# Chapter 1: Introduction

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# Course Structure

- Theory: 80
  - Chapter 1: Introduction — 8 marks
  - Chapter 2: RF and M/W Transmission Lines — 10 marks
  - Chapter 3: RF and M/W Network Theory and Analysis — 8 marks
  - Chapter 4: RF/MW Components and Devices — 10 marks
  - Chapter 5: Microwave Generator — 8 marks
  - Chapter 6: RF Design Practice — 20 marks
  - Chapter 7: Microwave Antennas and Propagation — 8 marks
  - Chapter 8: RF/MW Measurements — 8 marks
- Practical: 25

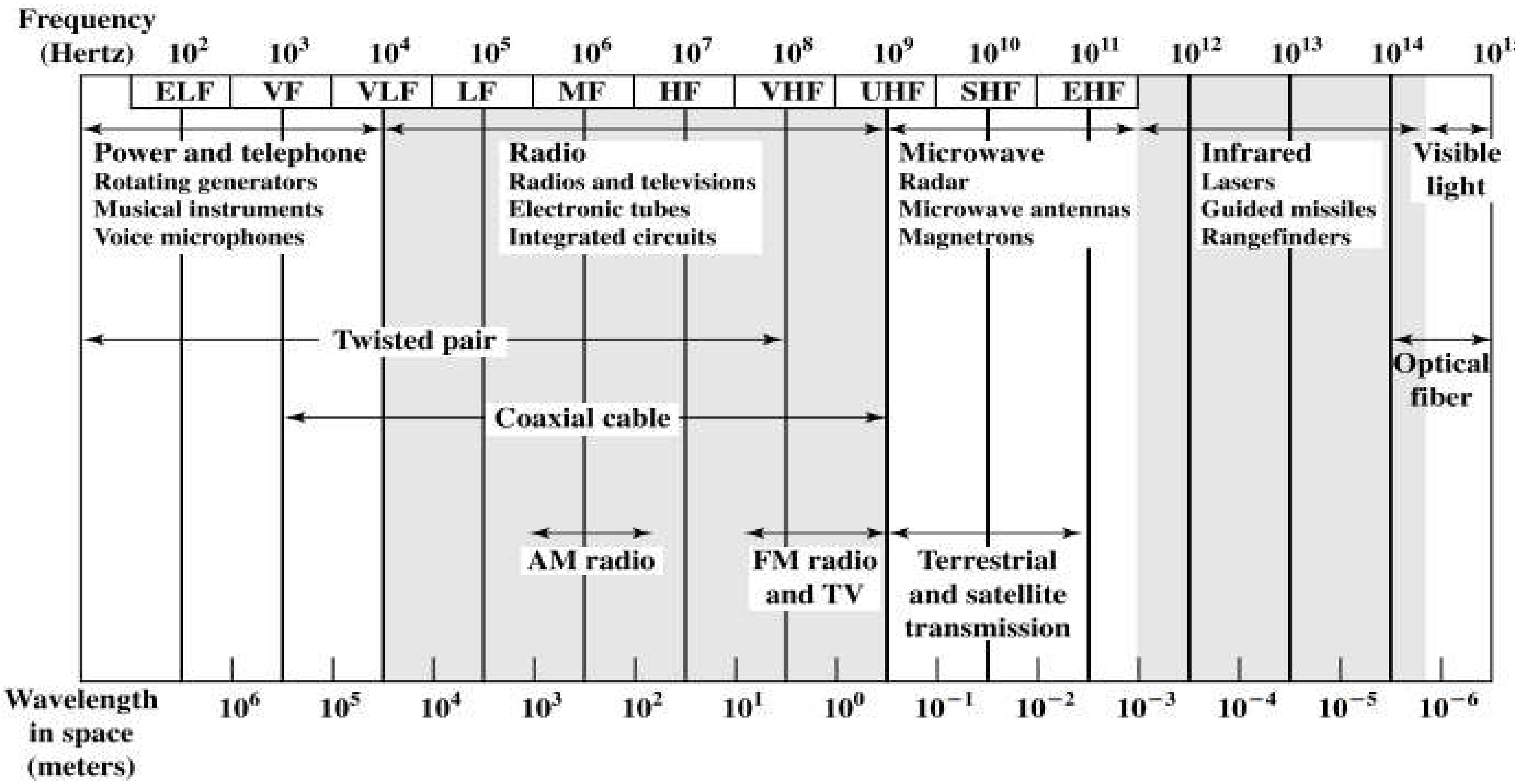
# Reference Books


1. Microwave Electronics- K.C Gupta, Tata McGraw Hill
2. Microwave Engineering- A.K. Gautam, S.K.Kataria & Sons
3. Microwave Techniques-D.C. Agrawal, Tata Mc Graw-hill
4. Microwave Devices and Circuits-Samuel Y. Liao, PHI 3rd Edition,1994
5. Microwave Engineering-David M. Pozar, 2nd Edition, Newington CT: 1997
6. Engineering Electromagnetic-W.H. Hyatt, McGraw-Hill Book Company
7. Electronic Transmission Technology: Lines, Waves and Antennas-William Sinnema, Prentice Hall

