Electromagnetic Compatibility

Véronique Beauvois
2019-2020

Electromagnetic Compatibility
Introduction

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2018-2019

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

LIÈGE université

0. Introduction - ULiège

In 20 years, more than 150 companies

ABB Gillam-FEi DELTATEC (LET'S DESIGN THE FUTURE) EVS SGS EURESYS (Excellence in vision) ALSTOM

0. Introduction - ULiège

2009

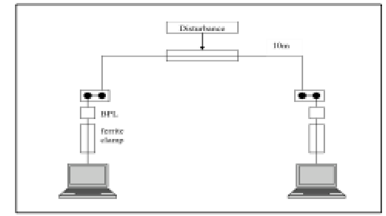
- New needs for military & spatial applications
- Reverberating Chamber
- High electric fields and larger frequency band
- Budget ~ 1.600.000 € (SPW)

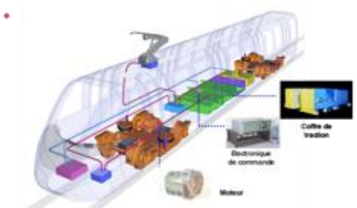
0. Introduction - ULiège

Research activities

Previously

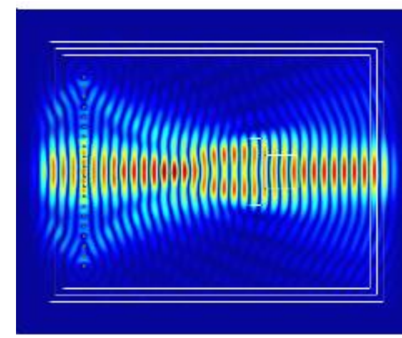
- On site measurements
- PLC
- Near-field measurements
- Railway applications
- Smart-Pod (FN)

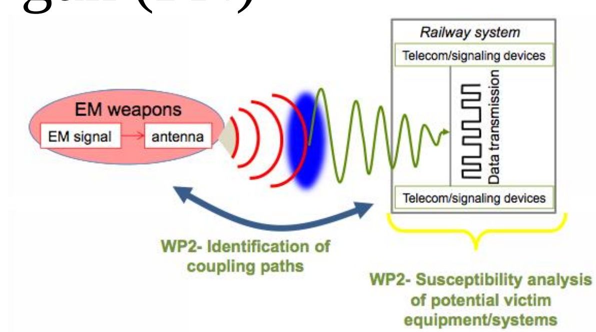




Currently

- EM field control
- Electric tommy gun (FN)





1. Introduction

Brief historical introduction

- Beginning of the 30s’: radio communication
- First radio interferences problems (especially related to electrical motors sparks).
- Germany 1924: High-Frequency Committee from VDE.
- Netherlands 1931: Radiostoringscommissie.
- England 1933: IEE creates a RFI committee.
- 1933: Creation of CISPR (International Special Committee on Radio Interference) by IEC (International Electrotechnical Commission) to develop standards to limit interferences.
- 2nd World War: Electronic and radio communication equipment (radio, navigation, radar) developments increase and the number of reported interferences problem also (e.g. air navigation).
- CISPR activities: technical publications with measurement procedures and emission limits. Some European countries adopt these recommendations.

1. Introduction

Brief historical introduction (2)

Electronic evolution: transistors, integrated circuits, high density components, microprocessors, ...  

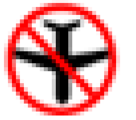
Enlarging frequency spectrum to increase information transfer capacity.

Electronic circuits susceptibility is increasing.

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

- ABS development/electronic on board of automotive vehicles
- Mobile phones or electronic equipment on planes

