Introduction

1. TLine can only support TEM wave whereas waveguide can support many possible field configurations.
2. At microwave frequencies (3 to 300 GHz), TLine becomes inefficient due to skin effect and dielectric losses, but waveguides are used at microwave frequencies to obtain larger bandwidth and lower signal attenuation.
3. TLine can operate above dc (f =0) to a very high frequency, but waveguide can operate only above *cutoff frequency* and therefore acts as a high pass filter.

Definition: A Hollow metallic tube of uniform cross section for transmitting electromagnetic waves by successive reflections from the inner walls of the tube is called ***waveguide.***

➢In order to determine the EM field configuration within the waveguide, **Maxwell's** equations. For simplicity, consider the guide filled with lossless, charge free media and the walls to be perfect conductors.

$$\nabla \bullet \mathrm{E}_S = 0 \rightarrow \nabla \bullet \mathrm{D} = 0 \qquad \nabla \bullet \mathrm{H}_S = 0 \rightarrow \nabla \bullet \mathrm{B} = 0$$

$$\nabla \times \mathrm{E}_S = -j\omega\mu \mathrm{H}_S \qquad \nabla \times \mathrm{H}_S = j\omega\varepsilon \mathrm{E}_S$$

$$\nabla^2 \mathrm{E}_S + \omega^2 \mu\varepsilon \mathrm{E}_S = 0 \qquad \nabla^2 \mathrm{H}_S + \omega^2 \mu\varepsilon \mathrm{H}_S = 0$$

Basic Features:

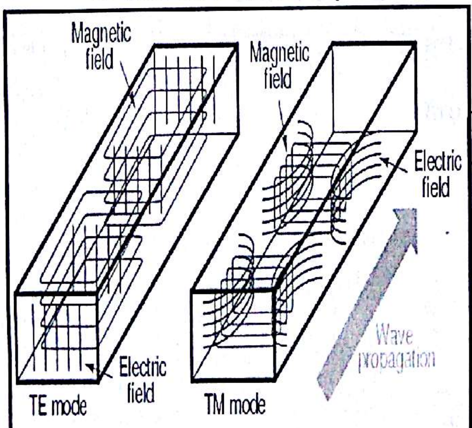
➢Waveguides may be used to carry energy between pieces of equipment or over longer distances to carry transmitter power to an antenna or microwave signals from an antenna to a receiver

➢Waveguides are made from copper, aluminum or brass.

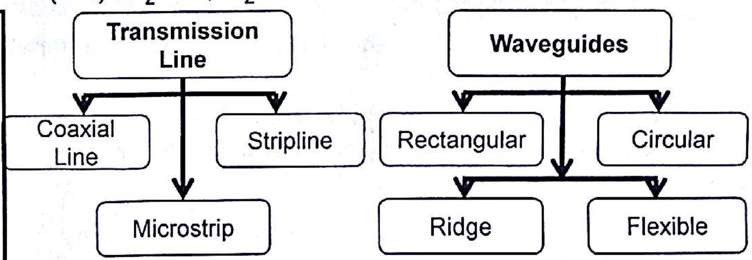
➢The electric and magnetic fields associated with the signal bounce off the inside walls back and forth as it progresses down the waveguide.

Possible Types of modes

1. Transverse Electro Magnetic **(TEM)** wave: Here both electric and magnetic fields are directed components. (i.e.) $E_z = 0$ and $H_z = 0$
2. Transverse Electric **(TE)** wave: Here only the electric field is purely transverse to the direction of propagation and the magnetic field is not purely transverse. (i.e.) $E_z = 0$, $H_z \neq 0$
3. Transverse Magnetic **(TM)** wave: Here only magnetic field is transverse to the direction of propagation and the electric field is not purely transverse. (i.e.) $E_z \neq 0$, $H_z = 0$.
4. **Hybrid (HE)** wave: Here neither electric nor magnetic fields are purely transverse to the direction of propagation. (i.e.) $E_z \neq 0$, $H_z \neq 0$.



Magnetic flux lines appear as continuous loops
Electric flux lines appear with beginning and end points



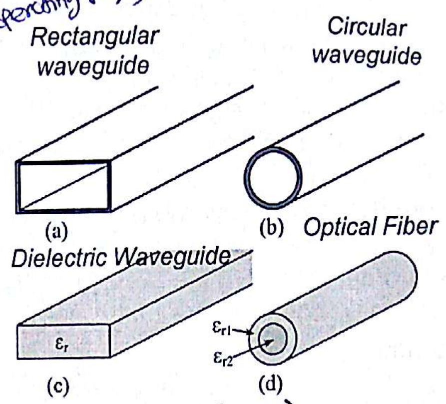
- hollow rectangular waveguide that can propagate TM and TE modes but not TEM since only one conductor is present.
- <u>Applications</u>: high-power systems, millimeter wave applications, satellite systems, precision test applications

