ECC203: Electromagnetics and Radiating Systems

Fundamentals

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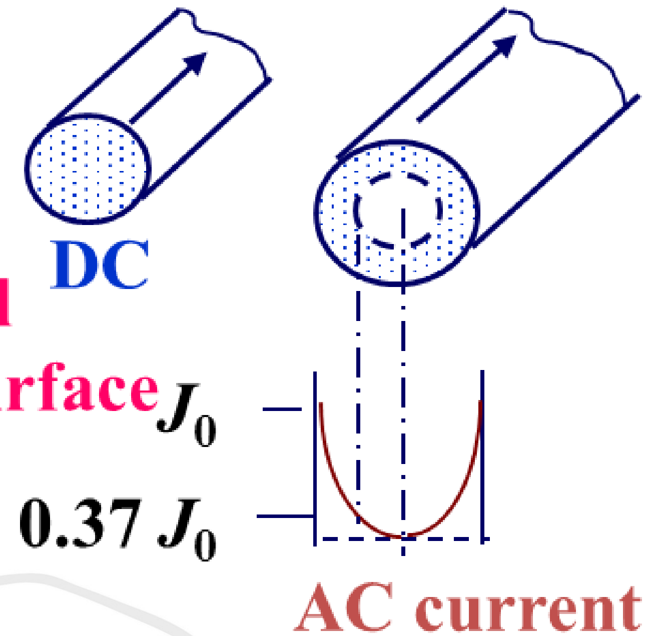
Contents

- Low Frequency vs. Radio Frequency
- Overview of Different Wave-Guides / Transmission Lines
- Decibel Definition

Low Frequency vs. Radio Frequency

Skin depth $\delta = \sqrt{\dfrac{2}{\omega \mu_0 \sigma}}$, $\omega = 2\pi f$



- δ is the depth at which the AC signal amplitude is 1/e of its value at the surface
- Higher the frequency, smaller is the depth of penetration

Example : Skin depth in copper

$$\sigma = 5.8\times10^{7}\ mhos/m\ ,\ \mu_0 = 4\pi\times10^{-7}\ H/m$$

$$f = 60\,Hz, \quad \delta = 0.85\,cm$$

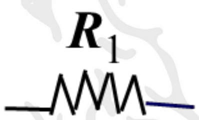
$$f = 100\,MHz, \quad \delta = 0.007\,mm$$

