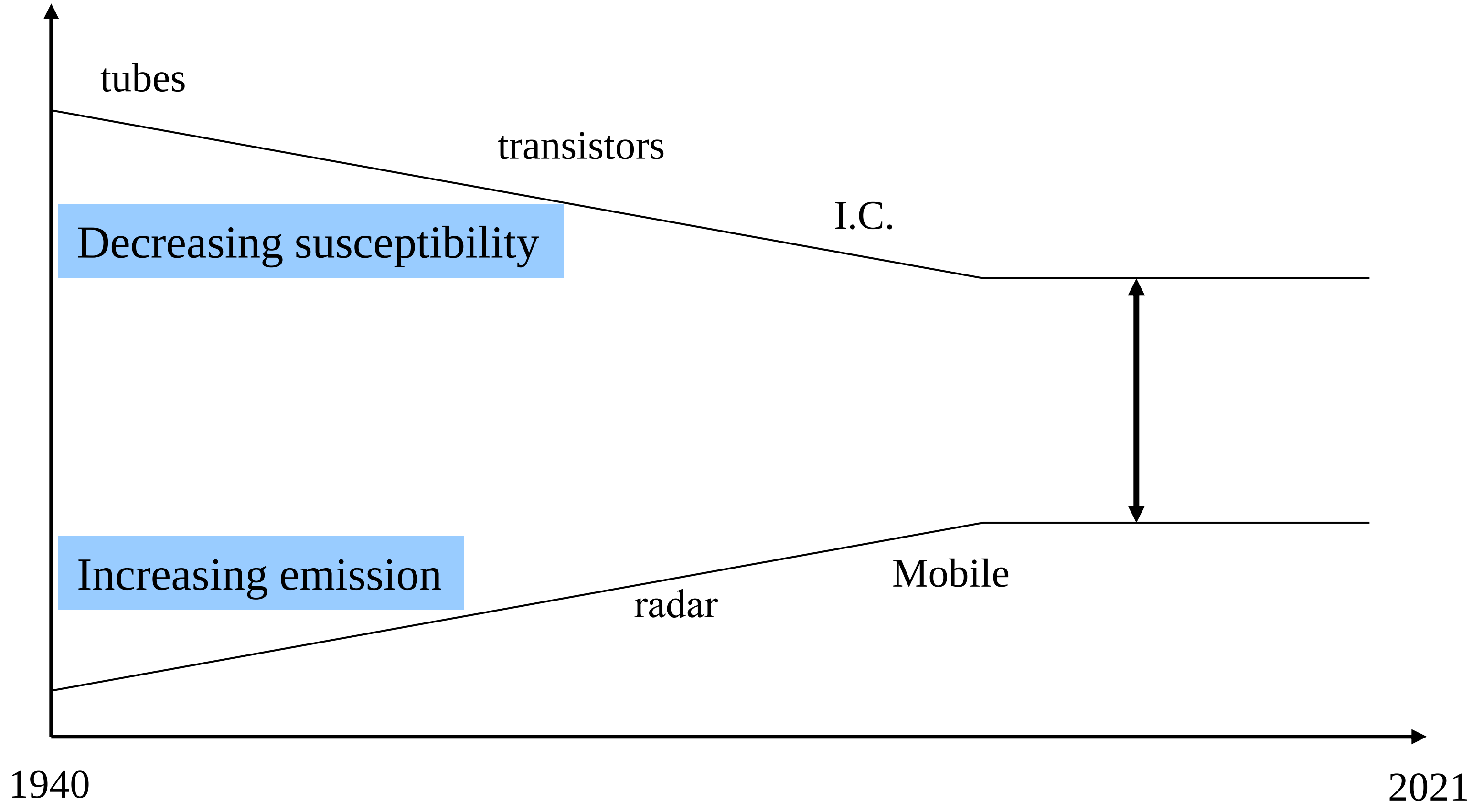
Equipment - Ports

Enclosure
(physical boundary of the apparatus which electromagnetic fields may radiate through or impinge)

EMC tests are related to these different ports: enclosure (electric and magnetic fields at low and high frequencies, ESD), power supply ports (AC/DC), signal/control ports (Ethernet, RS-232, ...)