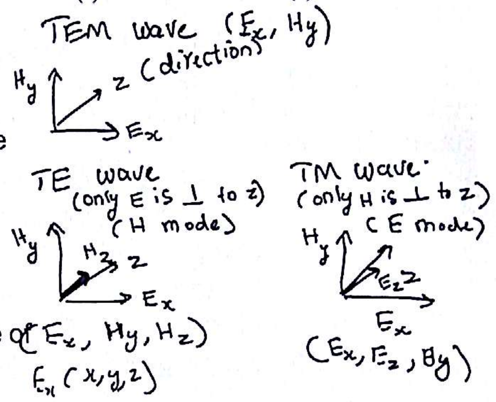
- waveguide refers to constructs that only support non-TEM mode propagation. Such constructs share an important trait: they are unable to support wave propagation below a certain frequency, termed the *cutoff frequency*.
- **Critical (cut-off) frequency, f_c(Hz):** the lowest frequency for which a mode will propagate in a waveguide. $f_c < f_o$ (operating freq)
- **Critical (cut-off) wavelength, λ_c (m/cycle):** the largest wavelength that can propagate in the waveguide without any / minimum attenuation $\lambda_c > \lambda_o$ (operating wavelength)
- **Group velocity (v_g, m/s):**
  a) The velocity at which a wave propagates.
  b) at which signals or energy is propagated.
- **Phase velocity (v_p, m/s):**
  a) The velocity at which the wave changes phase.
  b) It is the apparent velocity of the wave (i.e.: max electric intensity point).
  c) v_p always equal to or greater than v_g ($v_p \geq v_g$).
  d) It may exceed the velocity of light
- In theory: $c < v_g \leq v_p$. ……… $c^2 = v_g + v_p$
- **Propagation wavelength in the waveguide (λ_g, m/s):**

a) Wavelength of travelling wave that propagates down the waveguide.
b) λ_g greater in the waveguide than in free space (λ_o).

- **Waveguide characteristic impedance (Z_o, Ω):**

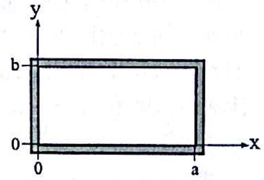
a) It depends on the cut-off frequency, which in turn is determined by the guide dimension.
b) It is also closely related to the characteristic impedance of free space (377 Ω). Generally, $Z_o > 377$ Ω.





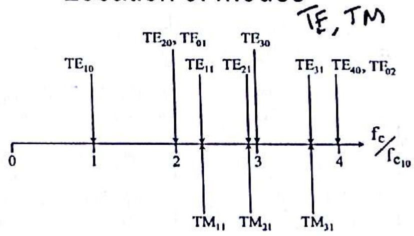
- Let us consider a ***rectangular waveguide with interior dimensions are a x b***,
- Waveguide can support ***TE and TM modes***.
  - In TE modes, the electric field is transverse to the direction of propagation. - Voltage wave
  - In TM modes, the magnetic field that is transverse and an electric field component is in the propagation direction.
- The order of the mode refers to the field configuration in the guide, TE_{mn} and TM_{mn}.
  - The **m** subscript corresponds to the number of half-wave variations of the field in the x direction, and
  - The **n** subscript is the number of half-wave variations in the y direction.
- A particular mode is only supported above its cutoff frequency. The cutoff frequency is given by

Rectangular Waveguide



Location of modes

TE, TM



$$f_{c_{mn}} = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} = \frac{c}{2\sqrt{\mu_r\varepsilon_r}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$u = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_o\mu_r\varepsilon_o\varepsilon_r}} = \frac{1}{\sqrt{\mu_o\varepsilon_o}}\frac{1}{\sqrt{\mu_r\varepsilon_r}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}$$

Number of conductors
TEM — 2 conductors
TE, TM — ≥1 conductors or Dielectric

For air $\mu_r = 1$ and $\varepsilon_r = 1$

$$f_{c_{mn}} = \frac{c}{2\sqrt{\mu_r\varepsilon_r}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \Longrightarrow f_{c_{mn}} = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

where $c = 3\times10^8$ m/s

Table 7.1: Some Standard Rectangular Waveguide

Waveguide Designation	a (in)	b (in)	t (in)	f_{c10} (GHz)	freq range (GHz)
WR975	9.750	4.875	.125	.605	.75 – 1.12
WR650	6.500	3.250	.080	.908	1.12 – 1.70
WR430	4.300	2.150	.080	1.375	1.70 – 2.60
WR284	2.84	1.34	.080	2.08	2.60 – 3.95
WR187	1.872	.872	.064	3.16	3.95 – 5.85
WR137	1.372	.622	.064	4.29	5.85 – 8.20
WR90	.900	.450	.050	6.56	8.2 – 12.4
WR62	.622	.311	.040	9.49	12.4 - 18

$$fc_{10} = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{1}{a}\right)^2 + \left(\frac{0}{b}\right)^2} \rightarrow fc_{10} = \frac{c}{2a}$$

Example: Calculate the cutoff frequency for the first four modes of WR284 waveguide.

