TRANSMISSION LINES

Lecture Notes

Branch: Electronics
Semester: Fourth
Subject : Network Filters & Transmission Lines

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Transmission line : It is a conductive medium consisting of two or more conductors through which electrical energy is transmitted from one place to another. These lubes act as a channel or medium through which electrical energy is sent from one place to another place. In short; Transmission line is defined as the path of carrying alternating electrical energy from source to load.

For example the wire used between T.V antenna and television set or the wire used between transmitter antenna and transmitter are known as transmission lines.

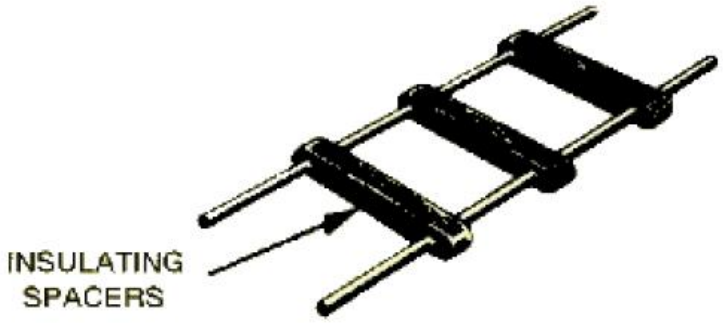
Types of transmisson lines

There are the following types of transmission lines.

- Parallel wires lines.
- Co-axial lines.
- Twin wire feeder.
- Wave guides.
- Micro strip
- Optical fibre.

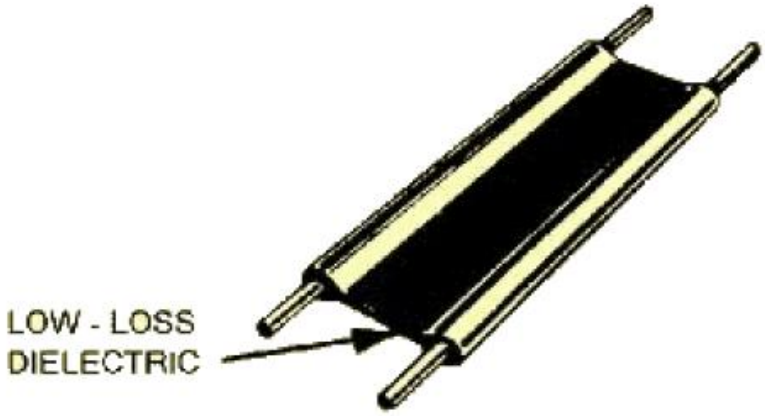
Parallel wires lines: Different types of constructions come under two wire transmission lines as shown below

1. In this type of construction for two wire transmission lines the insulated spacers are used in order to maintain the distance between the transmission lines or between the two conducting wire equally throughout.



Balance Two Wire Line - Insulating Spaces

2.In this type of transmission line the two conducting wires are kept parallel to each other with the help of plastic material. This is used throughout between the conducting wires.



Balance Two Wire Line - Low Loss Dielectric

3.In this type of transmission line the rubber piping is used in circular rectangular or square shape. The two conducting wires are kept inside the rubber at opposite sides of the piping. These conducting wires urn throughout the construction and remains parallel to each other.

Merits and Demerits

1.The cost of two wire transmission line is very low as compared to other types of lines.

2. To design the open two line transmission line is quite simple and easy too.

3. Open two wire lines are capable of handling high power.

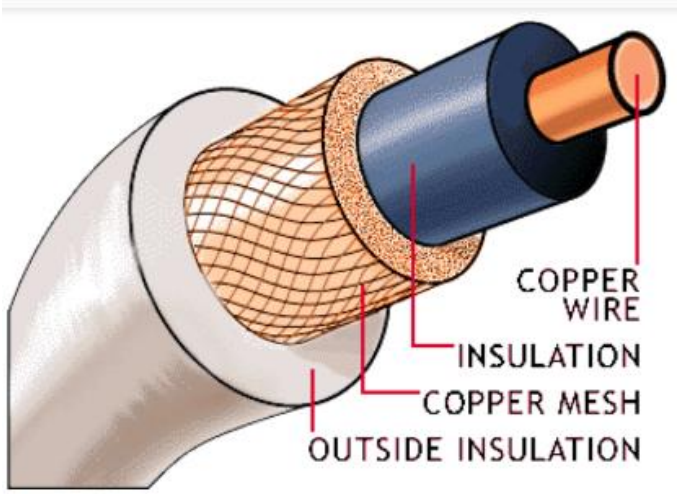
4. The external interference of the signal in open two wire lines is more as compared to other types of transmission lines.