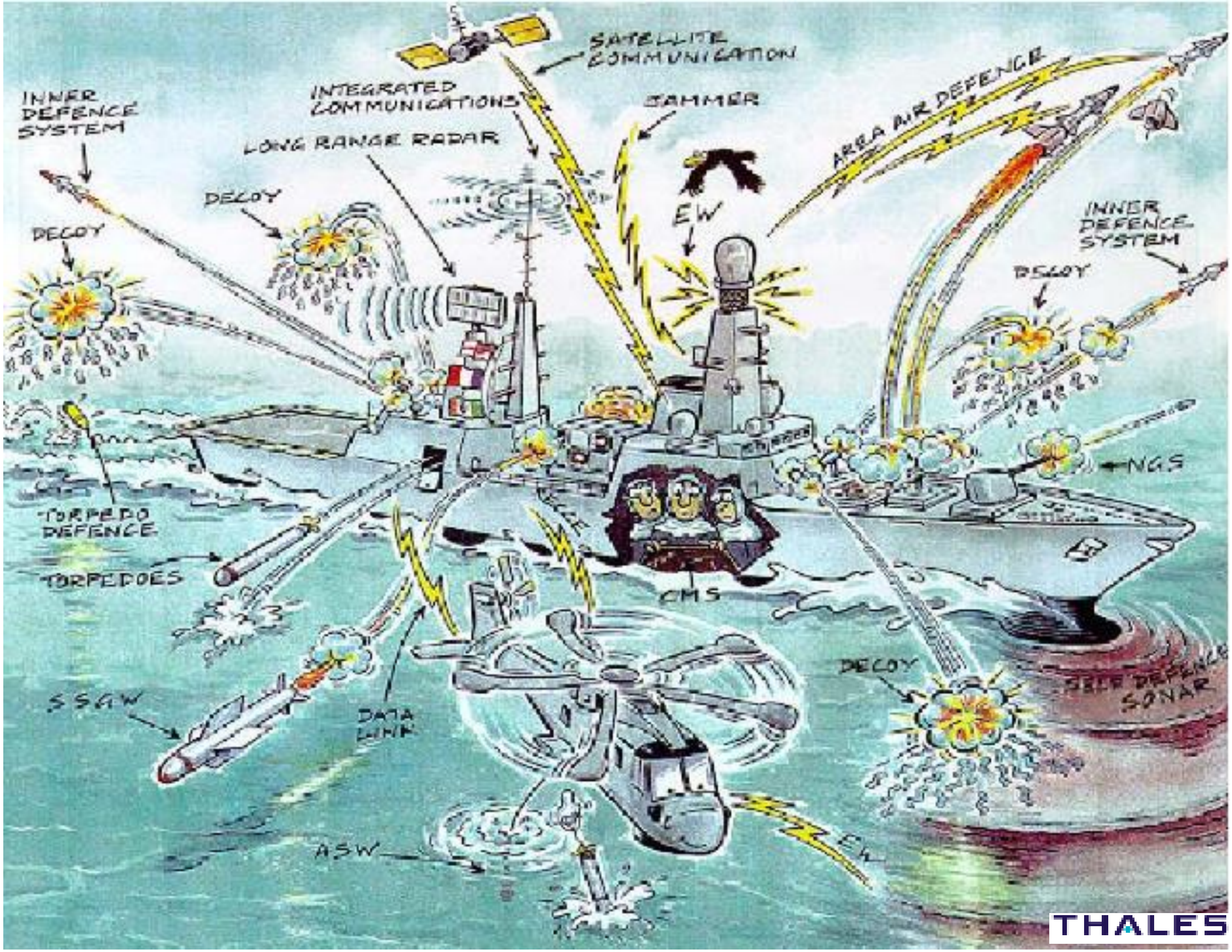


- Mobile phones in hospitals
- Pacemakers, hearing aids

- 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 on fire the deck.

- 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).
http://en.wikipedia.org/wiki/HMS_Sheffield_%28D80%29

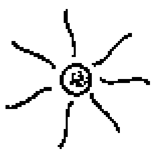
1. Introduction



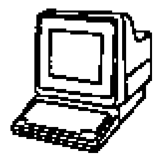
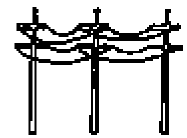
1. Introduction

Classification

Natural	Artificial



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

non intentional

intentional

1. Introduction

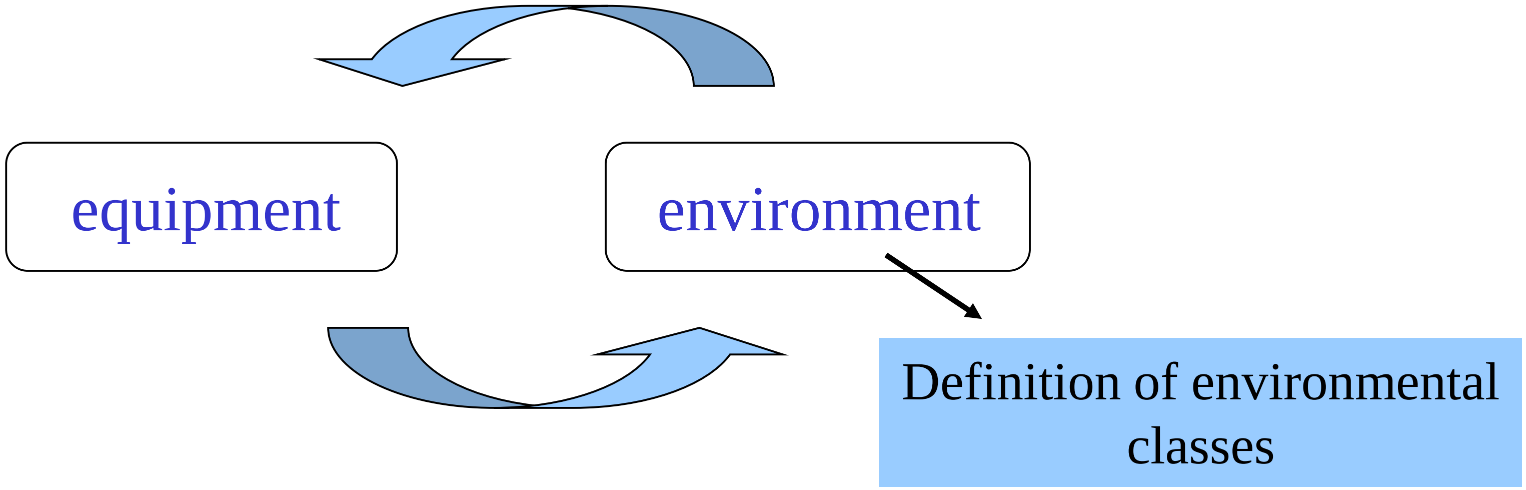
Electromagnetic interferences

→ Electromagnetic Compatibility (EMC)

→ What is EMC?

