EE2011 Engineering Electromagnetics

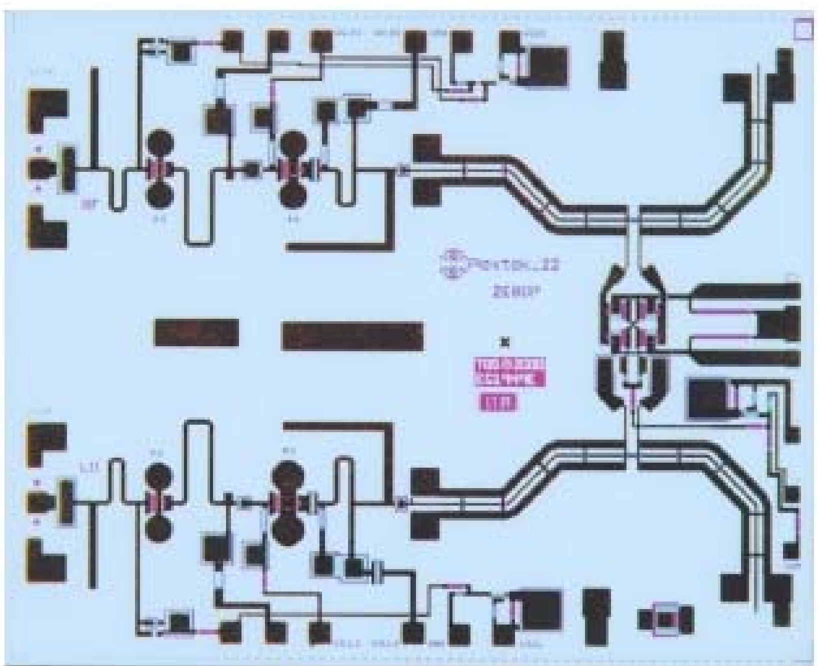
(Semester II of Academic Year 2011/2012)

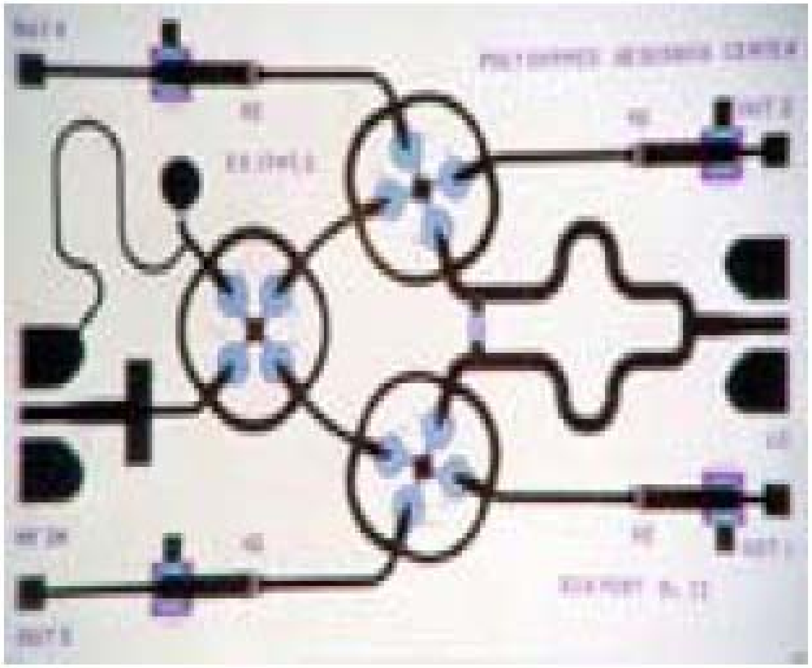
Yeo SP (eleyeosp) and Chen XD (elechenx)
Electrical & Computer Engineering Department

General Overview

special considerations required for designing integrated circuit (IC)

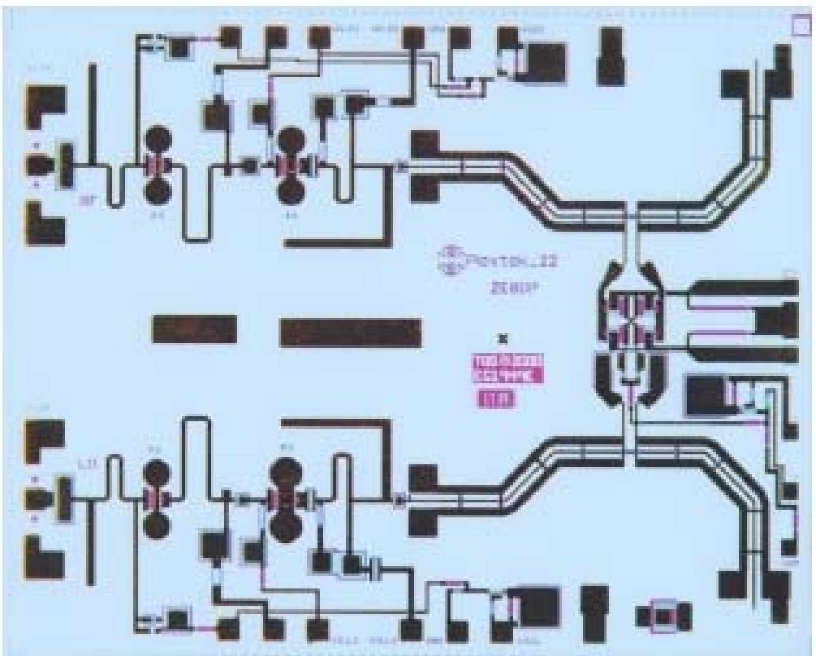
- when packing density keeps increasing for higher functionality
- when operating frequency keeps rising for broader bandwidth

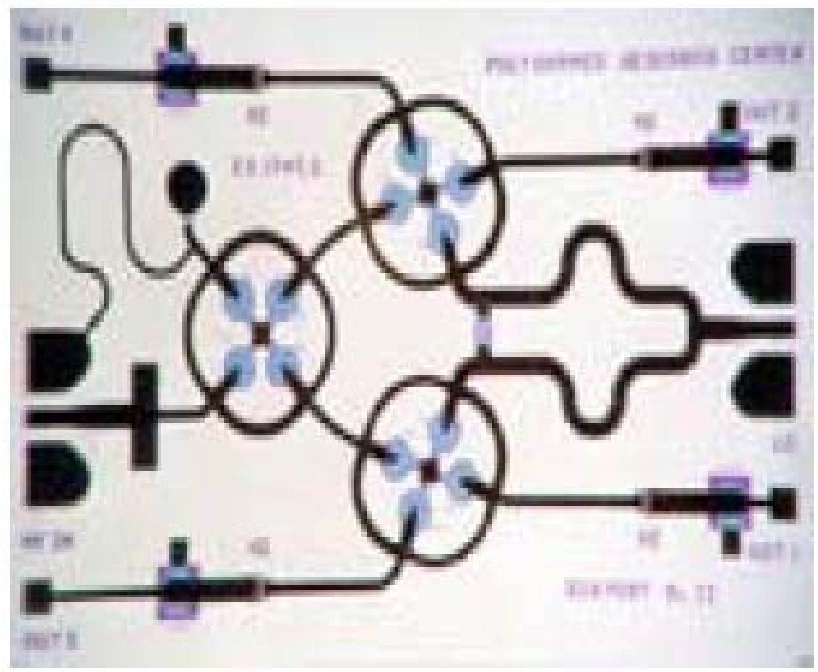




General Overview

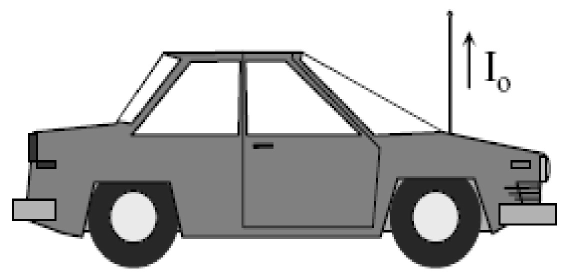
- transmission-line and mutual-coupling effects
  → novel microwave / RF components
- radiation (antennas, propagation, scattering, *etc*)
- electromagnetic interference / compatibility