5. Due to external interference the output at the load end of two wire transmission line will be noisy.

6. To use the two wire transmission lines in the twisty paths is quite difficult.

7. Characteristics impedance Zo of open two wire transmission line is given as.
Zo = 276 log10 2D/d
Here d stands for the diameter of the wire.
D stands for the distance between two wires from its aerials.
8. It cannot be used on very high frequencies because it will generate skin effect.

Co-axial cable : It consist of a inner conducting wire made of copper, over this conducting wire the coating of polyethylene or taplon material is carried out. Then it is enclosed in the braded wire in the shape of mash. The outer surface of this wire is enclosed in a plastic jacket.



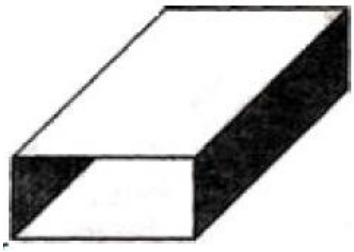
Co-axial Cable

Merits and Demerits
1. As the outer conductor (braded wire) is grounded, therefore the possibility of external interference is minimized. The output of the load end will be less noised.
2. The co-axial cable is used for high frequencies transmission.
3. This type of transmission cables can be easily used if the path of energy from source to load is twisty or complicated.
4. Co-axial cable occupies less space as compared to two wire lines.
5. The conductor which carries the energy from source to load is protected from dust, rust etc. due to proper insulation.

6. This type of transmission line is costly with respect to two wire lines.
7. Designing of co-axial cable is difficult as compared to two wire lines.
8. This type of transmission lines handles low power transmissions.
9. Characteristics impedance Zo of Co-axial cable is given as.
Zo = 233 log10 D/d
D stands for internal wire diameter of the braded wire.
d stands for diameter of the inner conductor.

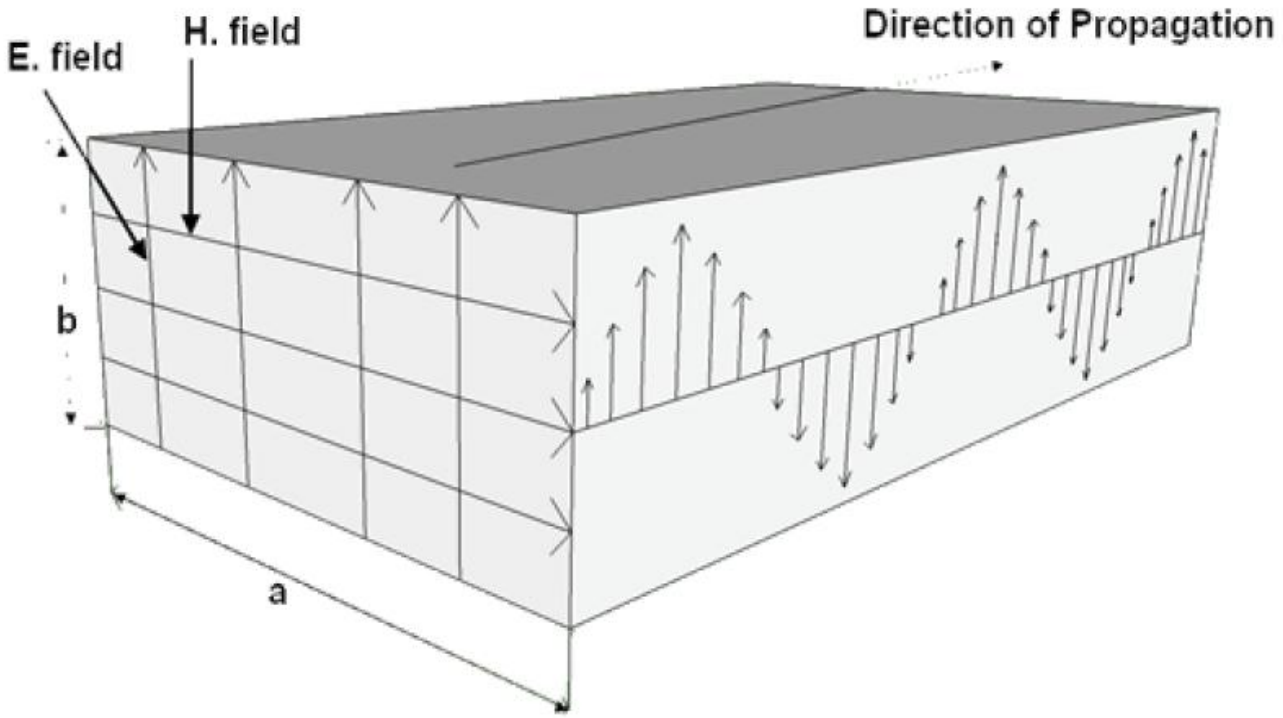
Wave Guide : A hollow conducting metallic tube of uniform cross-section used for transmitting electromagnetic waves by successive reflections from inner walls tube. The energy is in the form of electric field and magnetic field which are perpendicular to each other. The waveguide is also perpendicular to the direction of propagation as the energy is in the form of electric/magnetic field. Waveguides are used in transmission of UHF and microwave signals.
There are two basic types of the wave guide.
1. Circular wave guide
2. Rectangular wave guide