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

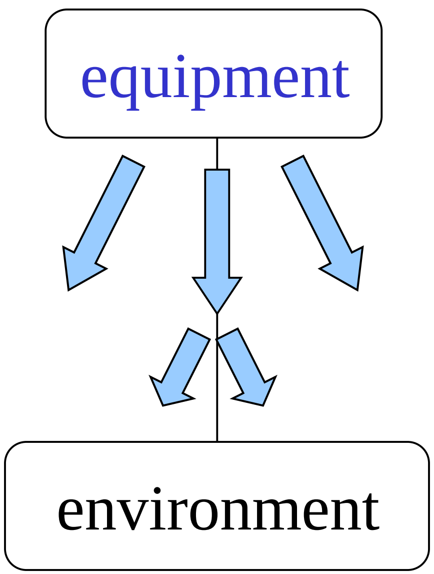
EMC (electromagnetic compatibility) means the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment.



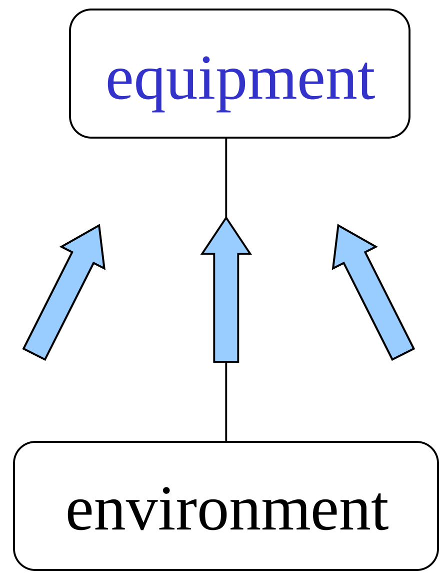
What is EMC?

