Transmission line (T.L.) module

Content

- What is transmission line(T.L.)?
- Types of transmission lines(T.L.).
- Comparison among different transmission lines.
- Equivalent   circuit of Transmission line(T.L.)
- Parameters of transmission line(T.L.).
- Transmission line (T.L.)equivalent circuit diagram
- T.L. primary parameters.
- T.L. secondary parameters.
- Lossy versus lossless T.L.

What is transmission line(T.L.)?

Transmission line is device that transfer energy from one point to another.

The energy may be electrical signal direct current (DC), alternating current(AC), radio frequency(RF) or light or electromagnetic wave (EMW).

The energy contains data about voice, data and video.

A transmission line is used for the transmission of electrical power from generating substation to the various distribution units.

Transmission lines(T.L.)

Transmission Lines

Transmission lines(T.L.)

Types of transmission lines(T.L.)

- Transmission line **made of two conductor** such as **twisted copper cable** and **coaxial cable.**
- Transmission line **made of Single conductor** such as **waveguide.**
- Transmission line **made of dielectric** such as **optical fiber**.

What is twisted copper pairs?

They are Two (or pair) of insulated copper wires twisted together of about 1 mm diameters, with a full twist every 2 to 6 inches in helical form. The insulation is plastic.

Types of twisted copper pairs

Twisted copper pairs are classified according to it twisting.

Category 3 (CAT3): twisted pairs, two insulated wires gently twisted. It handles signal up to 16 MHz. CAT3 transmit data with speed up to 10 Mbps.

Category 4 (CAT4): handles signal up to 20 MHz.

Types of twisted copper pairs

Category 5(CAT5): twisted pair has more twist per centimeter.It handles signal up to 100 MHz. it has less cross talk, better signal quality over longer distances. CAT5 transmit data with speed up to 100 Mbps

Category 6(CAT6): up to 250MHz.

Category 7(CAT7): up to 600 MHz

Advantages and disadvantages of twisted copper pairs

Advantages

- It is the least expensive. Thus, it is the most widely used.
- It is the easier to work with .
- It is easier to install.

Disadvantages

- It is limited in distance, bandwidth and data rate.
- It is susceptible to EMI (electromagnetic interference) and noise

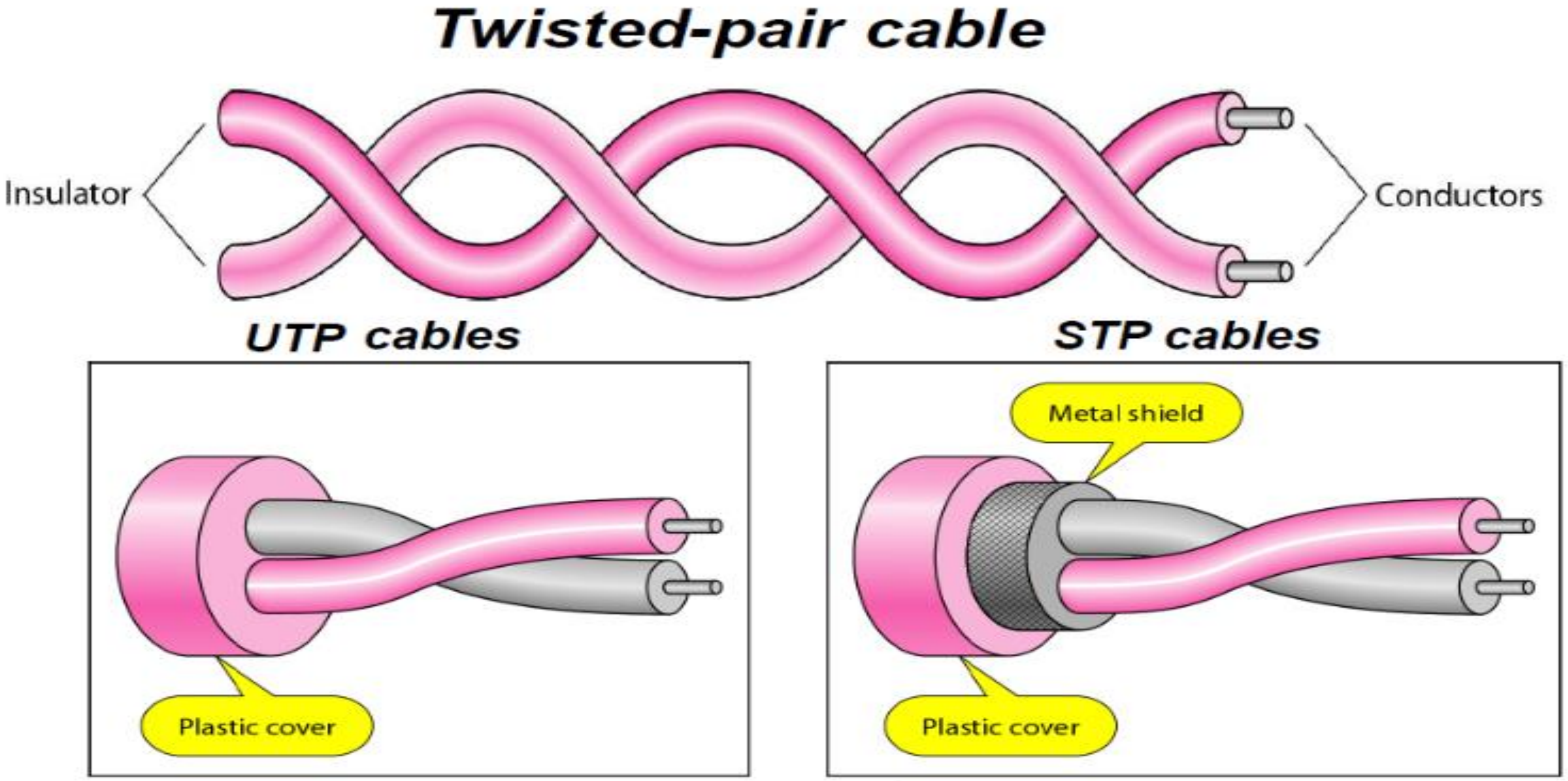
American wire Gauge (AWG) or simply Gauge

The diameter of wires varies from 19 Gauge to 26 Gauge. 26 gauge corresponds to 0.016 inch.24 gauge corresponds to 0.020 inch diameter. 22 gauage corresponds to 0.025 inch diameter. 19 gauage corresponds to 0.036 inch diameter.

