Unit 2
Chapter 3
Metallic Cable Transmission Media

1. In which layer of the OSI protocol hierarchy is the transmission medium found. What are the two general categories of transmission media?

Transmission medium is the path between a transmitter and a receiver in a communications system. It is included in the lowest layer of the OSI protocol hierarchy - the physical layer.

Transmission media can be generally categorized as either unguided or guided. Guided transmission media are those media with some form of conductor that provides a conduit in which electromagnetic signals are contained. Examples of guided transmission media are copper wire and optical fiber. Unguided transmission media are wireless systems (i.e., those without a physical conductor). Examples of unguided transmission media are air (earth's atmosphere) and free space (a vacuum).

2. What do you mean by a transmission line? Describe balanced and unbalanced transmission lines.

A transmission line is a metallic conductor system used to transfer electrical energy from one point to another using electrical current flow. More specifically, a transmission line is two or more electrical conductors separated by a nonconductive insulator (dielectric), such as a pair of wires or a system of wire pairs. It can be used to propagate dc or low-frequency ac (such as 60-cycle electrical power and audio signals), or they can also be used to propagate very high frequencies (such as microwave radio-frequency signals).

Balanced transmission line: With two-wire balanced lines, both conductors carry current; however, one conductor carries the signal and the other conductor is the return path. This type of transmission is called differential or balanced signal transmission. Figure below shows a balanced transmission line system. Both conductors in a balanced line carry signal currents. The two currents are equal in magnitude with respect to electrical ground but travel in opposite directions. Currents that flow in opposite directions in a balanced wire pair are called metallic circuit currents. Currents that flow in the same direction are called longitudinal currents. A balanced wire pair has the advantage that most noise interference (sometimes called common-mode interference) is induced equally in both wires, producing longitudinal currents that cancel in the load. The cancellation of common mode signals is called common-mode rejection (CMRR). Common-mode rejection ratios of 40 dB to 70 dB are common in balanced transmission lines. Any pair of wires can operate in the balanced mode, provided that neither wire is at ground potential.

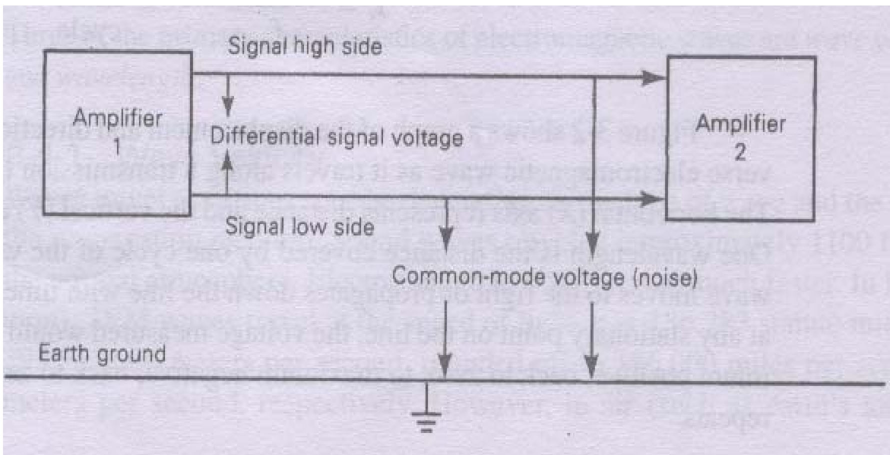

Fig: Differential, or balanced, transmission system

Unbalanced Transmission Lines: With an unbalanced transmission line, one wire is at ground potential, whereas the other wire is at signal potential. This type of transmission line is called single-ended or unbalanced signal transmission. With unbalanced signal transmission, the ground wire may also be the reference for other signal-carrying wires. If this is the case, the ground wire must go wherever any of the signal wires go. Sometimes this creates a problem because a length of wire has resistance, inductance, and capacitance, and therefore a small potential difference may exist between any two points on the ground wire. Consequently, the ground wire is not a perfect reference point and is capable of having noise induced into it.