The circular waveguide is designed from a conducting pipe which is hollow from the center and polished from interior portion. The outer surface of the waveguide is coded with the insulated paint in order to avoid dust and rust. These types of wave guide are available in different lengths and sizes in order to fulfill the requirement of the circuit.



Rectangular Wave Guide is designed from conducting material in rectangular shape which is hollow from the center and fully polished from interior. The outer surface of the waveguide is coded with insulating material or paint in order to avoid dust and rust. These types of wave guides are available in different lengths and sizes in order to fulfill the requirements of the circuit.

Direction of Propagation



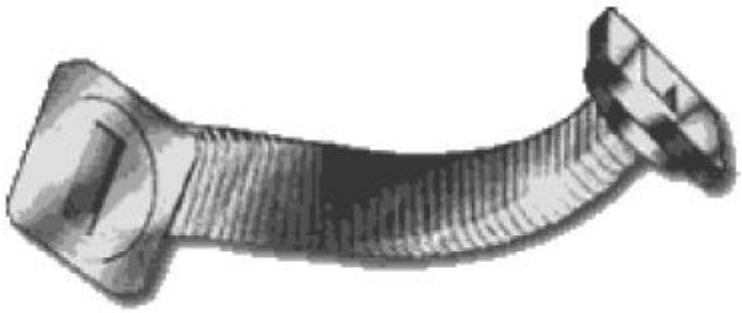
As shown in the given diagram, there are two dimensions of the rectangular waveguide where one is the broad dimension and the second is the narrow dimension. The broad dimension is denoted by “a” and the narrow is by “b”. In the wave guide the electric-field and the magnetic-field carry the signal from source to load. In this case electric-filed and the magnetic-field is perpendicular to each other and at the same time, these fields are perpendicular to the direction of propagation. Inside side the wave guide horizontal field is perpendicular to “a” and Vertical field is perpendicular to “b” according to the frequency both Horizontal and Vertical fields changes its amplitudes and direction .

Uses of Wave Guide:

There are the following uses of Wave Guide.

1. It is used where the transmission or reception is in the range of microwave frequencies.
2. It is also used for handling the high power of energy.
3. It is mostly used in the airborne radar.
4. In ground radar's we also use the wave guide.
5. The circular wave guide is mostly used in the ground radar to transmit or receive the energy from antenna. Which revolves in 360^{o} bearing continuously.
6. The wave guide is also used in communication system.
7. In satellite communication the wave guide is mostly used.
8. We also use the wave guide in the devices of navigation aids.
9. In some cases the wave guide is used as attenuator where very high frequencies are involved.
10. The wave guides are also used with the cavity resonators to carry the input and output signals.

Flexible Waveguide It is the type of waveguide which can be easily turn and twisted in circuits to connect the source with the load. This type of wave guide is designed in such a way that internal portion is made of conducting material in spring shape. The external portion is covered with the rubber to avoid dust, rust and humidity.



Uses of Flexible waveguide

1. The flexible waveguide is used in such microwave equipment's where the path from load to the source is twisty.

2. This waveguide is also used to minimize the size and design of the microwave equipment's.
3. We also used the flexible waveguide to reduce the weight due to reduction in size and to reduce the space occupied by the microwave equipment's.

