

Techniques in Electromagnetic Compatibility

Comprehensive Project Guidelines

- Team project for Elec 458 (3-4 students)
- Individual project for Elec 6381

Activity	Description	Deadline
1. Project selection	select a topic and submit a signed sheet with title of project	Mon. Sept 22
2. Report I 15%,	4-6 pages proposal including the title and describing your (a) motivation, (b) objectives, (c) anticipated outcome, (d) detailed literature review of the selected topic and (e) task splitting between team members. List also your references.	Mon. Oct 6
3. Report II 20%,	Up to 10 pages progress report on preliminary own simulation results using PSpice and EM cad tools (grad students),	Mon Nov 3
4. Final report 50 + 15%	TBA	Mon Nov 24

Suggested Tools (to be discussed): PSpice, ADS, CST, NEC....

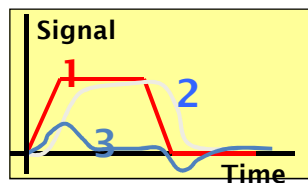
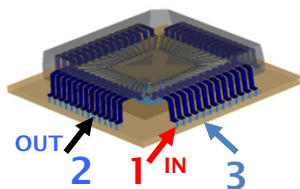
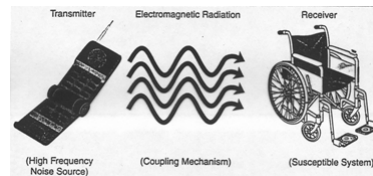
What is EMC ?

An electronic system that is *electromagnetically compatible* if it satisfies three criteria:

1. It does not cause interference with other systems.
2. It is not susceptible to emissions from other systems.
3. It does not cause interference with itself.

The Interference Problem

The operation of diverse circuits in close proximity gives rise to what is called EMI, which stands for Electromagnetic Interference.



Examples of EMC problems:



- your computer interferes with FM radio reception
- operating your vacuum cleaner causes "snow" on your TV
- your car radio buzzes when you drive under a power line
- a helicopter goes out of control when it flies too close to a radio tower
- your telephone is damaged by lightning-induced surges on the phone line
- the screen on your video display jitters when the fluorescent lights are on
- your new memory board is destroyed by an unseen discharge as you install it
- your laptop computer interferes with your aircraft's rudder control
- the airport radar interferes with your laptop computer display

3

Electromagnetic interference: Introduction

- **Electromagnetic interference** (EMI) - Electromagnetic emissions from a device or system that interfere with the normal operation of another device or system.

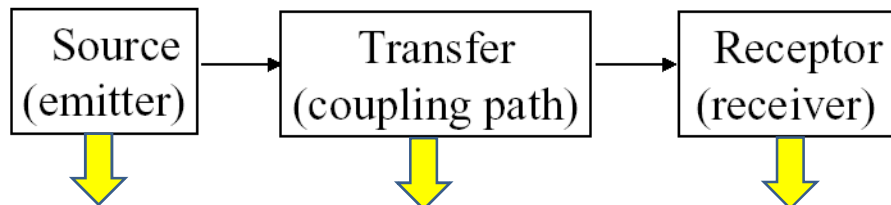
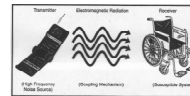


- Interference occurs if the received energy causes the receptor to behave in an undesired manner
- EMI is a major problem in all areas of society today.
- Some EMI is natural, but most of the problems are manmade origin:
 - aircraft , automobiles
 - broadcast station
 - medical devices, hospital, ambulance
 - cellular telephones



Types and Sources of EMI

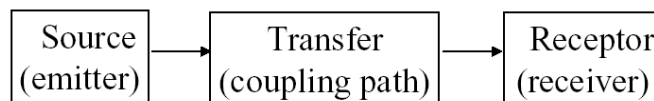
- EMI is produced by a source emitter and is detected by a susceptible victim via a coupling path. The coupling path may involve one or more of the following coupling mechanisms:



- | | | |
|--|---|---|
| <ul style="list-style-type: none"> • <i>Effective suppression</i> • <i>Proper circuit design</i> • <i>Shielding</i> • <i>Grounding</i> | <ul style="list-style-type: none"> • <i>Reduce coupling path efficiency</i> • <i>Reduce external radiators</i> • <i>Reduce radiation frequency</i> | <ul style="list-style-type: none"> • <i>Immunity</i> • <i>Make it non susceptible</i> • <i>Error correction code</i> |
|--|---|---|

5

Basic Decomposition of the EMC Coupling Problem



DEFINITIONS

Conducted Emission

Desired or undesired electromagnetic energy that is propagated along a conductor.

Electromagnetic Emission

The phenomenon by which EM energy emanates from a source.

Radiated Emission

Desired or undesired electromagnetic energy that is propagated into or across space, either as a transverse electromagnetic wave or by capacitive or inductive coupling.