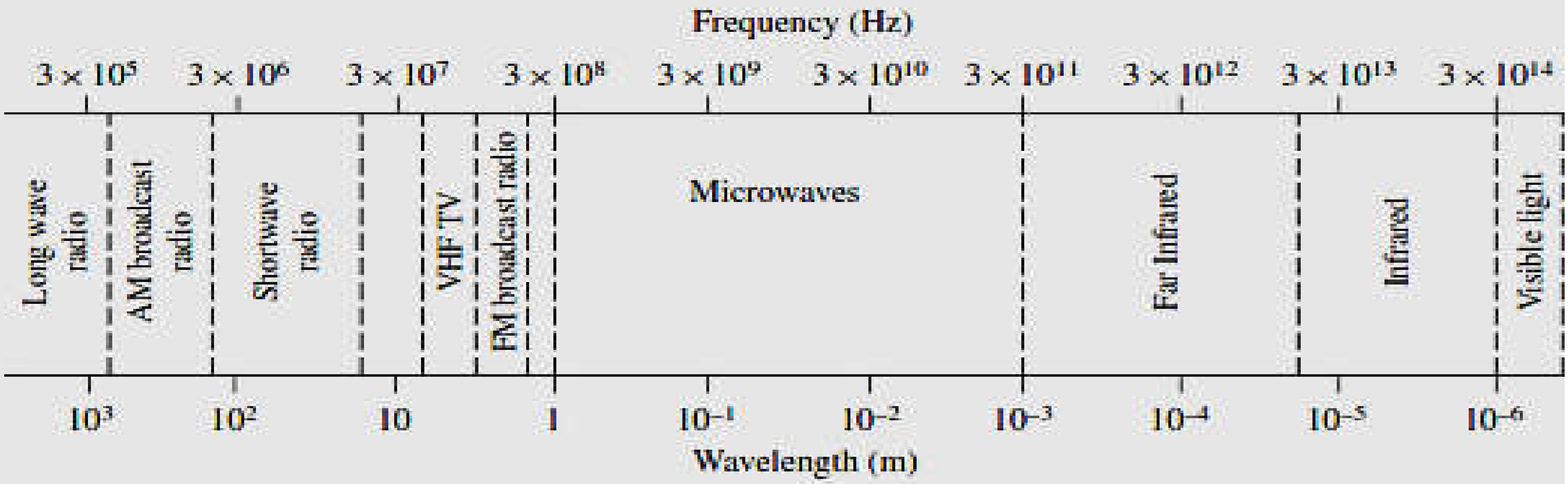
# RF/Microwave

- RF is a rate of oscillation in the range around 3KHz to 300GHz, which corresponds to the frequency of radio waves and the alternating currents which carry radio signals.
- Microwave: is not meant to suggest a wavelength micrometer, have smaller wavelength compared to radio broadcasting.
- Microwave Frequency Range: 300MHz-300GHz
- Wavelength: 1mm – 1m
- Both includes UHF (0.3-3GHz), SHF (3-30GHz) and EHF (30-300GHz) signals.