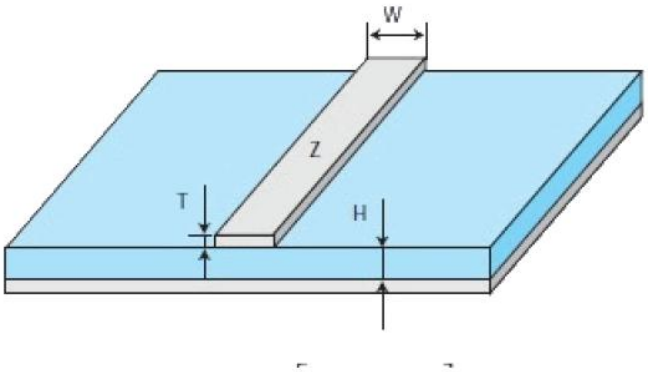
Higher Mode

It is the mode of operation which deals with the high range of frequency. The higher mode is from 30 MHz to 300 MHz. In the higher mode the transmission or propagation is carried out through the waveguide in form of electromagnetic and horizontal field. TE mode and TM mode are higher modes.

Lower Mode

The mode of operation which deals with the frequency less than 3 MHz is called the lower mode. In this case the transmission is carried out through the micro strip coaxial cable.The movement of electrons for the flow of current is taken in the lower mode of operation to carry the energy from the source to load.

Micro strip Line: A microstrip is simply a copper track running on a side of the PCB while the other side is plain ground plane. The characteristic impedance of the track, as well as the effective dielectric constant based on the geo-metric parameters is given below. The table provides usual values for 1.6 and 0.8 mm thick PCBs as well as for the standard FR4 substrate or the most advanced Rogers R04003.



Micro strip Line

As shown in the above diagram the micro strip consists of a conducting plate made of copper which works as an earth plate in the circuit. There is thick coat of insulating material over the copper plate which is made of fiber glass or polystyrene. This insulated plate works as a dielectric in the micro strip line. At the

$$Z \approx \frac{87}{\sqrt{\varepsilon_r + 1.41}} \bullet \ln\left[\frac{5.98\,H}{0.8\,W + T}\right]$$

$$\text{if } W > T: \varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\left(\frac{H}{W}\right)\right)^{-\frac{1}{2}}$$

Substrate	ε_r	Loss/inch per gigahertz	Z = 50 Ω, T = 35 µm			
			H = 1.6 mm		H = 0.8 mm	
			W	ε_{eff}	W	ε_{eff}
FR4	4.5 ± 10%	0.08 dB	2.95 mm	3.38	1.45 mm	3.38
RO4003	3.38 ± 1.5%	0.02 dB	3.30 mm	2.65	1.65 mm	2.65

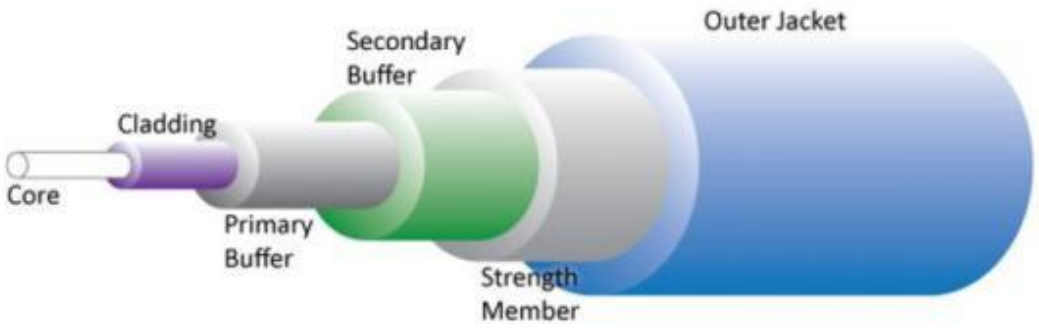
top of the insulated plate one or more than one strips of the best conducting material are plated which is made of gold.