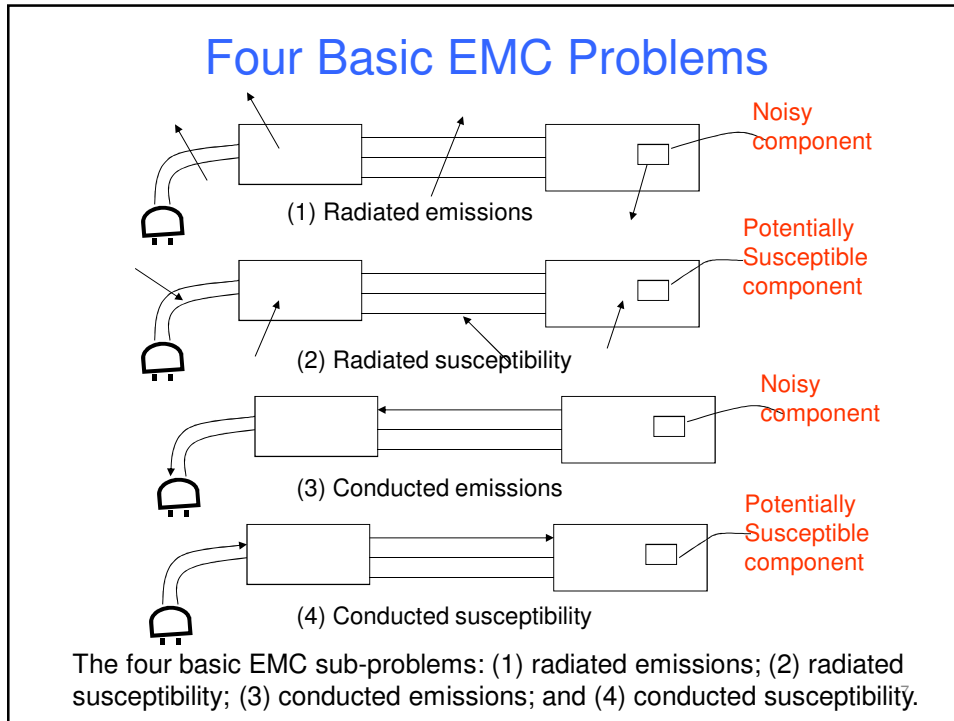
Immunity

The ability of equipment and/or system to perform without degradation in the presence of an electromagnetic disturbance.

Susceptibility (lack of immunity)

The inability of equipment and/or system to perform without degradation in the presence of an electromagnetic disturbance.

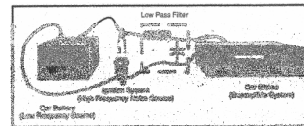
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Coupling mechanisms

1. Conduction

(electric current) is coupled between components through interconnecting wires such as through power supply and ground wires. Common impedance coupling is caused when currents from two or more circuits flow through the same impedance such as in power supply and ground wires.



2. Radiation (EM fields) may be treated as two cases:

- In the near field,

E and H field coupling are treated separately.

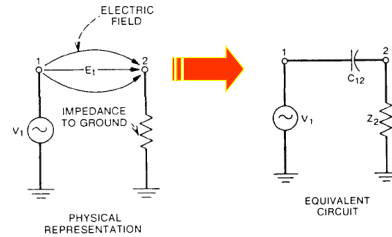
- In the far field,

coupling is treated as a plane wave coupling.



Coupling mechanisms (Cont.)

3. **Capacitive Coupling** (electric field) is caused by a voltage difference between conductors. The coupling mechanism may be modeled by a capacitor.
4. **Inductive Coupling** (magnetic field) is caused by current flow in conductors. The coupling mechanism may be modeled by a transformer.



5. A different class of EMI: **Electrostatic discharge (ESD)**: refers to the build up of *electrostatic potentials* on tools, objects, and the human body caused by mechanical action, such as rubbing.

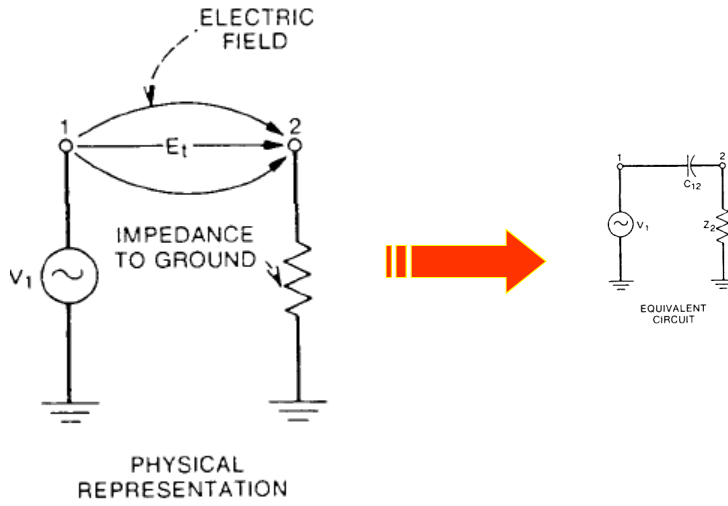
9

Inside Equipment - coupling classification

- **Electric field coupling** – caused by voltage difference between conductors.
- **Magnetic field coupling** – caused by current flow in conductors.
- **Conductive coupling** – noise coupled between components through interconnecting wires, e.g. through power supply and ground wires.
- **Common impedance coupling** – caused two or more currents flowing in the same impedance, e.g. in power supply and ground wires.

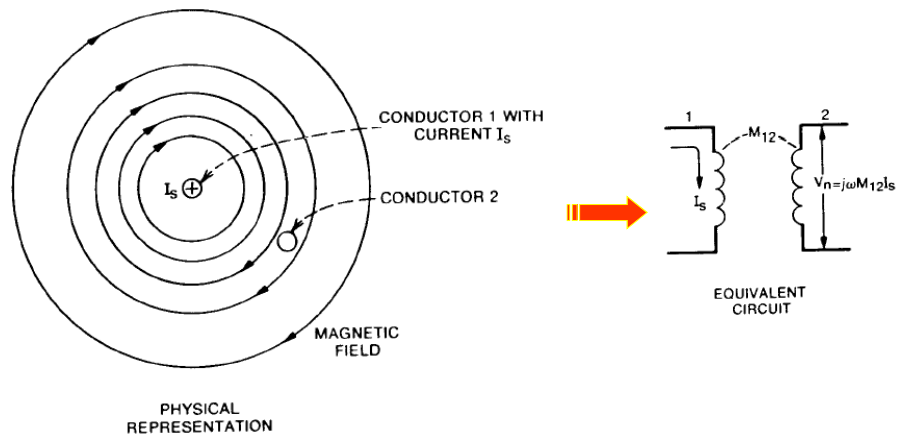
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Electric Field Coupling