Two-way phenomena

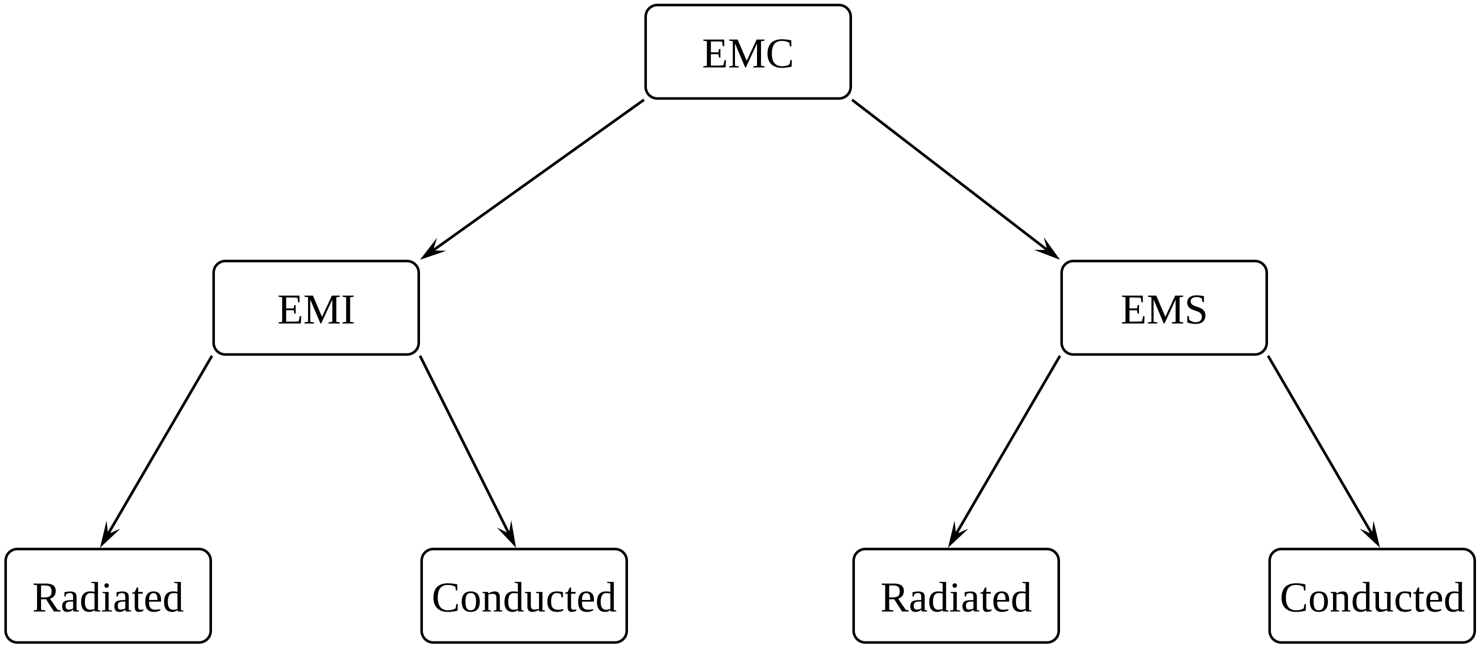
Emission



Susceptibility



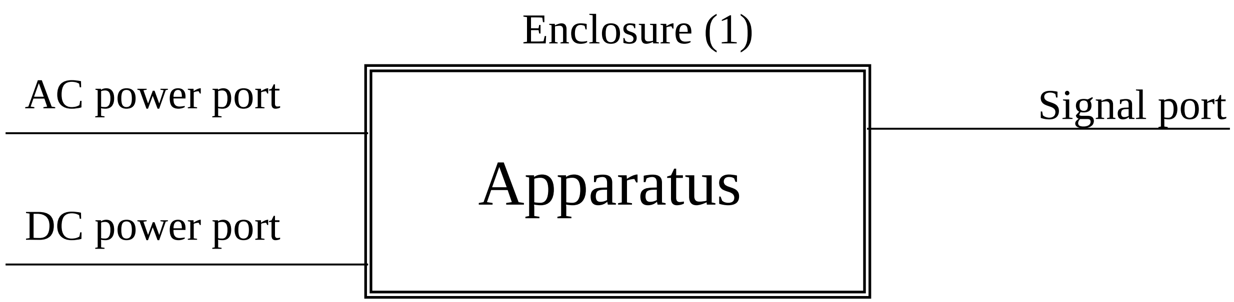
What is EMC?



EMI = ElectroMagnetic Interference
EMS = ElectroMagnetic Susceptibility

What is EMC?