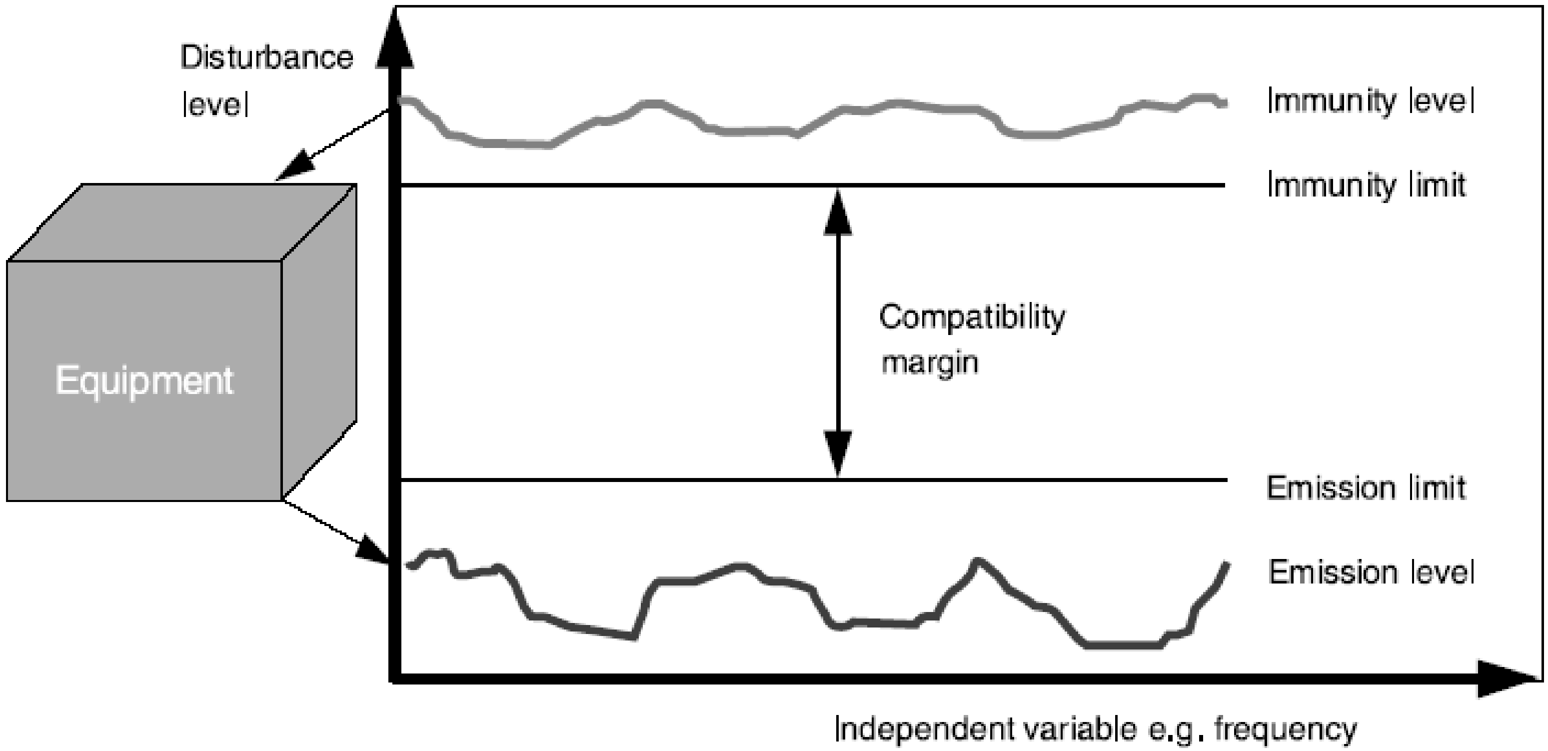
What is EMC?

Electromagnetic compatibility gap



What is EMC?

Compatibility margin



Electromagnetic Compatibility
Basic concepts

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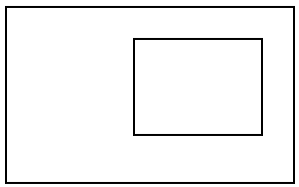
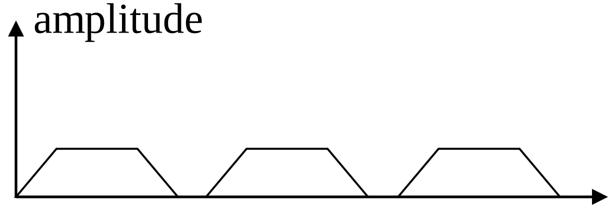
Basic concepts