Unbalanced transmission lines have the advantage of requiring only one wire for each signal and only one ground line is required no matter how many signals are grouped into one conductor. The primary disadvantage of unbalanced transmission lines is reduced immunity to common-mode signals, such as noise and other interference.

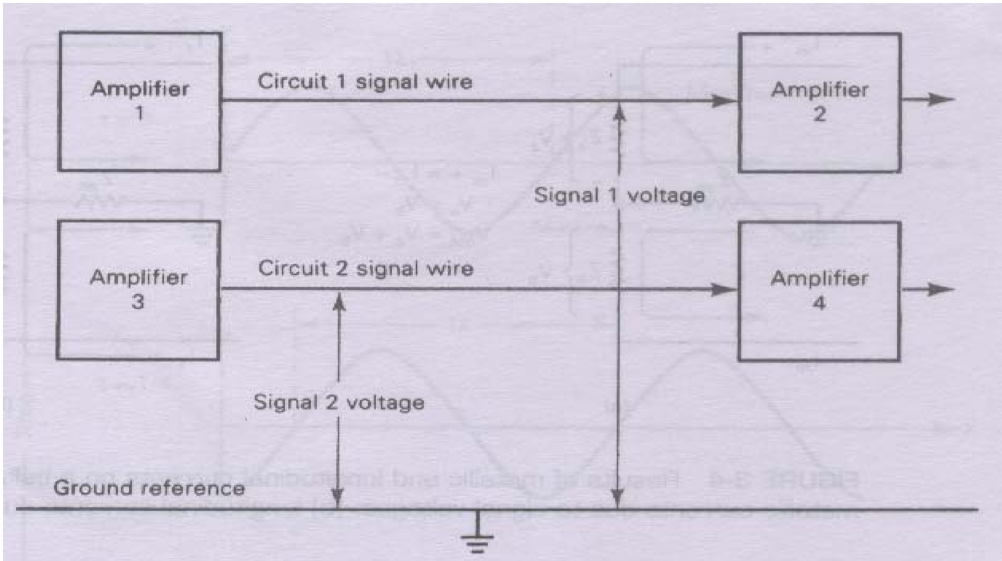

Fig: single ended, or unbalanced, transmission system

Figure above shows two unbalanced transmission systems. The potential difference on each signal wire is measured from that wire to a common ground reference. Balanced transmission lines can be connected to unbalanced lines and vice versa with special transformers called baluns.

3. Describe various metallic transmission line types.

Parallel Conductor Transmission Lines: Parallel-wire transmission lines are comprised of two or more metallic conductors (usually copper) separated by a nonconductive insulating material called a dielectric. Common dielectric materials include air, rubber, polyethylene, paper, mica, glass, and Teflon. The most common parallel-conductor transmission lines are open wire, twin lead, and twisted pair including unshielded twisted pair (UTP) and shielded twisted pair (STP).

Open-Wire Transmission Lines: Open-wire transmission lines are two-wire parallel conductors (see Figure below). Open-wire transmission lines consist simply of two parallel wires, closely spaced and separated by air. Nonconductive spacers are placed at periodic intervals not only for support but also to keep the distance between the conductors constant. The distance between the two conductors is generally between 2 inches and 6 inches. The dielectric is simply the air between and around the two conductors in which the TEM wave propagates. The only real advantage of this type of transmission line is its simple construction. Because there is no shielding, radiation losses are high, and the cable is susceptible to picking up signals through mutual induction, which produces crosstalk. Crosstalk occurs when a signal on one cable interferes with a signal on an adjacent cable. The primary use of open-wire transmission lines is in standard voice-grade telephone applications.