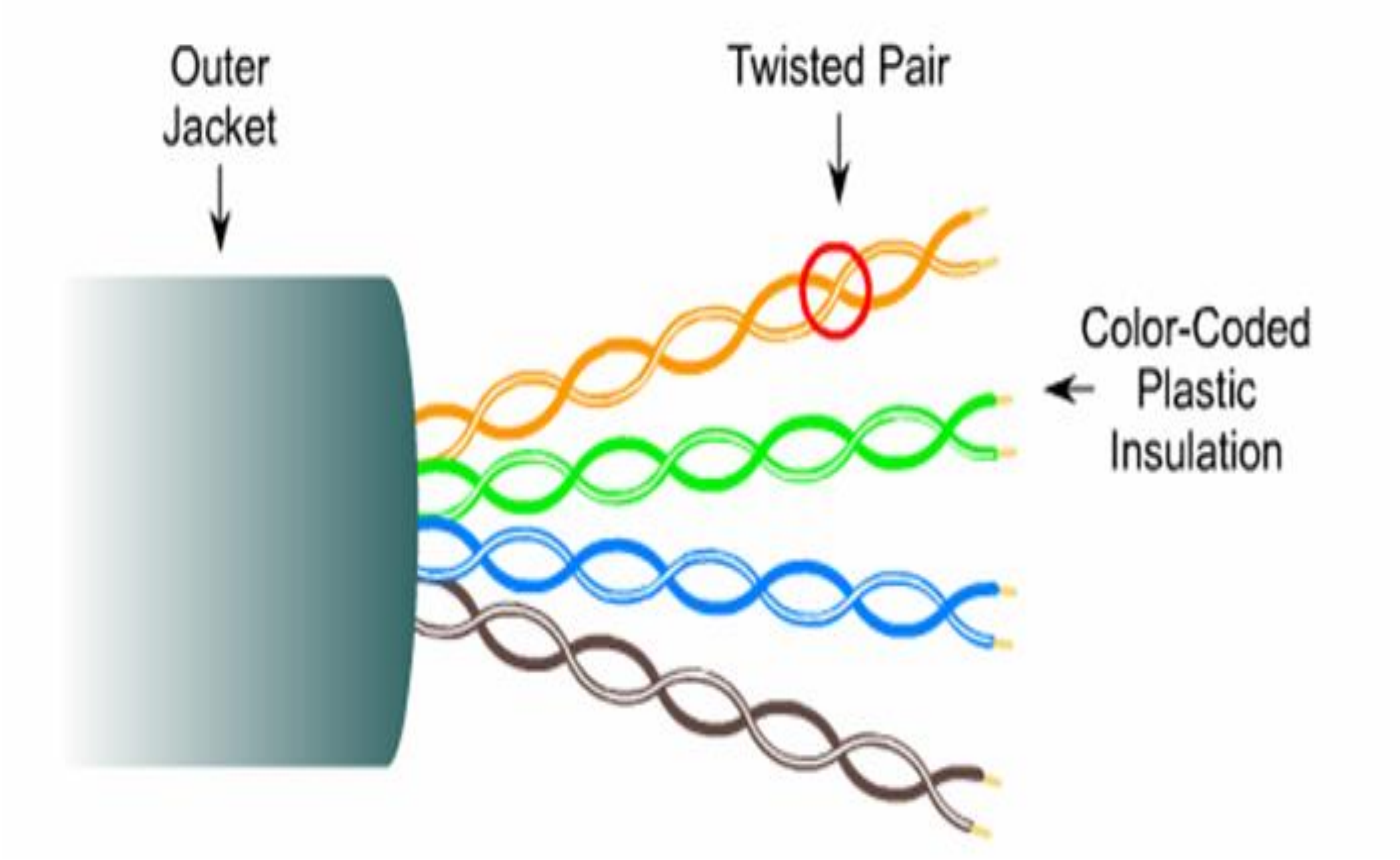
American wire Gauge (AWG)

Diameter in inch	Diameter in AWG
0.016	26
0.020	24
0.025	22
0.036	19

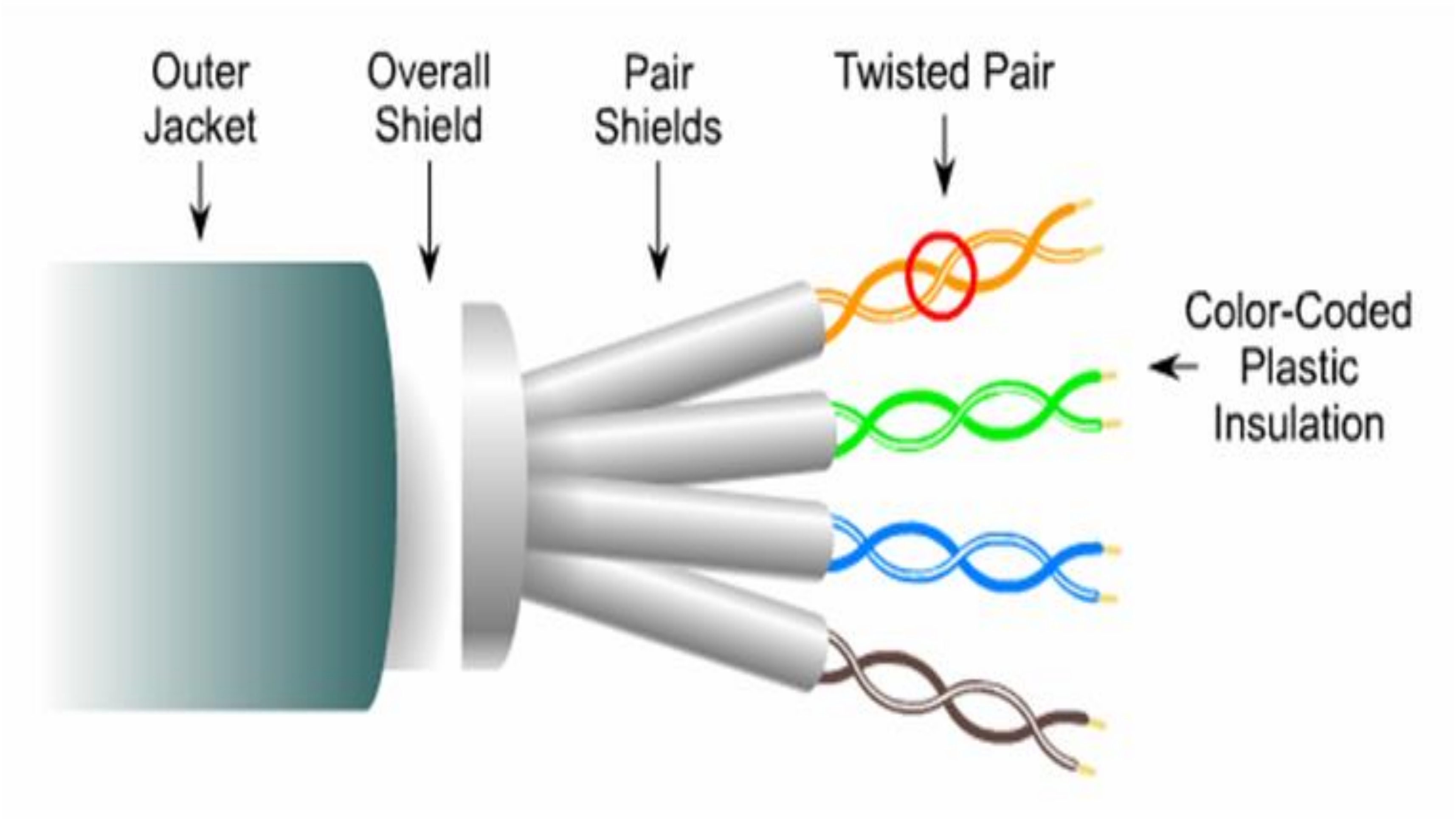
Twisted Copper pairs cable



Twisted Copper pairs cable(UTP)