Merits and Demerits

1. Very high frequency.
2. Small size
3. Low weight.
4. Losses are minimum.
5. This type of transmission line is used for very high frequency.
6. Micro strip lines are used in integrated circuits where distance between load and source is very short.
7. As the path of energy is made of very good conductor like gold, therefore the losses of energy are minimum possible.
8. The weight of micro strip line is low.
9. The cost of micro strip is very high as compared to co-axial and two wire line.
10. The micro strip line cannot be used as a transmission line when

the distance between source and load is long.
11. This type of transmission line cannot be used in twisty paths between source and load.

Optical Fibre : It consist of very thin hollow glass fibre through which light wave is transmitted. Basically optical fibers consist of two parts
1. Core and Cladding: These are made from fused silica glass (SiO_2) and are optically transparent.
2. Coating



The central portion of the optical fibers is called the core; it is this part in which light rays are guided. That portion which surrounds the core is called cladding. The refractive index of the core is always slightly greater than the refractive index of the cladding. Due to this difference in the refractive indices of the core and cladding, the light rays are always kept within the core of the optical fibers.
During manufacturing of the optical fibers, protective layers of plastic are uniformly applied to the entire length of the fiber. The refractive index of the coating is higher than that of cladding and core, to attenuate any undesirable light in the cladding. This coating can be removed when desired, i.e. (for jointing etc). The coating gives protection to the fibers from external influences and

absorbs shear forces. These coatings are usually colored to identify individual fibers in a multi-fibers cable.

A mode is a stable propagation state in optical fibers. When light rays travel along certain paths through the optic fibers, the electromagnetic fields in the light waves support each other to form a stable field distribution. Thus light travels in the fibers. These stable operating points (standing waves) are called modes. If the light follows other paths then a stable wave will not propagate through the fiber and hence there will be no mode.

The optical fibers are typed according to the following modes:

1. **Single Mode**

In this, the light propagates in a single or fundamental mode in the core. Such fibers with only one mode are called single-mode fiber. It allows a single light path, and typically used with LASER signaling. The single mode fibers can allow greater bandwidth and cable runs than that of multimode but it is more expansive. The single mode fiber has the best characteristics of highest data rates and least attenuation. The single mode fiber is of very small size. It has the core of approximatly 5 to 10 micro meter in diameters.

2**. Multi-Mode**

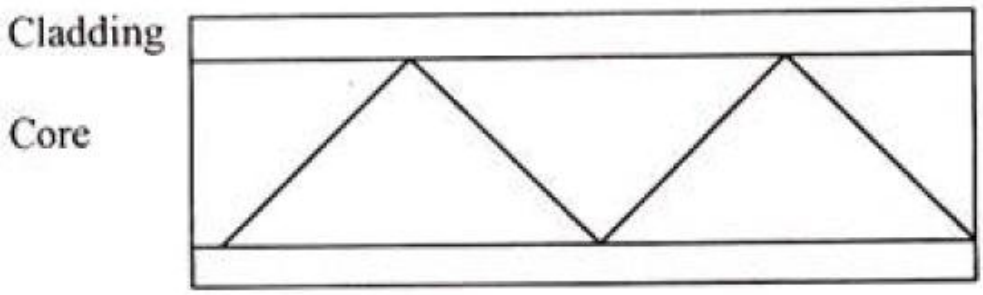
It is further divided into:

Step-Index

Graded-Index

Step-Index Multimode Fibers

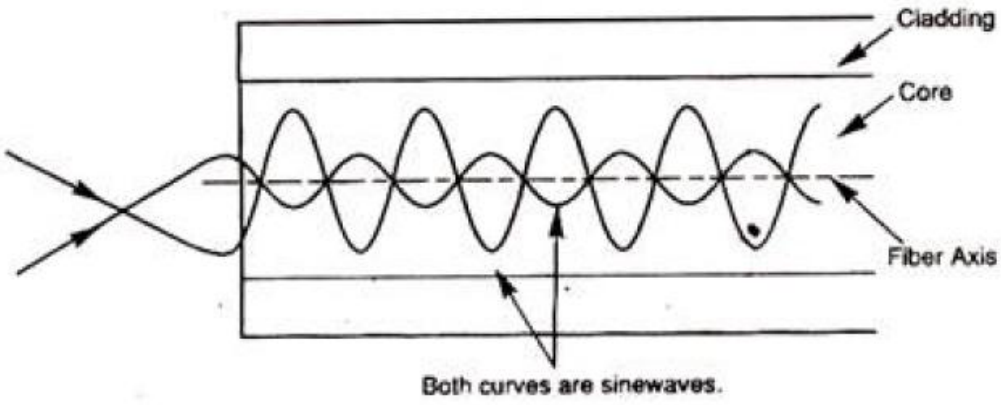
This fiber works in a very simplified way. The word step-index is used because the light to the core, by the principle of total internal reflection. The step-index multi mode fibers collect light easily but have a limited bandwidth.