$$f = 10\,GHz, \quad \delta = 0.7\,\mu m$$

Low Frequency vs. Radio Frequency

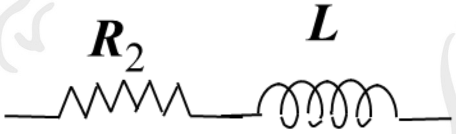
1. Section of wire

DC



$$R_1 = \frac{1}{\pi a^2 \sigma}$$

Low Freq. AC



$R_2 > R_1$

$$\frac{R_2}{R_1} \cong \frac{a}{2\delta}$$

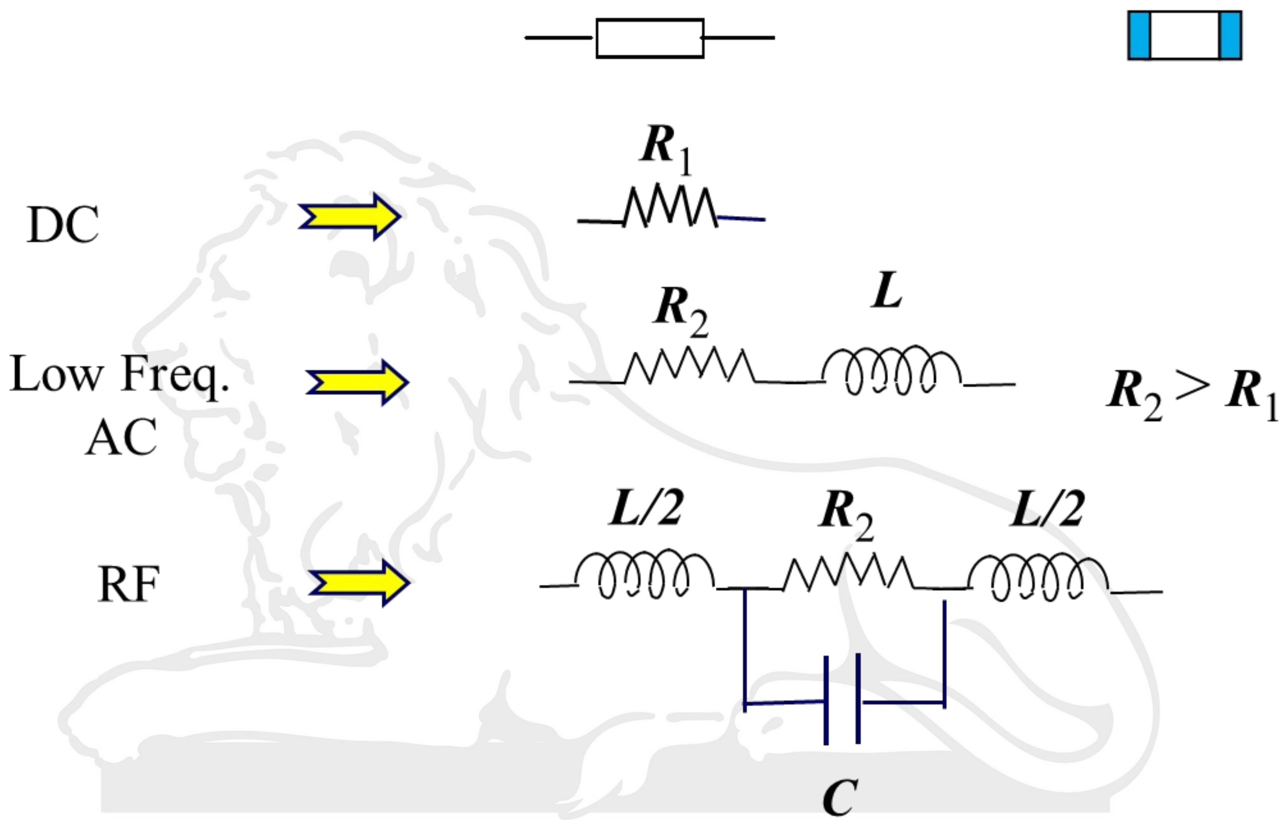
RF

$\omega L >> R_2$

Low Frequency vs. Radio Frequency

2. Resistor

