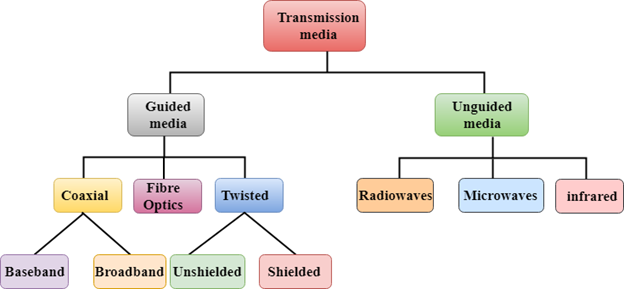
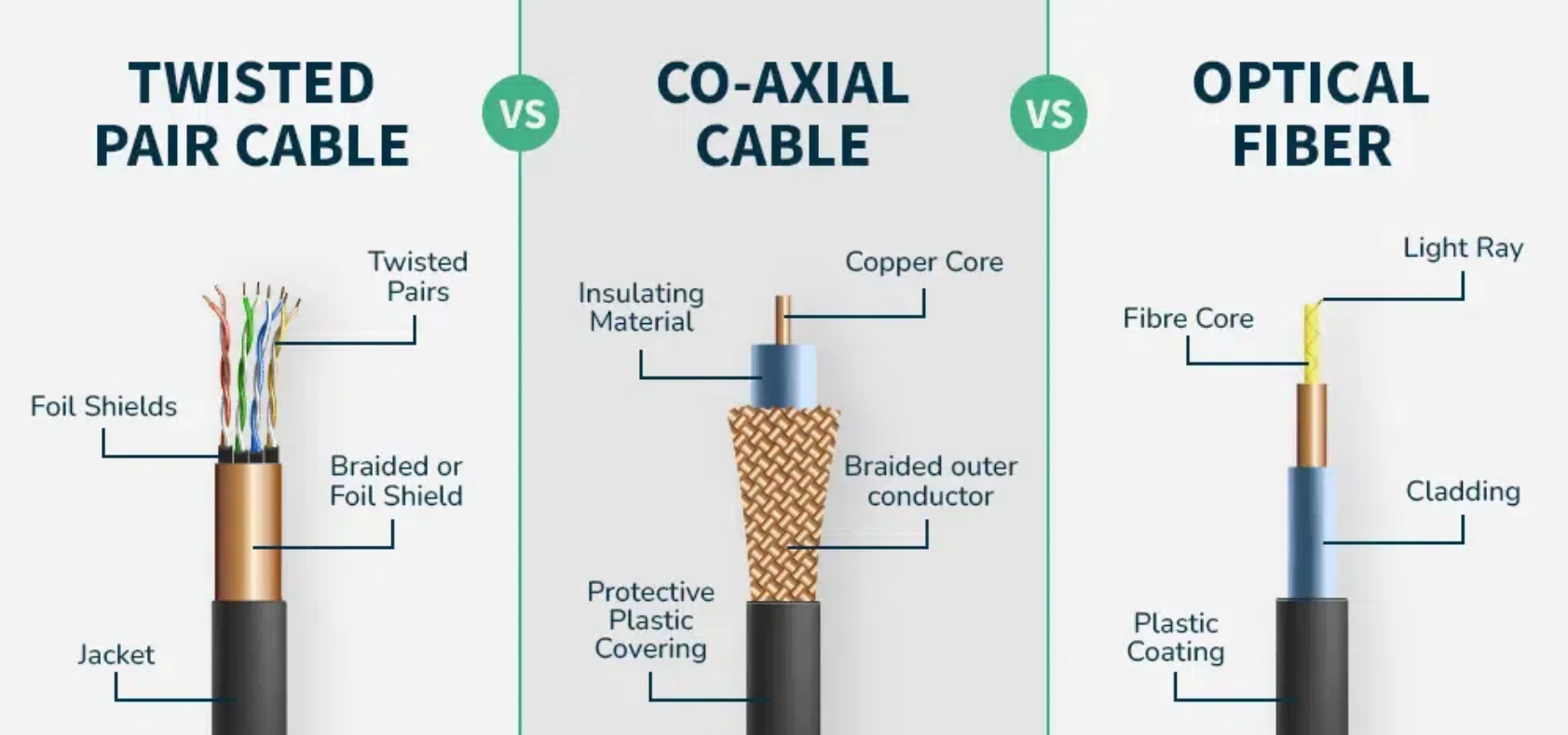
**UNIT – 2**