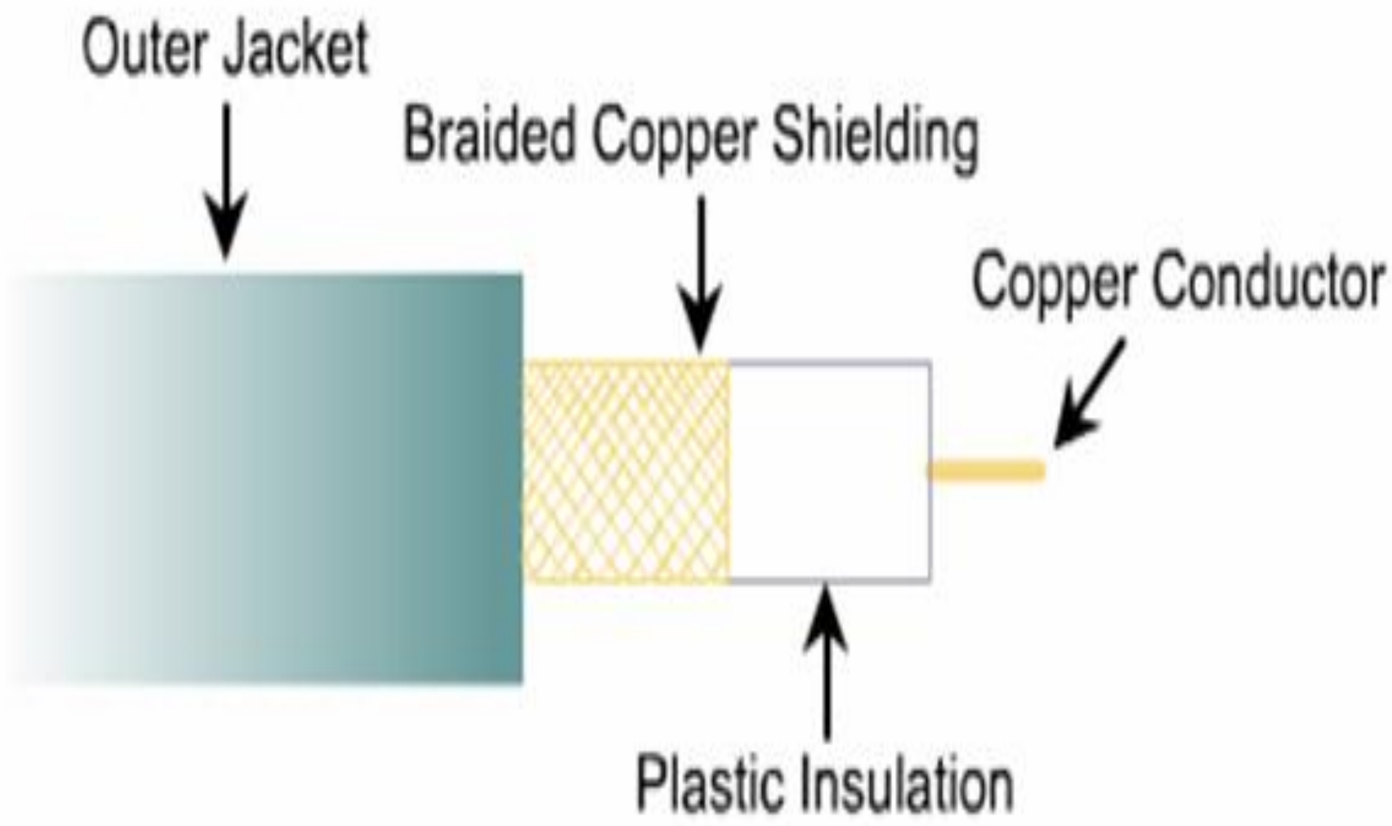
Twisted Copper pairs cable(STP)



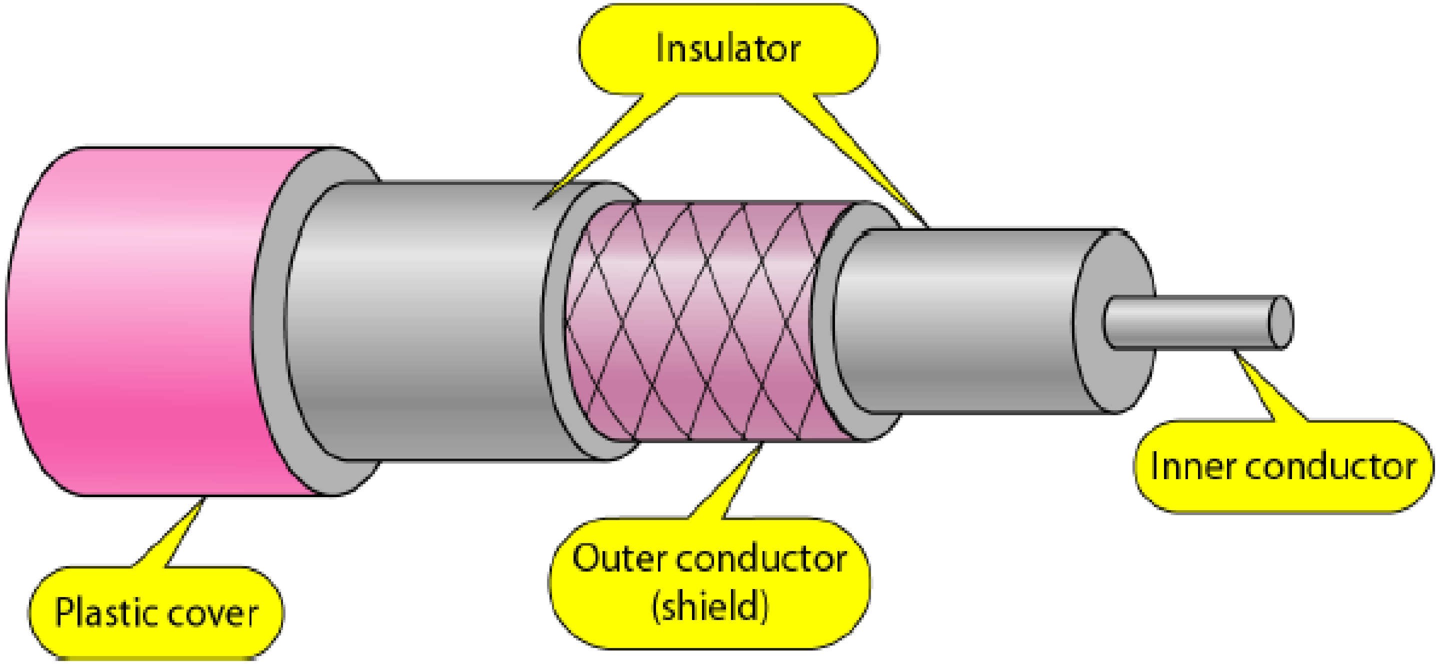
Coaxial cable

It consists of two concentric conductors: **inner copper wire conductor** surrounded by an insulating material encased by a cylindrical closely woven braided **outer conductor**. Finally it is covered by protective plastic cover

Coaxial cable



Coaxial cable



Coaxial cable

Advantages and Disadvantages of coaxial cable

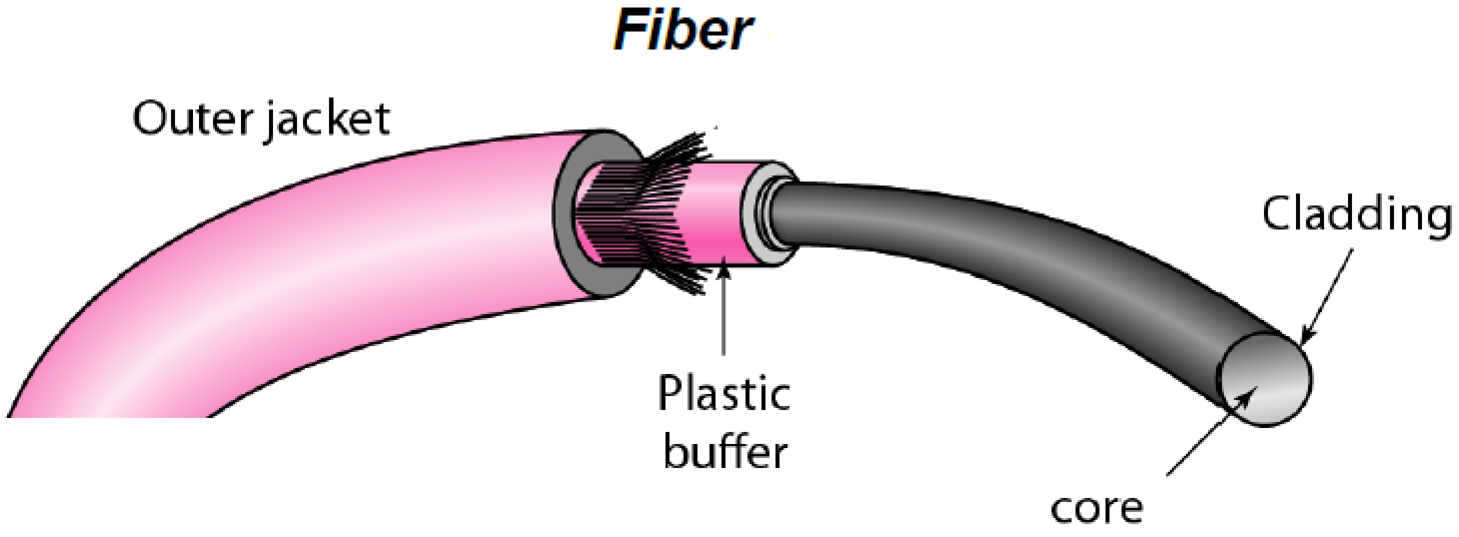
Advantages

- It has better shielding than twisted pairs. Thus, it has much less susceptible to electromagnetic interference (EMI) and cross talk.
- It has high bandwidth up to 1 GHz and has greater capacity.
- It has excellent noise immunity.
- It is cheap to install.
- It is conforms to standards and thus are widely used .