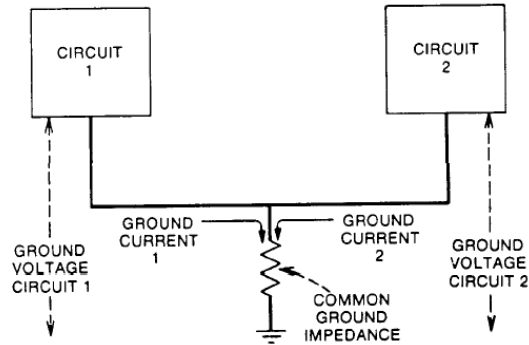
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Magnetic Field Coupling



12

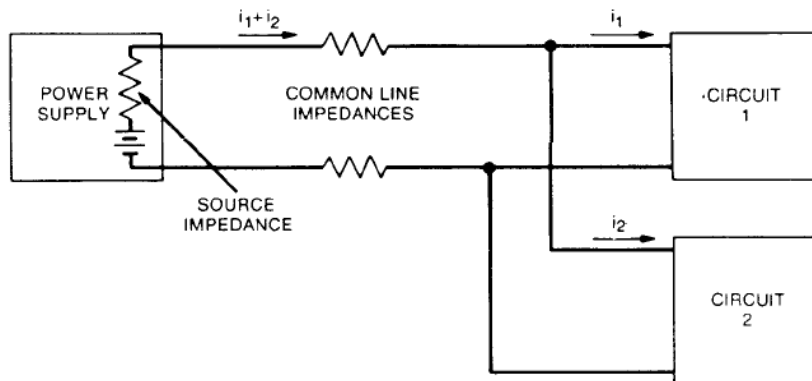
Common Impedance Coupling: Common Ground



The ground voltage of each circuit is affected by the ground current of the other

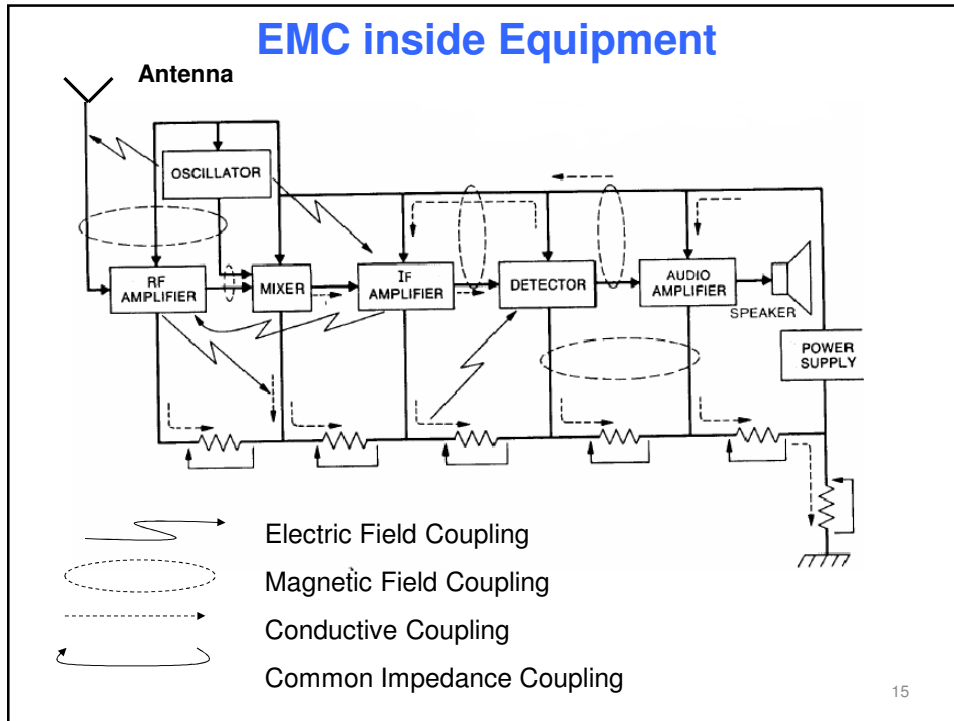
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Common Impedance Coupling: Common power supply



The current drawn by one circuit affects the voltage at the other circuit

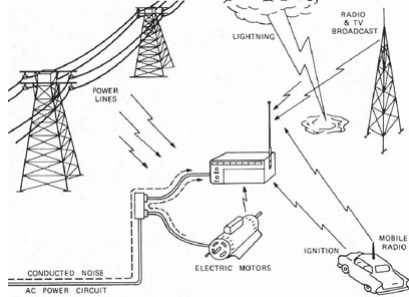
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The Electromagnetic Interference Problem (EMI)

Some sources of EMI (noise)

- Electric field coupling from:
 - High-voltage power lines.
 - Broadcast antennas.
 - Communications transmitters.
 - Vehicle ignition systems.
- Conductive coupling through AC power lines.




Examples

- Circuits for communications.
- Circuits for power distribution.
- Computers.

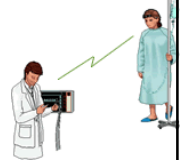
Major Equipment Design Objective

- Elimination (or avoidance) of EMI. This means that equipment should be designed so that it is not affected by noise nor is itself a source of noise.

16



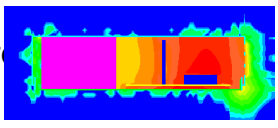
EMI in hospital environment



- The most common sources of EMI, and therefore of the greatest concern are:
 - Computing Devices, Radio Transmitters, Television Receivers and projection devices, Cellular Telephones ...