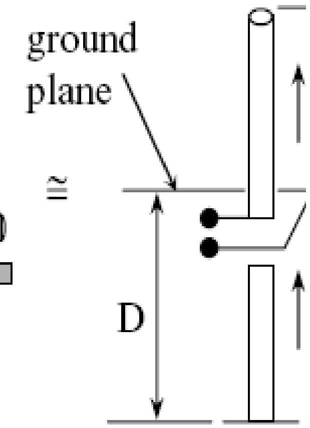


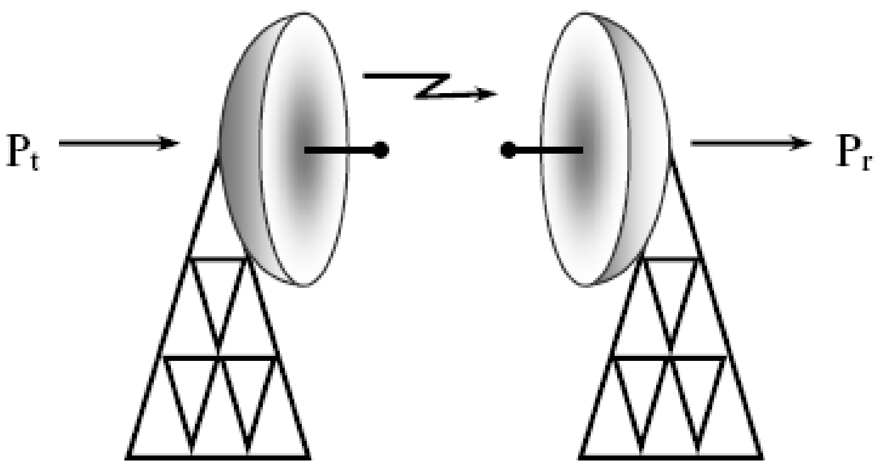


Electromagnetic Applications

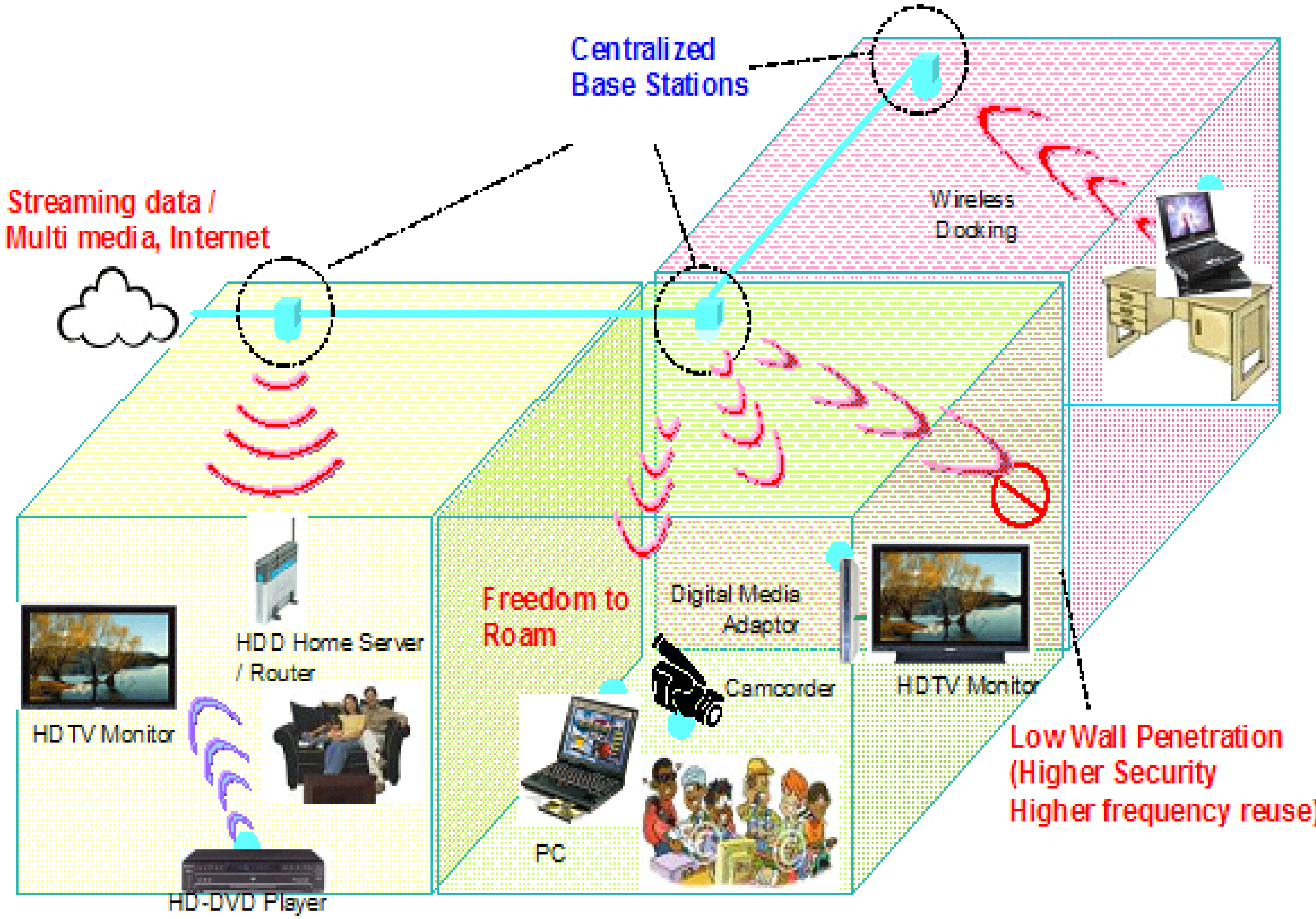
Electromagnetic Applications



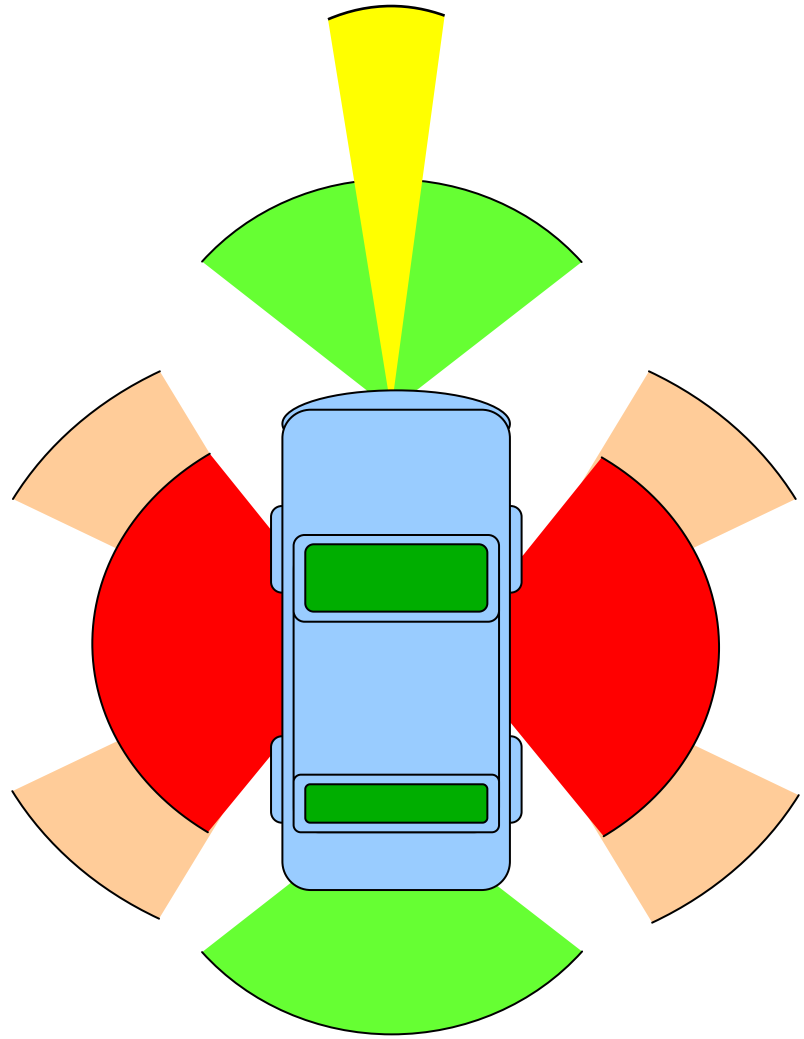




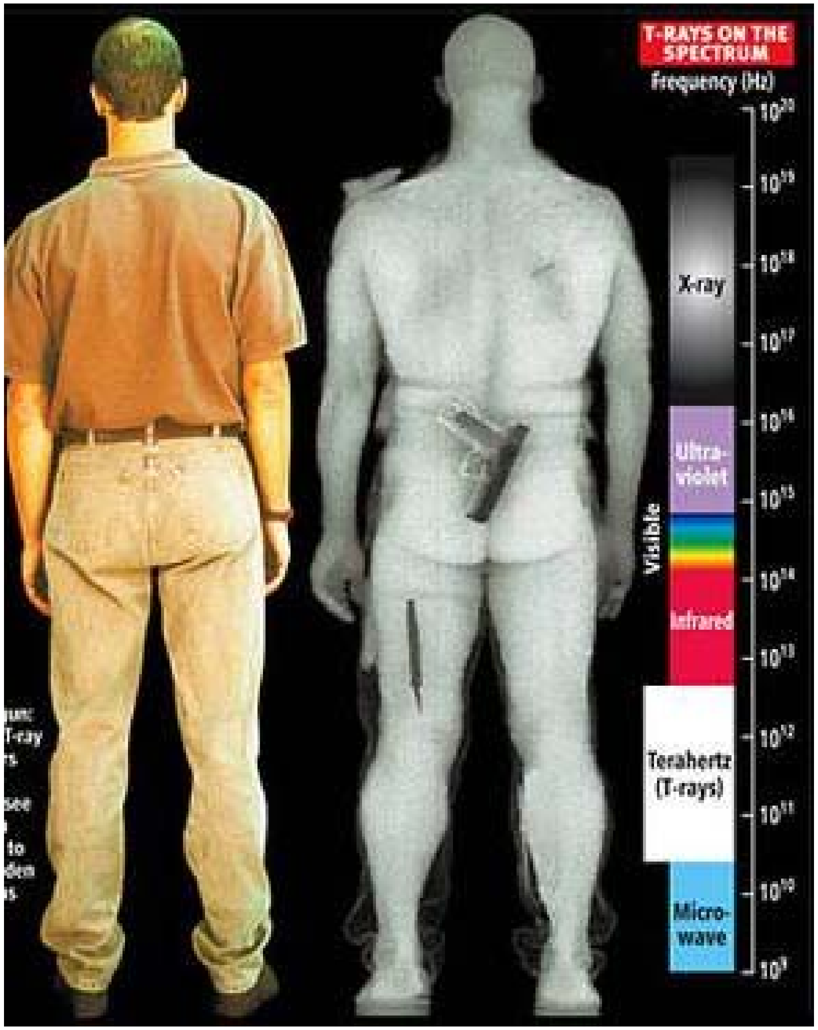
Electromagnetic Applications