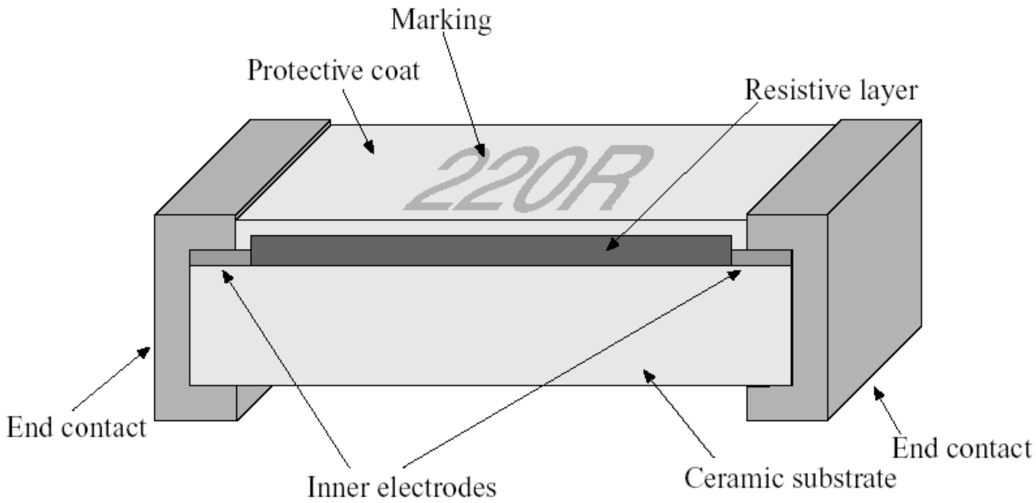
Conventional | Chip

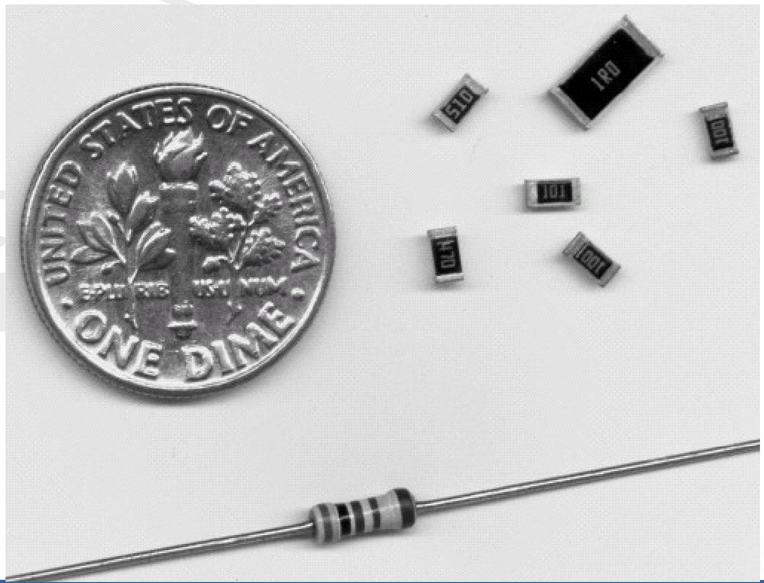


Impedance at RF

$$Z = j\omega L + \frac{1}{j\omega C + \frac{1}{R_2}}$$

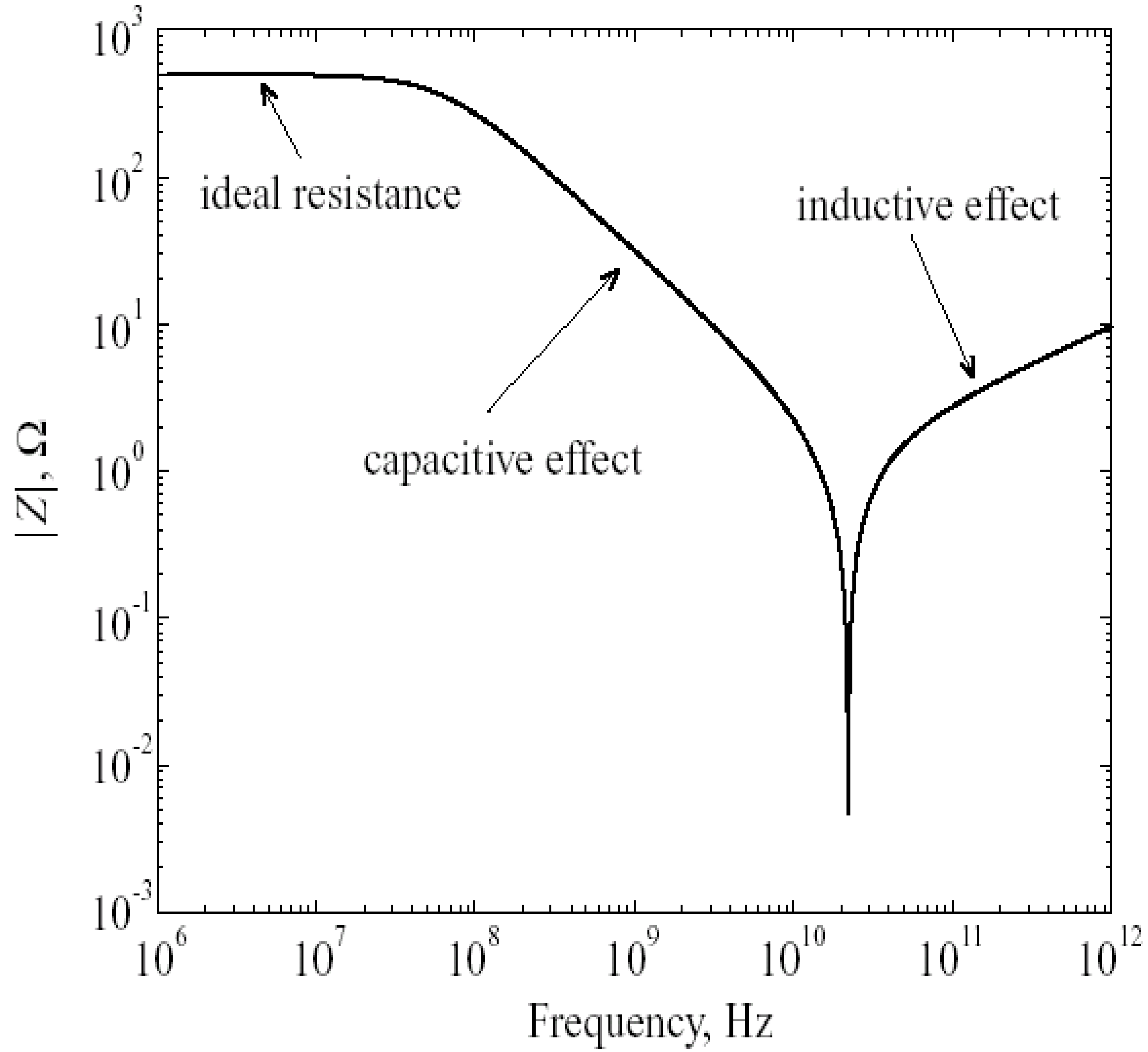
Low Frequency vs. Radio Frequency





Low Frequency vs. Radio Frequency

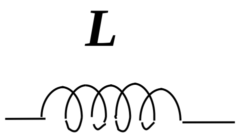
$$Z = j\omega L + \frac{1}{j\omega C + \frac{1}{R_2}}$$