EMI and PCs

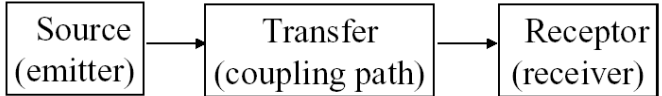
- There are actually two different issues here
 - EMI emissions by the PC, and
 - EMI emissions received by the PC.
- PCs generally do not cause very much interference with other devices; they are required by government regulations to be certified as *Class B* devices.



17

Three Ways to Prevent EMI

- Suppress the emission at its source
- Make the coupling path as inefficient as possible
- Make the receptor less susceptible to the emission



Techniques of Eliminating EMI

<ul style="list-style-type: none"> ■ Shielding ■ Grounding ■ Balancing ■ Filtering ■ Isolation 	<ul style="list-style-type: none"> ■ Separation and Orientation ■ Circuit Impedance Level Control ■ Cable Design ■ Cancellation Techniques (Frequency or Time Domain)
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18

Use of Network Theory

- Solving Maxwell's equations for an exact analysis is difficult
- *Electric circuit analysis* is used to obtain approximate solutions

- Assumptions in analyzing a circuit:
 - All electric fields are confined to the interior of capacitors
 - All magnetic fields are confined to the interior of inductors
 - Circuit dimensions are small compared to a wavelength. (At 300 MHz \approx 1 m.)

- Noise coupling channels are modeled as equivalent lumped component networks

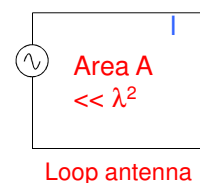
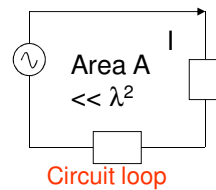
19

Radiation from Circuits

- Just like antennas – electronic circuits radiate (and by reciprocity receive) EM energy
- Currents radiate whether they are on antennas or in electric circuits
- In both cases, the total power radiated is

$$P_{rad} = \frac{4\pi^3}{3} \eta I^2 \left[\frac{A}{\lambda^2} \right]^2 \quad \left\{ \begin{array}{l} \eta \approx 377\Omega \\ I : \text{phasor current (peak)} \end{array} \right.$$

[More later on radiation](#)



- Note that the power radiated depends upon the electric size of the loop, i.e. Its size in wavelengths $\lambda = c/f = 3 \times 10^8 / f$

f	60Hz	1kHz	1MHz	1GHz	1THz
λ	5×10^6 m	3×10^5 m	300m	0.3m	3mm

20

Physical vs Electrical Size

- Physical Size – size measured in meters
- Electrical Size – size measured in wavelengths
 - L: physical length,
 - (L/λ) : electrical length
 - $\lambda=c/f$ c =speed of light $\approx 3 \times 10^8$ m/s, f = freq. In Hz
- Example: If $L = 10\text{m}$ and $\lambda = 0.5\text{m}$ $L = 20\lambda$
- Example: If $L = 10\text{cm}$ and $f = 60\text{ Hz}$ $L = ? \lambda$
- Example: If $L = 10\text{cm}$ and $f = 3\text{ GHz}$ $L = ? \lambda$
- For nonconductive media, other than free space, the velocity of wave propagation is

$$v = c / \sqrt{\epsilon_r \mu_r} \quad \& \quad \text{the wavelength is } \lambda = v / f$$



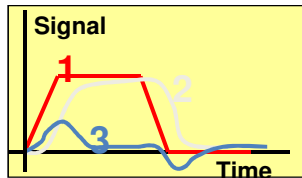
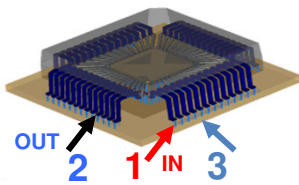
Signal Integrity

- Signal integrity is the ability of a signal to generate correct responses in a circuit. A signal with good signal integrity has digital levels at required voltage levels at required times.
- Signal Integrity is a field of study half-way between digital design and analog circuit theory. It's all about how to build really fast digital hardware that really works.
- Signal Integrity describes the environment in which the signals must exist.
- It covers various techniques and design issues that ensure signals to be undistorted and do not cause problems to themselves, or to other components in the system.
- At today's speeds even the simple, passive elements of a high-speed design—the wires, PC boards, connectors, and chip packages—can make up a significant part of the overall signal delay. Even worse, these elements can cause glitches, resets, logic errors, and other problems.

22

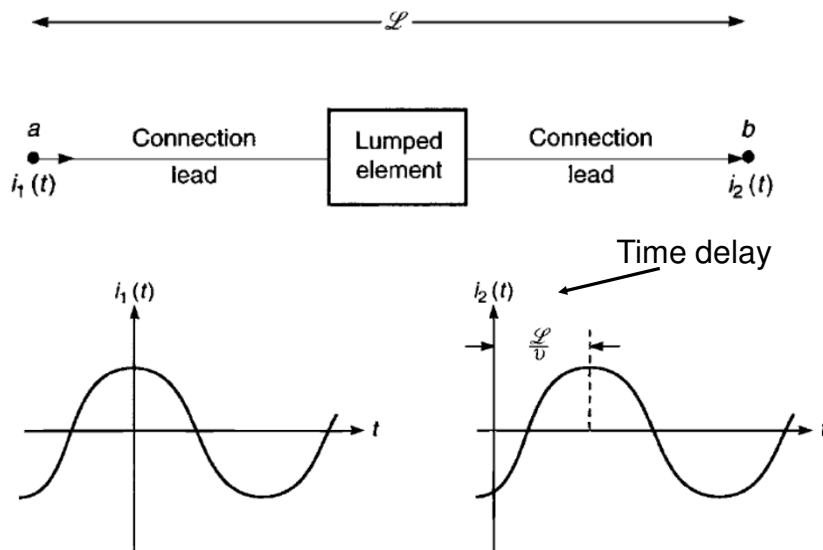
Issues in Signal Integrity

- Crosstalk noise
- Ringing
- Delay
- Manufacturing-related issues that if not addressed can lead to chip failure