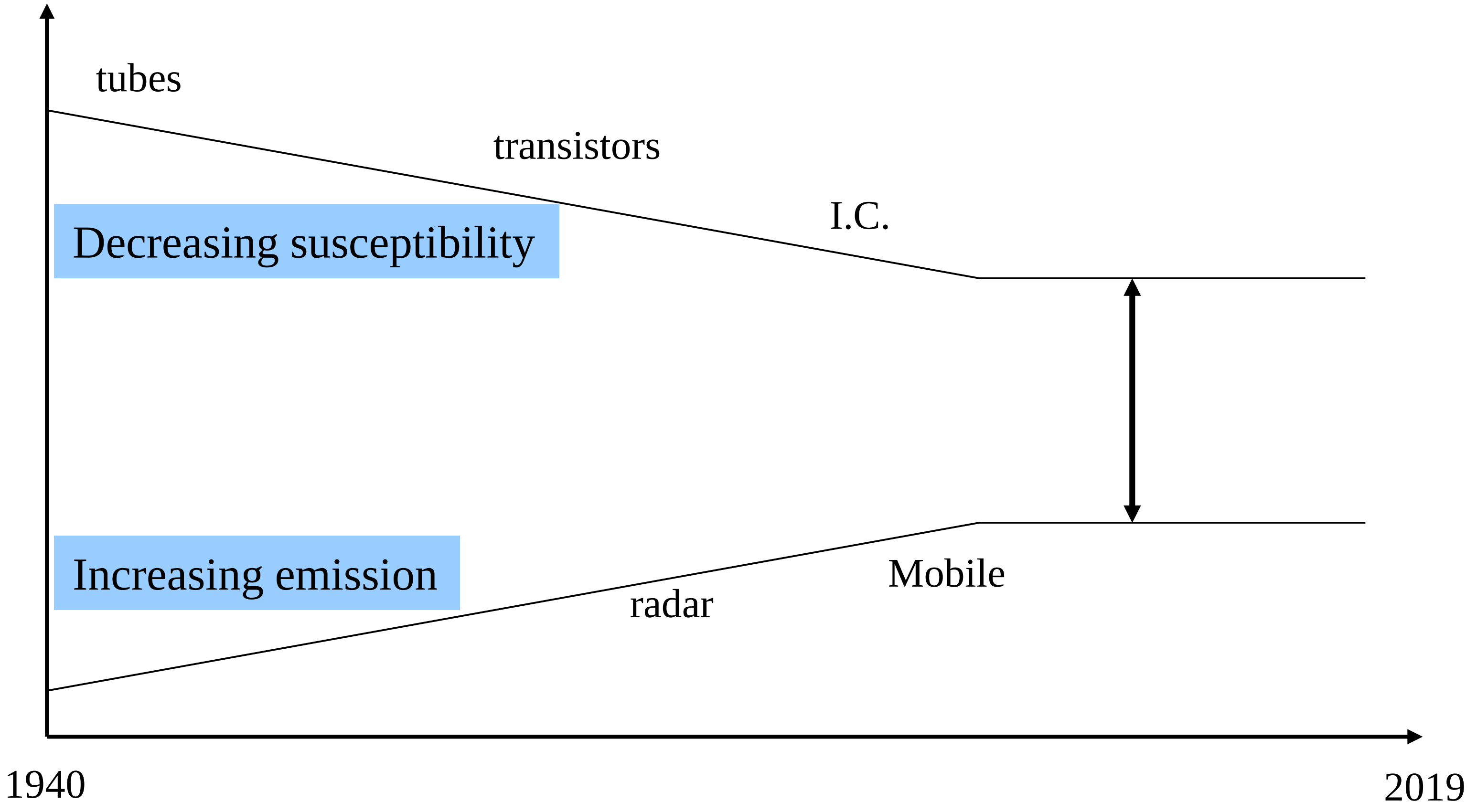
Equipment - Ports



(1) physical boundary of the apparatus which electromagnetic fields may radiate through or impinge on.

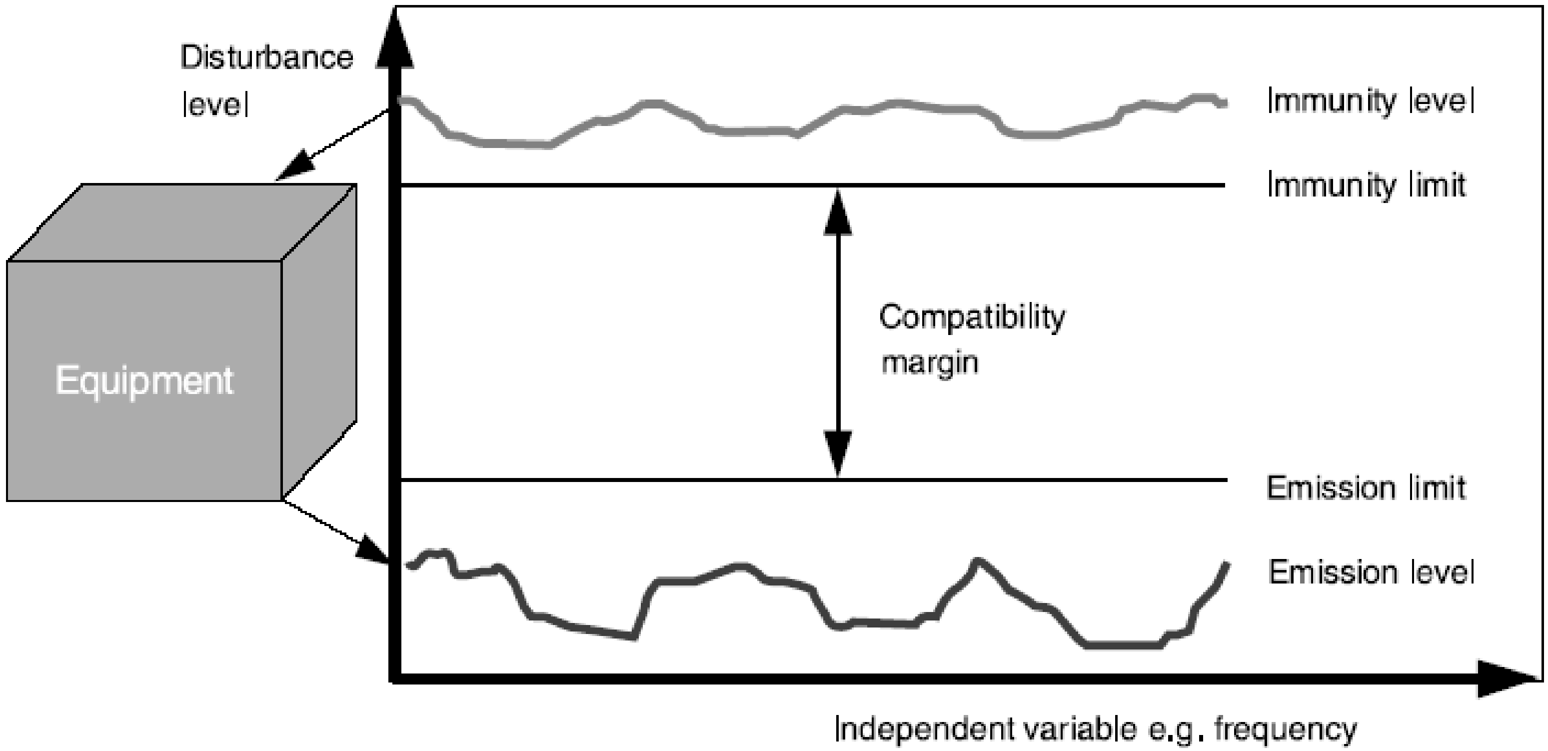
What is EMC?