# Electromagnetic Spectrum




ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency



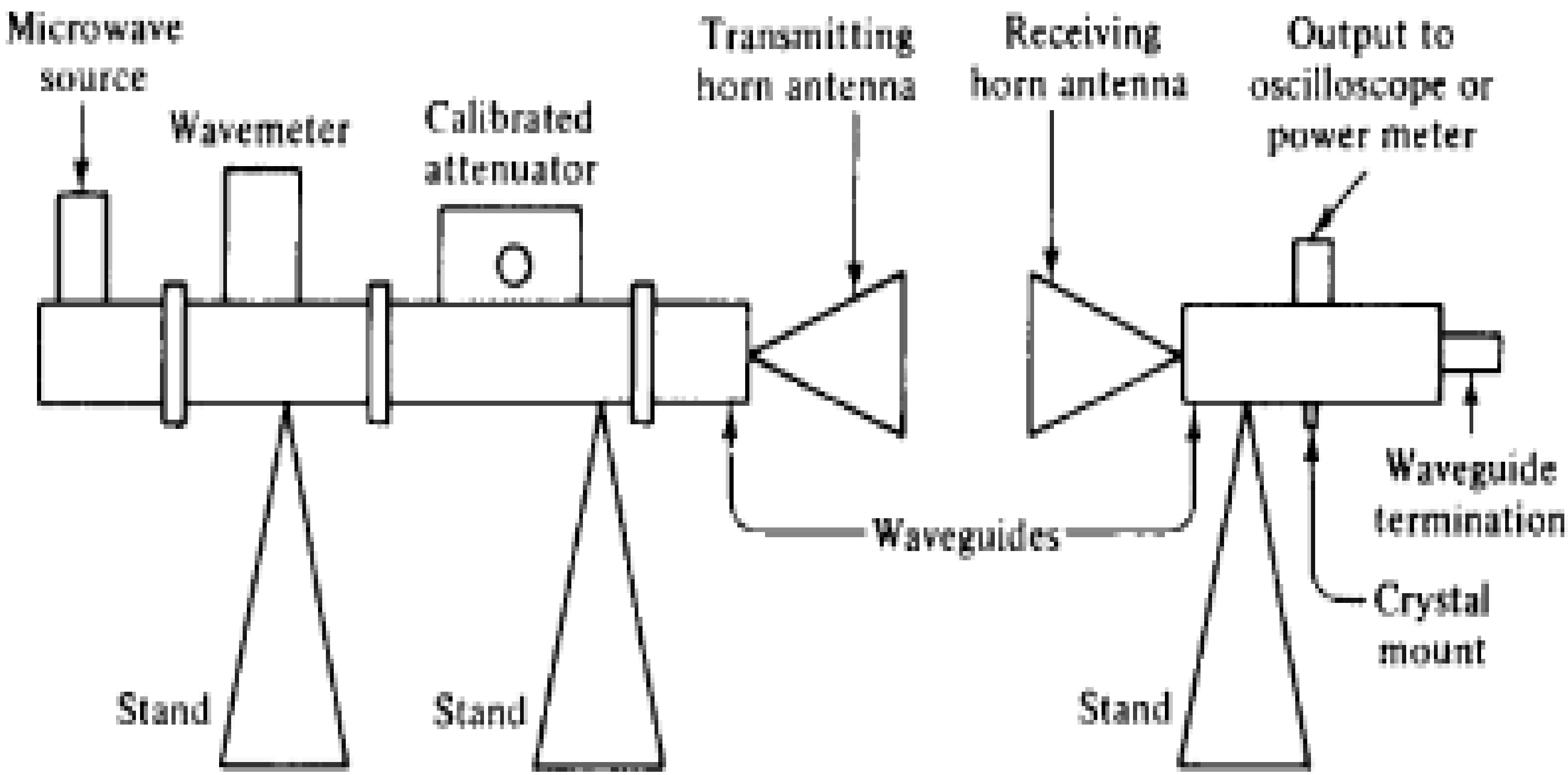

| Typical Frequencies | |
|---|---|
| AM broadcast band | 535–1605 kHz |
| Short wave radio band | 3–30 MHz |
| FM broadcast band | 88–108 MHz |
| VHF TV (2–4) | 54–72 MHz |
| VHF TV (5–6) | 76–88 MHz |
| UHF TV (7–13) | 174–216 MHz |
| UHF TV (14–83) | 470–890 MHz |
| US cellular telephone | 824–849 MHz |
| | 869–894 MHz |
| European GSM cellular | 880–915 MHz |
| | 925–960 MHz |
| GPS | 1575.42 MHz |
| | 1227.60 MHz |
| Microwave ovens | 2.45 GHz |
| US DBS | 11.7–12.5 GHz |
| US ISM bands | 902–928 MHz |
| | 2.400–2.484 GHz |
| | 5.725–5.850 GHz |
| US UWB radio | 3.1–10.6 GHz |

| Approximate Band Designations | |
|---|---|
| Medium frequency | 300 kHz–3 MHz |
| High frequency (HF) | 3 MHz–30 MHz |
| Very high frequency (VHF) | 30 MHz–300 MHz |
| Ultra high frequency (UHF) | 300 MHz–3 GHz |
| L band | 1–2 GHz |
| S band | 2–4 GHz |
| C band | 4–8 GHz |
| X band | 8–12 GHz |
| Ku band | 12–18 GHz |
| K band | 18–26 GHz |
| Ka band | 26–40 GHz |
| U band | 40–60 GHz |
| V band | 50–75 GHz |
| E band | 60–90 GHz |
| W band | 75–110 GHz |
| F band | 90–140 GHz |

# IEEE Microwave Frequency Band

| Designation | Frequency range in gigahertz |
|---|---|
| HF | 0.003– 0.030 |
| VHF | 0.030– 0.300 |
| UHF | 0.300– 1.000 |
| L band | 1.000– 2.000 |
| S band | 2.000– 4.000 |
| C band | 4.000– 8.000 |
| X band | 8.000– 12.000 |
| Ku band | 12.000– 18.000 |
| K band | 18.000– 27.000 |
| Ka band | 27.000– 40.000 |
| Millimeter | 40.000–300.000 |
| Submillimeter | >300.000 |

# Microwave System



# Microwave Sources

- High power microwave sources use specialized vacuum tubes to generate microwave.
- Operate on the principle of ballistic motion of electrons in a vacuum under the influence of controlling electric or magnetic field.
- Includes magnetron, klystron, travelling wave tube (TWT) and gyrotron.
- These devices work in the density modulated mode (work on the basis of clumps of electrons flying ballisticially through them, rather than using a continuous stream of electrons).

