

## **Module 2 : Transmission Lines**

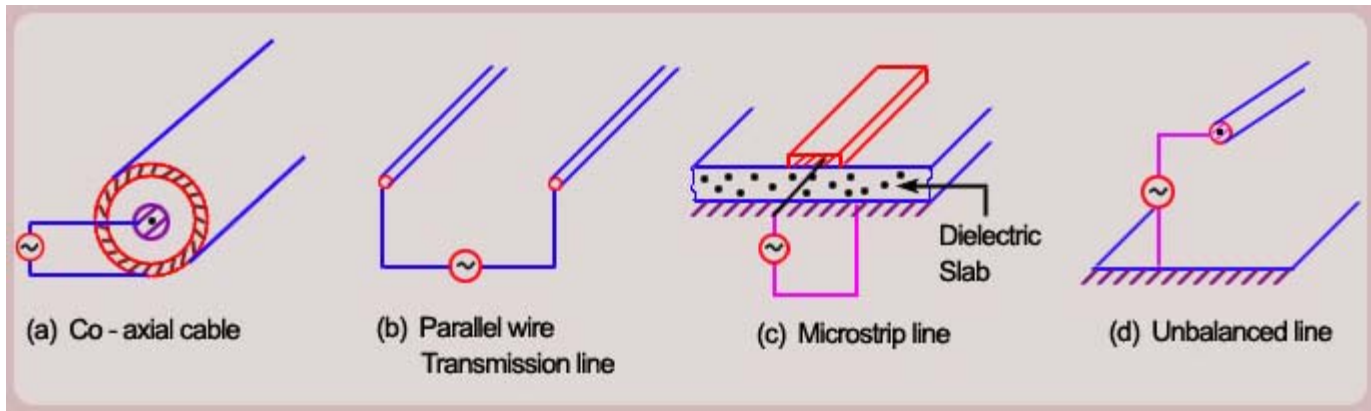
### **Lecture 2 : Transmission Lines in Practice**

#### **Objectives**

##### **In this course you will learn the following**

- What is a **Transmission Line**?
- Various types of two conductor transmission lines and their special features.
- Balanced and unbalanced transmission line.
- Transit time effect on a transmission line at high frequencies.
- Dominance of the reactive component over resistive component.
- Concept of distributed elements and conditions under which the lumped element circuit model is applicable.
- Approach to investigate transmission line characteristics treating the line as collection of infinitesimal lumped section.

## Various Types Of Transmission Line



- As the name suggests, the transmission line is a structure which can transport electrical energy from one point to another.
- At low frequencies, a transmission line consists of two linear conductors separated by a distance. When an electrical source is applied between the two conductors, the line gets energized and the electrical energy flows along the length of the conductors.
- A two-conductor transmission line may appear in any of the forms shown in the figure

### Co-axial cable

Consists of a solid conducting rod surrounded by the two conductors. This line has good isolation of the electrical energy and therefore has low Electromagnetic Interference (EMI).

### Parallel wire transmission line

Consists of two parallel conducting rods. In this case the electrical energy is distributed between and around the rods. Theoretically the electric and magnetic fields extend over infinite distance though their strength reduces as the distance from the line. Obviously this line has higher EMI.

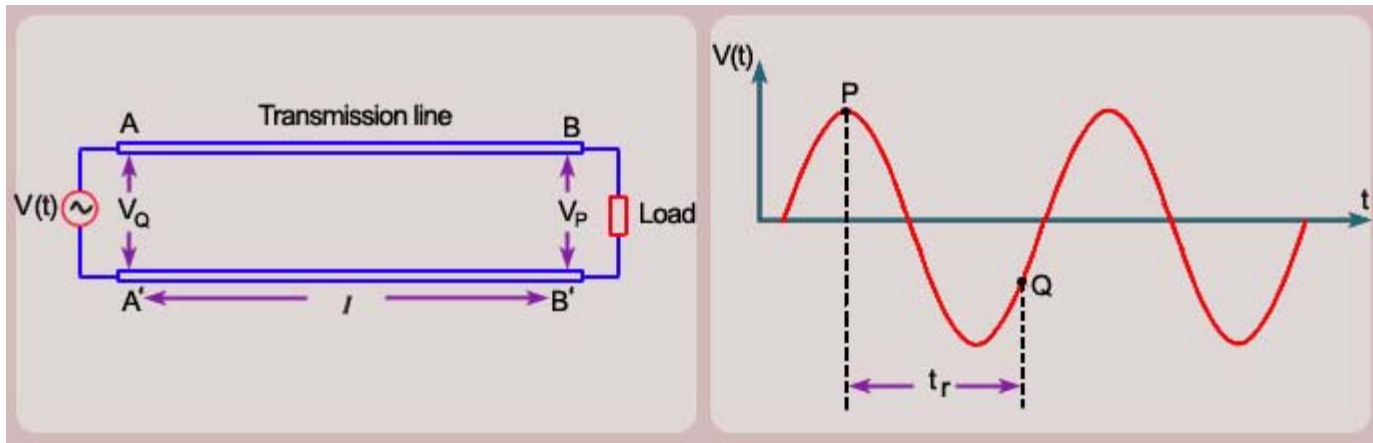
### Microstrip line

Consists of a dielectric substrate having ground plane on one side and a thin metallic strip on the other side. The majority of the fields are confined in the dielectric substrate between the strip and the ground plane. Some fringing field exist above the substrate which decay rapidly as a function of height. This line is usually found in printed circuit boards at high frequencies.