Sol:

From table, the guide dimensions are a=2.840 inches and b=1.340 inches.

Converting to metric units:

$$a = 7.214 \quad cm$$

$$b = 3.404 \quad cm$$

$$f_{c_{mn}} = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

TE_{10}: $f_{c10} = \dfrac{c}{2a} = \dfrac{3x10^8\ m/s}{2(7.214cm)}\dfrac{100cm}{1m} = 2.08$ GHz

TE_{20}: $f_{c20} = \dfrac{c}{a} = 4.16$ GHz

TE_{01}: $f_{c01} = \dfrac{c}{2b} = \dfrac{3x10^8\ m/s}{2(3.404cm)}\dfrac{100cm}{1m} = 4.41$ GHz

TE_{11}: $f_{c11} = \dfrac{3x10^8\ m/s}{2}\sqrt{\left(\dfrac{1}{7.214cm}\right)^2 + \left(\dfrac{1}{3.404cm}\right)^2}\dfrac{100cm}{1m} = 4.87$ GHz

TE_{10}	TE_{20}	TE_{01}	TM_{11} TE_{11}
2.08 GHz	4.16 GHz	4.41 GHz	4.87 GHz

Example

P7.2: Calculate the cutoff frequency for the first 8 modes of a waveguide that has a = 0.900 inches and b = 0.600 inches.

a = 0.900 in = 0.02286 m, b = 0.600in = 0.01524 m

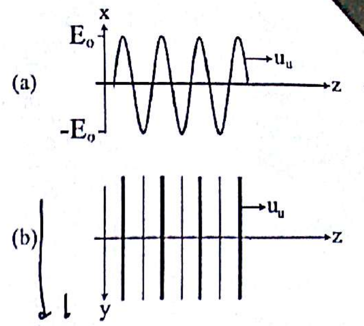
For air-filled guide we have:

$$fc_{mn} = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \qquad \text{For air } c = 3\times10^8 \text{ m/s}$$

Evaluating all the combination of modes for m = 0,1,2,3 and n = 0,1,2,3 we find

Mode	fc_{mn} (GHz)
TE_{10}	6.56
TE_{01}	9.84
TE_{11}	11.83
TM_{11}	11.83
TE_{20}	13.12
TE_{21}	16.40
TM_{30}	19.69
TE_{02}	19.69

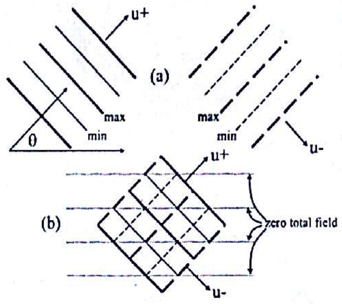
Rectangular Waveguide - Wave Propagation



We can achieve a qualitative understanding of ***wave propagation in waveguide*** by considering the wave to be a superposition of a pair of TEM waves.

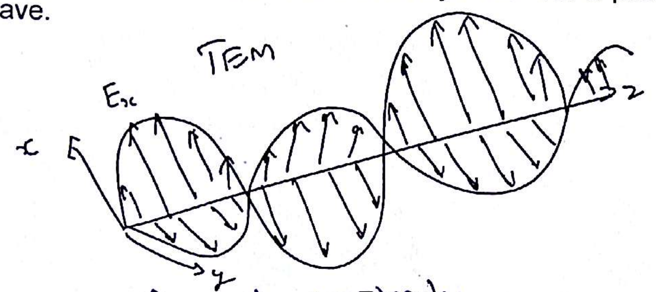
Let us consider a ***TEM wave propagating in the z direction (Fig. a)***. **Fig. b** shows the wave fronts; bold lines indicating ***constant phase at the maximum value*** of the field ($+E_0$), and lighter lines indicating constant phase at the ***minimum value*** ($-E_0$).

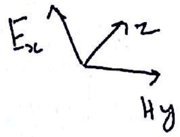
The waves propagate at a ***velocity*** u_u, where the u subscript indicates media unbounded by guide walls. In air, $u_u = c$.



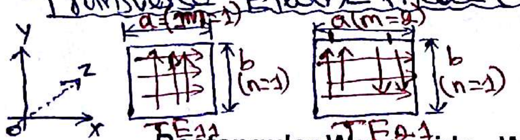
•Now consider a pair of identical TEM waves, labeled as u+ and u- in Figure (a). The u+ wave is propagating at an angle $+\theta$ to the z axis, while the u- wave propagates at an angle $-\theta$.

These waves are combined in Figure (b). Notice that horizontal lines can be drawn on the superposed waves that correspond to zero field. Along these lines the u+ wave is always 180° out of phase with the u- wave.