There are 2 common ways to represent a signal

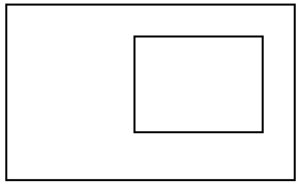
Time Domain



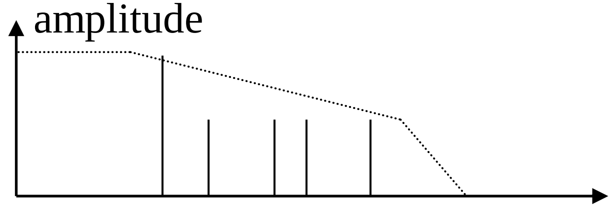
Scope



Frequency Domain



Spectrum Analyser



How to convert?

Mathematical Conversion Time vs Frequency

Periodic signal – Fourier Serie

s(t) period T : s(t) = s(t+kT) $\forall$k integer

$s(t) = \sum c_n \exp^{j2\pi nt/T}$ linear comb. of complex exponential functions

where $c_n = 1/T \int s(t).\exp^{-j2\pi nt/T}.dt$

Examples

***A cos(ωt)**

***Rectangular signal amplitude A, duty cycle ½ and period T**

Mathematical Conversion Time vs Frequency

Non periodic signals – Fourier Transform

Non periodic signal = periodic signal with T -> ∞

Discrete spectrum -> continuous spectrum (gap -> 0)

$$f(t) = \int F(f)\, \exp^{j2\pi ft}\, df$$

$$F(f) = \int f(t)\, \exp^{-j2\pi ft}\, dt$$

Basic concepts

Examples

- Pulse i(t) width τ and amplitude A
- Dirac pulse d(t) (limit of i(t) when τ–>0) amplitude A
- Single pulse ESD (τ_r 1ns / τ 60ns)
- …

Basic concepts

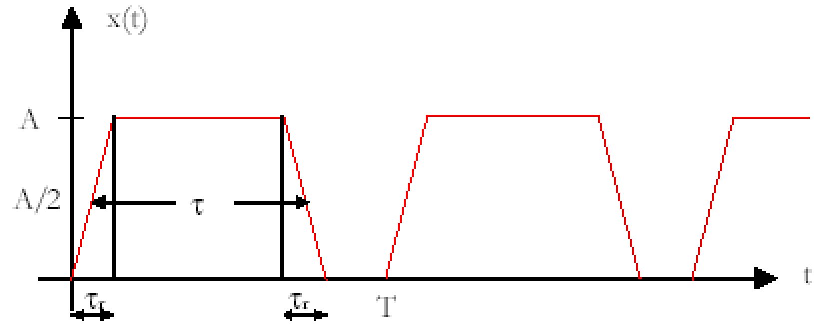
μP clock 8MHz, t_r = 5ns, τ=62,5ns (duty cycle τ/T)

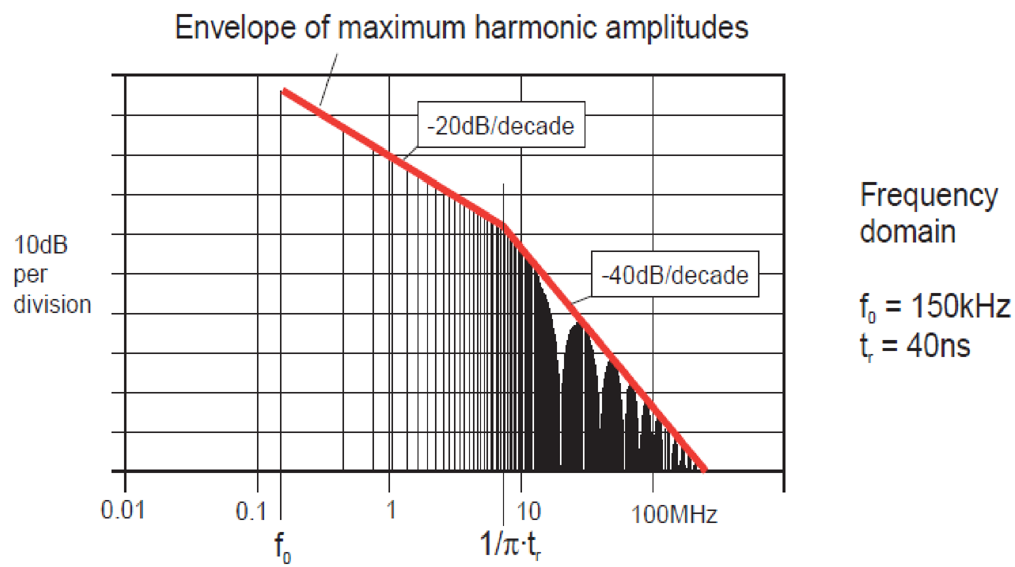
$f_{c1} = 1/\pi\tau$ = 5,1MHz,

then -20dB/dec.