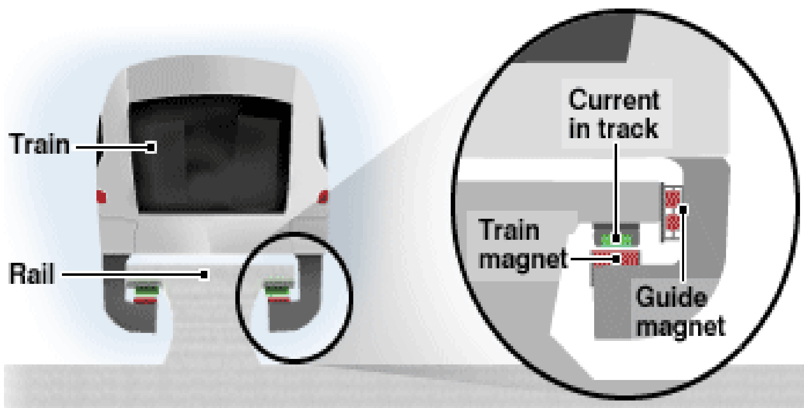
Electromagnetic Applications

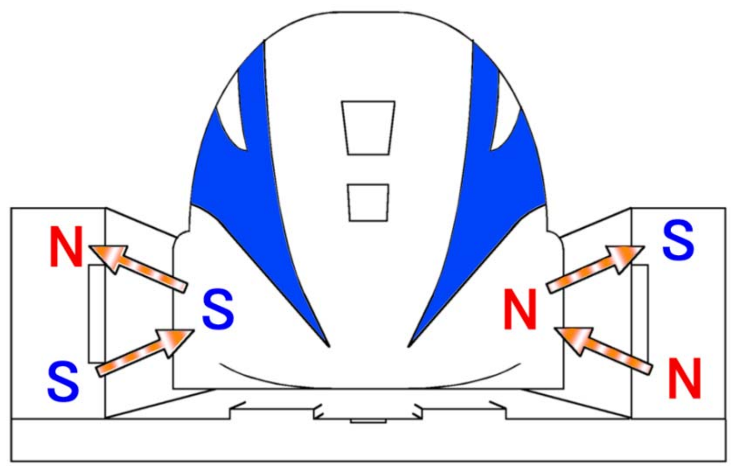


Electromagnetic Applications

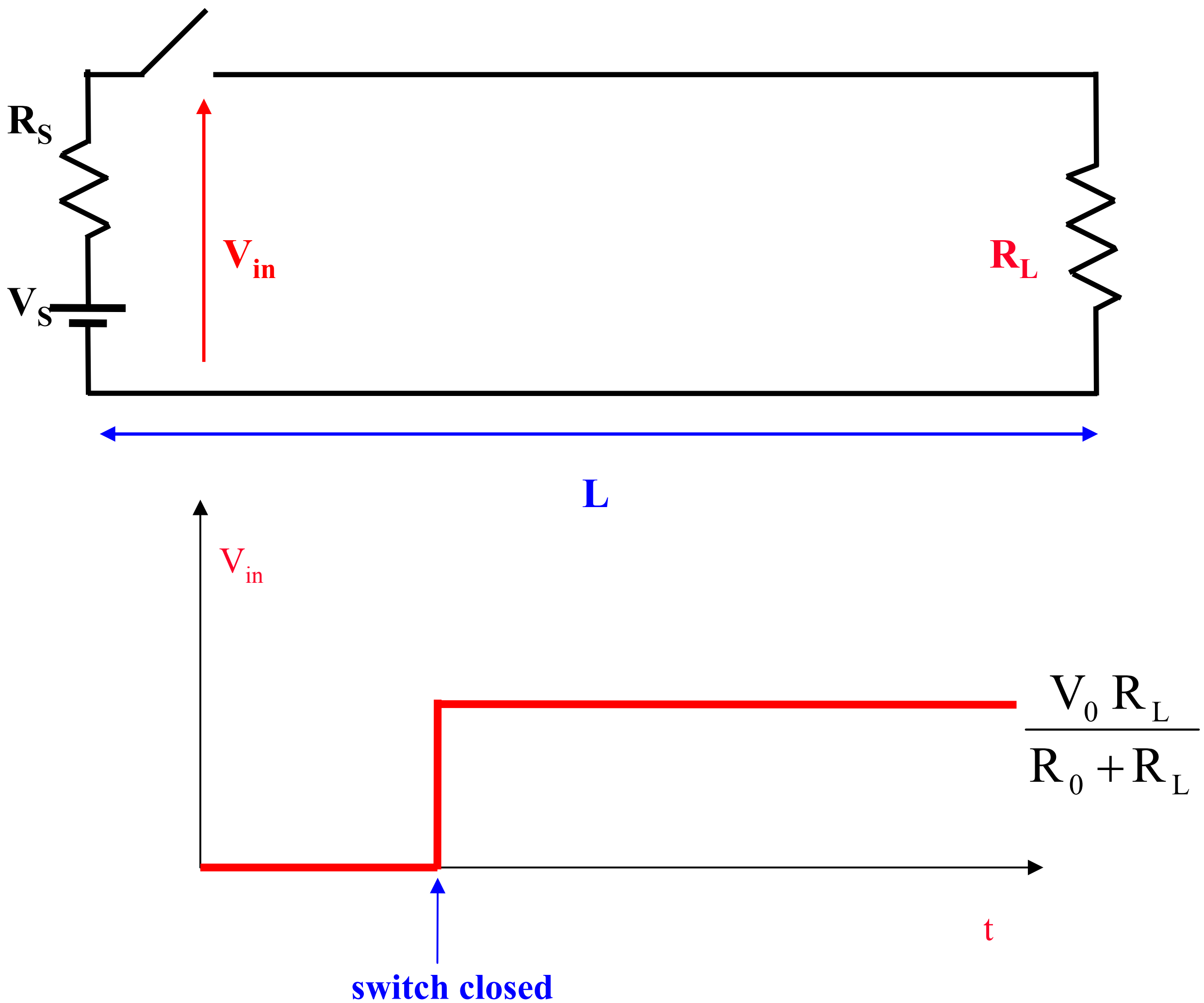


Electromagnetic Applications

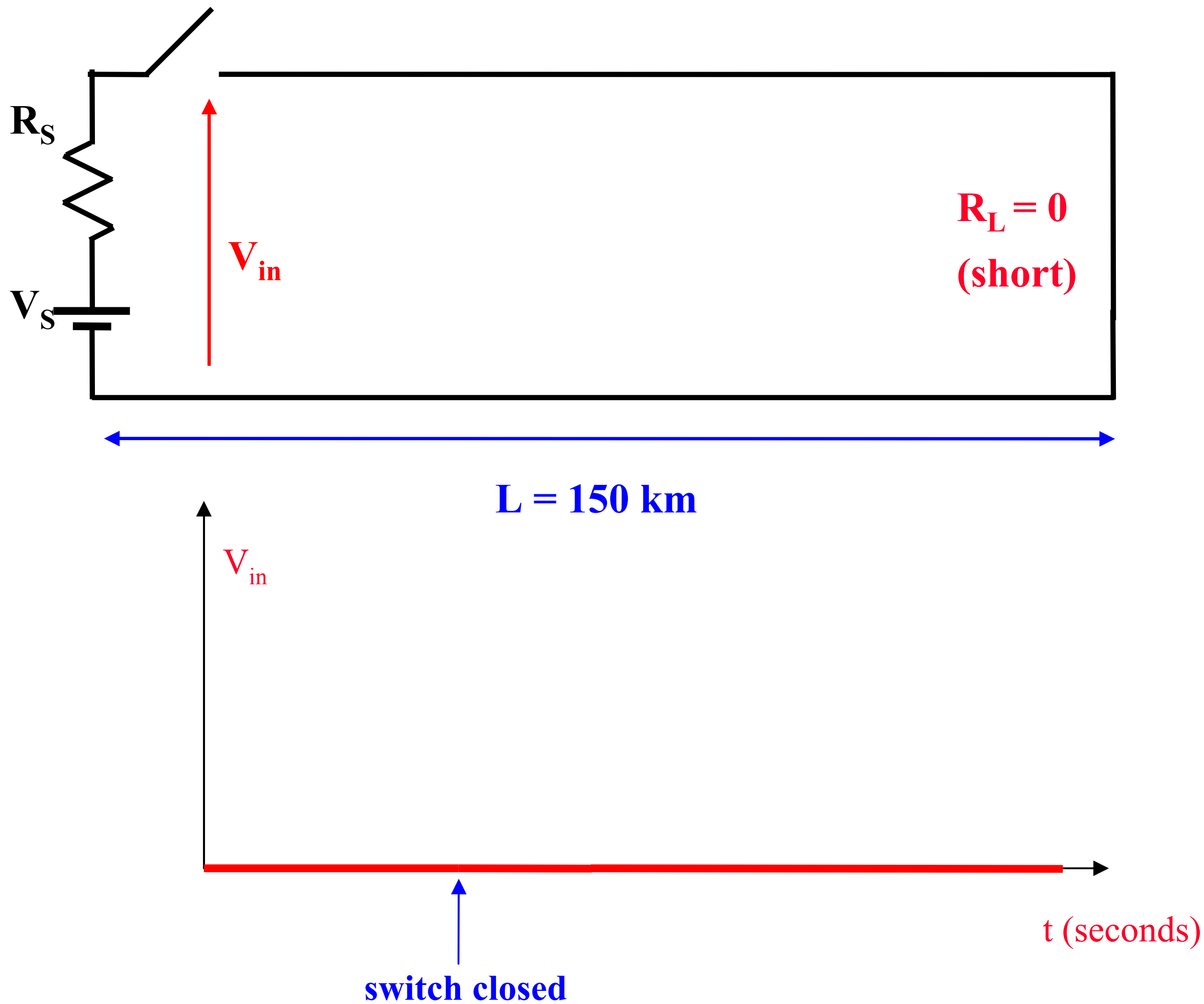




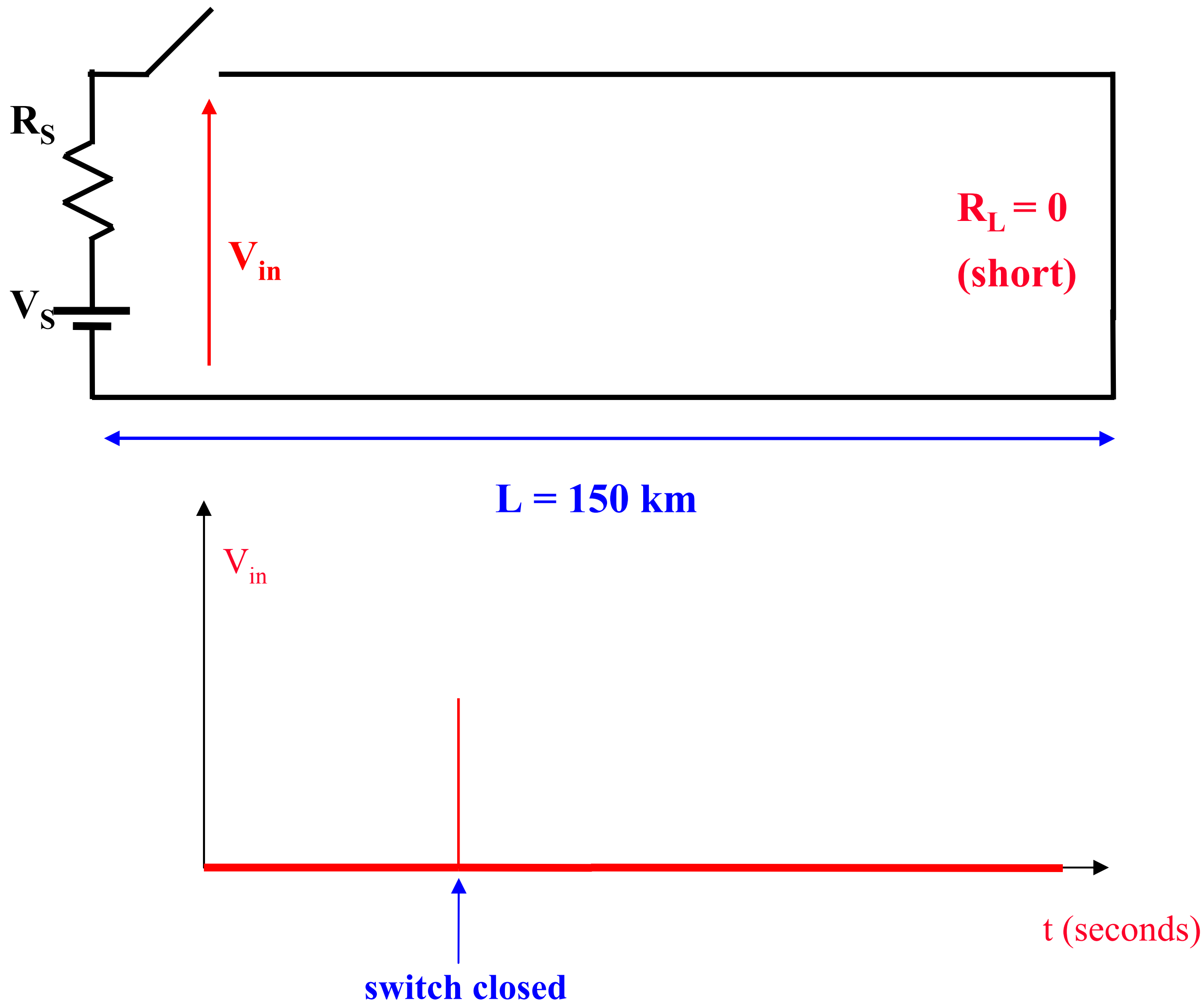