- Lower power microwave sources use solid state devices such as the FET, tunnel diodes, Gunn diodes and IMPATT diodes.
- MASER is a solid state device which amplifies microwave using similar principle to the LASER, which amplifies higher frequency light waves.

# Advantages of using higher frequency

- Larger instantaneous bandwidth for much information
- Higher resolution for radar imaging and sensing
- Less interference by near by application
- Higher speed for digital communication, signal processing and transmission
- Less crowded spectrum
- Difficulty in jamming (military application)

# Disadvantages of using high frequency

- More expensive component
- Higher atmospheric loss
- Reliance in GaAs technology rather than Si technology
- Higher component losses, lower output power from active devices

# Microwave Applications

- **Communication**
  - Before the advent of fiber-optic transmission, most long-distance telephone calls were carried via networks of microwave radio relay links using FDM.
  - Wireless LAN protocols, such as Bluetooth and the IEEE 802.11 specifications, also use microwaves in the 2.4 GHz ISM band.
  - Wireless internet access IEEE 802.11a uses microwaves at 3.5-4 GHz range.
  - Metropolitan area network (MAN) protocols, such as WiMAX (Worldwide Interoperability for Microwave Access) are based on standards such as IEEE 802.16, designed to operate between 2 to 11 GHz.
  - Mobile Broadband Wireless Access (MBWA) protocols based on standards specifications such as IEEE 802.20 operate between 1.6 and 2.3 GHz.

# Microwave Applications

- **Communication**
  - Mobile phone networks, like GSM, use the low-microwave/high-UHF frequencies around 1.8 and 1.9 GHz in the Americas and elsewhere, respectively.
  - Most satellite communications systems operate in the C, X, Ka, or Ku bands of the microwave spectrum.
  - Satellite TV either operates in the C band for the traditional large dish fixed satellite service or Ku band for direct-broadcast satellite.
  - Military communications run primarily over X or Ku-band links.
- **Commercial Applications**
  - Commercial implementations are in the 2.3 GHz, 2.5 GHz, 3.5 GHz and 5.8 GHz ranges (ISM band- Industry, Science and Medicine band).

# Microwave Applications

- **Navigation**
  - Global Navigation Satellite Systems (GNSS) broadcast navigational signals in various bands between about 1.2 GHz and 1.6 GHz.
  - These include the Chinese Beidou, the American Global Positioning System (GPS) and the Russian GLONASS.
- **RADAR**
  - Radar uses microwave radiation to detect the range, speed, and other characteristics of remote objects.
  - Weather prediction
  - Geological survey for natural resource exploration.
  - Air traffic control, road traffic surveillance.

# Microwave Applications

- **Radio astronomy**
  - Celestial body research.
  - Distance measurement.
- **Heating and Power Application**
  - A microwave oven uses microwave radiation at a frequency near 2.45 GHz.
  - Dielectric heating through energy absorption.
  - Microwave heating is used in industrial processes for drying and curing products.
- **Security**
  - RFID based identification system.
  - Motion detectors.

# Microwave Applications

- **<u>Medical Use</u>**
  - Photoacoustic imaging (ultrasound).
  - CT scan, X-rays, MRI like imaging.
  - Thermo-therapy, LASER therapy.
  - Cancer treatment.

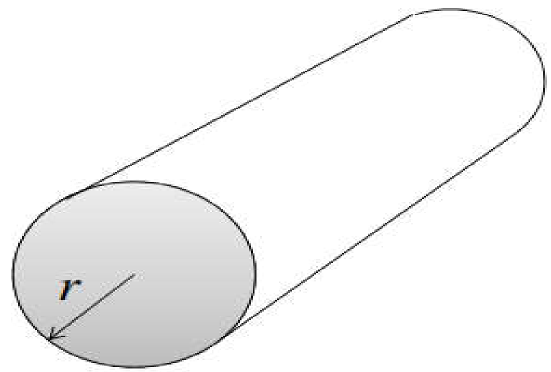
# Behavior of circuits at conventional and RF/Microwave bands