**Physical Layer: Concepts of Frequency, Spectrum, bandwidth. Wireless and Wired Transmission, Transmission media: twisted pairs, coaxial cable, fiber optics, Wireless transmission: Microwave, satellite communication etc.**





| **Basis** | **Wired Network** | **Wireless Network** |
| --- | --- | --- |
| **Definition** | A wired network employs physical cables (such as Ethernet cables) to connect devices like laptops, desktop PCs, printers, and servers to the Internet or a local network. | Wireless networks do not use physical cables for connectivity. Instead, they rely on electromagnetic waves (e.g., Wi-Fi) or infrared signals for data transmission. |
| **Transmission Speed** | Wired networks generally offer higher transmission speeds due to the use of direct connections, which minimizes data loss and interference during transmission. | Wireless networks typically have slower transmission speeds because data is transmitted through the air, making it susceptible to interference from other signals. |
| **Propagation Delay** | Wired networks have low propagation delays as signals travel quickly and with minimal interruptions through physical cables. | Wireless networks experience higher propagation delays due to signal attenuation, interference, and obstacles in the transmission path. |
| **Security & Reliability** | Wired networks are considered more secure and reliable as physical access to the network is required to intercept or manipulate data. | Wireless networks are generally less secure because data is broadcast over the air and can be intercepted, making them more vulnerable to hacking and interference. |
| **Installation Process** | Devices must be physically connected through wires, making the installation process time-consuming and dependent on cable management. | Wireless networks offer quick and easy installation as there is no need for physical cables; devices can connect wirelessly as long as they are within range. |
| **Cost of Cables and Equipment** | Wired networks are typically less expensive in terms of the cost of cables and the basic hardware required to set up the network. | Wireless networks may involve higher costs due to the need for more advanced wireless routers, access points, and network cards. |
| **Installation & Maintenance Cost** | Though the cables may be inexpensive, the overall installation and maintenance costs of a wired network are higher due to the complexity of laying cables and managing them. | Wireless networks have lower installation and maintenance costs because they don’t require extensive physical infrastructure, making setup simpler and more affordable. |
| **Networking Devices** | Wired networks utilize devices like hubs, switches, and network interface cards (NICs) to facilitate data transmission between connected devices. | Wireless networks depend on devices such as wireless routers, access points, and antennas to connect and communicate between different wireless-enabled devices. |
| **Mobility** | Wired networks limit mobility since devices must stay connected to a fixed location through physical cables, restricting movement. | Wireless networks provide excellent mobility, allowing devices to stay connected as long as they are within the signal range of the network. |
| **Interference** | Wired networks face minimal interference from external factors as data travels through physical cables, providing a stable connection. | Wireless networks are prone to interference from other wireless devices, walls, and even weather conditions, which can affect network performance and stability. |