Transmission Lines



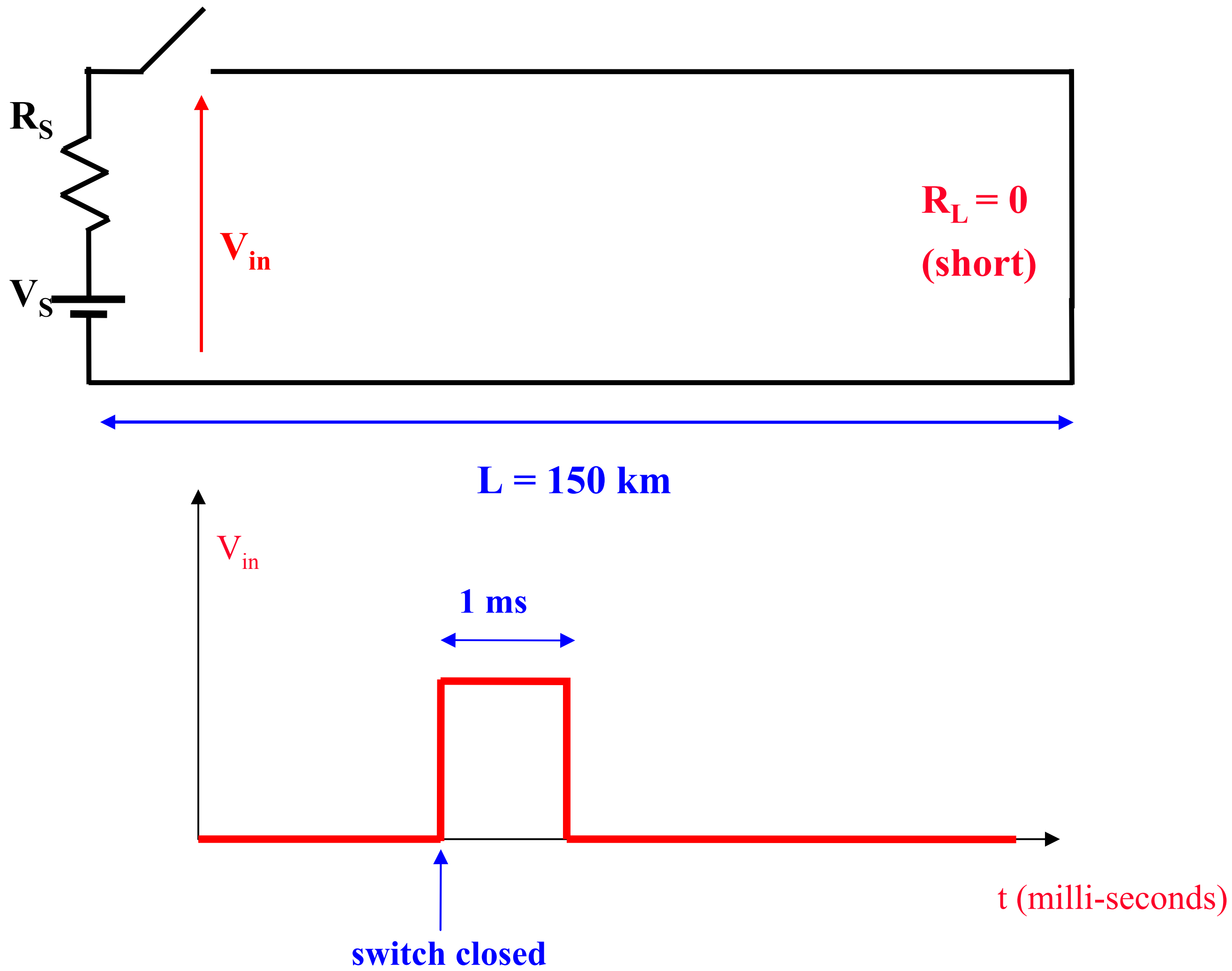
Transmission Lines



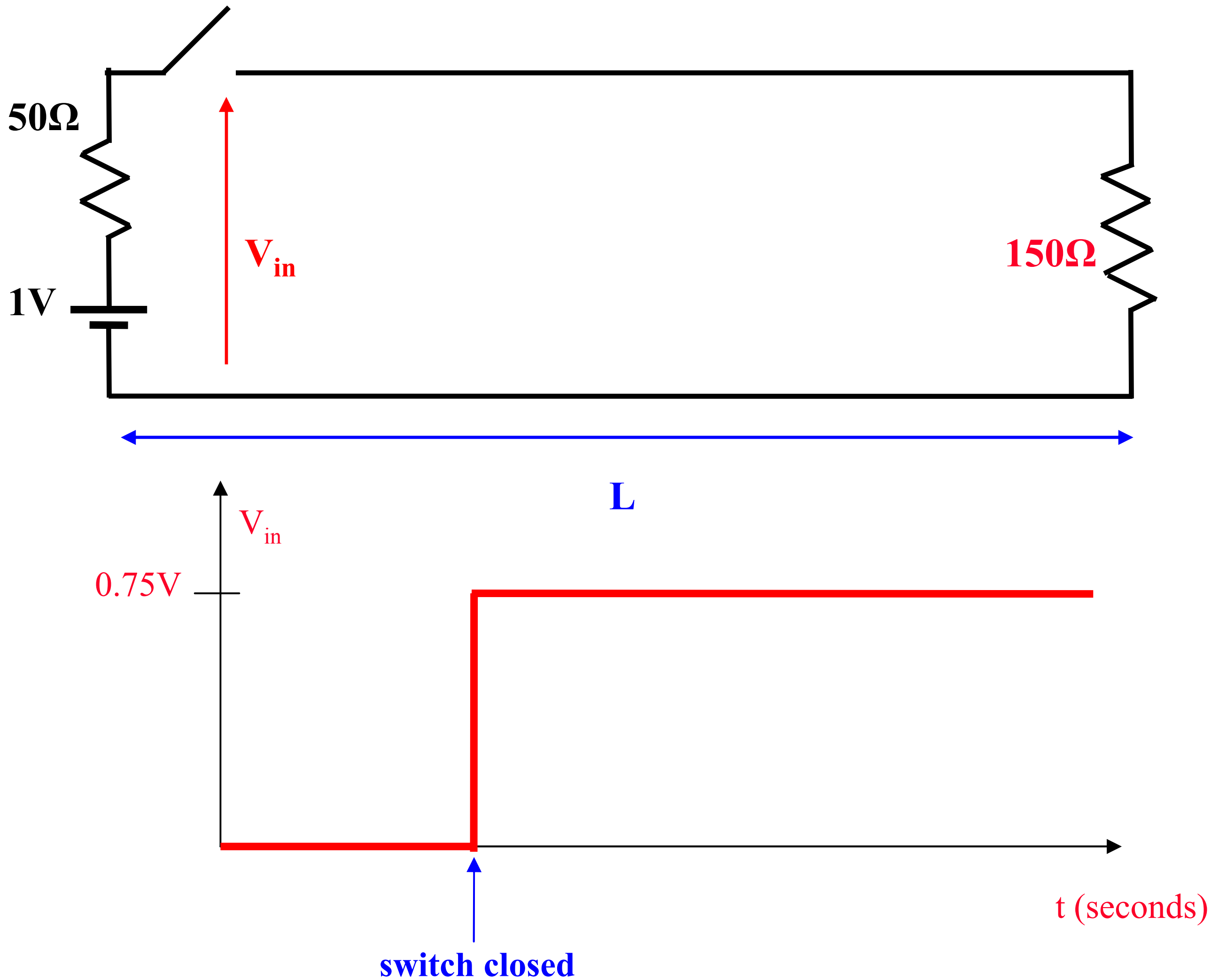
Transmission Lines



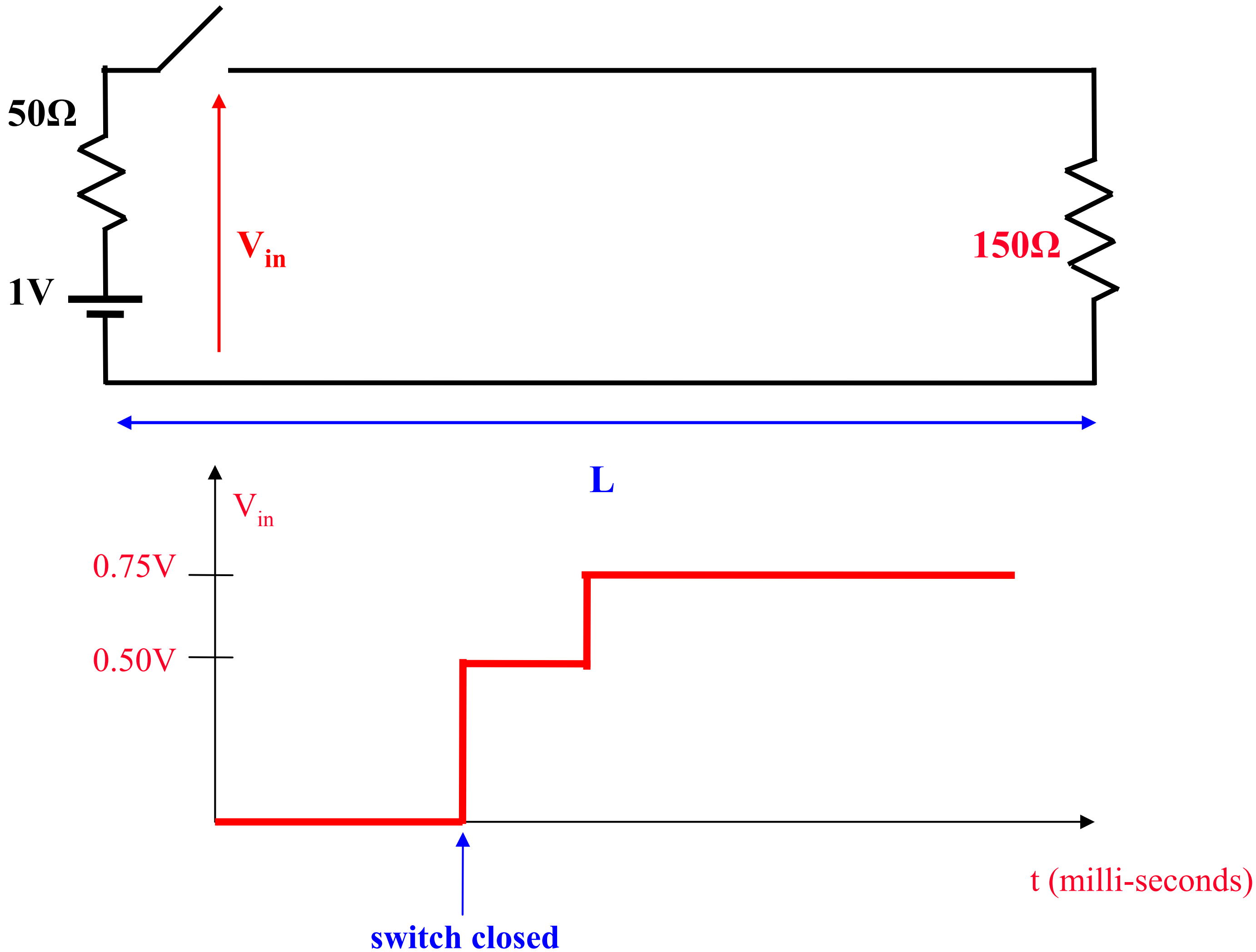
Transmission Lines



Transmission Lines

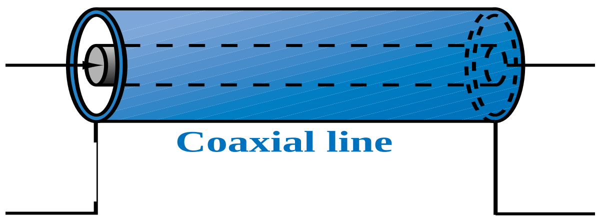