23

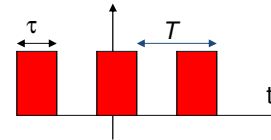
Signal Integrity: effect of element interconnection



Spectral Representation Of Signals

- Using Fourier series (periodic signals) or Fourier transform (non-periodic signals) any signal can be viewed in terms of its time or frequency domain (spectral) representation.
- Example: An even ($x(t) = x(-t)$) pulse train periodic function can be represented by the Fourier cosine series

$$x(t) = \sum_{n=0}^{\infty} a_n \cos(\omega_n t) \quad \begin{cases} \omega_n = n\omega_0 = n(2\pi f_0) \\ f_0 = \frac{1}{T} \end{cases}$$



Where:

$$a_0 = \frac{1}{T} \int_{-T/2}^{T/2} x(t) dt = \frac{1}{T} \int_{-\tau/2}^{\tau/2} A dt = A \frac{\tau}{T}$$

$$a_n = \frac{2}{T} \int_{-T/2}^{T/2} x(t) \cos(\omega_n t) dt = \frac{2}{T} \int_{-\tau/2}^{\tau/2} A \cos(\omega_n t) dt = \frac{4A}{\omega_n T} \sin\left(\frac{\omega_n \tau}{2}\right)$$

$$= \frac{4A}{T} (\tau/2) \frac{\sin(\omega_n \tau/2)}{\omega_n \tau/2} = 2A \frac{\tau}{T} \text{sinc}\left(n\pi \frac{\tau}{T}\right)$$

- This is a Fourier or spectral representation of $x(t)$ by an infinite number of sinusoids of freq. $f_n = nf_0$ & amplitude a_n $n=0,1,2,\dots$

Spectrum Analyzer



- A device which measures the frequency spectrum of the input signal



- $X(f)$ is the Fourier Transform of $x(t)$.
- A spectrum analyzer consists of
 - A narrow bandpass filter whose center frequency (f_c) is swept in time over the frequency band selected.
 - A "peak" detector
- The output of the peak detector is proportional to $X(f_c)$.

Phasors

- All of the currents, voltages, and fields are considered to be sinusoidal of radian frequency ω (unless noted)
 - Real sinusoidal

$$v_c(t) = V \cos(\omega t + \phi)$$

- Complex exponential or time-harmonic

$$v_e(t) = V e^{j\phi} e^{j\omega t} = V e^{j(\omega t + \phi)}$$

$$v_c(t) = \text{Re}[v_e(t)] = V \text{Re}[\cos(\omega t + \phi) + j \sin(\omega t + \phi)] = V \cos(\omega t + \phi)$$

- Phasor = a complex number which holds the magnitude and phase of a sinusoid

$$\underline{V} = V e^{j\phi} = V \angle \phi$$

27

Decibels (dB) – Section 1.5

- A log scale is used with dimensionless powers (or signal) ratios with large dynamic range

– Power Gain (Ratio) = $P_r = P_1/P_2$

– P_r in dB = $10 \log_{10} P_r \iff P_r = 10^{\text{dB}/10}$

- The voltage gain is defined as: $\text{Voltage gain}_{\text{dB}} \equiv 20 \log_{10} \left(\frac{v_{\text{out}}}{v_{\text{in}}} \right)$

- **Example:**

An amplifier with a gain of 20dB has the following losses

- Connectors = 1.0 dB
 - Cables = 2.0 dB
 - Aging = 1.0 dB
- } → Total loss = 4 dB

True gain $G = 20 \text{ dB} - \text{losses} = 16 \text{ dB}$

The losses reduce the gain by 4 dB which is a factor of $10^{-4/10} = 0.4$ 28

Decibels (Cont.)

- Relative dB

➤ implies the denominator in the power ratio is some fixed reference.

➤ For example, with respect to a reference power of

$P_1 = 1\text{mW}$, $P_2 = 20\text{W}$ corresponding to the power ratio

$$P_r = \frac{P_2}{P_1} = \frac{20}{0.001} = 20,000$$

$$P_{rdB} = 10 \log_{10} 20,000 = 43\text{dBmW} \text{ (or } 43\text{dB / mW)}$$

Which is read as “43 dB over a mW”

29

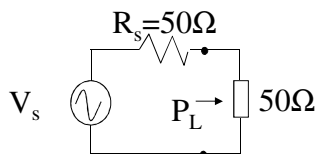
Decibels (Cont.)

- Other base quantity:

$$\text{dBmV} \equiv 20 \log_{10} \left(\frac{\text{volts}}{1\text{mV}} \right)$$

$$\text{dB}\mu\text{W} \equiv 10 \log_{10} \left(\frac{\text{watts}}{1\mu\text{W}} \right)$$

Example: Signal sources are often specified in terms of the power they will deliver to a matched 50 Ω load.



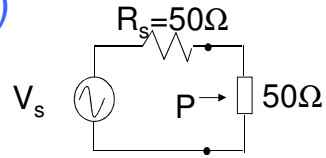
$$P_L = \frac{V_s^2}{4R_L} = \frac{V_s^2}{200}$$

Example: For a 20dBm load power:

$$P_{LdBm} = 10 \log_{10} \left[\frac{P_L}{1\text{mW}} \right] = 20\text{dBm} \Rightarrow \frac{P_L}{1\text{mW}} = 10^2 = 100 \Rightarrow P_L = 100\text{mW} = 0.1\text{W}$$

30

Decibels (Cont.)