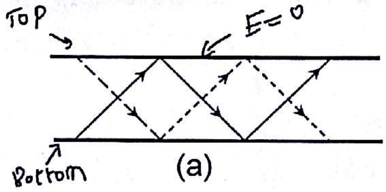




Transverse Electric mode (TE) mode:

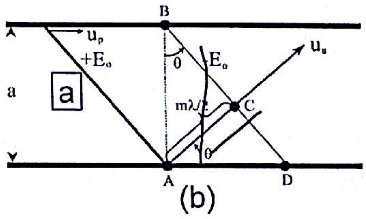


Rectangular Waveguide - Wave Propagation



Since we know **E** = 0 on a perfect conductor, we can replace the horizontal lines of zero field with perfect conducting walls. Now, u+ and u- are reflected off the walls as they propagate along the guide.

The distance separating adjacent zero-field lines in Figure (b), or separating the conducting walls in Figure (a), is given as the dimension **a** in Figure (b).



The distance *a* is determined by the angle θ and by the distance between wave front peaks, or the wavelength λ. For a given wave velocity u_u, the frequency is $f = u_u/\lambda$.

If we fix the wall separation at a, and change the frequency, we must then also change the angle θ if we are to maintain a propagating wave. Figure (b) shows wave fronts for the u+ wave.

The edge of a $+E_0$ wave front (point A) will line up with the edge of a $-E_0$ front (point B), and the two fronts must be λ/2 apart for the m = 1 mode.

For any value of m, we can write by simple trigonometry

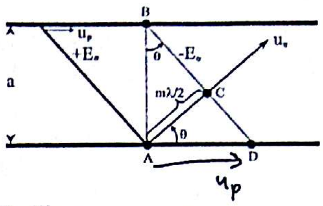
$$\sin\theta = \frac{m\lambda/2}{a} \quad \Longrightarrow \quad \lambda = \frac{2a}{m}\sin\theta = \frac{u_u}{f}$$

The waveguide can support propagation as long as the wavelength is smaller than a critical value, λ_c, that occurs at θ = 90°, or

$$\lambda_c = \frac{2a}{m} = \frac{u_u}{f_c}$$

Where f_c is the cutoff frequency for the propagating mode.

We can relate the angle θ to the operating frequency and the cutoff frequency by $\sin\theta = \frac{\lambda}{\lambda_c} = \frac{f_c}{f}$



The time t_{AC} it takes for the wavefront to move from A to C (a distance l_{AC}) is

$$t_{AC} = \frac{\text{Distance from A to C}}{\text{Wavefront Velocity}} = \frac{l_{AC}}{u_u} = \frac{m\lambda/2}{u_u}$$

A constant phase point moves along the wall from A to D. Calling this phase velocity u_p, and given the distance l_{AD} is

$$l_{AD} = \frac{m\lambda/2}{\cos\theta}$$

Then the time t_{AD} to travel from A to D is $t_{AD} = \frac{l_{AD}}{u_p} = \frac{m\lambda/2}{\cos\theta\, u_p}$

m λ/2, a, A, l_{AD}, D

$\cos\theta = \frac{m\lambda/2}{l_{AD}}$

Since the times t_{AD} and t_{AC} must be equal, we have $u_p = \frac{u_u}{\cos\theta}$

The *Wave velocity* is given by $u_u = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_o\mu_r\varepsilon_o\varepsilon_r}} = \frac{1}{\sqrt{\mu_o\varepsilon_o}}\frac{1}{\sqrt{\mu_r\varepsilon_r}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}$

5 The *Phase velocity* is given by

$$u_p = \frac{u_u}{\cos\theta} \Rightarrow \boxed{u_p = \frac{u_u}{\sqrt{1-\left(f_c/f\right)^2}}}$$

using

$$\cos\theta = \sqrt{\cos^2\theta} = \sqrt{1-\sin^2\theta} = \sqrt{1-(f_c/f)^2}$$

1 condition for wave propagation
$\lambda c > \lambda o$ & $fc < fo$

2 cutoff freq & cut-off wavelength

$\lambda c = \frac{2ab}{\sqrt{m^2b^2+n^2a^2}}$ | $fc = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2+\left(\frac{n}{b}\right)^2}$

Suppose m=1 & n=0

$\lambda c, TE10 = 2a$ and $fc, TE10 = \frac{c}{2a}$

9

4 Intrinsic wave impedance of Rectangular waveguide

$\eta_{TE} = \frac{120\pi}{\sqrt{1-(fc/f)^2}} = \frac{120\pi}{\cos\theta}$; $\eta_{TM} = 120\pi\sqrt{1-(fc/f)^2}$
$= 120\pi\cos\theta$