| **Basis** | **Twisted Pair Cable** | **Coaxial Cable** | **Fiber Optic Cable** |
| --- | --- | --- | --- |
| **Definition** | A type of cable made of two insulated copper wires twisted together, often used in telephone and Ethernet networks. | A single copper wire surrounded by a layer of insulation, a metallic shield, and an outer cover, commonly used for cable TV and internet. | A cable that transmits data as light signals through glass or plastic fibers, commonly used for high-speed internet and long-distance communication. |
| **Transmission Speed** | Twisted pair cables support moderate data transmission speeds, typically up to 1 Gbps (for Cat 5e/6 cables). | Coaxial cables offer higher speeds than twisted pair, supporting up to 10 Gbps in some setups. | Fiber optic cables provide the fastest data transmission speeds, easily supporting speeds of 100 Gbps or more. |
| **Bandwidth** | Limited bandwidth, suitable for short distances and basic applications like telephone lines and local networks. | Higher bandwidth than twisted pair, used for cable TV and internet, capable of handling medium to high data traffic. | Very high bandwidth, capable of transmitting vast amounts of data over long distances without signal degradation, ideal for high-speed internet and large-scale data transmission. |
| **Interference Resistance** | Twisted pair cables are prone to electromagnetic interference (EMI) and crosstalk unless shielded (STP), but Unshielded Twisted Pair (UTP) is more commonly used and less resistant. | Coaxial cables are more resistant to interference due to their metallic shielding, making them more stable for signal transmission over medium distances. | Fiber optic cables are immune to electromagnetic interference because they transmit light instead of electrical signals, ensuring extremely stable and interference-free communication. |
| **Distance and Signal Loss** | Twisted pair cables experience significant signal loss over long distances, typically requiring signal boosters for lengths beyond 100 meters. | Coaxial cables can transmit data over longer distances than twisted pair but still face some signal degradation over extended lengths. | Fiber optic cables have minimal signal loss, allowing data to travel over very long distances (up to hundreds of kilometers) without the need for repeaters. |
| **Security** | Twisted pair cables are relatively easy to tap, making them less secure for sensitive data transmission unless properly shielded. | Coaxial cables are more secure than twisted pair cables but can still be tapped if access to the physical cable is gained. | Fiber optic cables are extremely secure and difficult to tap without detection, making them ideal for secure communications and sensitive data transmission. |
| **Cost** | Twisted pair cables are the most affordable type, commonly used for home and office networks, making them cost-effective for short-distance applications. | Coaxial cables are moderately priced, more expensive than twisted pair but less costly than fiber optics, and commonly used in medium-scale network setups. | Fiber optic cables are the most expensive due to their advanced technology and higher installation costs, but they offer better long-term value for high-speed and large-scale network needs. |
| **Installation and Maintenance** | Twisted pair cables are easy to install and maintain, requiring minimal effort, though UTP may need protection against interference. | Coaxial cables are slightly harder to install due to their thickness but still relatively easy to manage, requiring moderate maintenance. | Fiber optic cables require professional installation and more complex maintenance due to their delicate nature and the need for specialized equipment for repairs and adjustments. |
| **Durability** | Twisted pair cables are less durable and more prone to wear and tear, especially when exposed to harsh environments or physical stress. | Coaxial cables are more durable than twisted pair cables due to their sturdy build, including a protective metal shield and thicker outer covering. | Fiber optic cables are durable for transmitting data, but the physical cable itself is delicate and can break if not handled carefully, especially during installation and maintenance. |
| **Usage** | Commonly used for short-distance applications like local area networks (LANs), telephone systems, and home internet connections. | Typically used for TV broadcasting, internet connections in homes, and medium-distance network applications. | Primarily used for long-distance, high-speed internet connections, telecommunications, and large-scale data transmission in businesses and service providers like ISPs. |

**What is Transmission media?**

* Transmission media is a **communication channel** that carries the information from the sender to the receiver. Data is transmitted through the electromagnetic signals.
* The main functionality of the transmission media is to carry the information in the form of **bits**.
* It is a **physical path** between transmitter and receiver in data communication.
* In a copper-based network, the bits travel in the form of electrical signals.
* In a fiber-based network, the bits travel in the form of light pulses.
* The characteristics and quality of data transmission are determined by the characteristics of medium and signal.
* Transmission media is of **two types** - wired media and wireless media. In wired media, **medium characteristics** are more important whereas, in wireless media, **signal characteristics** are more important.
* The transmission media is available in the lowest layer of the OSI reference model, i.e., **Physical layer**. In **OSI** (Open System Interconnection) phase, transmission media supports the Layer 1. Therefore, it is considered to be as a Layer 1 component.

1. **Wired (Guided) Media**: This type of media uses cables or physical connections to transmit data. The three main types of wired media include:

* **Twisted Pair Cable**: Consists of two copper wires twisted together. It is commonly used for telephone and Ethernet networks.
* **Coaxial Cable**: A single copper conductor surrounded by insulation and shielding, often used for cable TV and internet.
* **Fiber Optic Cable**: Uses light to transmit data through thin glass fibers, providing high-speed transmission over long distances with minimal signal loss.

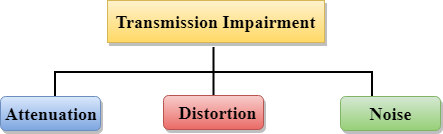
**2. Wireless (Unguided) Media**: Wireless media use electromagnetic waves to transmit data without physical cables. Common types include:

* **Radio Waves**: Used in Wi-Fi, Bluetooth, and cellular networks for short and medium-range communication.
* **Microwaves**: Used for long-distance communication, such as satellite and point-to-point connections.
* **Infrared**: Used in short-range communication, such as TV remotes and some wireless peripherals.

Some factors need to be considered for designing the transmission media:

* **Bandwidth:** All the factors are remaining constant, the greater the bandwidth of a medium, the higher the data transmission rate of a signal.
* **Transmission impairment:** When the received signal is not identical to the transmitted one due to the transmission impairment. The quality of the signals will get destroyed due to transmission impairment.
* **Interference:** An interference is defined as the process of disrupting a signal when it travels over a communication medium on the addition of some unwanted signal.