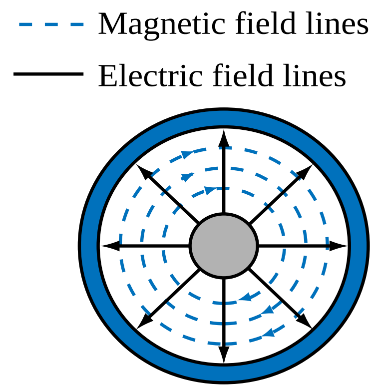
Transmission Lines

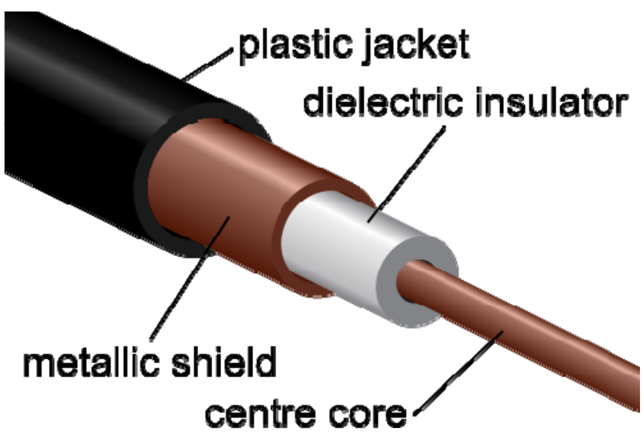


Transmission Lines

coaxial cable







Transmission Lines

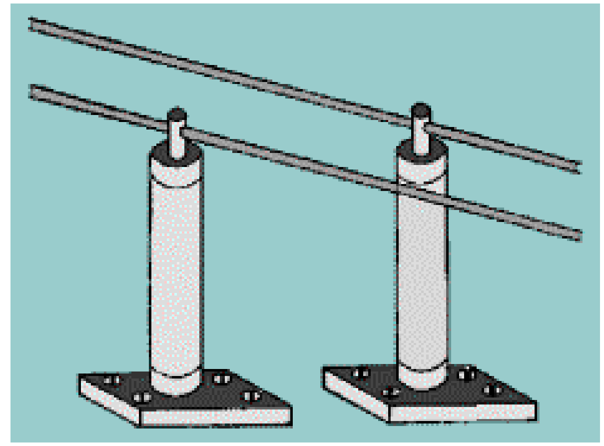
twin wires (without shielding)

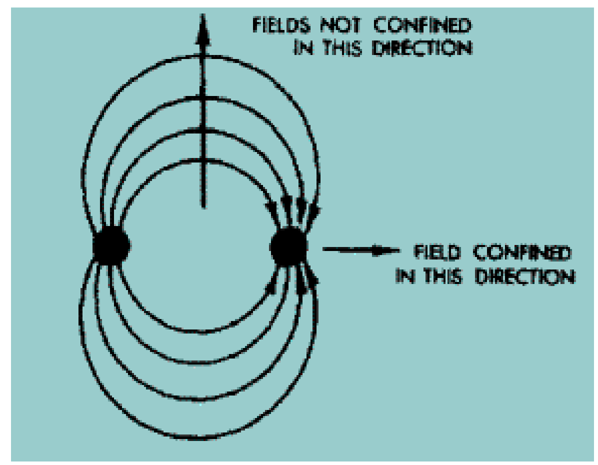
usually $d \gg a$