Disadvantages

- It is limited in distance.
- It is limited in number of connections.
- Its termination and connecters must be done properly.

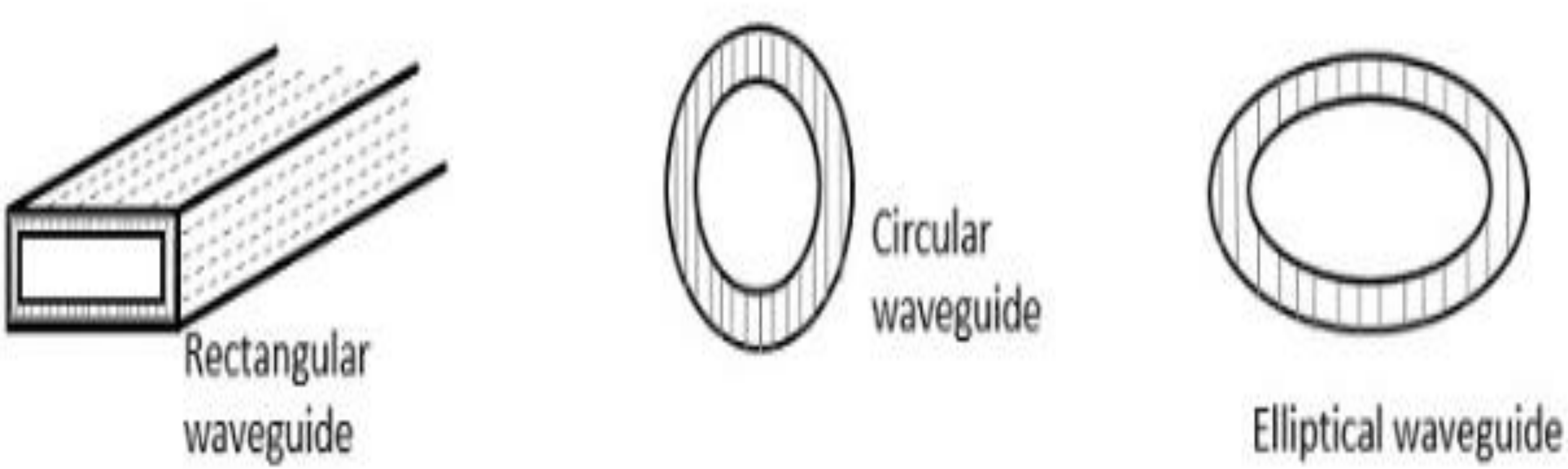
Optical fiber communication channel



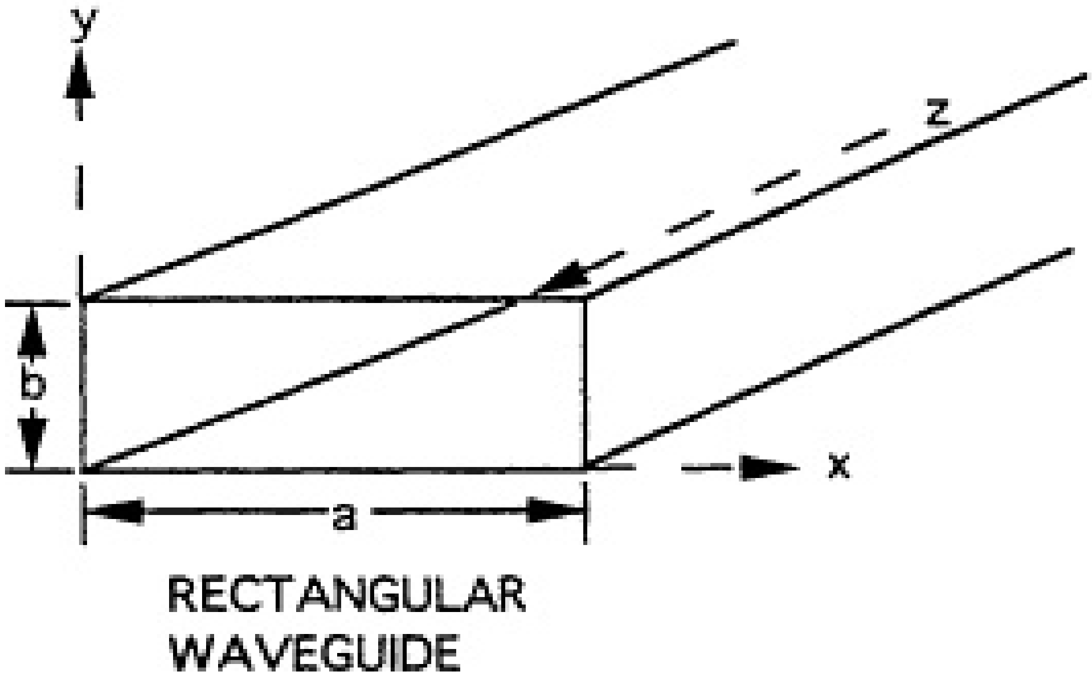
Wave guides

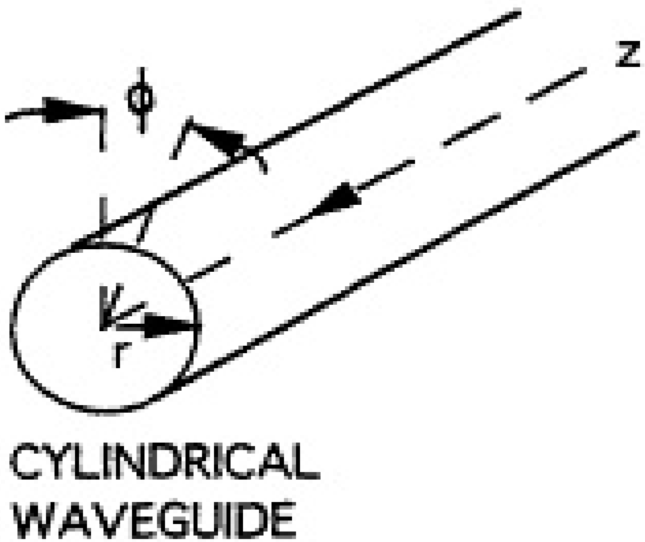
- It is made of one conductor. It is hollow pipe .
- It may be rectangular or circular cross section
- It operates in frequency band from 1GHz to 300 GHz