### Balanced and Un-balanced line

If the two conductors are symmetric around the ground, then the line is called the balanced line, otherwise the line is an un-balanced line. Transmission lines (a), (c) and (d) are un-balanced line, whereas the line (b) is a balanced line.

## Transit Time Effect



- It is important to note that No Signal can travel with infinite velocity. That is to say that if a voltage or current changes at some location, its effect cannot be felt instantaneously at some other location. There is a finite delay between the 'cause' and the effect. This is called the 'Transit Time' effect.
- Consider the two-conductor line which is connected to a sinusoidal signal generator of frequency ' $f$ ' at one end and a load impedance at the other end. Due to the transit time effect the voltage applied at AA' will not appear instantaneously at BB'.
- Let the signal travel with velocity  $v$  along the line. Then the Transit time

$$t_r = \frac{l}{v}, \quad l = \text{length of the line.}$$

- At some instant let the voltage at AA' be  $V_p$ . Then  $V_p$  will appear at BB' only after  $t_r$ . However, during this time the voltage at AA' changes to (say)  $V_Q$ .

### Important Observation

- Even for ideal conductors i.e., no resistance, there is a voltage difference between AA' and BB'

- When is transmit-time **effect important**?

Ideally the transit time effect should be included in analysis of all electrical circuits. However if the time period of the signal  $T (= 1/f)$  is much larger than the transit time, we may ignore the effect of transmit time. That is, the transit time effect can be neglected if

$$\begin{aligned} T &\gg t_r \\ \Rightarrow \frac{1}{f} &\gg \frac{l}{v} \\ \Rightarrow \frac{v}{f} &\gg l \quad \text{since } \frac{v}{f} = \text{wavelength } \lambda, \text{ we get} \\ \Rightarrow \lambda &\gg l \end{aligned}$$

- Transit time effect becomes important when the length of the line becomes comparable to the wavelength. As the frequency increases, the wavelength reduces, and the transit time effect becomes more and more important.

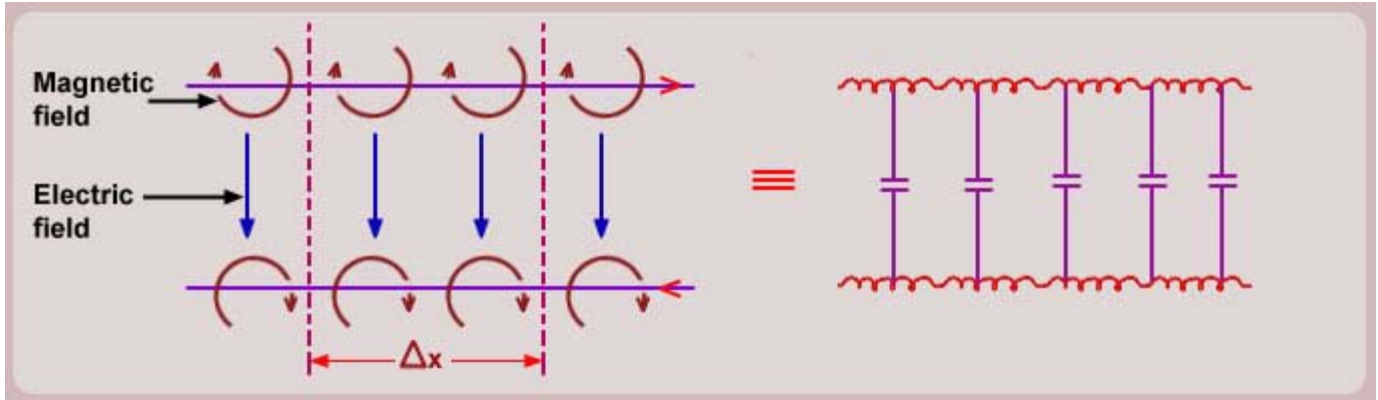


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#### Distributed Circuit Elements

- Due to transit time effect, the Kirchoff's laws cannot be applied to the circuit at a whole. However, if we take a small section of the line such that its length  $\Delta x$  is  $\ll \lambda$ , the transit time effect would be negligible and consequently the Kirchoff's laws can be applied.