$$E_r = \frac{V}{2 \ln \frac{d}{a}} \left(\frac{1}{r} + \frac{1}{d - r} \right)$$

$$H_\phi = \frac{I}{2\pi} \left(\frac{1}{r} + \frac{1}{d - r} \right)$$

$$\left. \begin{aligned} C &= \frac{\pi\varepsilon}{\ln \frac{d}{a}} \\ L &= \frac{\mu \ln \frac{d}{a}}{\pi} \end{aligned} \right\} \quad Z_o = \frac{1}{\pi}\sqrt{\frac{\mu}{\varepsilon}} \ln \frac{d}{a}$$



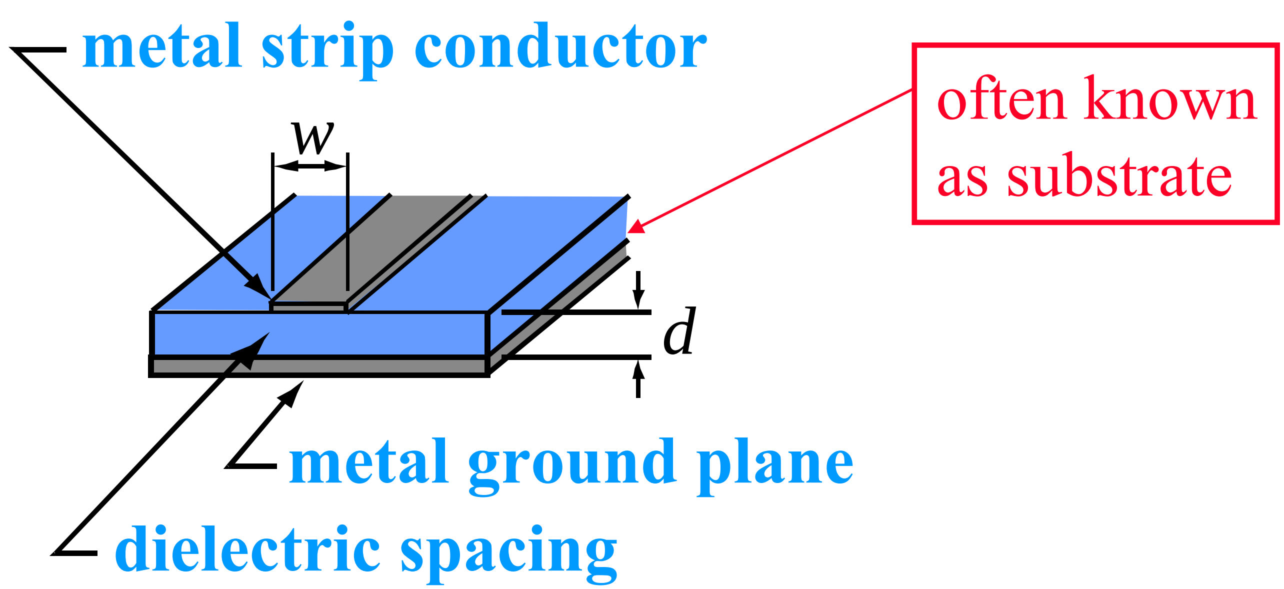


Transmission Lines

planar lines (such as micostrip lines) for use in

microwave integrated circuit (MIC)

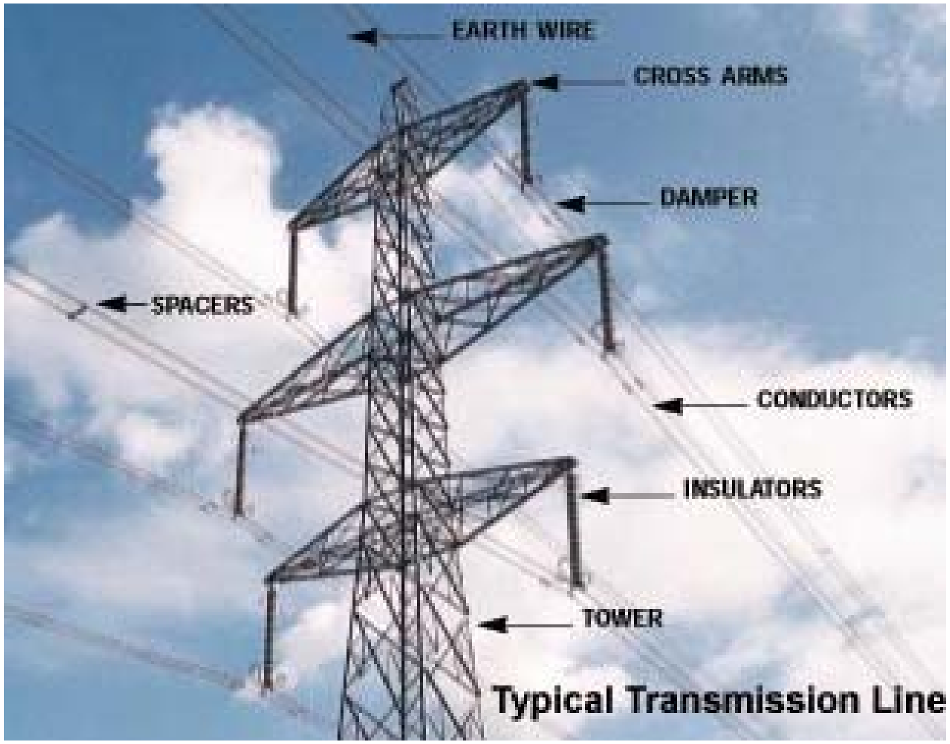
monolithic microwave integrated circuit (MMIC)