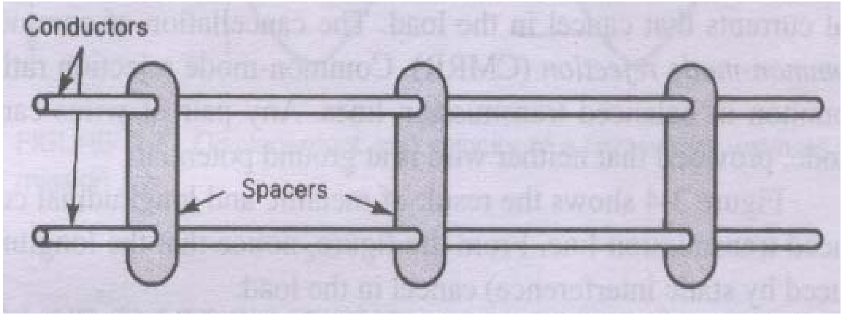

Fig: Open-wire transmission line

Twin lead: Twin lead is another form of two-wire parallel-conductor transmission line and is shown in Figure below. Twin-lead is essentially the same as open-wire transmission line except that the spacers between the two conductors are replaced with a continuous solid dielectric that ensures uniform spacing along the entire cable. Twin- lead transmission line is the flat, brown cable typically used to connect televisions to rooftop antennas. Common dielectric materials used with twin-lead cable are Teflon and polyethylene.

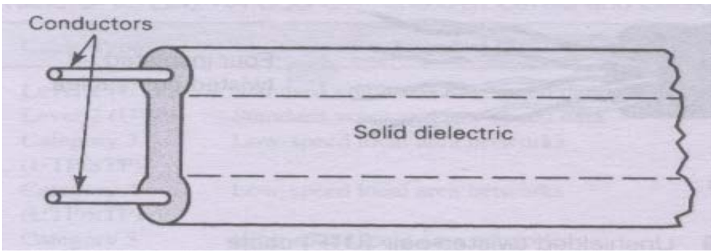

Fig: Twin lead two-wire transmission line

Twisted-pair transmission lines: A twisted-pair (TP) transmission line (shown in Figure below) is formed by twisting two insulated conductors around each other. Twisted pairs are often stranded in units, and the units are then cabled into **cores** containing up to 3000 pairs of wire. The cores are then covered with various types of sheaths forming cables. Neighboring pairs are sometimes twisted with different pitches (twist length) to reduce the effects of electromagnetic interference (EMI) and radio-frequency interference (RFI) from external sources (usually man-made), such as fluorescent lights, power cables, motors, relays, and transformers. Twisting the wires also reduces crosstalk between cable pairs.

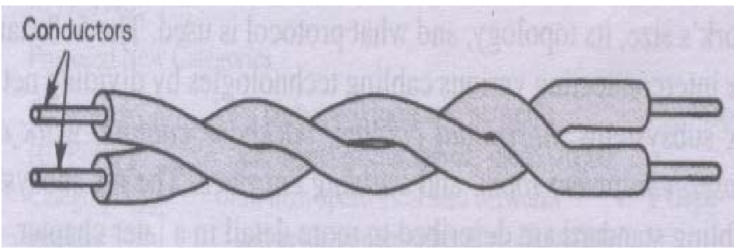

Fig: Twisted-pair two-wire transmission line

The size of twisted-pair wire varies from 16 gauge (16 AWG [American Wire Gauge]) to 26 gauge. The higher the wire gauge, the smaller the diameter and the higher the resistance. Twisted-pair cable is used for both analog and digital signals and is the most commonly used transmission medium for telephone networks and building cabling systems. Twisted-pair transmission lines are also the transmission medium of choice for most local area networks because twisted-pair cable is simple to install and relatively inexpensive when compared to coaxial and optical fiber cables.

There are two basic types of twisted-pair transmission lines specified by the EIA/TIA 568 Commercial Building Telecommunications Cabling Standard for local area networks: 100-ohm unshielded twisted pair (UTP) and 150-ohm shielded twisted pair(STP). A typical network utilizes a variety of cabling technologies, depending on the network's size, its topology, and what protocol is used. The 568 standard provides guidelines for interconnecting various cabling technologies by dividing network-wiring systems into six subsystems: horizontal cabling, backbone cabling, work area, telecommunications closet, equipment room, and building entrance.