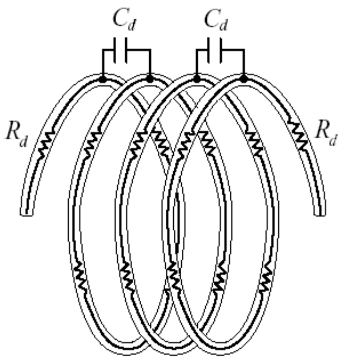


Low Frequency vs. Radio Frequency

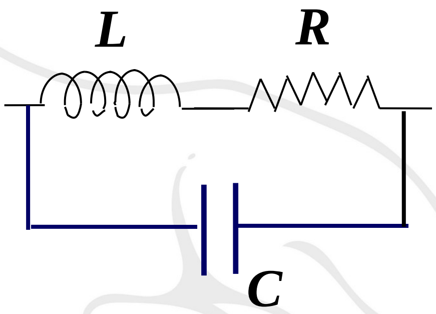
3. Inductor Coil

Low Freq.
AC





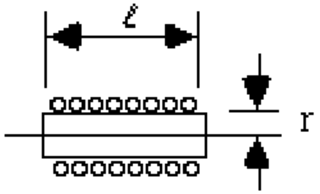
RF/MW



$$Z = \frac{1}{j\omega C + \frac{1}{j\omega L + R}}$$

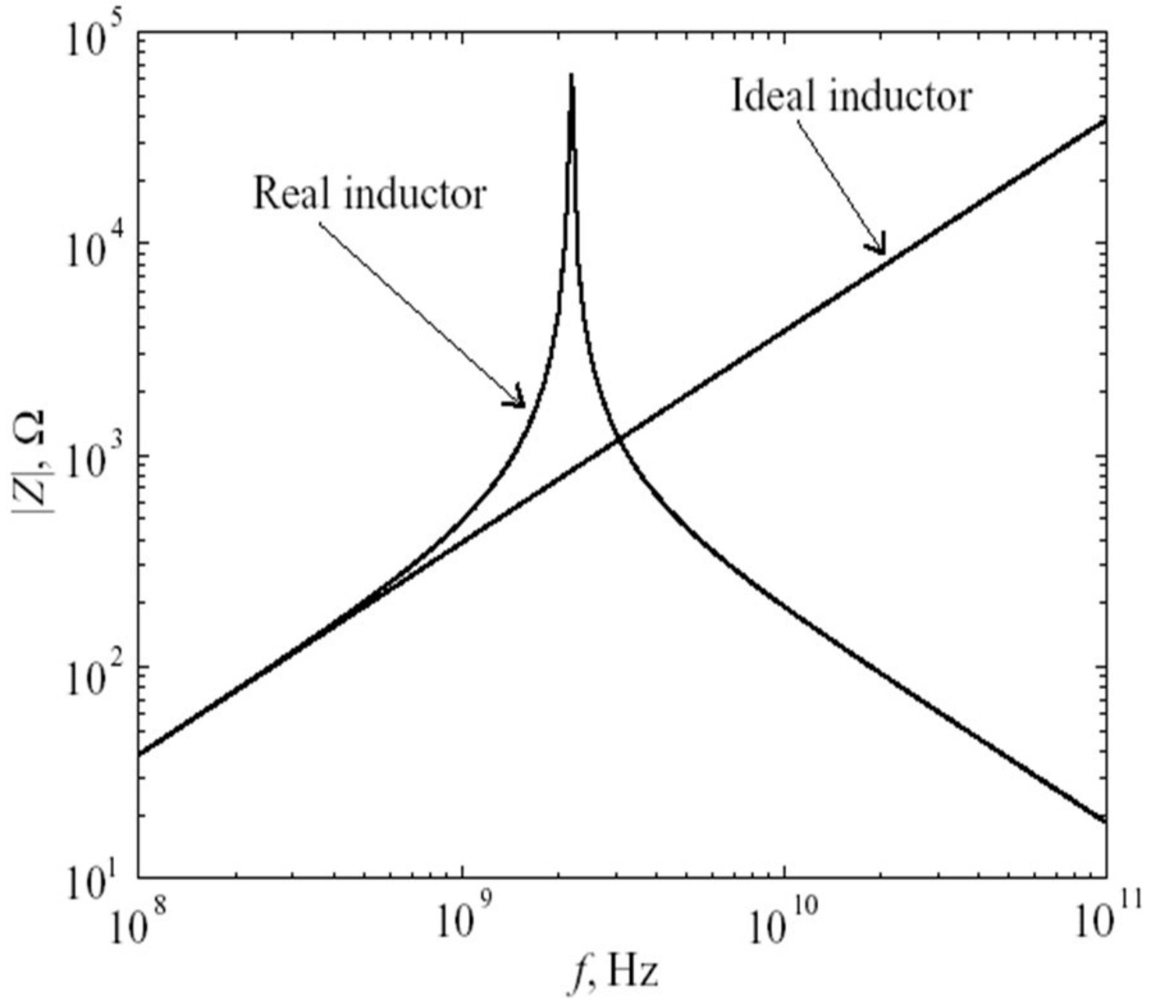
Low Frequency vs. Radio Frequency

Inductor Coil

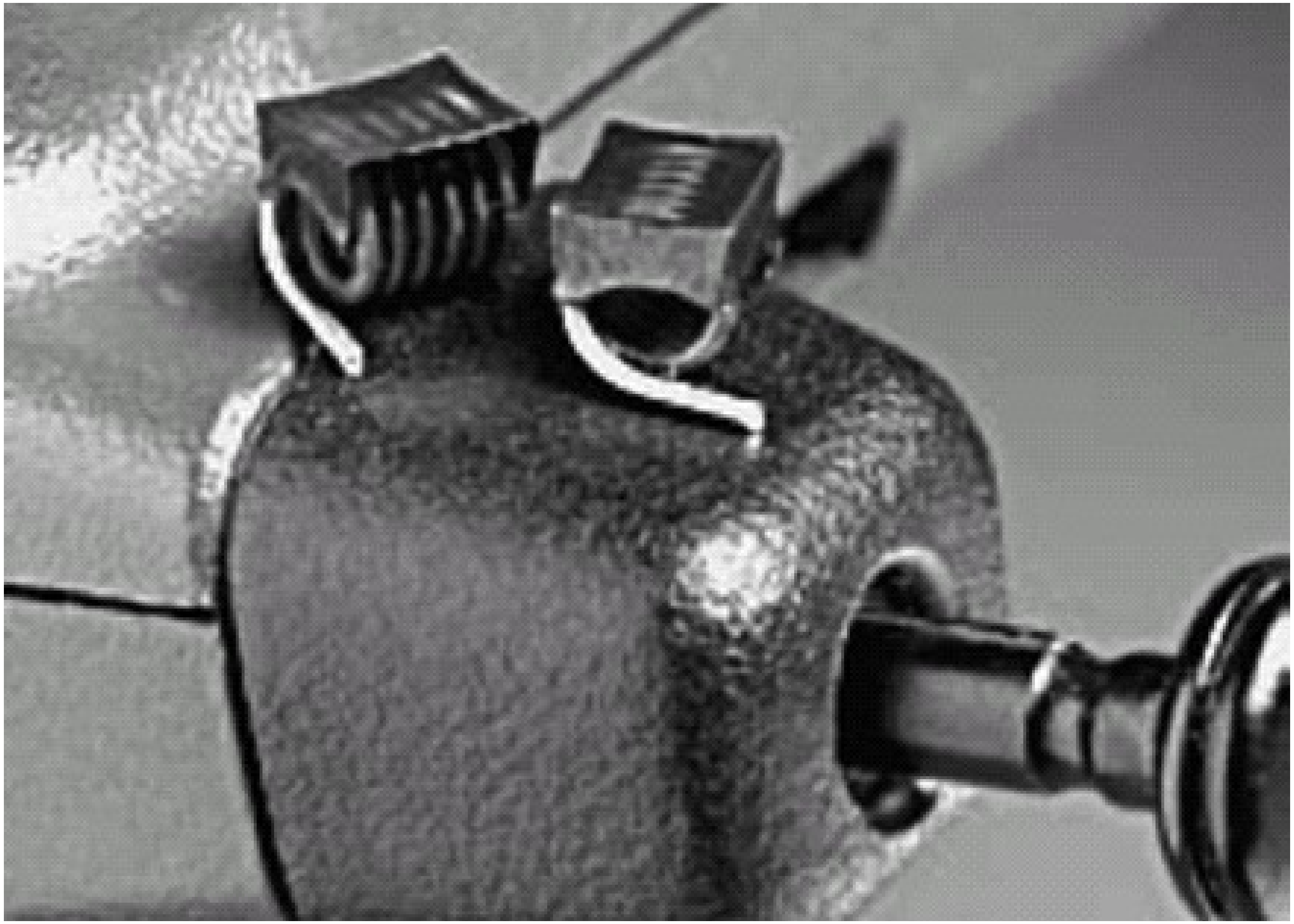


$$L = \frac{0.394 r^2 n^2}{9r + 10\ell} \text{nH}$$

$$Z = \frac{1}{j\omega C + \frac{1}{j\omega L + R}}$$

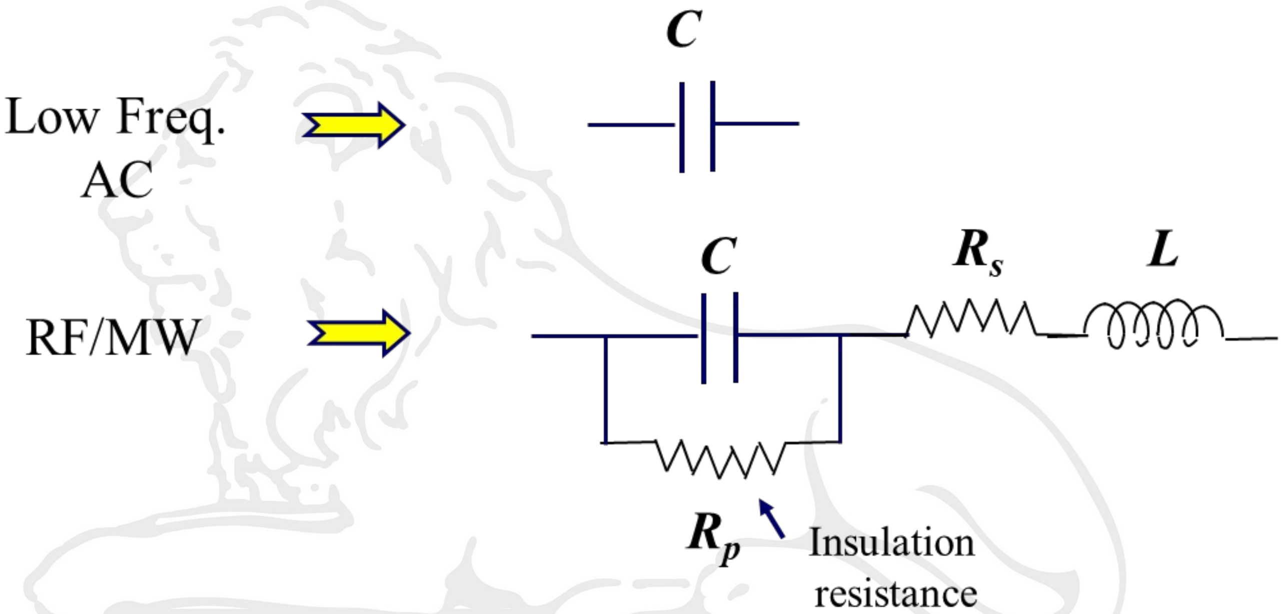


Low Frequency vs. Radio Frequency



Low Frequency vs. Radio Frequency

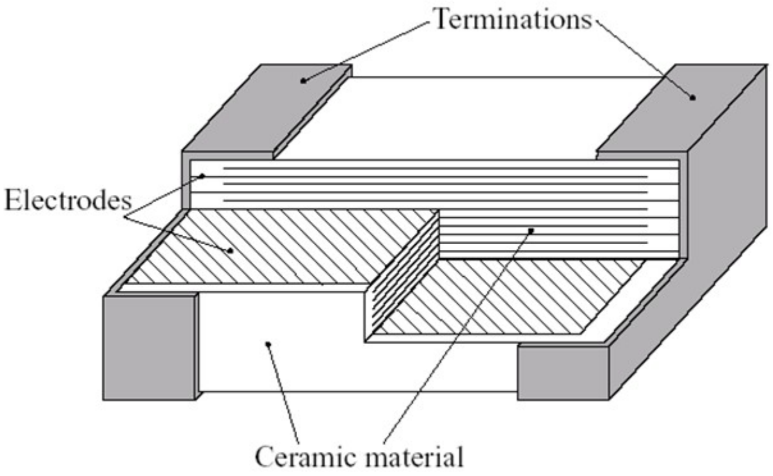