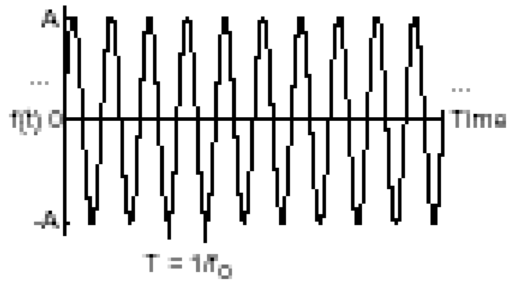
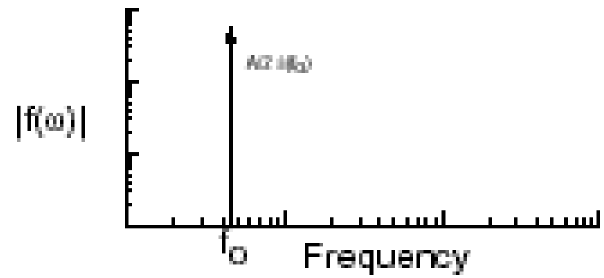
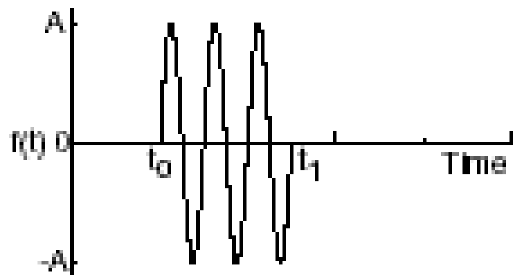
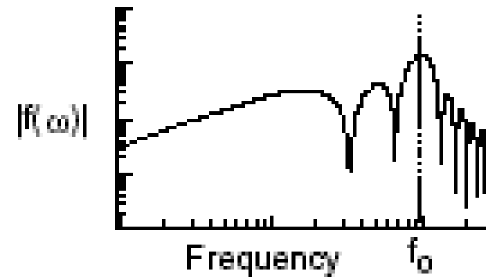
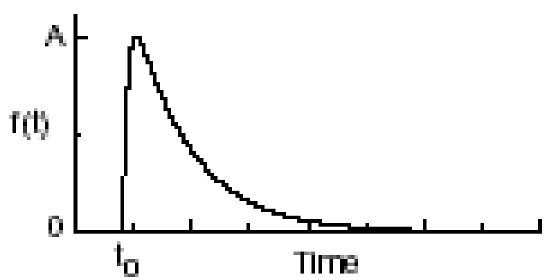
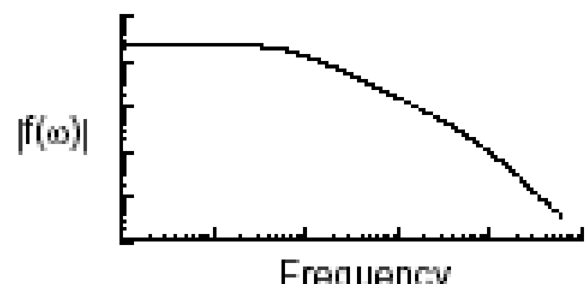
$f_{c2} = 1/\pi t_r$ = 63,7MHz,

then -40dB/dec.