Unshielded twisted-pair: An unshielded twisted-pair (UTP) cable consists of two copper wires where each wire is separately encapsulated in PVC (polyvinyl chloride) insulation (see Figure below). Because a wire can act like an antenna, the wires are twisted two or more times at varying lengths to reduce crosstalk and interference. By carefully controlling the number of twists per foot and the manner in which multiple pairs are twisted around each other, manufacturers can improve the bandwidth (i.e., bit rate) of the cable pair significantly. The minimum number of twists for UTP cable is two per foot.

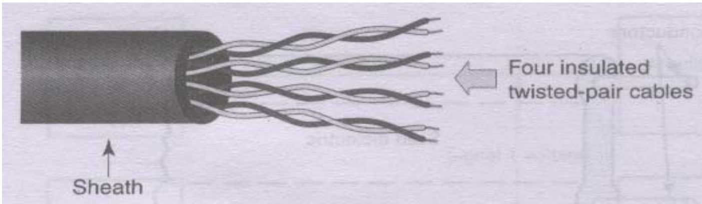

Fig: Unshielded twisted-pair(UTP) cable

To meet the operational requirements for local area networks, the EIA/TIA 568 standard classifies UTP twisted-pair cables into levels and categories that certify maximum data rates and recommended transmission distances for both UTP and STP cables (see Table below). Standard UTP cable for local area networks is comprised of four pairs of 22-gauge or 24-gauge copper wire where each pair of wires is twisted around each other.

There are six primary unshielded twisted-pair cables classified by the EIA/TIA 568 standard: level 1, level 2, category 3, category 4, category 5, enhanced category 5, and category 6.

Table: EIA/TIA 568 UTP and STP Levels and Categories

Cable Type	Intended Use	Data Rate	Distance
Level I (UTP)	Standard voice and low-speed data	2400 bps	18,000 feet
Level 2 (UTP)	Standard voice and low-speed data	4 Mbps	18,000 feet
Category 3 (UTP/STP)	Low-speed local area networks	16Mbps and all level 2 applications	100 meters
Category 4 (UTP/STP)	Low-speed local area networks	20 Mbps and all category 100 meters 3 applications	100 meters
Category 5 (UTP/STP)	High-speed local area networks	100Mbps	100 meters
Enhanced category 5	High-speed local area networks and asynchronous transfer mode (ATM)	350 Mbps	100 meters or more

(UTP/STP)			
Proposed New Categories			
Category 6 (UTP/STP)	Very high-speed local area networks and asynchronous transfer mode (ATM)	550 Mbps	100 meters or more
Category 7 shielded screen twisted pair(STP)	Ultra -high-speed local area networks and asynchronous transfer mode (ATM)	1Gbps	100 meters or more
Foil twisted pair (STP)	Ultra -high-speed local area networks and asynchronous transfer mode (ATM); designed to minimize EMI susceptibility and maximize EMI immunity	>1Gbps	?
Shielded foil twisted pair (STP)	Ultra -high-speed local area networks and asynchronous transfer mode (ATM); designed to minimize EMI susceptibility and maximize EMI immunity	>1Gbps	?

Shielded twisted pair: Shielded twisted-pair (STP) cable is a parallel two-wire transmission line consisting of two copper conductors separated by a solid dielectric material. The wires and dielectric are enclosed in a conductive-metal sleeve called a foil. If the sleeve is woven into a mesh, it is called a braid. The sleeve is connected to ground and acts as a shield, preventing signals from radiating beyond their boundaries (see Figure below). The sleeve also keeps electromagnetic noise and radio interference produced in external sources from reaching the signal conductors. STP cable is thicker and less flexible than UTP cable, making it more difficult and expensive to install. In addition, STP cable requires an additional grounding connector and is more expensive to manufacture. However, STP cable offers greater security and greater immunity to interference.

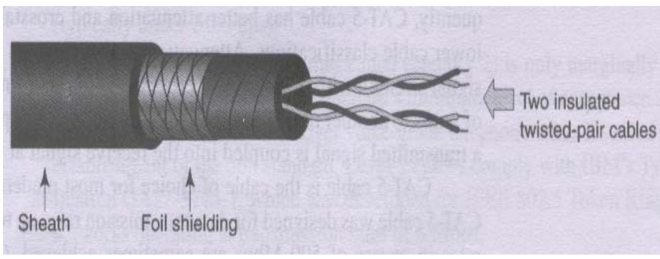

Fig: Shielded twisted-pair (STP) cable

There are seven primary STP cables classified by the EIA/TIA 568 standard: category 3, category 4, category 5, enhanced category 5, category 7, foil twisted pair and shielded-foil twisted pair. Categories 3 through 5e STP have essentially the same parameters as their UTP counterparts, except the added shielding provides greater immunity to interference.