6 The *Group velocity* is given by

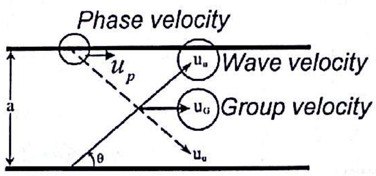
$$u_G = u_u\cos\theta$$

$$\boxed{u_G = u_u\sqrt{1-\left(f_c/f\right)^2}}$$

$\boxed{u_p u_G = c^2}$

7 The phase constant is given by $\boxed{\beta = \beta_u\sqrt{1-\left(f_c/f\right)^2}}$

8 The guide wavelength is given by $\boxed{\lambda = \frac{\lambda_u}{\sqrt{1-\left(f_c/f\right)^2}}}$



The ratio of the transverse electric field to the transverse magnetic field for a propagating mode at a particular frequency is the *waveguide impedance.*

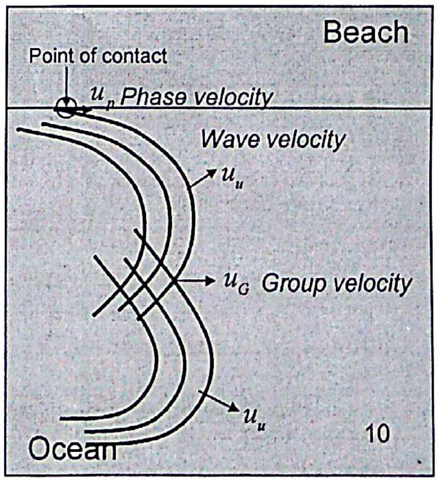
For a TE mode, the wave impedance is

$$\boxed{Z_{mn}^{TE} = \frac{\eta_u}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}},$$

For a TM mode, the wave impedance is

$$\boxed{Z_{mn}^{TM} = \eta_u\sqrt{1-\left(\frac{f_c}{f}\right)^2}}.$$

Analogy!



3 checking of modes in Rectangular waveguide

TE10, TE01, TE11, TE21, TE12, TE22....
TM11, TM21, TM12 TE22 $\boxed{\text{TM01, TM10}}$ not possible due to Evenscent mode

Scanned by CamScanner

Example

P7.5: Consider WR975 is filled with polyethylene. Find (a) u_u, (b) u_p and (c) u_G at 600 MHz.

From Table 7.1 for WR975 we have $a = 9.75$ in and $b = 4.875$ in. Then

$$fc_{10} = \frac{c}{2\sqrt{\varepsilon_r}a} = \frac{3x10^8\ m/s}{2\sqrt{2.26}}\frac{1}{9.75in}\left(\frac{1in}{0.0254m}\right) = 403MHz$$

$$F = \sqrt{1-\left(\frac{fc}{f}\right)^2} = \sqrt{1-\left(\frac{403}{600}\right)^2} = 0.741$$

fc f=600MHz

403 MHz

TE_{10}

Now,

$$u_U = \frac{c}{\sqrt{\varepsilon_r}} = \frac{3x10^8}{\sqrt{2.26}} = 2x10^8\frac{m}{s}$$

$$u_u = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}} = \left(\frac{1}{\sqrt{\mu_0\varepsilon_0}}\right)\frac{1}{\sqrt{\mu_r\varepsilon_r}} = c\,\frac{1}{\sqrt{\mu_r\varepsilon_r}}$$

For $\mu_r=1$, $\varepsilon_r\neq1$

$$\boxed{u_u = \frac{c}{\sqrt{\varepsilon_r}}}$$

$C = 3\times10^8\ m/s$

$$u_P = \frac{u_U}{F} = 2.7x10^8\frac{m}{s}$$

$$u_G = u_U F = 1.48x10^8\frac{m}{s}$$

- Physical Transmission
  - Transmission Media
    - Wire (guided)
      - Coaxial cable
      - Twisted Pair
        - UTP
        - STP
      - Fiber Optic
    - Wireless (unguided)
      - Radio waves
      - Microwave
      - Infrared
      - Satellite
      - Laser
  - Signaling Techniques
    - Baseband Transmission
    - Broadband Transmission

Transmission media:

Wired (Guided) media
A signal travelling along **guided media** is directed and **contained by the physical limits** of the medium

Wireless (Unguided) media
Unguided media transport signals **without** using a **physical conductor.**

Components of a computer network:
1. Computer with NIC (PCs, laptops, handhelds); 2. routers & switches (IP router, Ethernet switch)
3. Links" Transmission media" (wired, wireless); 4. protocols (IP,TCP,CSMA/CD,CSMA/CA)
5. applications (network services) i.e. Network Operating System (NOS);
6. humans and service agents

Factors to be considered while choosing transmission media
1) Transmission rate
2) Cost and Ease of Installation
3) Resistance of Environmental condition
4) Distance.