Types of wave guides

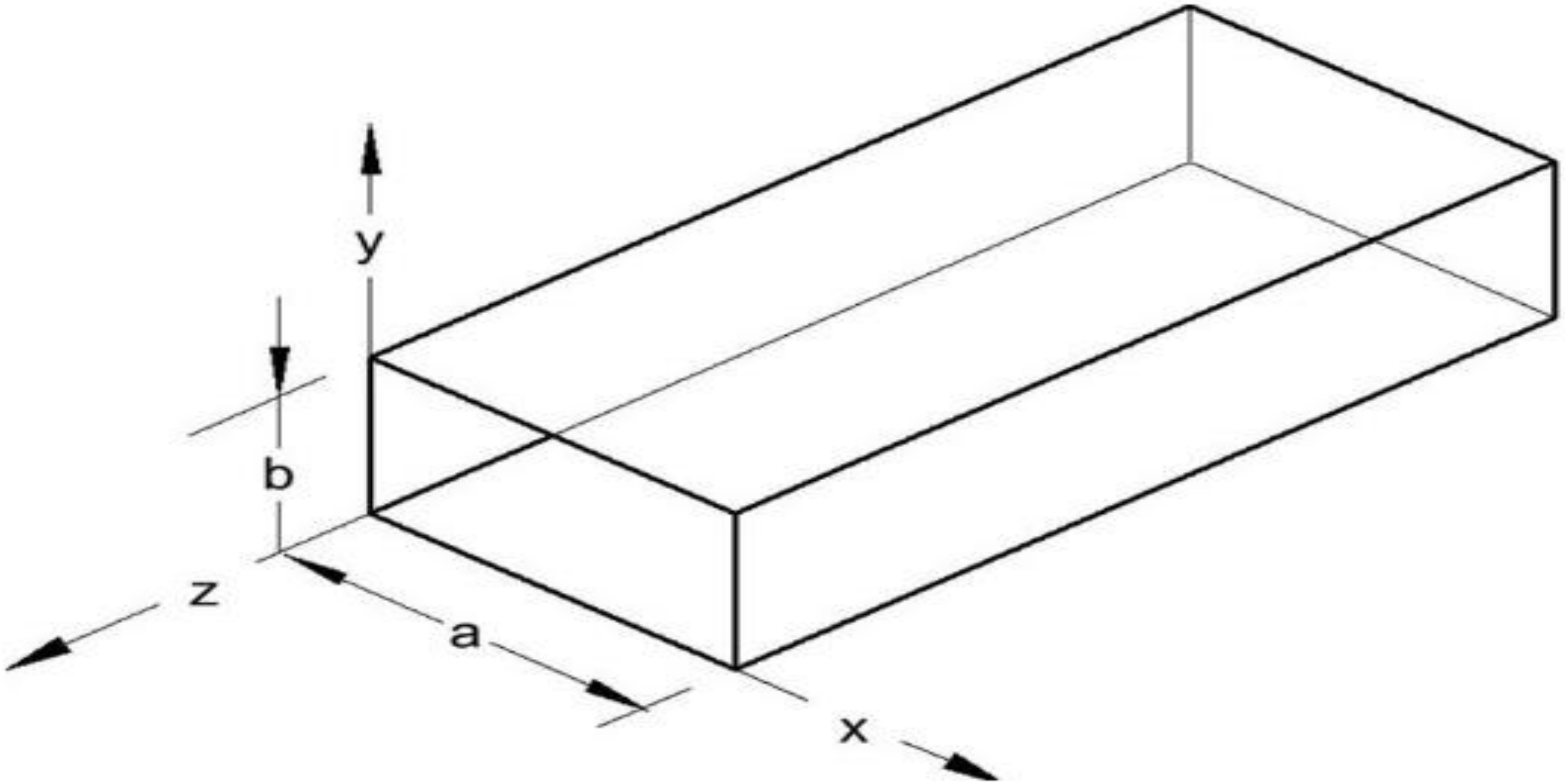


Types of wave guides

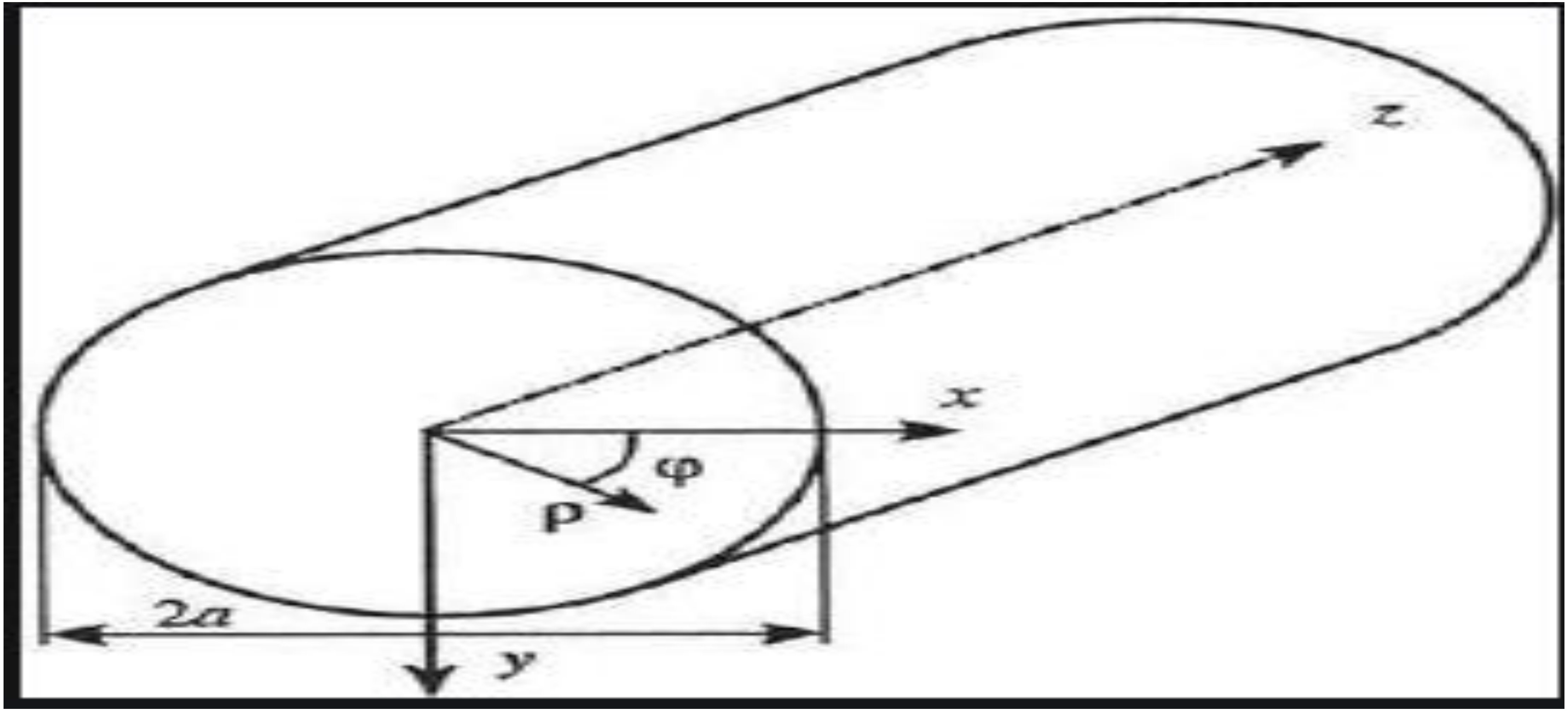




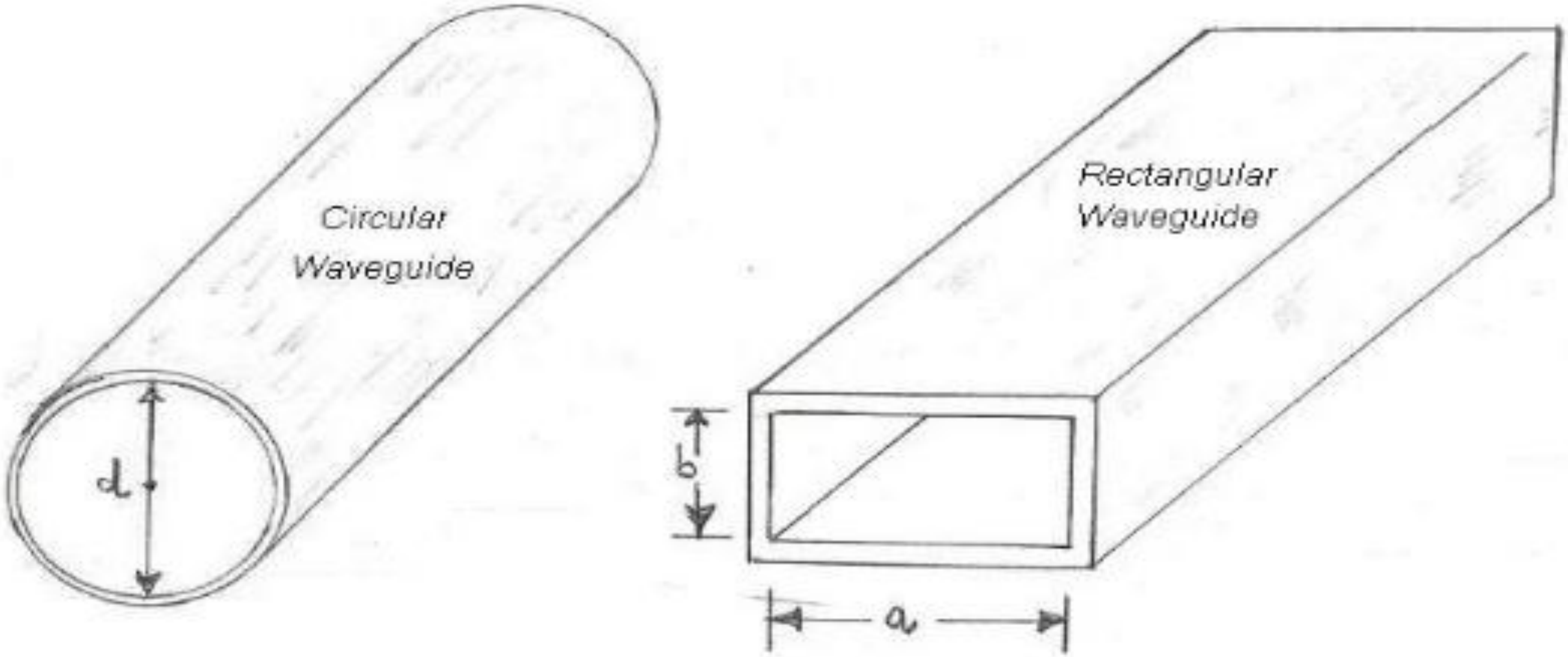
Rectangular wave guides



Circular wave guide



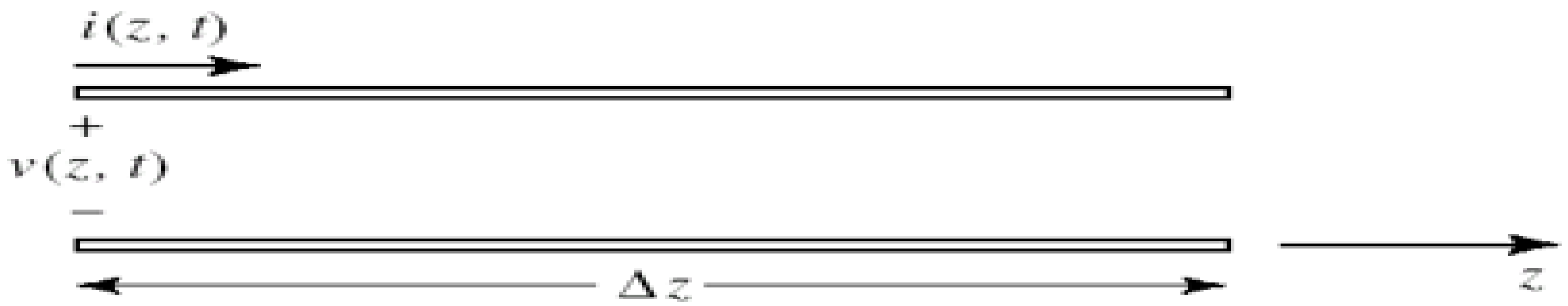
Types of wave guides



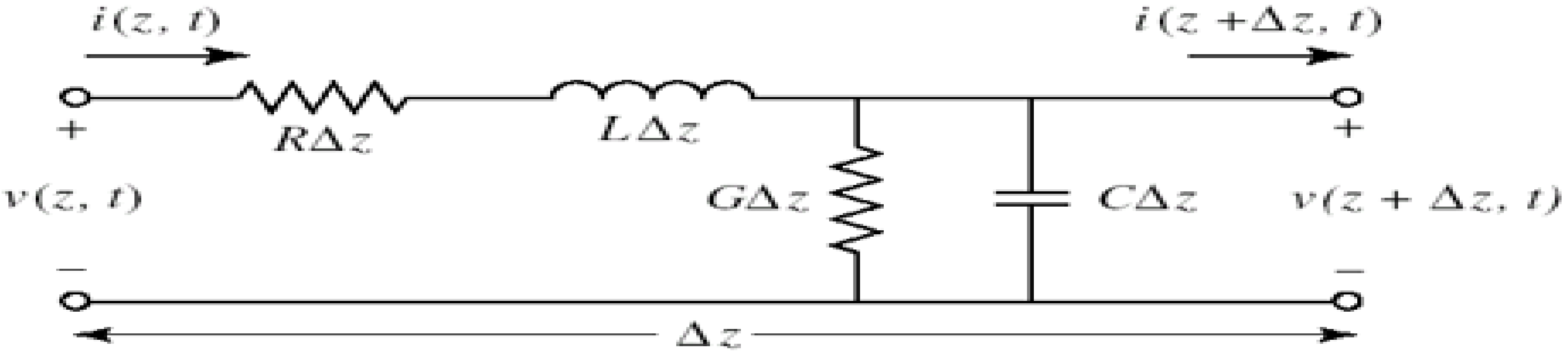
Comparison among different transmission lines

Transmission line type	Convey what	Frequency range	Applications
Twisted copper pairs cables	DC and AC	From 16 MHz to 700 MHz	It is used to convey electrical power as distribution