4. Capacitor

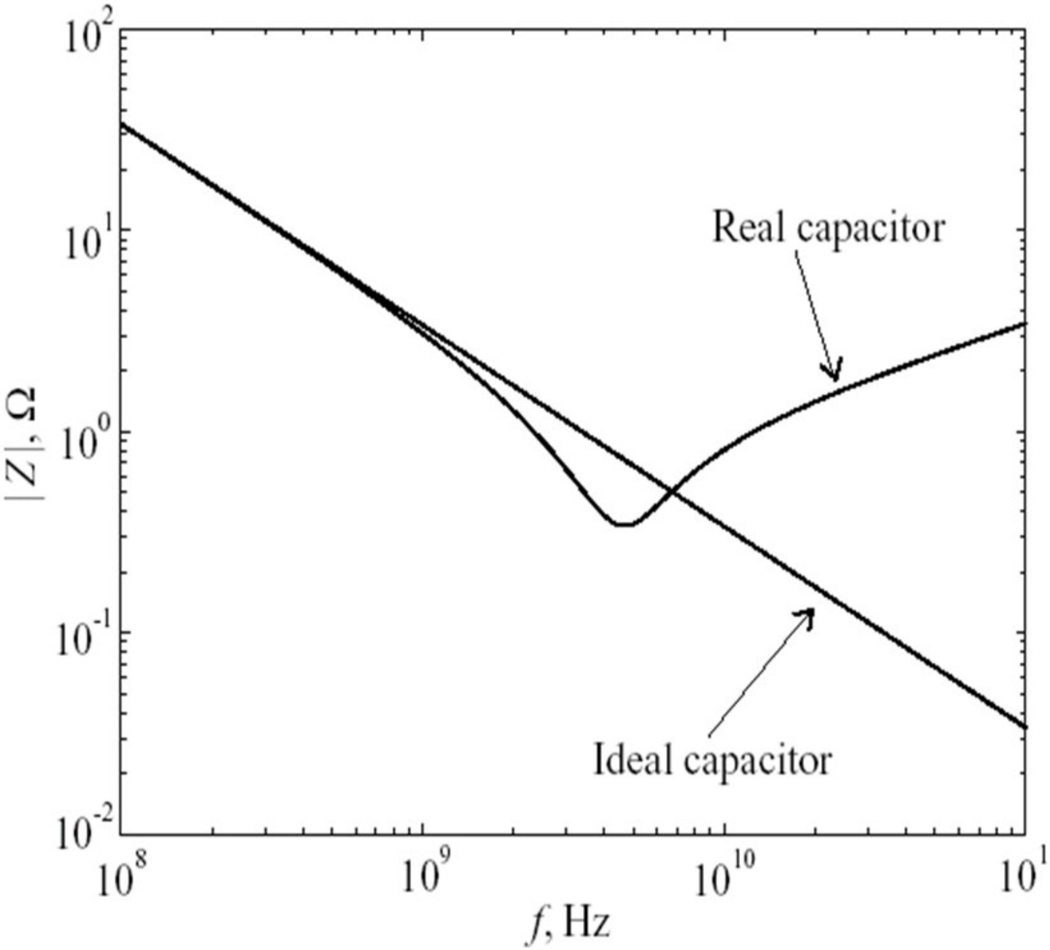


$$Z = j\omega L + R_s + \frac{1}{j\omega C + \frac{1}{R_p}}$$

Low Frequency vs. Radio Frequency

$$Z = j\omega L + R_s + \frac{1}{j\omega C + \frac{1}{R_p}}$$





Low Frequency vs. Radio Frequency

Physical dimensions of the circuit <<< λ

($\ell < \lambda/20$, λ is the wavelength in circuit medium)

- **Practically no variation in phase along the circuit**

  (Time delay ~ 0)

- **Maxwell's equations reduce to**

  KVL, KCL and Ohm's Law

- **All elements of the circuit can be considered Lumped**

RF Circuit falls within the Realm of Circuit Theory

