Module 2 : Transmission Lines

Lecture 1 : Transmission Lines in Practice

Objectives

In this course you will learn the following

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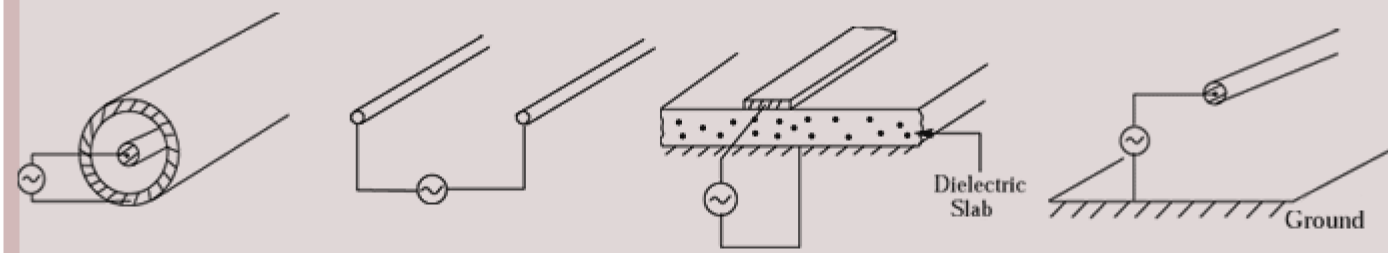
Various Types Of Transmission Line



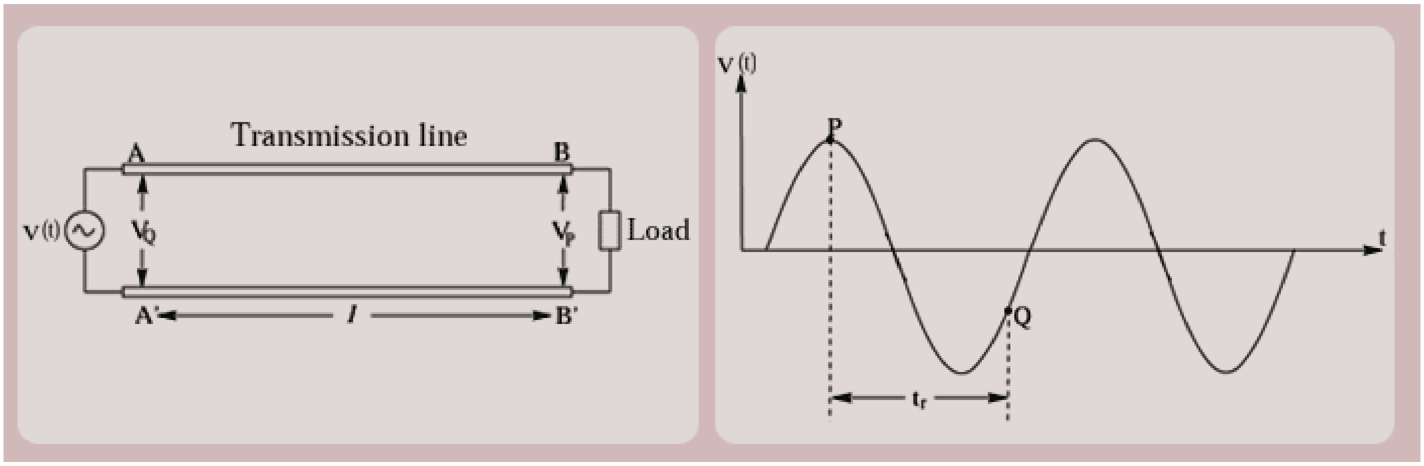
(a) Co-axial cable (b) Parallel wire Transmission line (c) Microstrip line (d) Unbalanced line

Explanation:

- As the name suggests, the transmision 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 therfore has low electromagnetic interference (EMI) .
- **Parallel wire transmission line**: Consists of two parallel conducting rods. In this case the electrical energy is distrubuted between and around the rods. Theoretically the electric and magnetic fields extend over infinite distance though its 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



Explanation:

- 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 travels with velocity v along the line. Then the Transmit time

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

- 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

$$T >> t_r$$
$$\Rightarrow \frac{1}{f} >> \frac{l}{v}$$
$$\Rightarrow \frac{v}{f} >> l \quad where, \quad \frac{v}{f} = \text{wavelength } \lambda$$
$$\Rightarrow \lambda >> l$$