*"At high frequencies all components are R, L and C."*

# Behavior of circuits at conventional and RF/Microwave bands
# Resistor

$$R_{dc} = \frac{l}{\sigma A}$$

$$R_{dc} = \frac{1}{\sigma \pi r^2} \quad \Omega / m$$

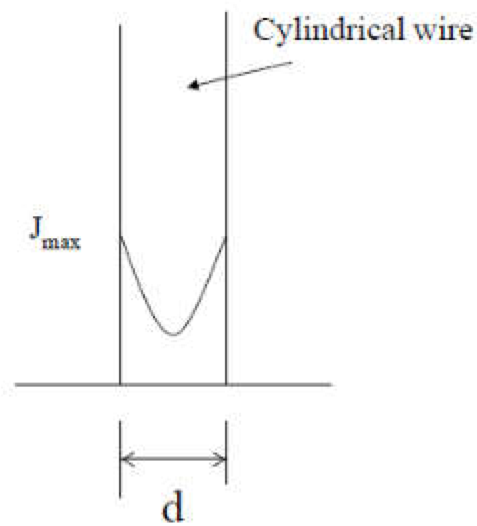



Resistance

AC $\rightarrow$ B-fields $\rightarrow$ Force on charge carriers

Skin depth

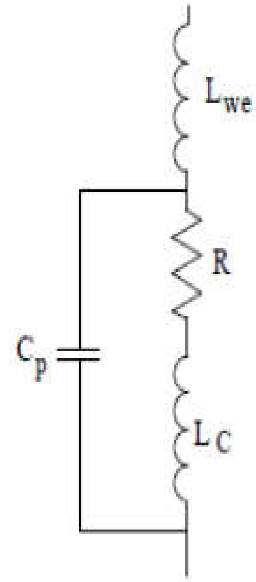
$$\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}$$

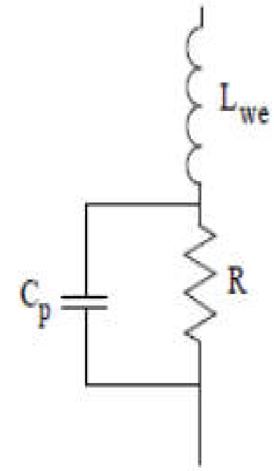


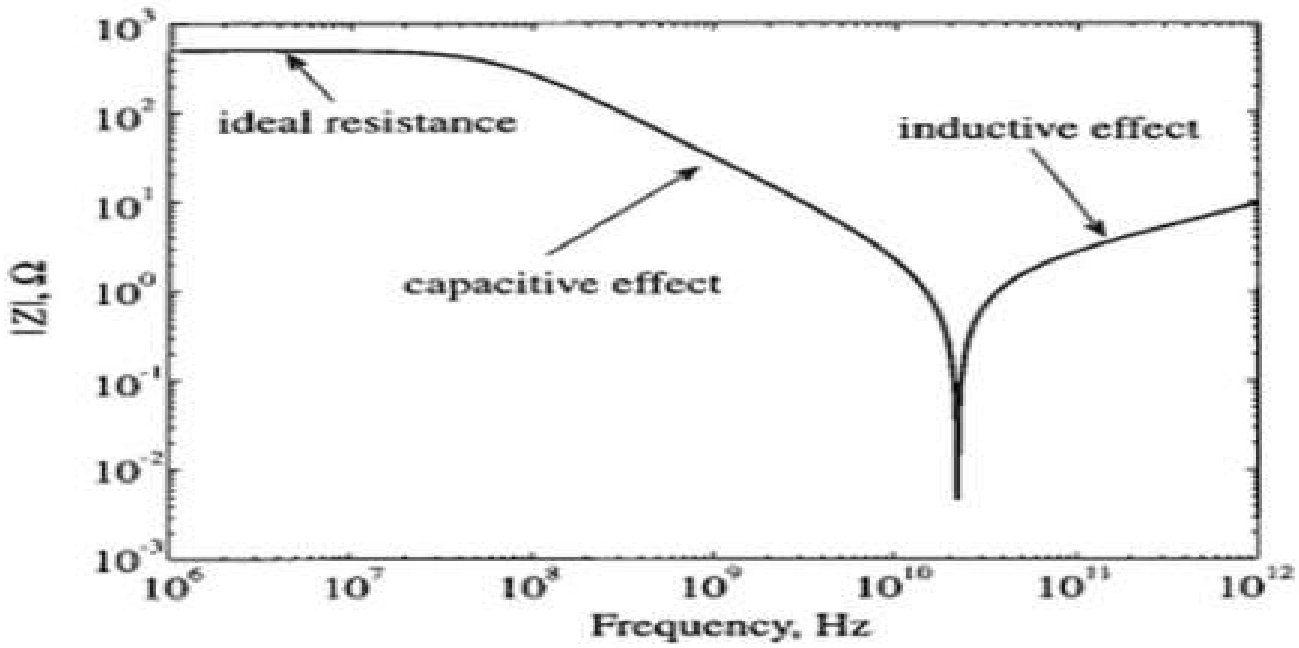
$$Z(j\omega) = j\omega L_{we} + (R // \frac{1}{j\omega C_p})$$