network from production source to consumers. it is used in telephone networks to convey telephone signals in buried cables
Coaxial cable	DC, AC and RF	From 100 KHz to 500 MHz From 3MHz to 3 GHz	It is used as transmitter feeder, receiver feeder and TV feeder
Wave guides	Microwave (μW)	From 1 to 26 GHz	It is used as feeders in satellite communications earth station (ES).
Optical fiber	Light	From 10^{14} to 10^{16} Hz	It is used in LAN,MAN and WAN communication networks

T.L. equivalent circuit diagram

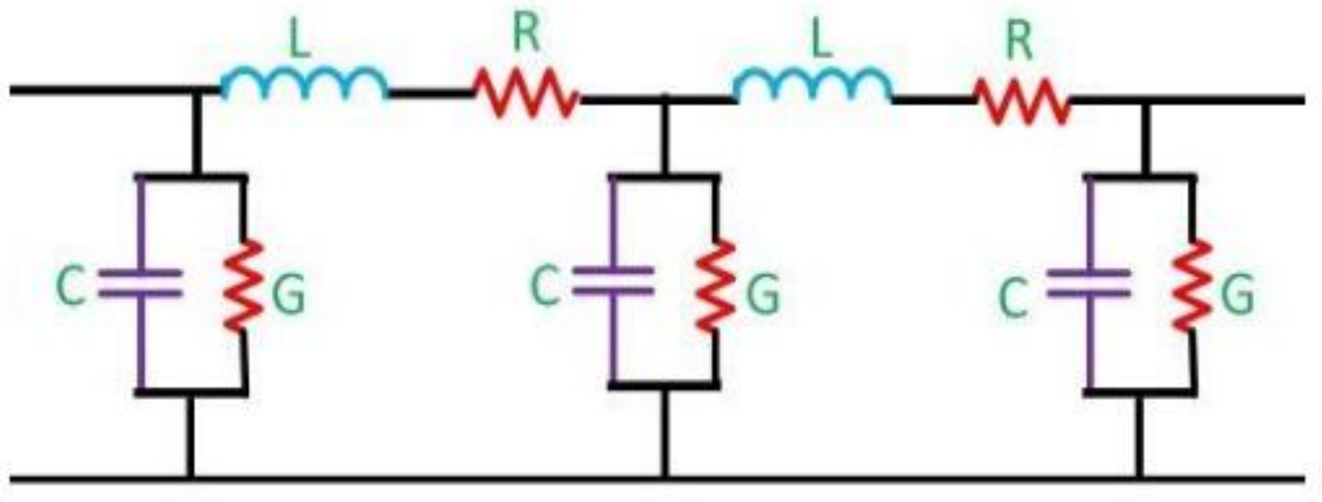


(a)