Useful Conversion for 50 Ω System:Start with $P = V^2 / 50$ Show $P \text{ (dBm)} = V \text{ (dB}\mu\text{V)} - 107$ Note $P \text{ (dBmV)} = V \text{ (dB}\mu\text{V)} - 60$ $P \text{ (dBm)} = V \text{ (dB}\mu\text{W)} - 30$ Other useful conversions:

$$\text{Watts} = 10^{\text{dB}\mu\text{W}/10} \times 10^{-6}$$

$$\text{Watts} = 10^{\text{dBm}/10} \times 10^{-3}$$

$$P_{\text{out dB}} = \text{Gain}_{\text{dB}} + P_{\text{in dB}}$$

$$P_{\text{out dBm}} = \text{Gain}_{\text{dB}} + P_{\text{in dBm}}$$

$$P_{\text{out dB}\mu\text{W}} = \text{Gain}_{\text{dB}} + P_{\text{in dB}\mu\text{W}}$$

31

• Problem 1.5.1 #4

- $V = 0.1 \mu\text{V}$

$$\begin{aligned} V(\text{dB } \mu\text{V}) &= 20 \log(0.1 \mu\text{V} / 1 \mu\text{V}) \\ &= 20 \log 0.1 \\ &= -20 \text{ dB } \mu\text{V} \end{aligned}$$

- $P(\text{dBm}) = V(\text{dB}\mu\text{V}) - 107$
 $= -20 - 107 = -127 \text{ dBm}$

• Problem 1.5.2 #5

- $V = 36 \text{ dBmV}$

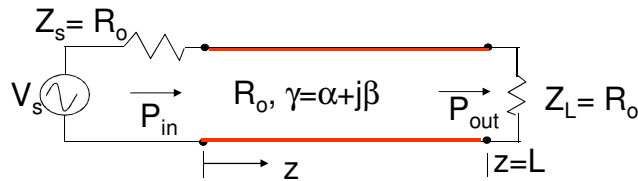
$$V(\text{dBmV}) = 20 \log(V / 1 \text{mV})$$

$$36 = 20 \log(1000 \text{ V})$$

$$V = (10^{36/20}) / 1000 = 63.1 \mu\text{V}$$

32

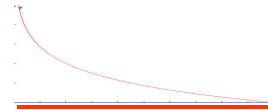
Cable Loss/Attenuation – Section 1.5.1



- The power absorbed by the load at $z = L$

$$P_{out} = P_{in} e^{-2\alpha L} (1 - |\Gamma|^2) = P_{in} e^{-2\alpha L} \quad (\Gamma \equiv 0)$$

$$\alpha = \text{Re}(\gamma) = \text{attenuation const.}$$



$$\frac{P_{in}}{P_{out}} = e^{2\alpha L} \Rightarrow \alpha = \frac{1}{2L} \ln \left(\frac{P_{in}}{P_{out}} \right)$$

$$\text{Cable Loss dB} = 10 \log_{10} (P_{in}/P_{out}) = P_{in} \text{ dB} - P_{out} \text{ dB}$$

Example:

A loss of 2 ($\approx 3\text{dB}$) is equivalent to an efficiency of 0.5 (-3dB)

33

Cable Loss/Attenuation (Cont.)

- Attenuation is usually specified in terms of loss per given length, instead of α .
 - Power loss in dB/m is the drop in power for each meter of propagation
 - Absolute Power Loss in neper/m is the factor by which the power is reduced for each meter of propagation

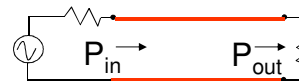
- Example:** Cable loss

- A 20 dBm source is connected to matched load via a 10 m cable with loss of 0.1 dB/m.

Find the power delivered to the load.

- The total cable loss = $0.1 \times 10 = 1 \text{ dB}$

Power delivered = $20 - 1 = 19 \text{ dBm}$

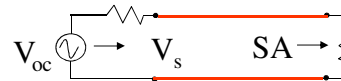


34

Problem 1.5.8

A 50-Ω source is tuned to 100 MHz and attached to a 50-Ω spectrum analyzer with 200 ft of 50-Ω coaxial cable that has a loss of 4.5 dB/100 ft at 100 MHz. The spectrum analyzer reads a level of signal at 100 MHz of 56.5 dBμV. If the cable is removed and the signal source is attached directly to a 100-Ω load, determine the voltage across this load in dBμV. [67.98 dBμV]. Determine the reading on the meter of the source in dBm. [-41.5 dBm]

It is not a matched case..
1st consider 50 Ω system



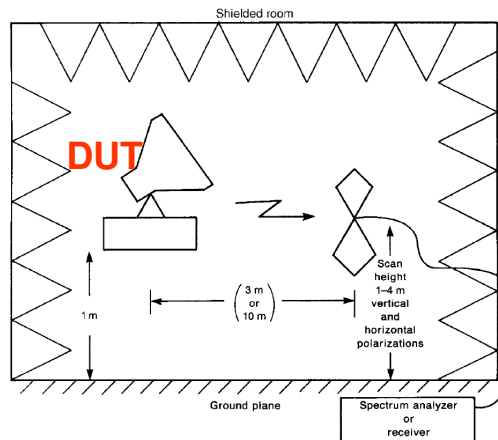
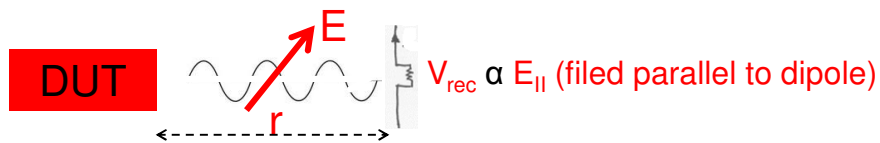
$$V_{rec} = V_s - \text{Cable losses} \Rightarrow V_s = 65.5 \text{ dB}\mu\text{V}$$

$$V_{oc} = 2V_s = 61.5 \text{ dB}\mu\text{V}$$

When connected to 100 Ω load

$$V_{out} = V_{oc} * \frac{100}{(50 + 100)} = 71.5 + 20 \log(2/3) = 67.98 \text{ dB}\mu\text{V}$$