4. Define Characteristic impedance, velocity factor, and dielectric constant and tell how they affect the performance of a transmission line.

Characteristic Impedance: Characteristic impedance (sometimes called *surge impedance)* is defined simply as the ratio of the source voltage ***(Eo)*** to the line current (Io) and is given by,

$$Z_o = \frac{E_o}{I_o}$$

For maximum power transfer from the source to the load, a transmission line must be terminated in a purely resistive load equal to the *characteristic impedance* of the transmission line. The characteristic impedance of a transmission line is a complex quantity that is expressed in ohms, is ideally independent of line length, and cannot be directly measured.

Velocity factor: *Velocity factor* (sometimes called *velocity constant)* is defined simply as the ratio of the actual velocity of propagation of an electromagnetic wave through a given medium to the velocity of propagation through a vacuum (free space) and is given by,

$$V_f = \frac{V_p}{c}$$

The velocity at which an electromagnetic wave travels through a transmission line depends on the dielectric constant of the insulating material separating the two conductors. The velocity factory is closely approximated with the formula

$$V_p = \frac{1}{\sqrt{\varepsilon_r}}$$

where ε_r is the dielectric constant of a given material (the permittivity of the material relative to the permittivity of a vacuum-the ratio $\varepsilon / \varepsilon_0$, where ε is the permittivity of the dielectric and ε_o is the permittivity of air).

Dielectric constant: *Dielectric constant* is simply the relative permittivity of a material. The relative dielectric constant of air is 1.0006. However, the dielectric constant of materials commonly used in transmission lines ranges from 1.4872 to 7.5, giving velocity factors from 0.3651 to 0.8200.

5. List and describe the five types of transmission line losses.

For analysis purposes, metallic transmission lines are often considered to be totally loss- less. In reality, however, there are several ways in which signal power is lost in a transmission line. They include conductor loss, radiation loss, dielectric hearing loss, coupling loss, and corona. Cable manufacturers generally lump all cable losses together and specify them as attenuation loss in decibels per unit length (e.g., dB/m, dB/ft and so on).

Conductor Losses: Because electrical current flows through a metallic transmission Line and the Line has a finite resistance, there is an inherent and unavoidable power loss. This is sometimes called conductor loss or conductor heating loss and is simply an I^2R power loss.

Dielectric Heating Losses: A difference of potential between two conductors of a metallic transmission line causes dielectric heating. Heat is a form of energy and must be taken from the energy propagating down the line. For air dielectric transmission lines, the heating loss is negligible. However, for solid-core transmission lines, dielectric heating loss increases with frequency.

Radiation Losses: If the separation between conductors in a metallic transmission line is an appreciable fraction of a wavelength, the electrostatic and electromagnetic fields that surround the conductor cause the line to act as if it were an antenna and transfer energy to any nearby conductive material. The energy radiated is called **radiation loss** and depends on dielectric material, conductor spacing, and length of the transmission line. Radiation losses are reduced by properly shielding the cable. Therefore, shielded cables (such as STP and coaxial cable) have less radiation loss than unshielded cables (such as twin lead. open wire, and UTP). Radiation loss is also directly proportional to frequency.

Coupling Losses : Coupling loss occurs whenever a connection is made to or from a transmission line or when two sections of transmission line are connected together. Mechanical connections are discontinuities, which are locations where dissimilar materials meet. Discontinuities tend to heat up, radiate energy, and dissipate power.

Corona : Corona is a luminous discharge that occurs between the two conductors of a transmission line when the difference of potential between them exceeds the breakdown voltage of the dielectric insulator. Generally, when corona occurs, the transmission line is destroyed.