(b)

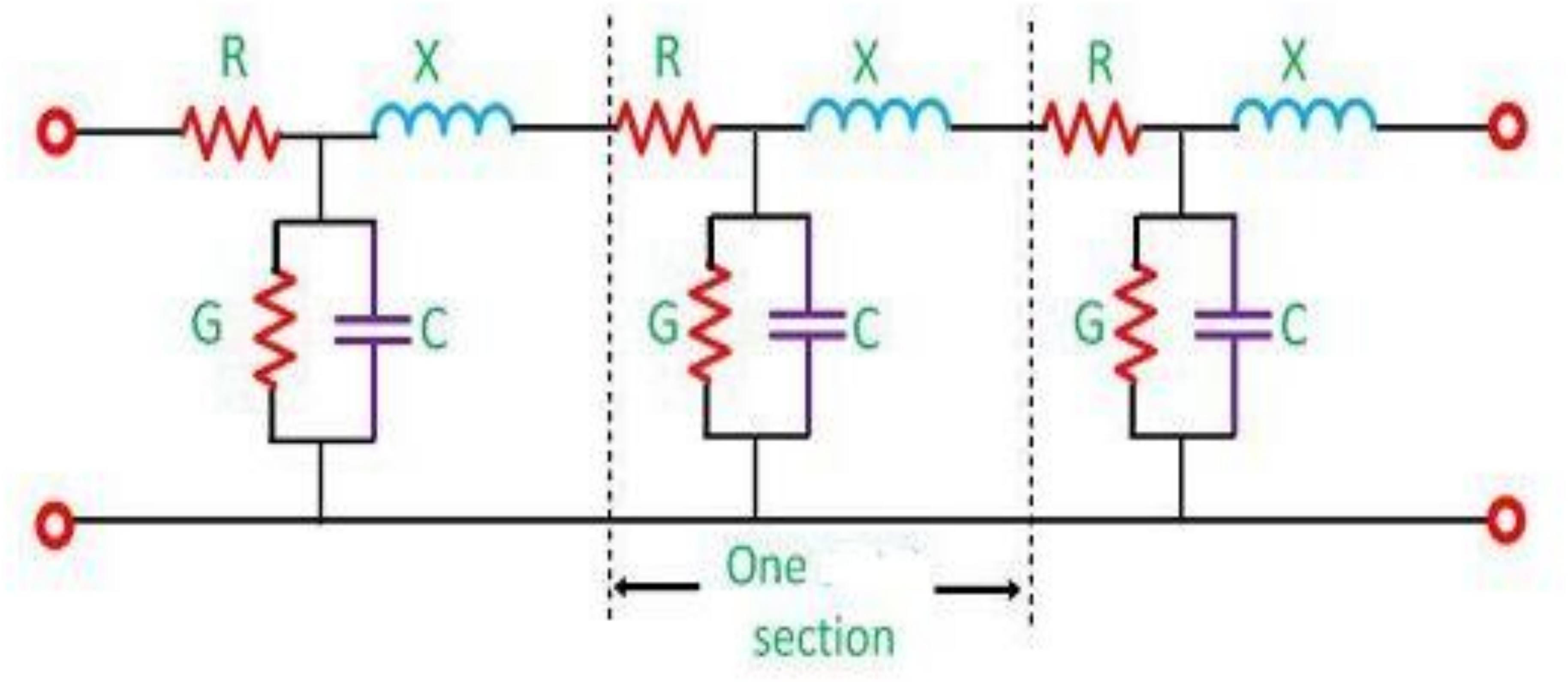
T.L. equivalent circuit diagram



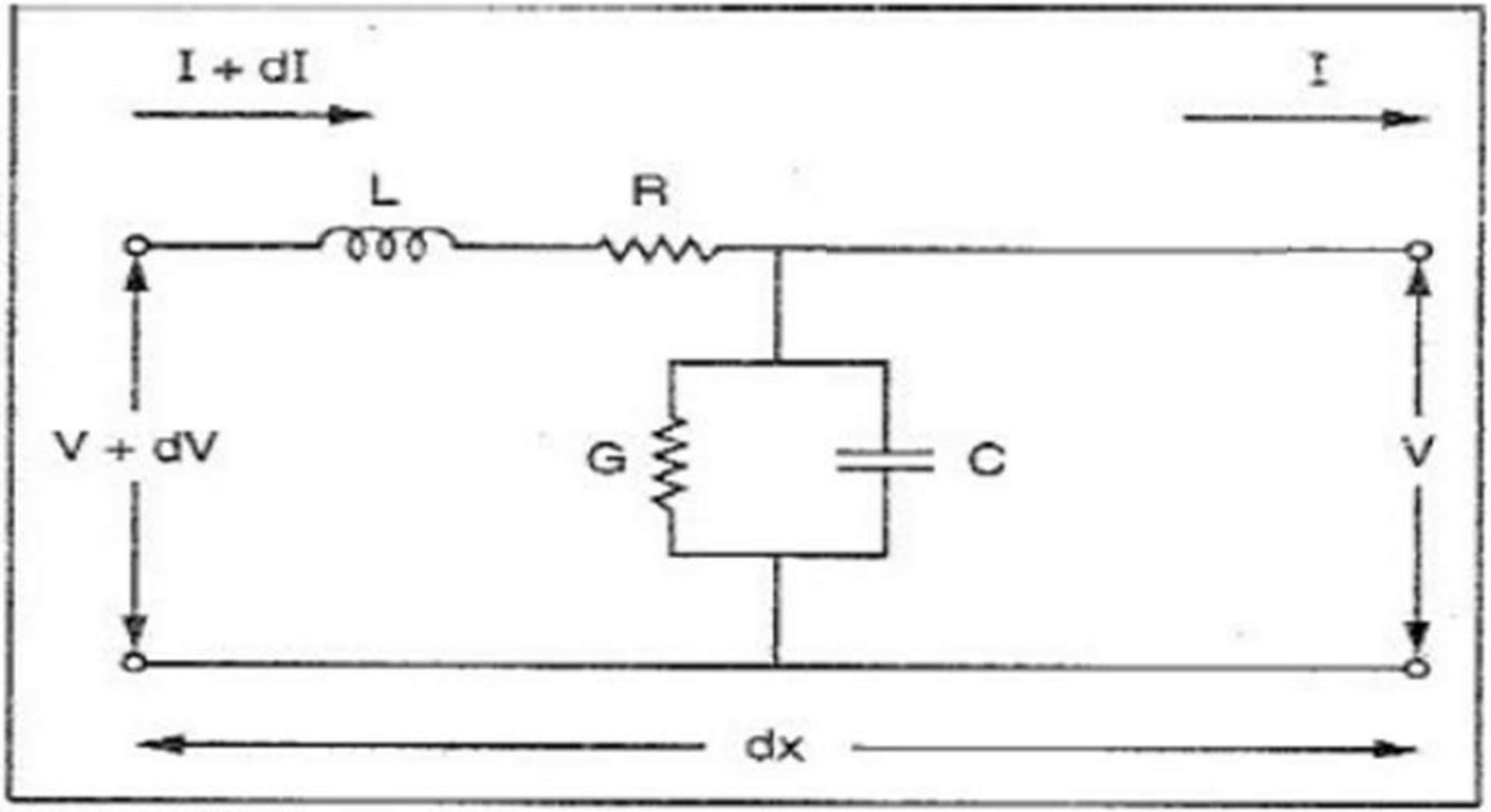
Tranmission Line Model

Z = R + jwL, Y = G + jwC

T.L. equivalent circuit diagram



T.L. equivalent circuit diagram (one section)