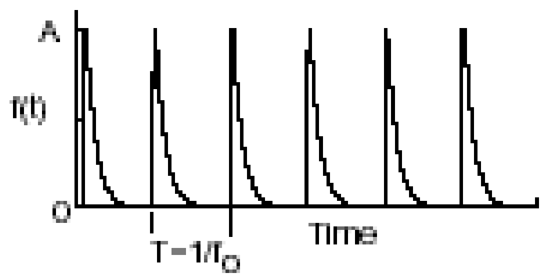
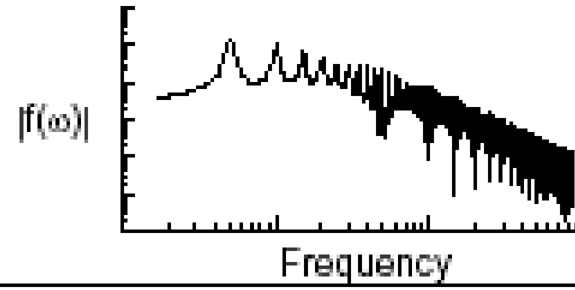
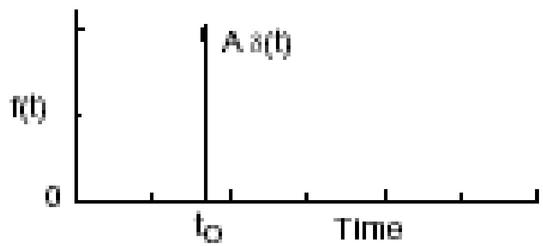
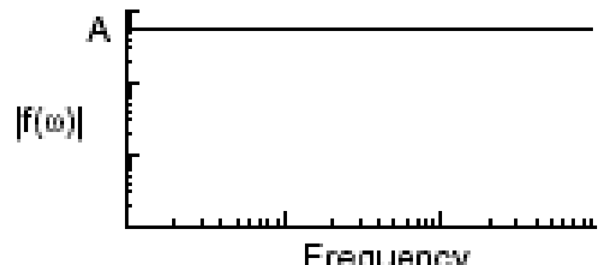
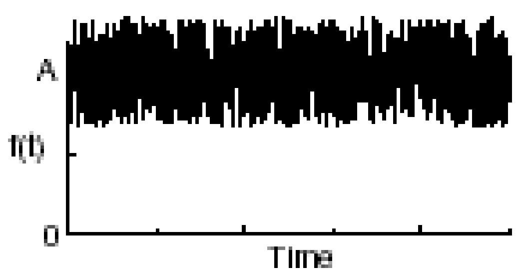
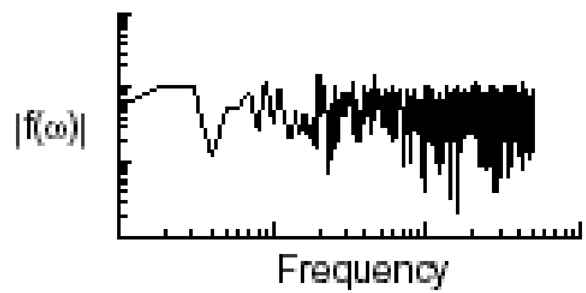




Basic concepts

Signal	Forme d'onde	Spectre
1. Sinusoïde		
2. Impulsion sinusoïdale		
3. Impulsion unique		

Basic concepts

Signal	Forme d'onde	Spectre
4. Train d'impulsions		
5. Impulsion de Dirac		
6. Bruit avec une composante DC		