- Transit time effect become important when the length of the circuit 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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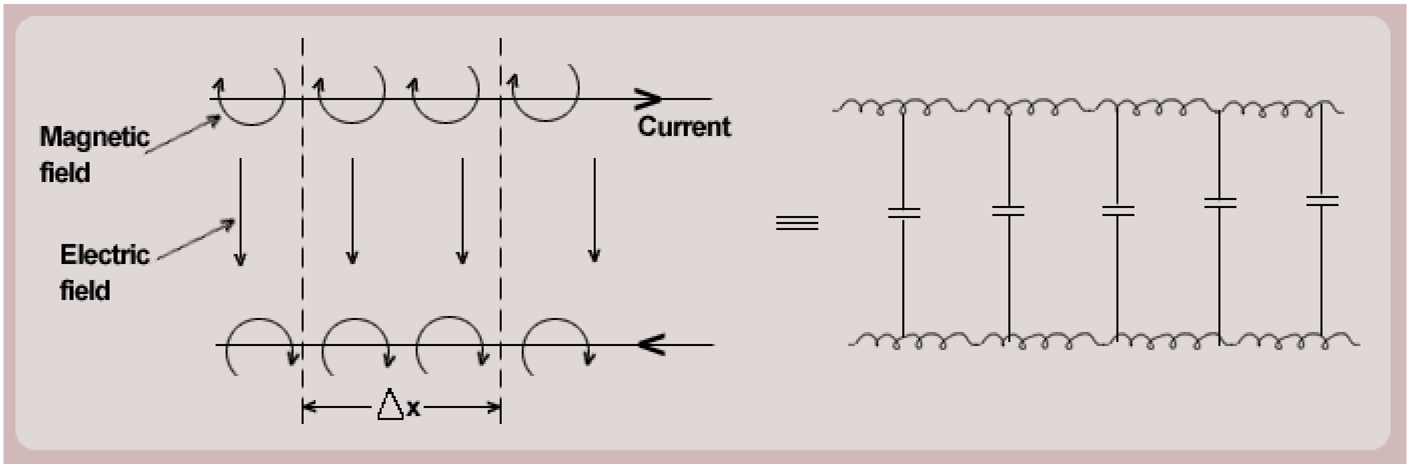
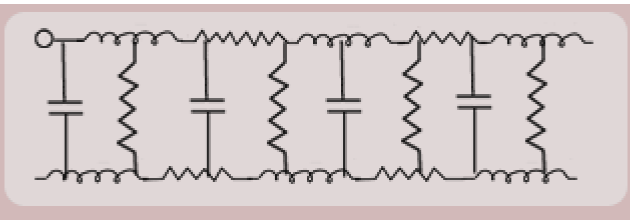
Distributed Circuit Elements

- 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 if length Δx is $<<\lambda$, 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 ' Distributed Parameters'.

Distributed Circuit Elements



Explanation:

- 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 hte line (Henery/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).

Lumped Circuit Model

- A small section of the line of length Δx has

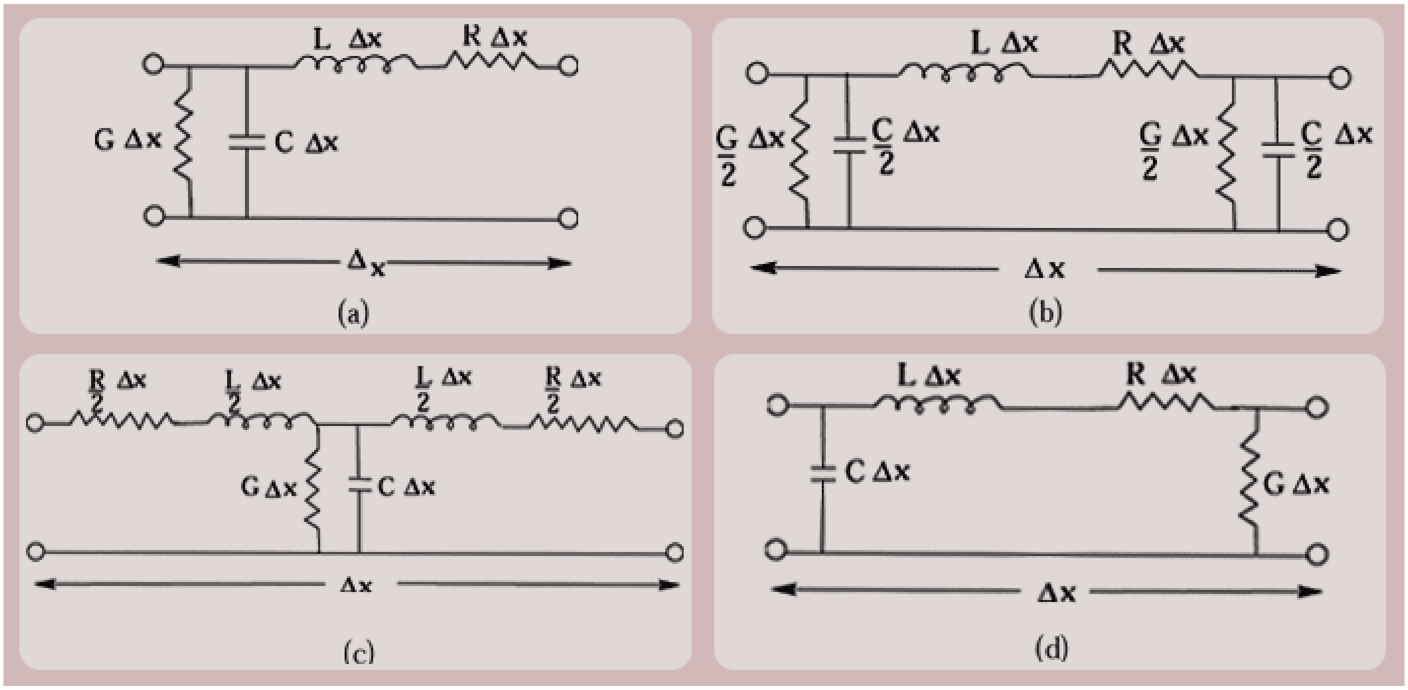
  Inductance ΔR = $L\,\Delta x$

  Resistance ΔL = $R\,\Delta x$

  Capacitance ΔC = $C\,\Delta x$

  Conductance ΔG = $G\,\Delta x$

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



Note : All representations are equivalent in the limit $\Delta x = 0$.

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Recap

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