Twisted Pair

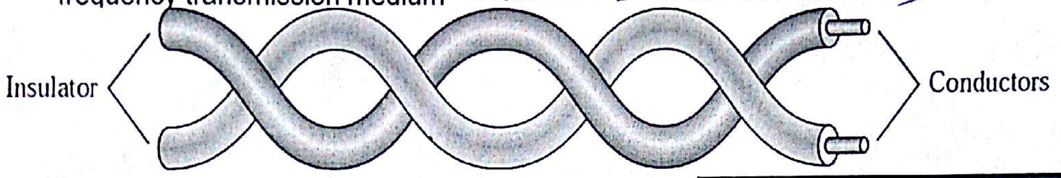
- Wires Consists of two insulated copper wires, each with its own plastic insulation, twisted together arranged in a regular spiral pattern to minimize the electromagnetic interference between adjacent pairs
- Often used at over distances to carry voice as well as data communications
- Low

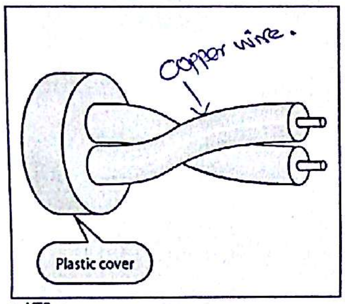
STP (shielded twisted pair)

the pair is wrapped with metallic foil or braid to insulate the pair from electromagnetic interference

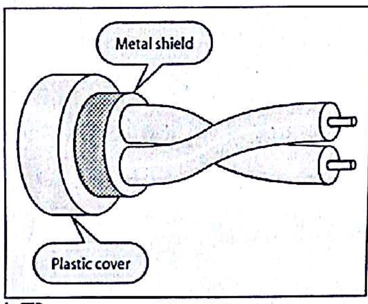
UTP (unshielded twisted pair) ⇒ no shield provided only two twisted copper wire with there own colour plastic insulator.

each wire is insulated with plastic wrap, but the pair is encased in an outer covering frequency transmission medium (affected by noise interference)

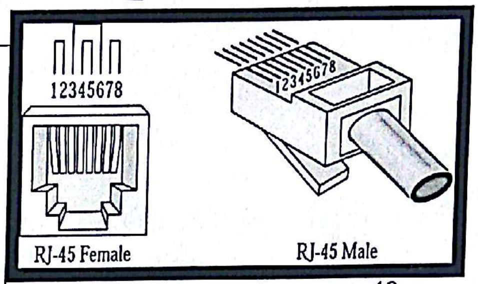




a. UTP



b. STP



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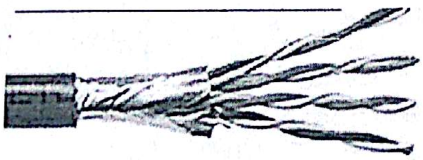
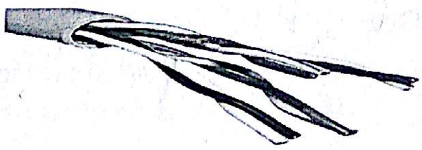




The characteristics of UTP are:
- Cheap
- Ease of use
- flexible
- easy to install.

The characteristics of STP:
- less susceptible to noise
- materials and manufacturing requirements make STP more expensive than UTP

Parameter	UTP	STP
1) Data rate	10-1000mbps	& 150Mbps
2) cable length	100 meter max	& 500 meter max
3) Electrical Interferene	most interference and cross talk occurs	& Less Interferene...
4) Installation	Easy to install	& very very easy to install.
5) cost	Low	→ Little costly.

Advantages
- Inexpensive and available
- Flexible and light weight
- Easy to work with and install

Disadvantages
- Sensitivity to interference and noise
- Relatively low bandwidth (3000Hz)

two conductors are parallel to each other (so coaxial means at same axis.

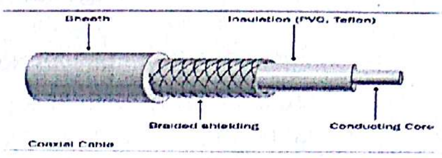
Coaxial Cable (or Coax)

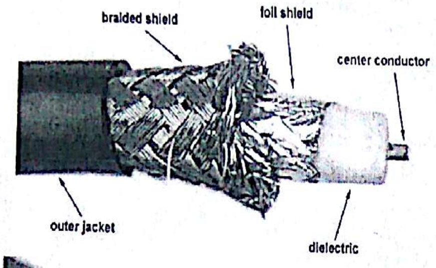
Carries signals of higher frequency ranges than twisted pair cable.