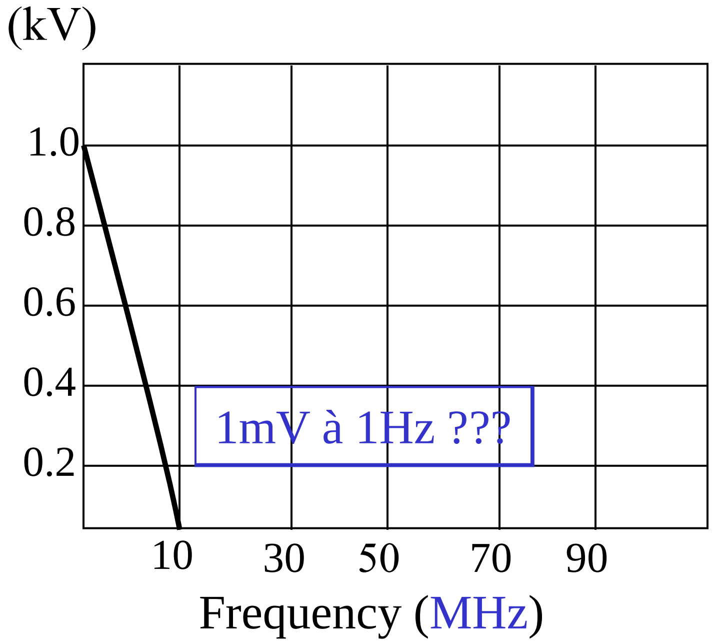
Basic concepts

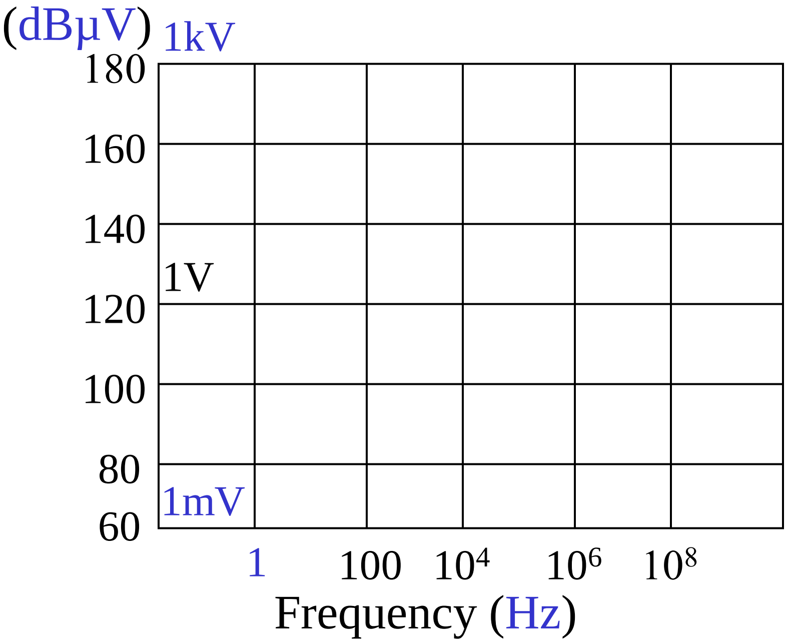
Units in EMC? Why dB and logarithmic scales?

1mV @ 1 Hz and 1kV @ 10MHz on the same graph?

-Linear scale (f in MHz and V in kV)

-Log scale (f in Hz and V in dBµV)





Basic concepts

Units in EMC?

$$\log (ab) = \log a + \log b$$

$$\log (a/b) = \log a - \log b$$

$$\log (1/a) = - \log a$$

$$\log a^n = n \log a$$

Basic concepts

Units in EMC?

dB

= logarithmic division between 2 quantities (without units)

Power (initially)

dB = **10** log ($P_{\mathbf{1Meas}}/P_{2Ref}$) →

dBW > P_2 = 1 Watt

dBm (dBmW) > P_2 = 1 mW

Voltage ($P_i=V_i^{2}/Z$)

dB = **20** log ($V_{\mathbf{1Meas}}/V_{2Ref}$)

dBV > V_2 = 1 V

dBµV > V_2 = 1 µV

	dB(P)	dB(V)
1	0	0
2	3	6
10	10	20

Exercises

Convert 50W in dBW

50W = 10 x 10 / 2 W > 10 + 10 –3 = 17 dBW

Convert 50W in dBm (1mW as reference)

50W x 1000 mW/W > (10 x 10 /2) x 10^3 > 10+10-3+(3x10)=50-3=47 dBm

Relationship V(dBµV) - P(dBm) for any value of Z and for Z 50Ω

$P=V^2/Z$

$10\log P/1W=10\log P/10^3 mW= 10\log P/1mW-30=20\log V/1V – 10\log Z$

$=20\log V/10^6 \mu V-10\log Z=20\log V/1\mu V-120-10\log Z$

P(dBm)=V(dBµV)-90-10logZ

If Z=50Ω

V(dBµV)=P(dBm)+107 dB

Basic concepts

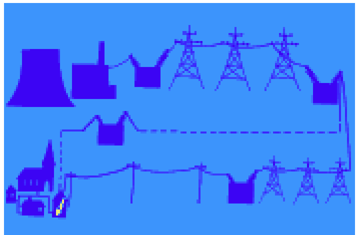
Units in EMC?

	Power		Voltage	Current
	W	EMS →	V	A
	dBW		dBV	dBA
→	**dBm**	EMI →	**dBµV**	dBµA
	dBm/kHz		dBµV/MHz	dBµA/MHz

	E	H
EMS →	**V/m**	A/m
	dBV/m	dBA/m
EMI →	**dBµV/m**	dBµA/m
	dBµV/m/MHz	dBµA/m/MHz

Frequency / Wavelength

$$\lambda = c/f$$
$$c = 3.10^8 \text{ m/s}$$



	Frequency	Wavelength
	50Hz	6000km
EMI-V	150kHz	2km
EMI-V	1MHz	300m
EMI-V / EMI-F	30MHz	10m
EMI-F	300MHz	1m
EMI-F	900MHz	33.3cm
EMI-F	1GHz	30cm
	2.4GHz	12cm
	18GHz	1.67cm