Smaller the size of the Circuit Element, higher the frequency Up to which RF Circuit Theory applies.

Low Frequency vs. Radio Frequency

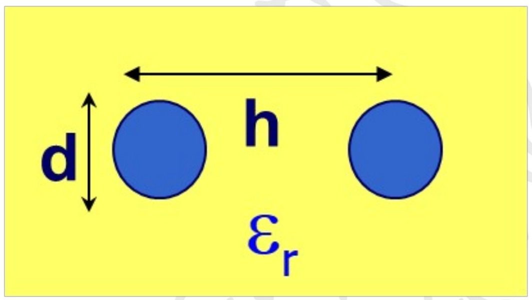
Physical dimensions of the circuit are comparable to the wavelength

- **Phase of the signal varies significantly over the physical length of the device (finite time delay)**
- **Need to introduce transmission line concepts and radiation of energy**
- **Not possible to identify individual inductance and capacitance (Electric and magnetic energy share the same region of space)**
  - Need to use Maxwell's equations

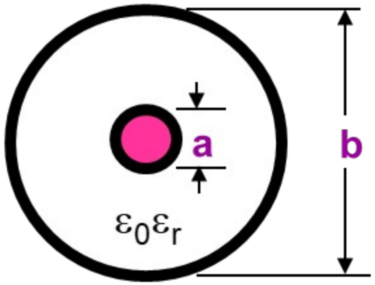
Microwave Circuit belongs to Distributed Realm