Measurements of Radiated Emissions



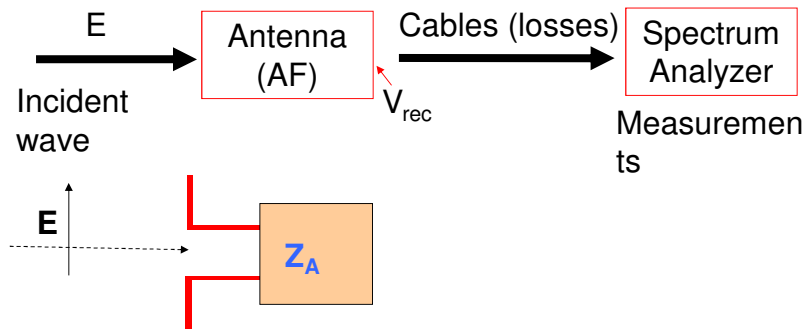
- Government regulatory agencies specify a maximum V_{rec} at a given r .
- It can be scaled to a different value at a different r :
- In the far-field ($r \gg \lambda$):

$$V_{rec}(r) \propto E(r) \propto \frac{1}{r}$$

$$\therefore \text{If } V_{rec}(5m) = 100 \mu\text{V}$$

$$\Rightarrow V_{rec}(10m) = 50 \mu\text{V}$$

Antenna Factor (More later)



For EMC applications (measurements), the Antenna Factor (AR) is defined as

$$AF = \frac{|E_{inc}|}{|V_{rec}|} = \frac{E - \text{Field Strength (V/m) in incident wave}}{V \text{ received}}$$

$$AF_{dB} = \text{dB}\mu\text{V/m (incident field)} - \text{dB}\mu\text{V (received voltage)}$$

EMC Regularity Requirements (Why?)

Two Classes of EMC Requirements for Electronic Systems:

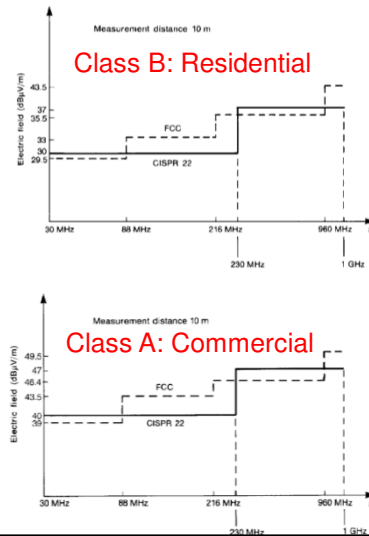
- Those mandated by governmental agencies.
- Those imposed by the product manufacturer.
 - For digital devices, there are two classes:
 - **Class A** – marketed for use in commercial, industrial or business environment
 - **Class B** – marketed for use in a residential environment (even if it is also used in industry).
 - A digital flow control valve would be class A
 - A PC would be class B

Class B regulations are more stringent since we assume (engineers in) industry are better equipped to deal with interference probs.

The World: EMC Standards, and Regulations

- In the United States, there are a number of regulatory issues dealing with EMI, consist of **FCC** (Federal Communications Commission), **IEEE**,.....
- In Europe, the EMI situation was deal with by EC, CISPR (International Special Committee on Radio Interference),
- International EMC standard developed in 1985 by CISPR (International Special Committee on Radio Interference)

The graphs compare Radiated Emission Limits



Digital devices emission limits

TABLE 2.4 FCC Emission Limits for Class B Digital Devices

Frequency (MHz)	Measured at 3 m	
	$\mu\text{V}/\text{m}$	$\text{dB}\mu\text{V}/\text{m}$
30–88	100	40
88–216	150	43.5
216–960	200	46
>960	500	54
>1 GHz	500 (AV) 5000 (PK)	54 (AV) 74 (PK)

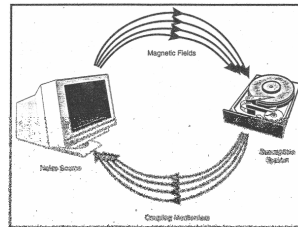


TABLE 2.5 FCC Emission Limits for Class A Digital Devices

Frequency (MHz)	Measured at 10 m	
	$\mu\text{V}/\text{m}$	$\text{dB}\mu\text{V}/\text{m}$
30–88	90	39
88–216	150	43.5
216–960	210	46.4
>960	300	49.5
>1 GHz	300 (AV) 3000 (PK)	49.5 (AV) 69.5 (PK)

Radiation emission limits for information technology equipment (ITE)

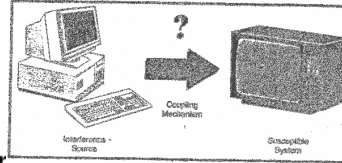


TABLE 2.6 CISPR 22 Radiated Emission Limits for Class B ITE Equipment (10 m)

Frequency (MHz)	$\mu\text{V}/\text{m}$	$\text{dB}\mu\text{V}/\text{m}$
30–230	31.6	30
230–1000	70.8	37

TABLE 2.7 CISPR 22 Radiated Emission Limits for Class A ITE Equipment (10 m)

Frequency (MHz)	$\mu\text{V}/\text{m}$	$\text{dB}\mu\text{V}/\text{m}$
30–230	100	40
230–1000	224	47

41

Problem 2.1.8

The radiated emissions from a product are measured at 50 MHz at 15 m away and are found to be 21 $\mu\text{V}/\text{m}$. Does the product comply with the FCC Class B limit? [No] By how much does the product pass or fail?