**Causes Of Transmission Impairment:**



* **Attenuation :-** Attenuation means the **loss of energy**, i.e., the strength of the signal decreases with increasing the distance which causes the loss of energy.
* **Distortion :-** Distortion occurs when there is a change in the shape or form of the signal. This type of distortion is examined from different signals having different frequencies. Each frequency component has its own propagation speed, so they reach at a different time which leads to the delay distortion.
* **Noise :-** When data is travelled over a transmission medium, some unwanted signal is added to it which creates the noise.

**Frequency, Bandwidth and Spectrum:**

**What is Frequency?**

The term ***"frequency"*** defines the number of oscillations that happen in a data transmission per second. In terms of networking, the data is transmitted in the form of signals, which are composed of waves. The number of oscillations per second specifies the signal frequency.

It is commonly measured in ***Hertz (Hz)***.

Frequency is also significant in wireless communication, where a signal's frequency is mathematically connected to its wavelength.

**f = (1 / T) Hz**

Here, ***f*** is the **frequency** of the signal wave,

and ***T*** is the ***time*** of the oscillation in seconds.

**What is Bandwidth?**

Bandwidth refers to the maximum amount of data that can be transmitted over a

network or communication channel in a given amount of time. It is typically measured

in bits per second (bps) or its multiples (Kbps, Mbps, Gbps). The greater the

bandwidth, the more data can be transferred, improving the performance of

communication systems.

**Key Points about Bandwidth:**

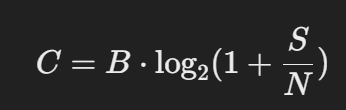
* **Data Rate**: It represents how fast data is transferred.
* **Channel Capacity**: The theoretical maximum data rate supported by a network.
* **Units**: Often expressed in Hertz (Hz) when referring to analog communication or bps for digital.

**Shannon Capacity Formula**

Claude Shannon, in his famous work on information theory, derived a formula to

calculate the maximum data transmission rate (capacity) of a communication channel.

The **Shannon Capacity** formula is:



Where:

* **C** = Maximum channel capacity in bits per second (bps)
* **B** = Bandwidth of the channel in Hertz (Hz)
* **S** = Signal power (strength of the transmitted signal)
* **N** = Noise power (background noise in the channel)
* **S/N** = Signal-to-noise ratio (SNR)

**Explanation of the Shannon Capacity Formula:**

1. **Bandwidth (B)**:This is the range of frequencies available for transmitting the signal, usually measured in Hertz. The wider the bandwidth, the higher the potential data rate.
2. **Signal Power (S)**:The strength of the signal being transmitted. Higher signal power leads to clearer communication, allowing for better data transmission.
3. **Noise Power (N)**:Noise is the unwanted interference that disrupts the signal. The higher the noise power, the harder it is to transmit data accurately.
4. **Signal-to-Noise Ratio (S/N)**:This ratio indicates how much stronger the signal is compared to the background noise. A higher S/N ratio means that the signal is clearer and less affected by noise, allowing for higher transmission rates.
5. **Logarithmic Relationship**:The use of the logarithmic function (log₂) means that increases in the signal-to-noise ratio (S/N) result in diminishing returns for channel capacity. This reflects the real-world limitations of improving data rates by just increasing power.

**Key Insights:**

* **Channel Capacity Increases with Bandwidth**: As the bandwidth (B) increases, the overall channel capacity (C) increases, allowing more data to be transmitted.
* **Impact of Noise**: If the noise (N) increases, the signal-to-noise ratio (S/N) decreases, which reduces the channel capacity.
* **Diminishing Returns with S/N**: The logarithmic nature of the formula shows that increasing the signal-to-noise ratio has less effect on capacity as S/N gets higher. Beyond a certain point, improving S/N has only a marginal impact on capacity.