Electromagnetic compatibility gap



What is EMC?

Compatibility margin



Electromagnetic Compatibility
Basic concepts

Véronique Beauvois
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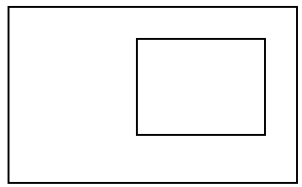
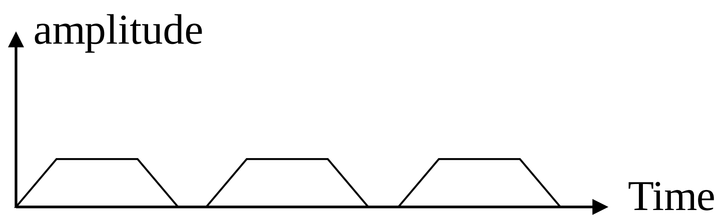
Basic concepts

There are 2 common ways to represent a signal

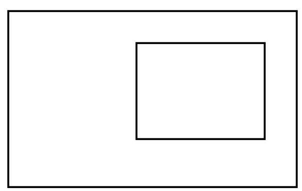
Time Domain



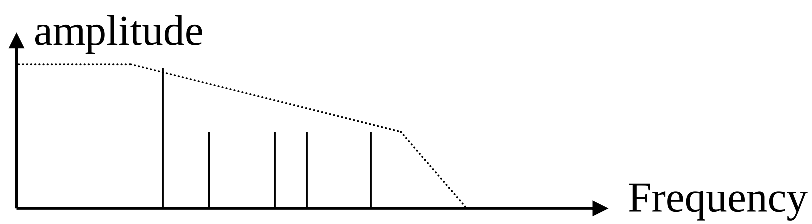
Scope



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

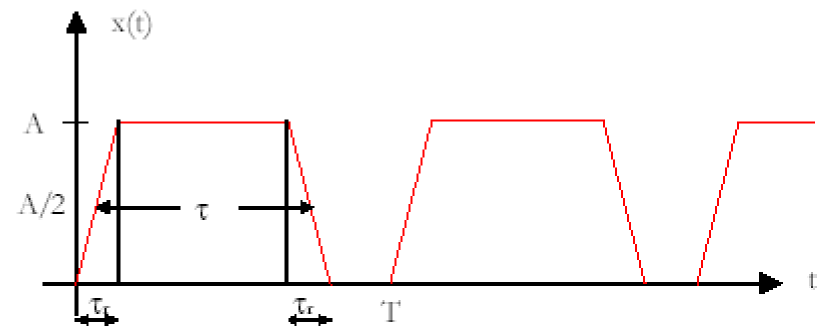
µP clock 8MHz, tr = 5ns, τ=62,5ns (duty cycle τ/T)

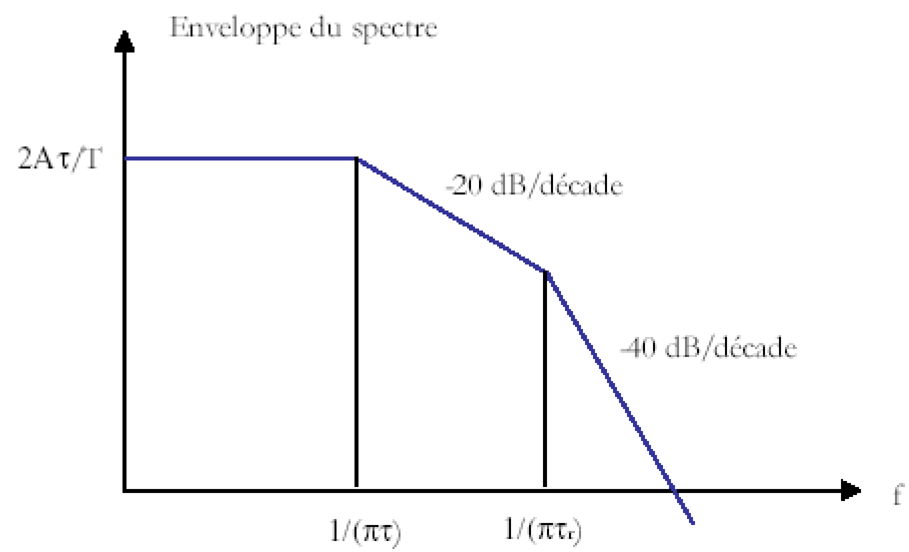
fc1 = 1/πτ = 5,1MHz,

then -20dB/dec.