1st consider the allowed value at 15 m

TABLE 2.4 FCC Emission Limits for Class B Digital Device

Frequency (MHz)	Measured at 3 m	
	$\mu\text{V}/\text{m}$	$\text{dB}\mu\text{V}/\text{m}$
30–88	100	40
88–216	150	43.5
216–960	200	46
>960	500	54
>1 GHz	500 (AV) 5000 (PK)	54 (A) 74 (B)

$$E_{\text{max}} = 100\mu\text{V}/\text{m} \quad @ 3\text{m}$$

$$@ 15\text{m}, \quad E_{\text{max}} = 100 * 3/15 = 20\mu\text{V}/\text{m} = 26.021\text{dB}\mu\text{V}/\text{m}$$

The measured value:

$$E = 21\mu\text{V}/\text{m} = 26.444\text{dB}\mu\text{V}/\text{m}$$

It fails by 0.423 dB

42

Problem 2.1.9

The voltage induced at the terminals of an antenna V_{ant} is 5 V for every V/m of incident field E_{ant} . What level in $\text{dB}\mu\text{V}$ at the base of the antenna would correspond to the FCC Class B limit at 100 MHz? [57.48 $\text{dB}\mu\text{V}$] Determine the reading of the spectrum analyzer if it is connected to the antenna with 200 ft of RG58U coaxial cable that has 4.5 dB/100 ft of loss at 100 MHz. [48.48 $\text{dB}\mu\text{V}$]

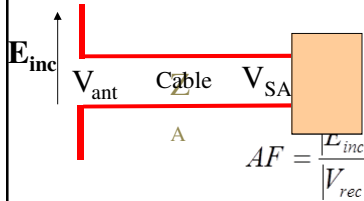


TABLE 2.4 FCC Emission Limits for Class B Digital Devices

Frequency (MHz)	Measured at 3 m	
	$\mu\text{V}/\text{m}$	$\text{dB}\mu\text{V}/\text{m}$
30-88	100	40
88-216	150	43.5

$$\frac{E_1}{E_2} = \frac{V_1}{V_2} = AF \Rightarrow \frac{5\text{V}/\text{m}}{150\mu\text{V}/\text{m}} = \frac{1}{V_{\text{max}}} \Rightarrow V_{\text{max}} = \dots$$

$$V_{ant} = V_{\text{max}} = \dots = V_{SA} + \text{Cable losses} \Rightarrow V_{SA} = \dots$$

43

Non ideal

Behavior of Elements

Clock Skew

Interconnect RC-lump model.
 $Z_0=82.5$ $TD=2.88\text{n}$

Interconnect trans. line model.

44

Designing for EMC

Equipment should be designed to:

- Function properly in its intended electromagnetic environment, i.e. to be immune to EMI.
- Not be a source of pollution to that environment, i.e. not to be an emitter of EMI.
- Susceptibility tends to be self-regulating. For example, consumers will avoid purchasing it.
- Emission tends to not be self-regulating if the product is not affected by its own emissions. As a result, regulatory bodies impose standards to

45

EMC Design

- Crisis approach is to consider EMC after the design is finished
- Systems approach is to apply EMC design principles throughout the entire development
- Note: Early and consistent attention to EMC will minimize cost and schedule delays and will provide the best chance for complying with the regulatory requirements.

46

Canada: EMI Management

- Electromagnetic Interference (EMI) is managed by:
 - Industry Canada (Radiocommunication Act)
 - Other departments – e.g. Health Canada
 - Parties in control of discrete EM Environment (EME) – e.g. ship, plane, hospital...
- Industry Canada & Radiocommunication Act
 - Jurisdiction limited to “radio” spectrum
 - “Radio apparatus” → licensed & unlicensed
 - Licensed tend to be most powerful emitters
 - Control - frequency, power, location & time
 - Legal hierarchy of uses and users of RF spectrum
 - Maximize users w/o unacceptable interference
 - 100 year history of spectrum regulation:
<http://strategis.ic.gc.ca>

47

Conducted emission limits

Conducting emission is important since currents conducted out the ac power cord can radiate efficiently on the electrically larger power grid “antenna”.

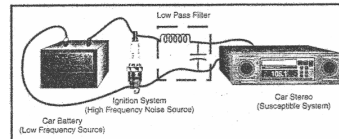


TABLE 2.1 FCC and CISPR 22 Conducted Emission Limits for Class B Digital Devices

Frequency (MHz)	$\mu\text{V QP (AV)}$	$\text{dB}\mu\text{V QP (AV)}$
0.15	1995 (631)	66 (56)
0.5	631 (199.5)	56 (46)
0.5–5	631 (199.5)	56 (46)
5–30	1000 (316)	60 (50)

The conducted emissions are measured with a Line Impedance Stabilization Network (LISN), see Fig 2.10.

TABLE 2.2 FCC and CISPR 22 Conducted Emission Limits for Class A Digital Devices

Frequency (MHz)	$\mu\text{V QP (AV)}$	$\text{dB}\mu\text{V QP (AV)}$
0.15–0.5	8912.5 (1995)	79 (66)
0.5–30	4467 (1000)	73 (60)