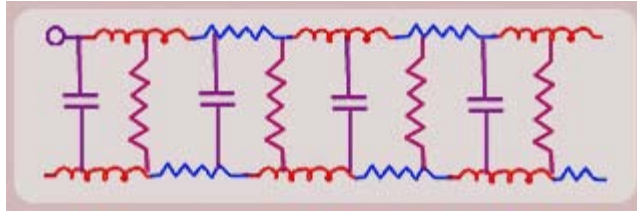


- A conductor carrying a current has magnetic field and consequently has flux linkage. The conductor therefore has inductance.
- Similarly the two conductors form a capacitance.
- Due to transit time effect the whole line inductance or capacitance cannot be assumed to be located at a particular point in space. The inductance and capacitance are distributed throughout the length of the line. These are therefore called the 'Distributed Parameters' of the line.

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#### Distributed Circuit Elements



- For non ideal conductors there is resistance along the length of the line. Also if the medium separating the conductors is non - ideal, there is leakage current through the medium which can be accounted for by placing equivalent conductance between the conductors.
- In the presence of transit time effect, all the line parameters, the inductance, the capacitance, the resistance, and the conductance are of distributed nature.
- The distributed parameters can be defined per unit length of the line.
  - $R$  = Resistance of both conductors together for unit length of the line (ohms/m)
  - $L$  = Inductance (self and mutual) for both conductors together for unit length of the line (Henry/m)
  - $C$  = Capacitance between two conductors for unit length of the line (Farad/m)
  - $G$  = Leakage conductance between two conductors for unit length of the line (Mho/m).

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#### Lumped Circuit Model

- A small section of the line of length  $\Delta x$  has

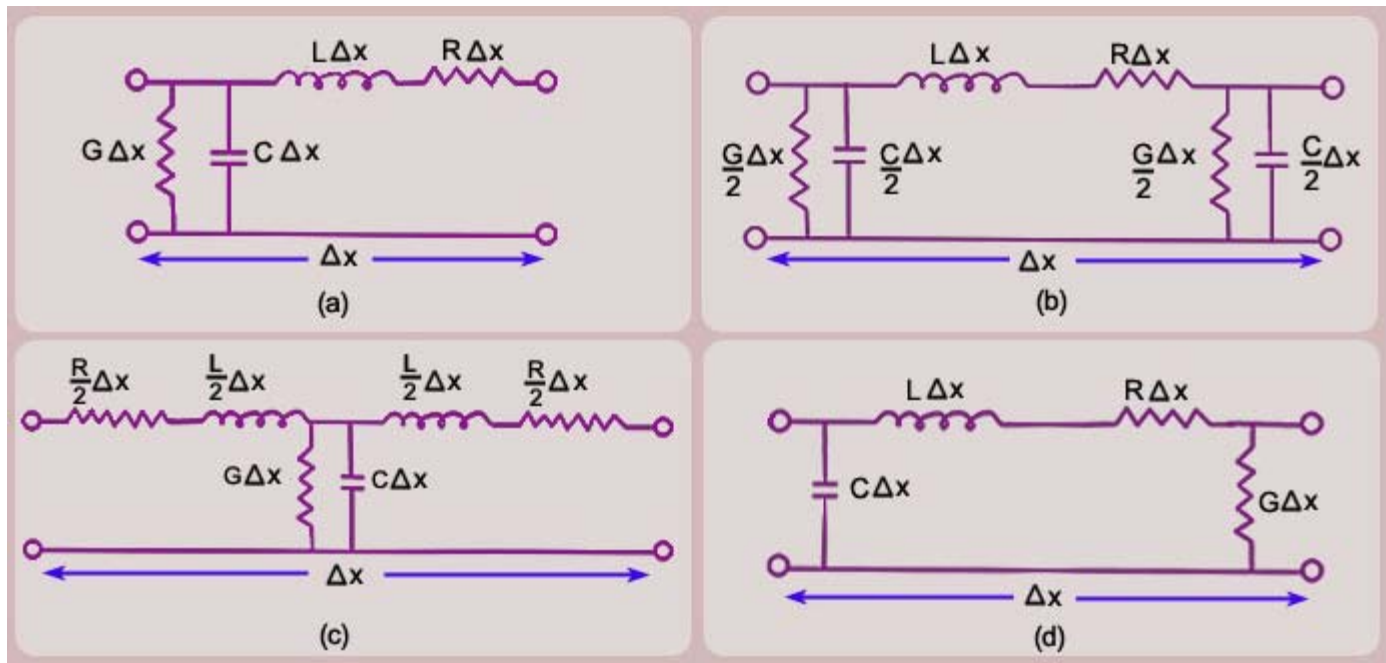
Resistance  $\Delta R = R \Delta x$

Inductance  $\Delta L = L \Delta x$

Capacitance  $\Delta C = C \Delta x$

Conductance  $\Delta G = G \Delta x$

- The lumped circuit for a small section of the line can be any one of that shown below :



#### Note

- For the analysis of the transmission to be valid at all frequencies,  $\Delta x$  should be much less than  $\lambda$  at all frequencies. In other words the analysis is to be carried out in the limit  $\Delta x \rightarrow 0$ .
- All above representations are equivalent in the limit  $\Delta x = 0$ .

## **Module 2 : Transmission Lines**

### **Lecture 2 : Transmission Lines in Practice**

#### **Recap**

**In this course you have learnt the following**

- What is a **Transmission Line**?
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