$$f_{RC} = \frac{1}{2\pi R C_p}$$

$$f_r = \frac{1}{2\pi\sqrt{L_{we} C_p}}$$

Low value resistor → Parasitic inductance as main problem

High value resistor→ Parasitic capacitance as main problem

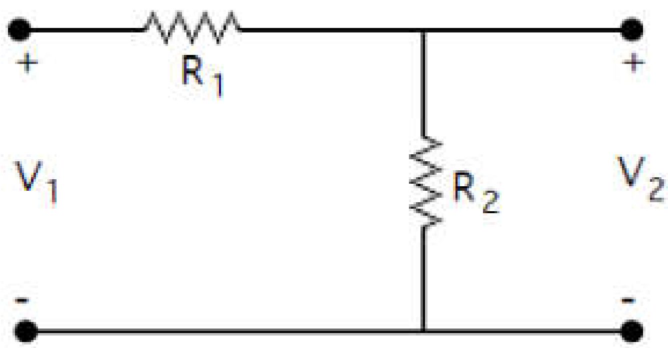
Practical tips to avoid this

-Use short leads

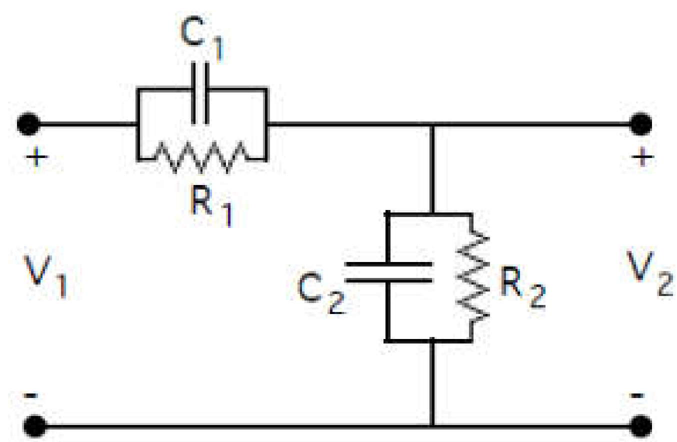
-low value resistors in series for high resistance