Transmission line equivalent circuit diagram

The equivalent circuit consists of the following: series combination of inductor and resistance and is is express by:

Z = R+jωL.

and parallel combination of capacitance and conductance and is express by:

Y = G+jωc

R = series resistance per unit length for both conductors

L = series inductance per unit length for both conductors

G = shunt conductance per unit length

C = shunt capacitance per unit length

The primary parameters of transmission line

- R is Resistance per unit length [Ω/m]
- L is inductance per unit length [H/m]. it is associated with magnetic flux linking in the transmission line
- C is capacitance per unit length [F/m]. it is associated with electric charge in the transmission line
- G is conductance per unit length [S/m]. it is associated with leakage current in the transmission line

The secondary parameters of transmission line

- The propagation coefficient(γ)
- The attenuation coefficient(α)
- The phase shift coefficient (β)
- The characteristic impedance (Z_0)
- The propagation (or phase) velocity(V_p)
- The wave length (λ)

In general case (lossy transmission line)

1. The propagation coefficient

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

$$\gamma = \alpha + j\beta \qquad [m^{-1}]$$

2. The attenuation coefficient(α)

It is the real part of γ and its unit is [Np/meter]

3. The phase shift coefficient (β)

It is the imaginary part of γ and its unit is [radian/meter].

4. The characteristic impedance (Z_0) in ohm

$$Z_0 = \sqrt{\frac{(R + j\omega L)}{(G + j\omega C)}} \qquad [\Omega]$$

Where

Z_0 is the ratio of traveling wave voltage and the current when no reflection.

$$Z_0 = \frac{V'}{I'}$$

$$Z_0 = R_0 + jX_0$$

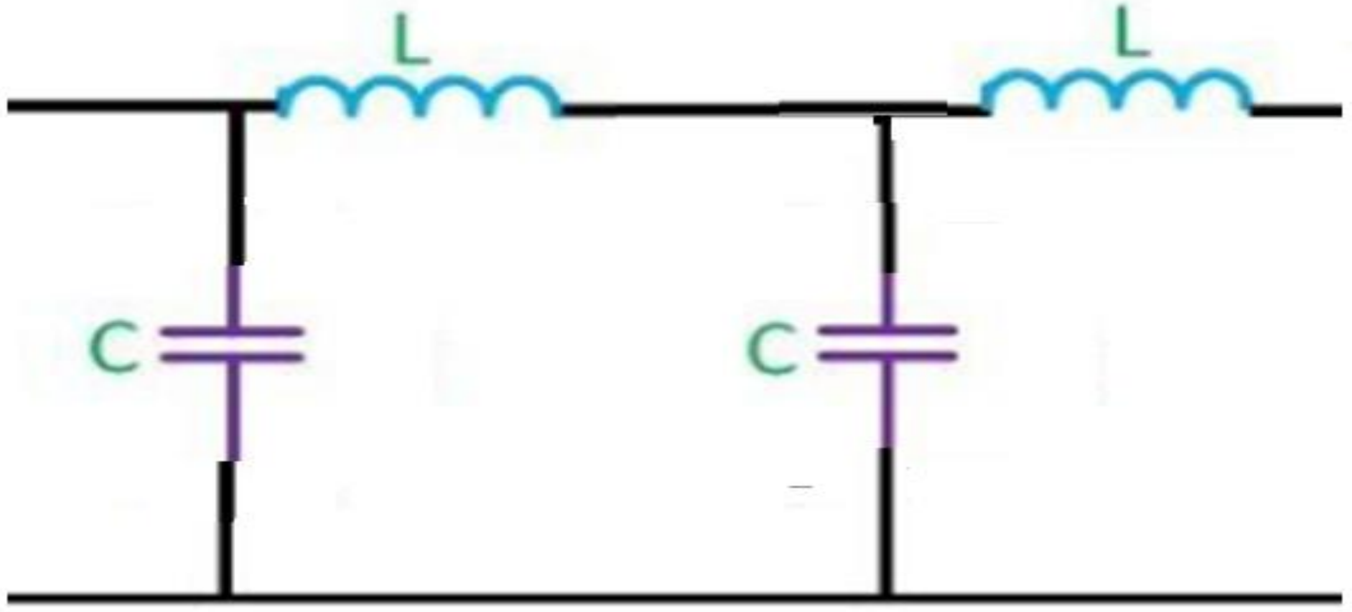
5. The propagation (or phase) velocity

$$V_P = \frac{\omega}{\beta} \qquad [\text{meter/sec ond}]$$

6. The wave length

$$\lambda = \frac{2\pi}{\beta}$$

Lossless T.L. Equivalent circuit diagram



Lossless transmission lines secondary parameters

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$$

where γ the complex propagation constant.

α = attenuation constant,

β = phase constant

R = G = 0 gives $\gamma = \alpha + j\beta = j\omega\sqrt{LC}$ or

$$\beta = \omega\sqrt{LC}, \quad \alpha = 0$$

$$Z_0 = \sqrt{\frac{L}{C}}$$

Lossless transmission lines secondary parameters

The wavelength of the waves:

$$\lambda = \frac{2\pi}{\beta}$$

The phase velocity of the wave is defined as the speed at which a constant phase point travels down the line,

$$v_p = \frac{\omega}{\beta}$$

In case of lossless transmission line

1. The propagation coefficient

$\gamma = \alpha + j\beta$ [m $^{-1}$]

R $= 0$

G $= 0$

$\gamma = j\omega\sqrt{LC}$ [m $^{-1}$]

2. The attenuation coefficient

$\alpha = 0$ [Np/m]

3. The phase shift coefficient

$\beta = \omega\sqrt{\mathrm{LC}}$ [radian/me ter]

4. The characteristic impedance

$$Z_o = \sqrt{\frac{L}{C}} \qquad [\Omega]$$

$$R_o = \sqrt{\frac{L}{C}}$$

$$X_o = 0$$

5. The phase propagation velocity

$$V_P = \frac{1}{\sqrt{LC}} \qquad [\text{meter/sec ond}]$$

6. The wave length

$$\lambda = \frac{2\pi}{\beta}$$

Lossy T.L. versus lossless T.L.

T.L. Type / Parameters	Lossy T.L.	Lossless T.L.
Propagation coefficient $[m^{-1}]$	$\gamma = \alpha + j\beta$	$\gamma = j\beta = j\omega\sqrt{LC}$
Attenuation coefficient [Np/m]	$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$	$\alpha = 0$
Phase shift coefficient [radian/m]		$\beta = \omega\sqrt{LC}$
Propagation phase velocity [meter/second]	$V_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$	$V_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$
Characteristic impedance [Ω]	$Z_o = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$	$Z_o = \sqrt{\frac{L}{C}}$ $R_o = \sqrt{\frac{L}{C}}$

Relation ship between decibel and Neper

$$\alpha|_{dB} = 10\log\frac{P_1}{P_2}$$

$$\alpha|_{NP} = 10\ln\frac{P_1}{P_2}$$

$$\alpha|_{NP} = 8.686 * \alpha|_{dB}$$

$$\alpha|_{dB} = 0\cdot115 * \alpha|_{NP}$$