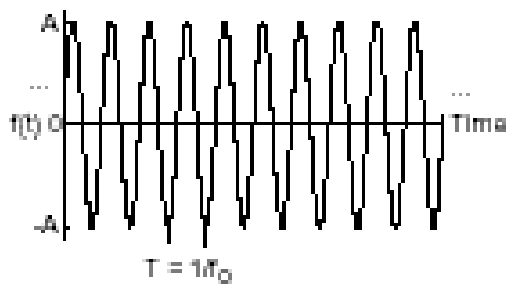
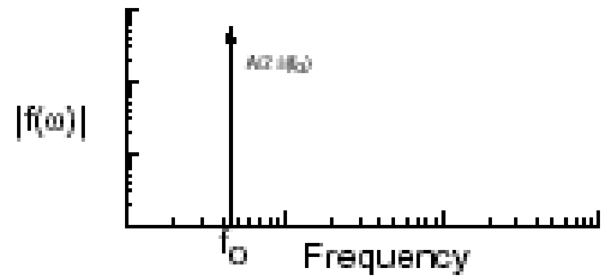
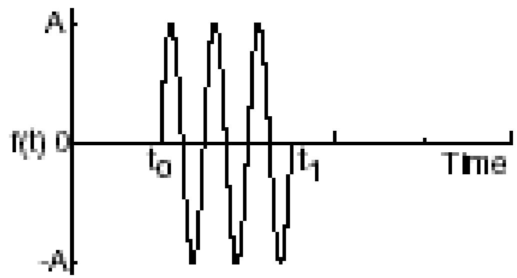
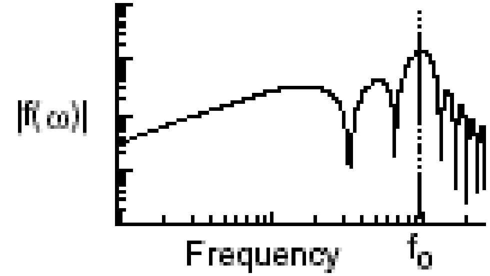
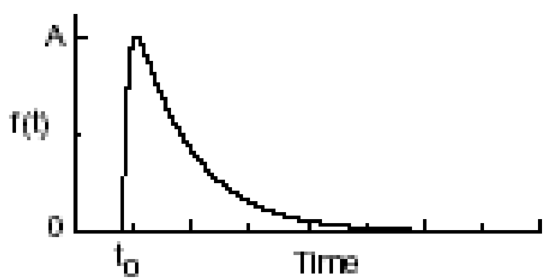
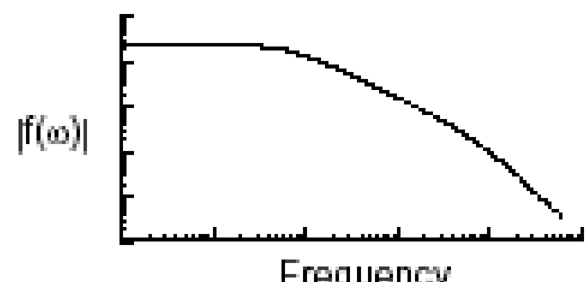
fc2 = 1/πtr = 63,7MHz,

then -40dB/dec.

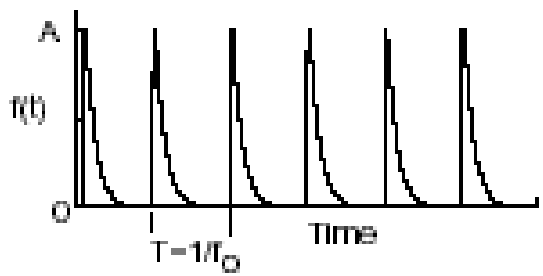
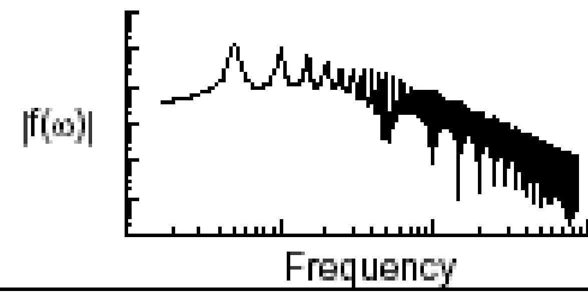
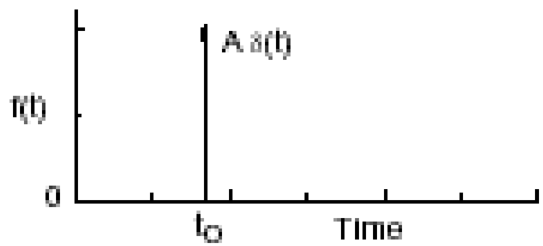
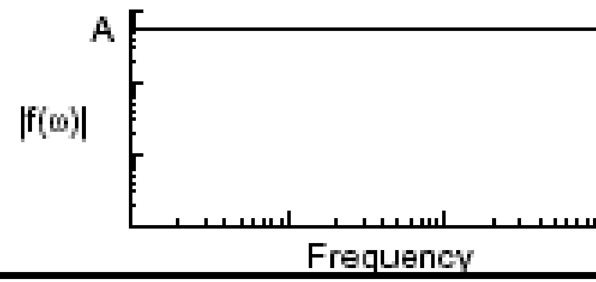
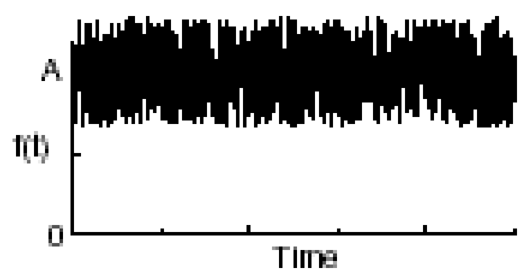
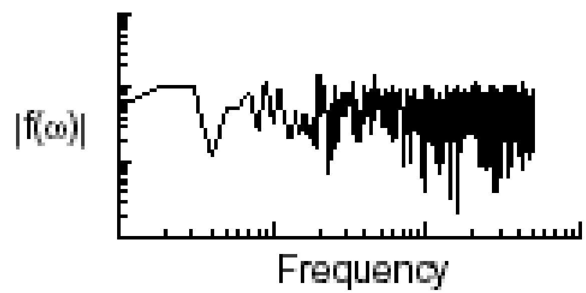