-high value resistors in parallel for low resistance

Practical Example- Voltage divider



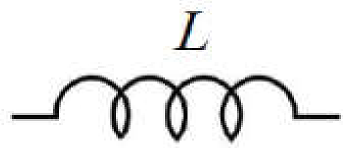

**Purely resistive**
Ideal resistors give a frequency independent transfer function




**Compensated**
C1 and C2 provide a path for current at high frequency

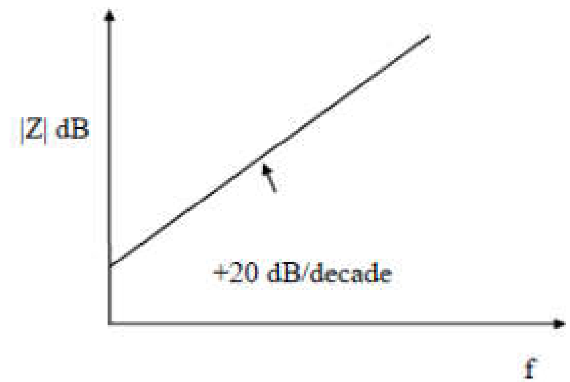
# Inductor

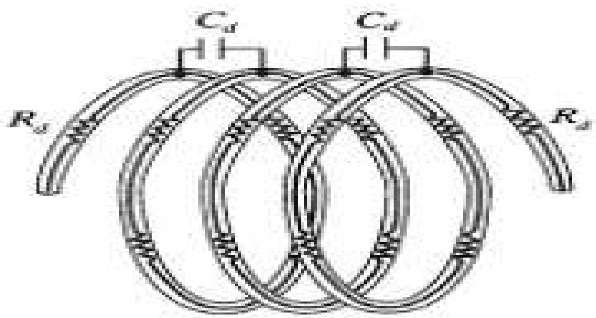
Ideal

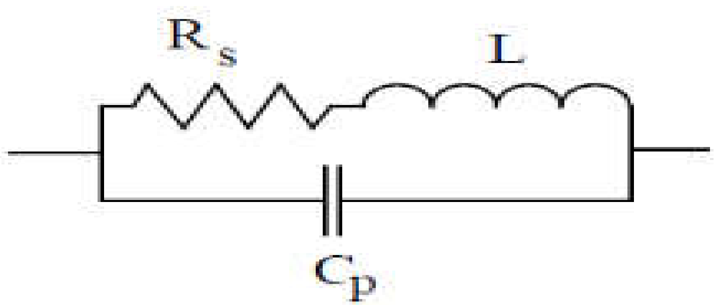



$$Z_L = j\omega L = \omega L \angle +90^{\circ}$$

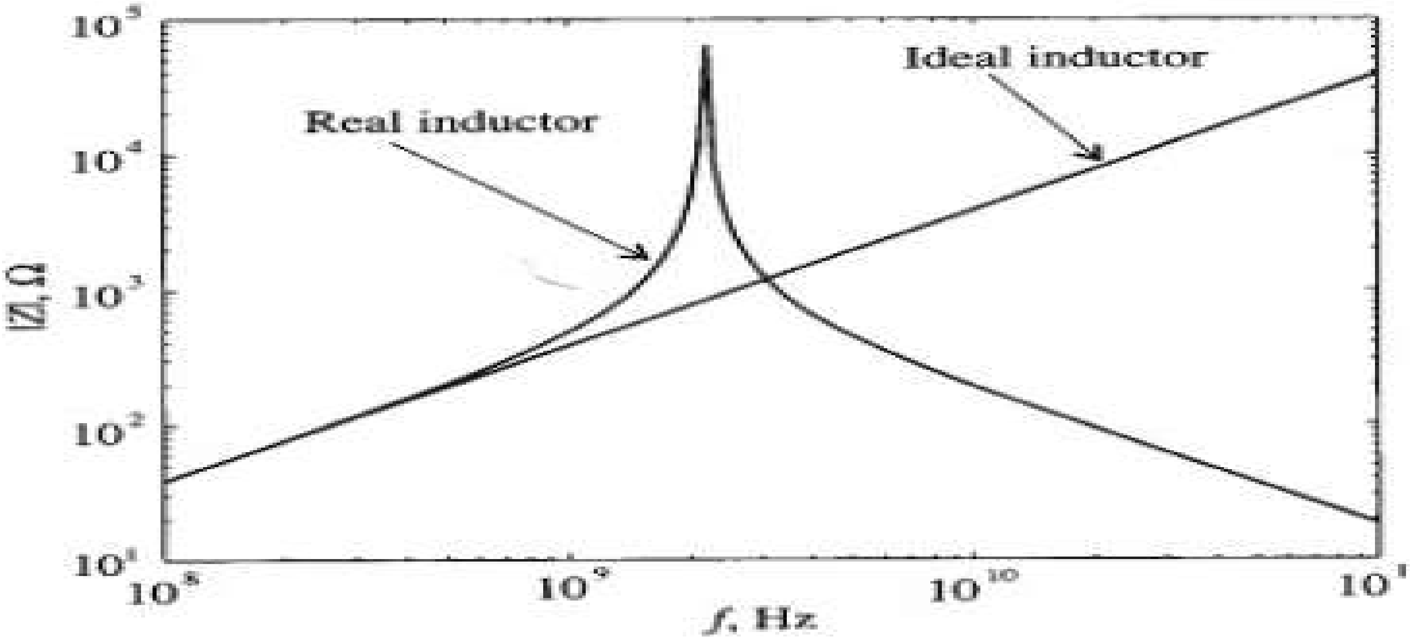
$$\left|Z_L\right| = 2\pi L \cdot f$$



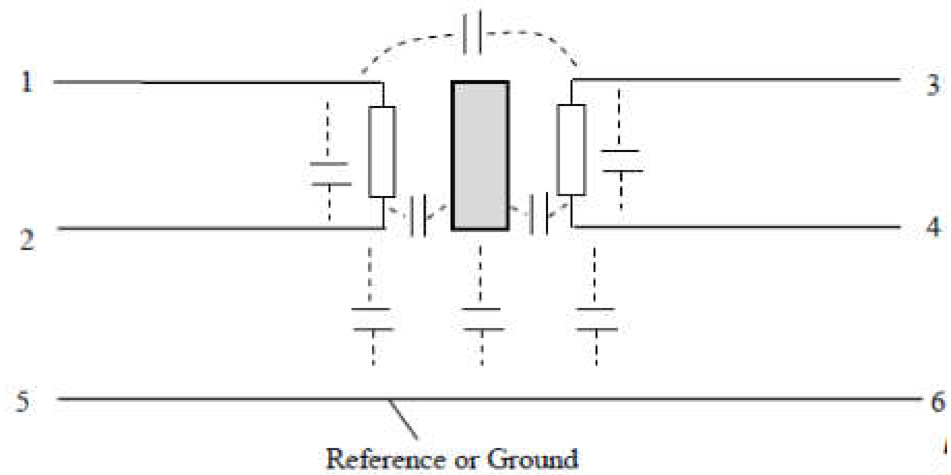






$$Z(j\omega) = (R_S + j\omega L) \,//\, \frac{1}{j\omega C} \qquad f_r = \frac{1}{2\pi\sqrt{LC}}$$

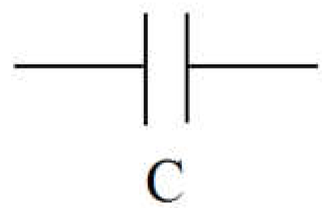



Parasitic capacitances cause the transfer of unwanted signals.