Overview of TLs

❑ Two Wire and Coaxial Lines



Two-wire Line



a=3.07 mm,
b=7.00 mm

Coaxial Line

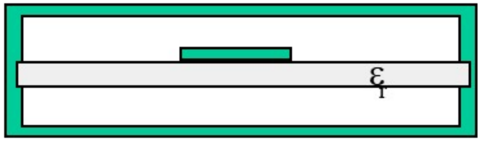
Technologies :

➡ **Precision Mechanical Fabrication**

Overview of TLs

- **Planar Transmission Lines**

Microstrip line



Suspended stripline

- **Hybrid Technology**

Dielectric Substrates (metallized)

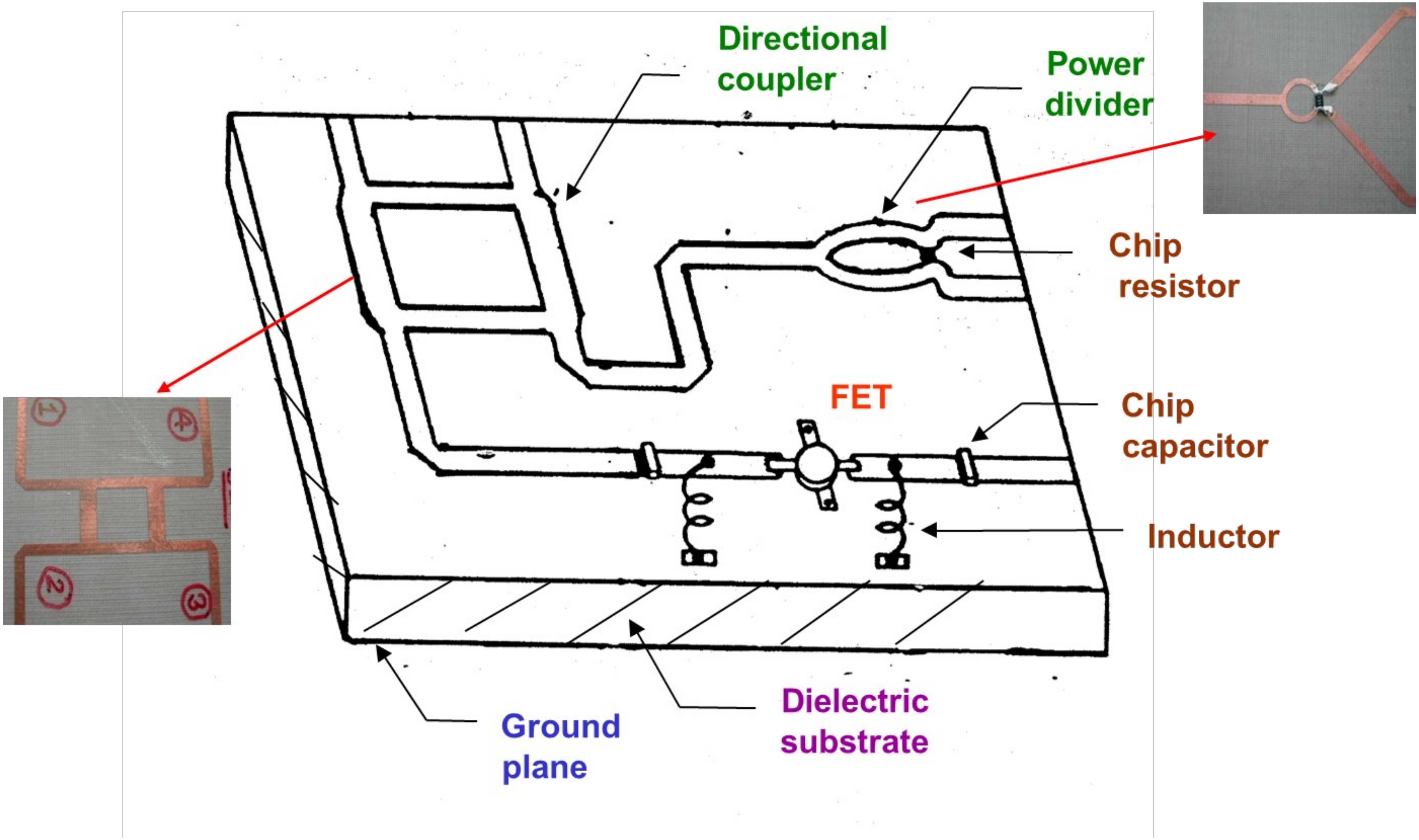
RT Duroid	ε_r = 2.2 to 10.2
Alumina	ε_r ~ 9.6

Circuit Fabrication

-- Photolithography (Chemical etching)

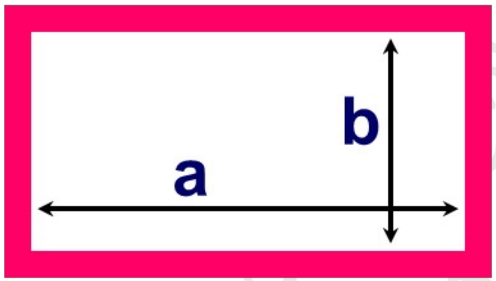
-- Discrete passive and active devices bonded or soldered