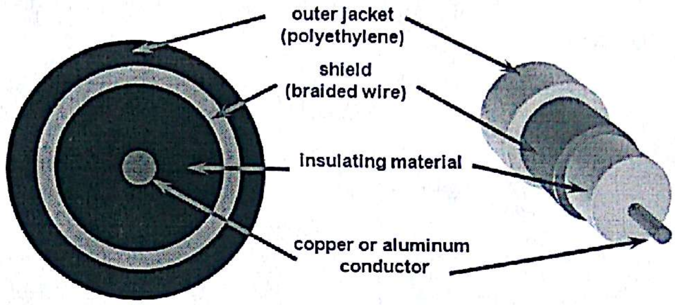
Has an inner conductor enclosed in an insulator, which is in turn encased in an outer conductor of metal braided mesh.

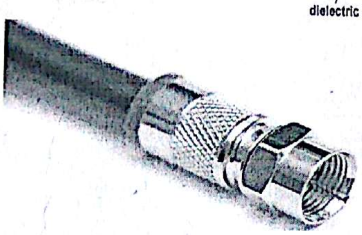
Both conductors share a common center axial, hence the term "co-axial"

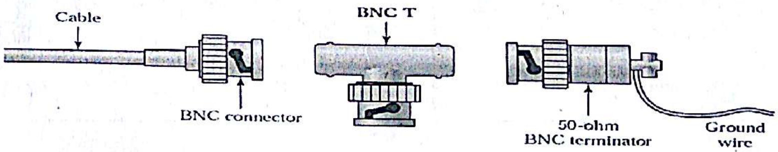
Used for cable television, LANs, telephony











Overview:

- ➢ Necessary to avoid bouncing of the signal off the cable's ends – accomplished by using connectors or special terminators with the same impedance as the cable used
- ➢ Two common types – F-type and BNC

F-Connector:

- ➢ Suitable for cables with a solid metal core – becomes the pin in the center of the connector (used in RG-6)
- ➢ Mounted on a cable by crimping or compression – both male and female connectors are threaded and screw together like a nut and bolt assembly

Bayonet Neill-Concelman (BNC) Connector:

- ➢ Mounted on a cable by crimping, compression, or twisting – connects to another BNC connector via a turning and locking mechanism ("*bayonet coupling*")
- ➢ Male connector uses its own conducting pin – not the core of the cable like F-type ones
- ➢ Commonly used with RG-59 cable

Advantages

- Higher bandwidth
  - 400 to 600Mhz
- Much less susceptible to interference than twisted pair
- It will not cause a toxic gas when its burned. That's why they use it in some buildings.

Disadvantages

- High attenuation rate makes it **expensive over long distance**
- It's not used anymore due to high cost and other technical factors.

Two types

① Baseband
- transmission of Digital Signal
- used for LANs
- Very high speed
- Drawback → needs amplification after every 1000 feet.

② Broadband
- transmission of Analog signal.
- Cable television.
- simultaneous signal using diff. freq.
- Cover large area.

Fiber Optic Cable

➢Relatively new transmission medium used by telephone companies in place of long-distance trunk lines

➢Fiber Optic works on the properties of light. When light ray hits at critical angle it tends to refracts at 90 degree. This property has been used in fiber optic. The core of fiber optic cable is made of high quality glass or plastic. From one end of it light is emitted, it travels through it and at the other end light detector detects light stream and converts it to electric data form.

➢Fiber Optic provides the highest mode of speed.

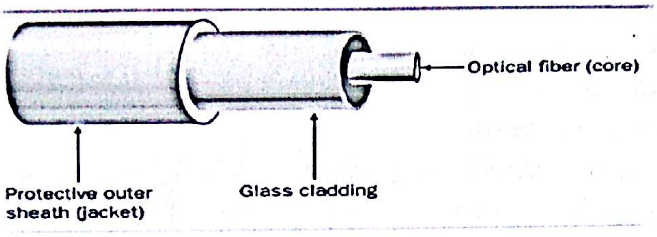
➢Also used by private companies in implementing local data communications networks

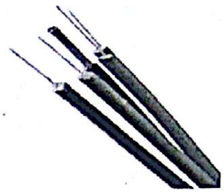
➢Require a light source with injection laser diode (ILD) or light-emitting diodes (LED)

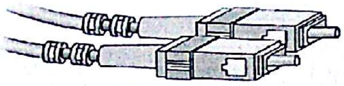
➢Optical fiber is made of glass or plastic and transmits signals in the form of **light.**

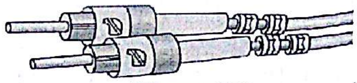
➢The cable consists of a strand of glass (***core)*** surrounded by a glass tube (***cladding***).

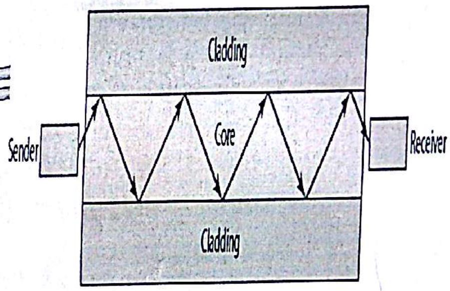
➢Its surrounded by a plastic isolation layer for protection .