Step Index Multimode Fibers

Graded-Index Fibers

These are called graded-index fibers because in these fibers the refractive index changes gradually from the core to the cladding and at the boundary between the core and cladding, the change is abrupt. The refractive index decreases gradually from the center of the core to the edge of the cladding. Graded-index multi mode fibers collect light better than small core single mode fibers and have broader bandwidth than step-index multi mode fibers.



Graded Index Fibers

Merits and Demerits

1.The Transmission rate is possible on optical fiber is 10GB/sec while in coaxial cable is1GB/sec.

2. when high freq signal are propagated through convention coaxial cable ,it loss half of its power only after a few hundred meters where as the optical fiber loss the same amount of power in 15km or more .Thus repeater will be required at verylong distance.

3.Because of very small size and light in weight and large Flexibility, it produces a number of advantages over copper wires at the installation time.

4. As the fiber optic has no electrical conductivity, therefore Grounding and protection are not necessary.

5. Using optical fiber the transmission loss is very low.

6. Also the long distance transmission is possible with fibers with out the need to amplify and retransmits the signal along the way.

7. Fiber is lighter and less bulky than equivalent copper cable

8. In fiber optic communication, there is no need of electrical connection between the sender and receiver.

9. There is no interference in the transmission of light from electrical disturbances such as lighting or electrical noise because the electromagnetic waves generated by electrical appliances cannot interfere with the light signal.

10. Optical fiber is more reliable than copper cables.

11. Optical fiber can be bend at any signal angle or even in circle.

12. The transmission through optical fiber is more secure and private.

13. The optical fiber communication provides much higher bandwidth because of uses light, which has much higher frequency than electricity.

14. The optical fiber has much lower attenuation, where the attenuation is the communication term referring to distance. Note that length of cable and its resistance can affect the amount of attenuation.

15. The fiber optic cable does not leak the signals rather than the copper cable.

16. Optical fiber is smaller and lighter than copper wire.

17. The optical is free from base rust making them ideal choice under or upper the ground surface.

18. The optical fiber communication is relatively soft way to send the data, means that fiber optic cable cannot be tapped and data

cannot be stolen from it. Which is possible in any other copper cable.

19. As the fiber optics have no electrical conductivity, therefore additional copper cable is not used with optical fiber to provide power supply to the repeaters.

20. The joining of fiber optics cables need greater care because if the joining is not correct; a lot of attenuation will produce in high Wave length.

21. The installation cost is very high as compare to the other types of transmission lines.

22. The big and base disadvantage of optical fiber is its cost, means its cost is slightly more expansive than copper cable. However its cast is falling day by day. When it comes down in price, then the fiber will be the choice of everyone for network/communication cabling.

23. Since fiber optic cable is relatively new technology so its installation and maintenance needs a expertise, which is not available everywhere.

24. We know that the propagation of light is unidirectional. If we need bidirectional communication than two fibers are needed increasing the overall cost of the system.

25. The reconnection of two ends of fiber is done by the optic connector, which has very high cost and very time consuming installation.

Application of Transmission line

- To transmit electrical energy from one place to another place.
- To transmit communication signals from a transmitter to receiver.
- To work as circuit elements like capacitor , resistor , inductor , filter etc
- For Impedance matching purpose.

In communications and electronic engineering, a **transmission line** is a specialized cable or other structure designed to conduct alternating current of radio frequency, that is, currents with a frequency high enough that their wave nature must be taken into account. Transmission lines are used for purposes such as connecting radio transmitters and receivers with their antennas (they are then called feed lines or feeders), distributing cable television signals, trunklines routing calls between telephone switching centres, computer network connections and high speed computer data buses.