Basic concepts

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		

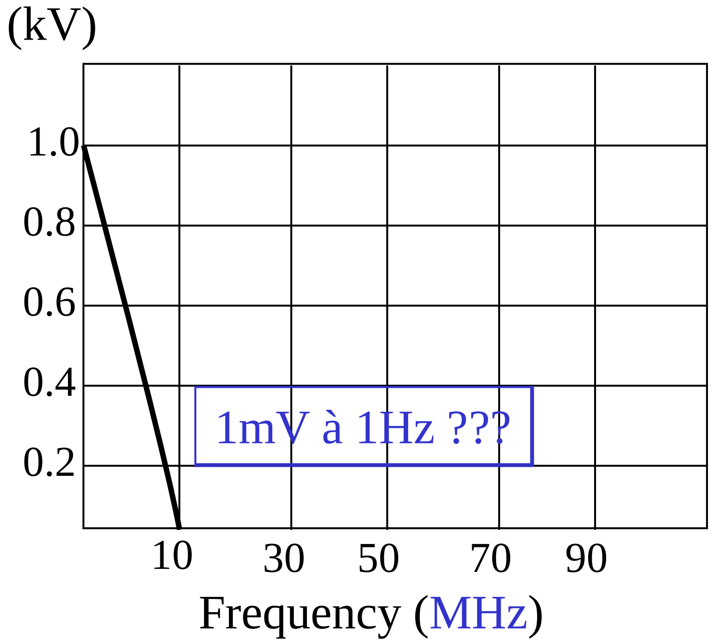
Basic concepts

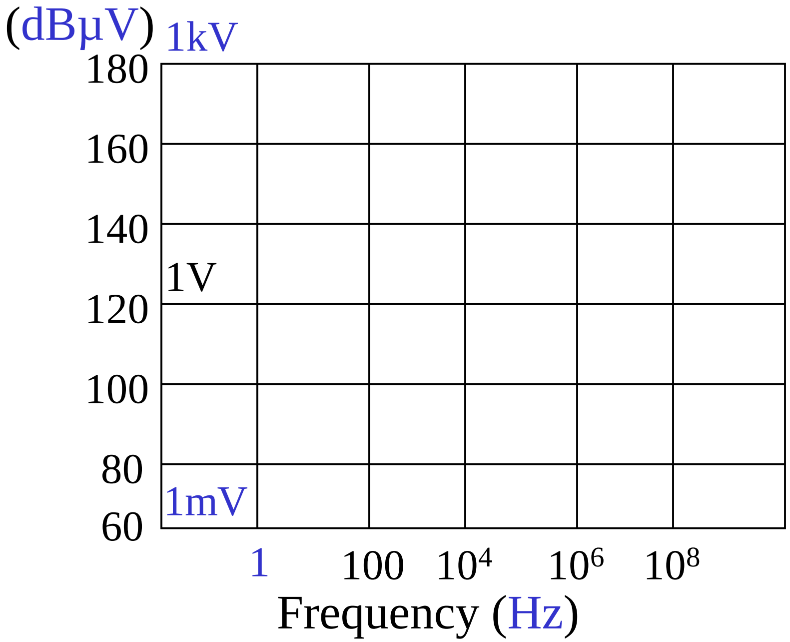
Units in EMC? Why dB and logarithmic scales?

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

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

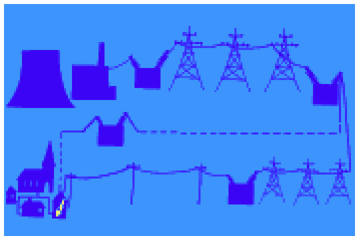
Units in EMC?

	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