Overview of TLs

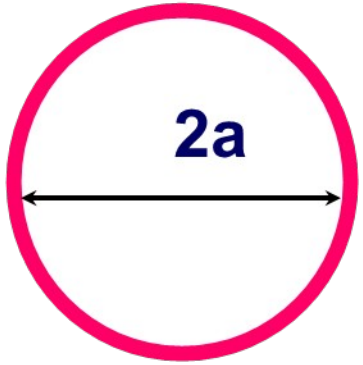


Overview of TLs

- **Wave guides**



Rectangular Waveguide

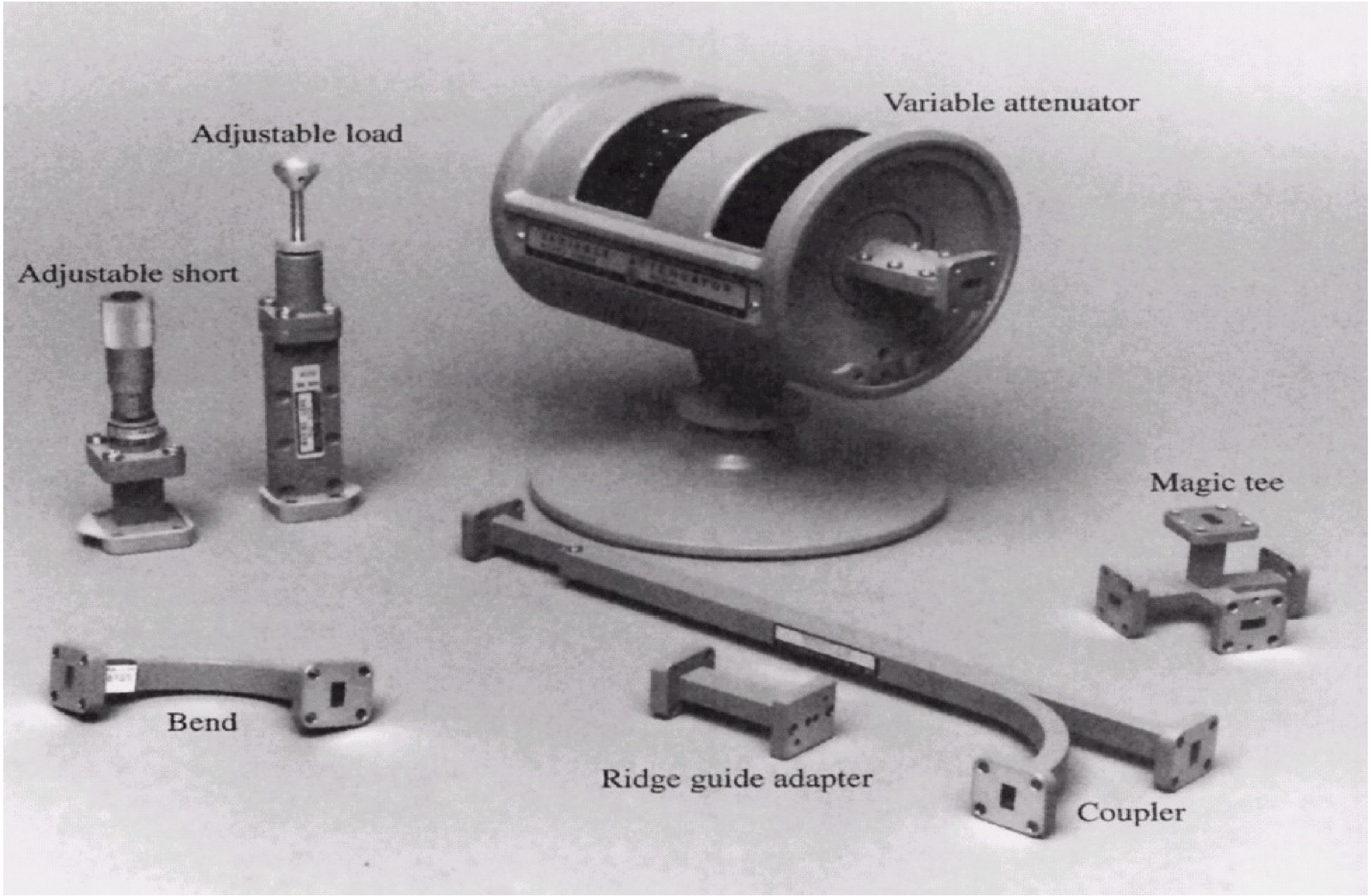


Cylindrical Wave guide

Technologies :

➡ **Precision Mechanical Fabrication**

Overview of TLs



Decibel (dB) Definition

Decibel $N(dB) = 10\log_{10}(P_2 / P_1)$; $(P_2 / P_1) = 10^{N(dB)/10}$

Decibel above or below 1 Watt (dBW) $N(dBW) = 10\log_{10}(P_2 / 1W)$

Decibel above or below 1 Milliwatt (dBm) $N(dBm) = 10\log_{10}(P_2 / 1mW)$

Decibel above or below 1 microwatt (dBμW) $N(dB\mu W) = 10\log_{10}(P_2 / 1\mu W)$

Decibel (dB) Definition

$$P = 1mw \quad \Rightarrow \quad P = 0dBm$$

$$P = 10mw \quad \Rightarrow \quad P = 10dBm$$

$$P = 0.1mw \quad \Rightarrow \quad P = -10dBm$$

$$P = 1W \quad \Rightarrow \quad P = 0dBW$$

$$P = 0.1W \quad \Rightarrow \quad P = -10dBW$$

$$P = 10W \quad \Rightarrow \quad P = 10dBW$$

Thank You

Questions?