For the purposes of analysis, an electrical transmission line can be modelled as a two-port network (also called a quadripole), as follows:

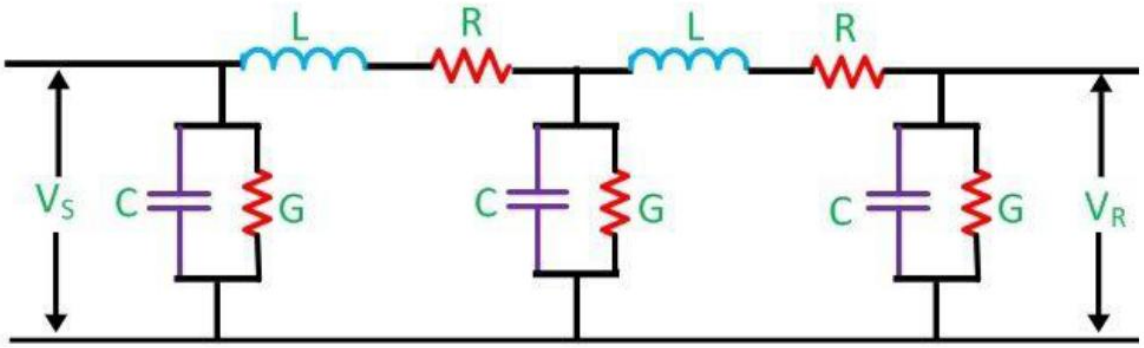
In the simplest case, the network is assumed to be linear (i.e. the complex voltage across either port is proportional to the complex current flowing into it when there are no reflections), and the two ports are assumed to be interchangeable. If the transmission line is uniform along its length, then its behaviour is largely described by a single parameter called the *characteristic impedance*, symbol Z_0. This is the ratio of the complex voltage of a given wave to the complex current of the same wave at any point on the line. Typical values of Z_0 are 50 or 75 ohms for a coaxial cable, about 100 ohms for a twisted pair of wires, and about 300 ohms for a common type of untwisted pair used in radio transmission.

When sending power down a transmission line, it is usually desirable that as much power as possible will be absorbed by the

load and as little as possible will be reflected back to the source. This can be ensured by making the load impedance equal to Z_0, in which case the transmission line is said to be *matched*.

Parameters of Transmission Line:

The performance of transmission line depends on the parameters of the line. The transmission line has mainly four parameters, resistance, inductance, capacitance and shunt conductance. These parameters are uniformly distributed along the line. Hence, it is also called the distributed parameter of the transmission line.



Tranmission Line Model

Z = R + jwL, Y = G + jwC

Circuit Globe

The inductance and resistance form series impedance whereas the capacitance and conductance form the shunt admittance. Some critical parameters of transmission line are explained below in detail

Line inductance – The current flow in the transmission line induces the magnetic flux.When the current in the transmission line changes, the magnetic flux also varies due to which emf induces in the circuit. The magnitude of inducing emf depends on the rate of change of flux. Emf produces in the transmission line resist the flow of current in the conductor, and this parameter is known as the inductance of the line.

Line capacitance – In the transmission lines, air acts as a dielectric medium. This dielectric medium constitutes the capacitor between the conductors, which store the electrical energy, or increase the capacitance of the line. The capacitance of the conductor is defined as the present of charge per unit of potential difference.

Capacitance is negligible in short transmission lines whereas in long transmission; it is the most important parameter. It affects the efficiency, voltage regulation, power factor and stability of the system.

Shunt conductance – Air act as a dielectric medium between the conductors. When the alternating voltage applies in a conductor, some current flow in the dielectric medium because of dielectric imperfections. Such current is called leakage current. Leakage current depends on the atmospheric condition and pollution like moisture and surface deposits.

Shunt conductance is defined as the flow of leakage current between the conductors. It is distributed uniformly along the whole length of the line. The symbol Y represented it, and it is measured in Siemens.

Losses of Transmission Line

There are the following losses of transmission line.

1. **Radiation Losses**

When the high frequency current or voltage wave form flow through the transmission lines, the magnetic field expands and collapse around the transmission lines at the same rate of input frequency. As we know that around the magnetic field there is also an electric field, therefore at high frequency radiation causes the attenuation in the energy provided by the source towards the load.

2. **Conductor heating**

When the current flow takes place through the transmission line, the conducting wires of the line starts to become heat up. This heating of the lines reduces the energy provided by the source to the load.

3. **Dielectric Loss or Heating**

As the transmission lines are composed of two parallel conducting wires and current flow take place through the line. The potential difference exists between the two lines. This potential difference causes the leakage current through dielectric. As a result the heating of dielectric material takes place which reduces the energy provided by source to load.