# Capacitors

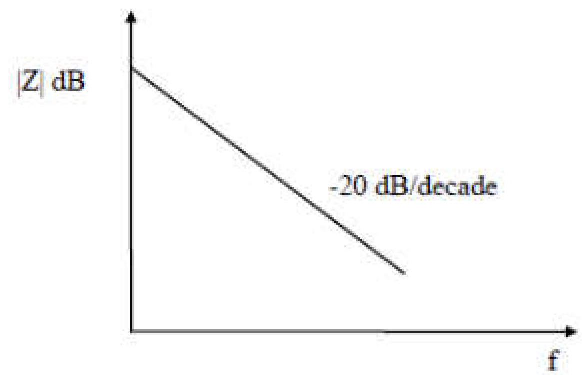
## Capacitors

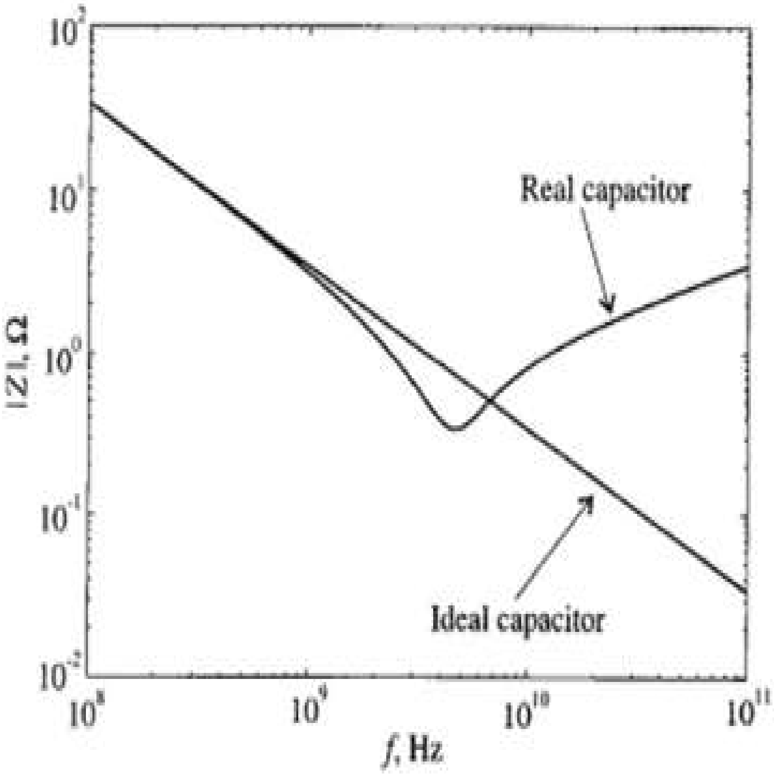


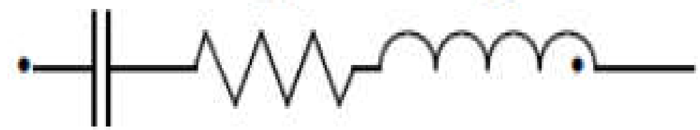

Ideal

$$Z(j\omega) = \frac{1}{j\omega C} = \frac{1}{\omega C}\angle -90^{\circ}$$

$$|Z| = \frac{1}{2\pi C}\cdot\frac{1}{f}$$






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

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

# Behavior of Circuits at Conventional and RF/Microwave Bands

**Low Frequency/ Conventional**

- Bandwidths are limited hence small no. of channels can be adjusted.
- It uses lumped element circuit theory.
- Current flow and voltage drops are used to calculate power.
- Open wire, twisted cables, co-axial cables are used as transmission lines.

**RF/Microwaves**

- Provide large bandwidth so its possible to adjust large no. of channels.
- It uses distributed circuit theory (ohm/m, H/m, F/m).
- Scattering phenomena like absorption, reflection, refraction, etc. are used in power calculation.
- Optical fibers, waveguides, strip lines, micro-strip lines are common transmission lines.

# Behavior of Circuits at Conventional and RF/Microwave Bands

**Low Frequency/ Conventional**

- Lumped circuit elements are used such as resistors, filters, oscillators, etc.
- It uses current modulated mode.
- Almost all the solid state devices can be used.
- It can handle low power.

**RF/Microwaves**

- Cavity resonators or resonant lines are used as oscillators, resonators, etc.
- Density modulation or velocity modulation are used using magnetrons, klystrons, TWTs, etc.
- Vacuum tube like devices, micro-miniaturised solid state devices like Gunn diodes, tunnel diodes, IMPITT, TRAPPIT, etc. are used.
- It can handle higher power.

# Thank You