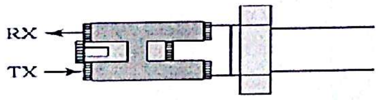


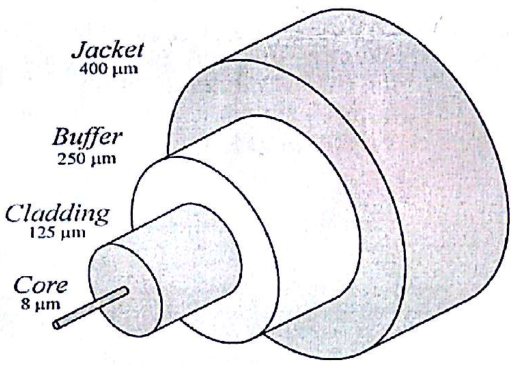



SC connector


ST connector







Layered Structure:

Inner core – glass or plastic fibers at the center tha carry laser pulses or an LED light used for data transmission

Cladding – a layer of plastic or glass around the fibers that reflects the light back to the core

Plastic buffer – an opaque layer that protects the cladding and the core and absorbs any light that escapes

Strands of Kevlar – a polymeric fiber that surrounds the plastic buffer and prevents stretching and damaging

Plastic sheath – providing the overall cable protection

Single-Mode Fiber (SMF):

- Uses narrow core – less than 10 microns in diameter
- Propagates light without reflections – causes no dispersion and no significant energy loss
- Provides the highest bandwidth of all media and allows the longest distance without requiring repeaters
- Allows 60 km (37 mi) long segments at 10 Gbps
- Good for connecting large networks together
- The most expensive networking medium
- Suitable for WANs

Multi-Mode Fiber (MMF):

- Uses wider core – from 50 to 115 microns in diameter, with 62.5 microns being most common size
- Multiple laser or LED pulses are sent over the fiber at different angles
- Allows 300 m (910 ft) long segments at 10 Gbps, 550 m (1670 ft) at 1 Gbps, and 2 km (6060 ft) at 100 Mbps
- Used for connecting network devices to a backbone
- Suitable for both LANs and WANs

Characteristics:

- Highest throughput – no resistance allows achieving 100 Gbps per channel and reduces errors
- Highest cost – most expensive medium, NICs, and hubs, plus the highest installation costs – not practical for small networks
- Best EMI and noise immunity – no current used
- *Size and scalability* – segment length is limited by degradation of the signal ("*optical loss*"), with typical values from 150 to 40,000 meters (455 to 121,200 ft)
- Imperfections at connection points affect segment length

Connectors:

- Ten different types exist, with four being being most common – *Straight Tip (ST), Standard Connector (SC), Local Connector (LC), and Mechanical Transfer Registered Jack (MT-RJ)*

Fiber Optic Types - Digital data is converted to light
Single mode - one light source flashes a light down the cable.
can carries single ray of light
Multimode - supports many simultaneous light transmissions.
capable of carrying multiple beams of light.

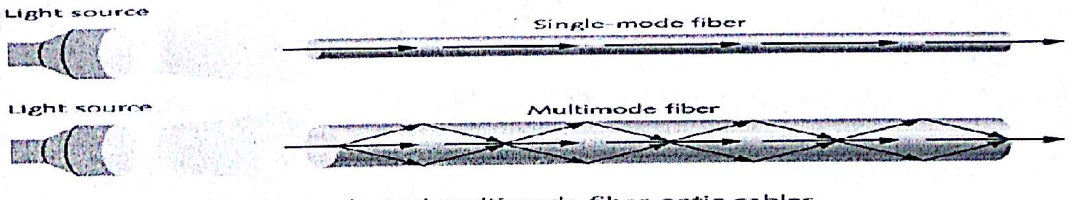
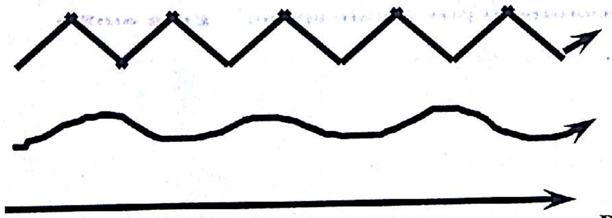


Figure 8-13 Single-mode and multimode fiber-optic cables



fiber optic multimode step-index

fiber optic multimode graded-index

fiber optic single mode

Advantages
1. greater capacity (bandwidth of up to 2 Gbps)
2. Speed (100 - 500 mbps)
3. smaller size and lighter weight
4. lower attenuation
5. immunity to environmental interference
6. highly secure

Disadvantages
1. expensive over short distance
2. requires highly skilled installers
3. adding additional nodes is difficult

Type of Cable depends on:
1. Transmission speed.
2. Maximum cable length.
3. Shielded requirements.
4. Price