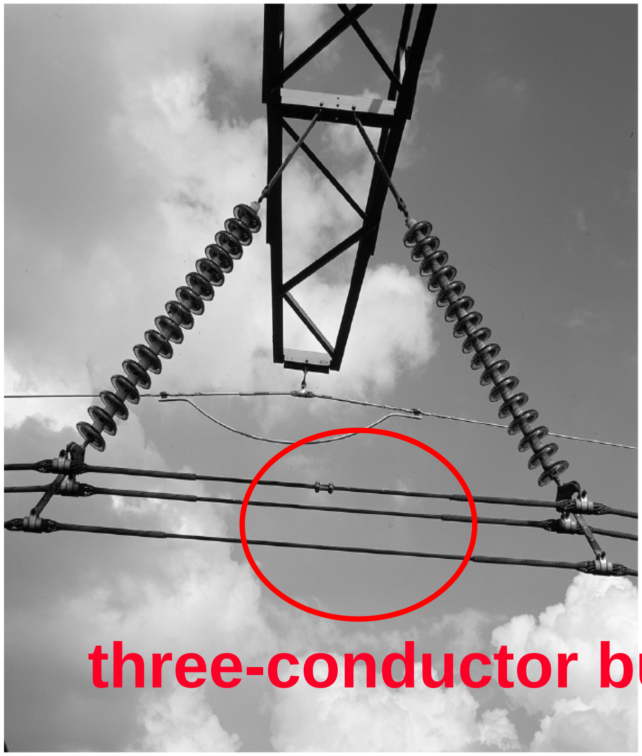


Transmission Lines

extension to multi-conductor lines

three-phase lines (EE2022 Electrical Energy Systems)





three-conductor bund

Syllabus Outline

1. **Transmission Lines** (CXD)
   transmission line equations
   Smith Chart
   stub-matching

2. **Review of Vector Calculus** (YSP)
   scalar and vector fields
   line and surface integrals
   grad, div and curl operators

3. **Electric Fields** (YSP)
   electric potential (*scalar*)
   Coulomb's and Gauss's Laws, Laplace and Poisson equations
   capacitance and resistance

Syllabus Outline

4. **Magnetic Fields** (YSP)
   magnetic potential (*vector*)
   Biot-Savart's Law, Ampere's Law and Faraday's Law
   mutual and self inductance

5. **Electromagnetic Waves** (CXD)
   Maxwell's Laws, wave equation, Poynting's Theorem
   plane waves in source-free and lossless medium
   attenuation losses
   reflection and transmission at normal incidence

6. **Case Studies**
   industrial applications
   research developments

Syllabus Outline

Fundamentals of Applied Electromagnetics

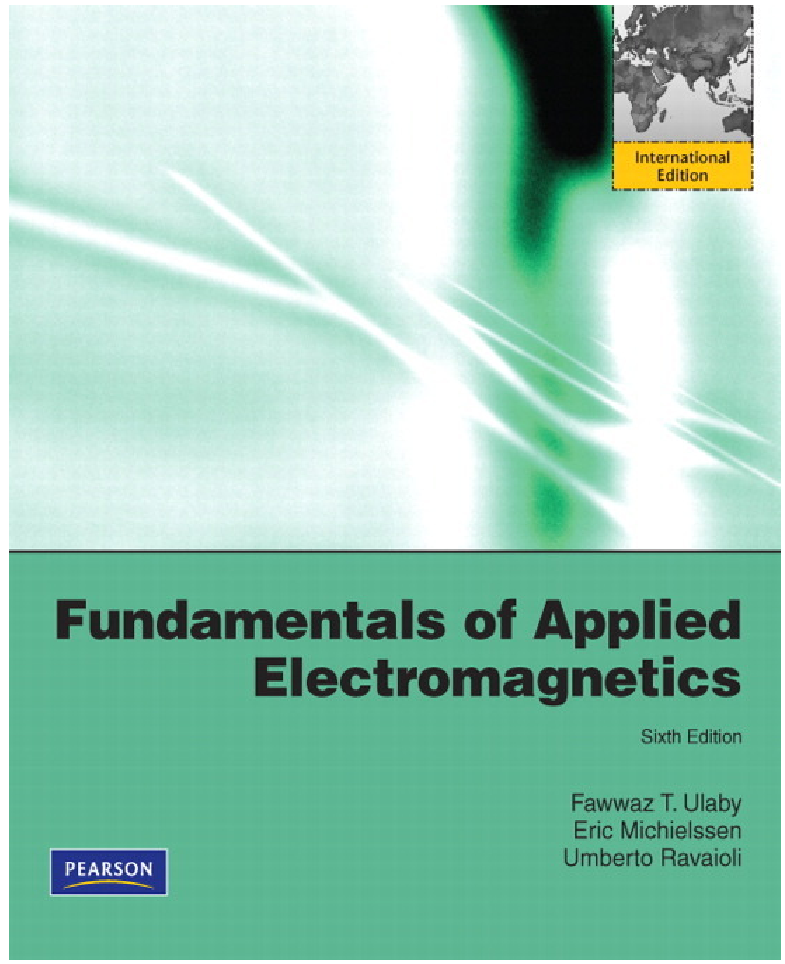
6th edition

(International Edition)

Michielssen, Ravaioli and Ulaby

Publisher: Pearson

ISBN: 9780132550086



Syllabus Outline

- **Antennas** (*also covered in textbook*)

  parameters — radiation impedance, gain, effective area

  retarded potential

  radiating structures

  array antennas

- **Electromagnetic Interference** (*not covered in textbook*)

  metallic shield — effectiveness, high/low-impedance waves

  multi-laminar shields

  aperture leakage

  inductive / capacitive couplings

Microwave-Related Modules

EE2011	Engineering Electromagnetics
EE3104	Introduction to RF/Microwave Systems and Circuits
EE4101	RF Communications
EE4104	Microwave Circuits and Devices
EE4110	RFIC and MMIC Design
EE4111	HF Techniques

Historical Background

BC centuries	magnetostatics
18^{th} century	electrostatics / electricity
1820	Oersted: current → magnetic field
	(Ampere and Biot-Savart)
1831	Faraday: changing magnetic field → EMF
1862	Maxwell: electromagnetic equations
1888	Hertz: experimental demonstration
1895	Marconi: commercialization (Nobel prize)
WW2	boost to microwaves because of radar
1960s	laser (several Nobel Prizes)
1970s	optical fiber (recent Nobel Prize for Prof Kao)

Electromagnetic Spectrum