| **Basis of Comparison** | **Bandwidth** | **Throughput** | **Spectrum** |
| --- | --- | --- | --- |
| **Basic Definition** | Bandwidth refers to the **maximum capacity** of data that can be transmitted via a channel. | Throughput refers to the **actual amount** of data successfully transmitted through a channel. | Spectrum refers to the range of **frequencies** over which data can be transmitted. |
| **Measured in** | Measured in **bits per second (bps)** or multiples like Mbps, Gbps, etc. | Measured as the **average rate** of data transfer over time, in bits per second (bps). | Measured in **Hertz (Hz)**, indicating frequency ranges (e.g., radio, microwave, optical). |
| **Concerned With** | Refers to the **theoretical data capacity** of a communication channel. | Refers to the **real-world data flow** between two points or devices. | Concerns the **frequency band** used for communication, such as radio waves, microwaves, etc. |
| **Relevance to OSI Layer** | Primarily a **Physical layer** characteristic. | Can apply to **any OSI layer** where data transmission occurs. | Relates to the **Physical layer**, as it deals with the transmission medium. |
| **Dependence** | Bandwidth does **not depend** on latency. It is a fixed characteristic of the medium. | Throughput depends on **latency**, network conditions, and traffic. | The spectrum does not inherently depend on latency but can influence how signals are transmitted. |
| **Definition** | The **maximum potential** data transfer rate that a medium can support. | The **actual rate** at which data is transferred through a channel under real-world conditions. | The range of **electromagnetic frequencies** used for transmitting data. |
| **Effect of Obstructions** | Not affected by **physical obstructions** as it is a theoretical unit. | Can be **affected by interference, traffic, network devices**, and other factors. | The spectrum can be **interfered with** by overlapping frequencies or external signals. |
| **Real-World Example (Water Tap)** | Bandwidth is like the **speed** at which water can flow out of the tap. | Throughput is the **total amount** of water that comes out of the tap. | The spectrum is like the **pipe** size or range, defining how much water can flow through at once. |
| **Real-World Application** | **Fiber optic cables**, Wi-Fi networks, etc., have different bandwidth capacities. | The actual speed you get while downloading a file is throughput, which is **lower** than the maximum bandwidth. | Used in technologies like **radio**, Wi-Fi, and satellite communication to specify frequency bands. |
| **Affected by Latency** | Bandwidth is **independent** of latency and delays. | Throughput is directly affected by **latency**, congestion, and other delays. | Spectrum defines the communication range and quality but is not directly affected by latency. |

**Satellite Communication :**

**Satellite communication** is an electronic communication package placed in an orbit.

Its prime objective is to initiate or assist through space. It has made a major

contribution to the pattern of international communication. The satellite microwave is

basically a microwave relay station in space. It uses a geosynchronous satellite to

relay the radio signal transmitted from the ground station. For communication signals,

these satellites act as relay stations. From the earth station, the satellite accepts

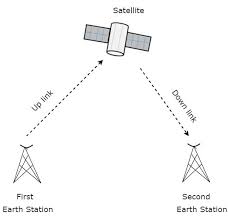
data/signals, amplifies them, and re-transmit them to another earth station. Data can

be transmitted to the other side of the earth using such a setup in only one step.

Most companies that use **satellite microwave** lease access to the satellites for an

exorbitant fee.

**Advantages :**

* Through satellite transmission, coverage over geographical area is quite large mainly for sparsely populated areas.
* High bandwidth and broadcast possibilities .
* Wireless and mobile communication applications can be easily established by satellite communication independent of location.
* It is used in wide variety of applications such as global mobile communication, private business networks, Long distance telephone transmission, weather forecasting, radio/TV signal broadcasting, gathering intelligence in military, navigation of ships and air crafts, connecting remote areas, television distribution etc.
* Security in satellite transmission is usually provided by the coding and decoding equipment.
* Service from one single provider is easy to obtain and uniform service is available.
* Over long distances, it can be cheaper.
* The laying and maintenance is easy and cheap in satellite communication therefore it is best alternative.
* During critical condition, each Earth Station may be removed relatively quickly from a location and reinstalled somewhere else.
* Ground station sites are easy to install and maintain.
* Point to multipoint communication is possible.
* Satellite cost is independent of the distance.
* Sending and receiving information is independent of distance.
* 24 hours communication can be possible.
* High capacity in comparison to terrestrial networks.
* High-quality components are used to work in robust conditions and links are also designed to work in extreme weather conditions.

**Disadvantages :**

* Design, development, investment, and insurance of satellite requires higher cost.
* There can be a congestion of frequencies.
* propagation issues and interference may arise.
* Launching satellites into orbit is an expensive process.
* To reach the satellite from Earth, time can vary between 270 milliseconds and return again to 320 milliseconds. This propagation delay can cause an echo over telephone connections
* Satellites are not easy to repair and maintain.
* Some circumstances like weather or sunspots affect the satellite’s signal and can cause interference and make proper operation of the satellite very difficult.
* It requires to be monitored and controlled on regular periods so that it remains in the orbit, once it has been launched.
* Propagation delay of satellite system is more than that of conventional terrestrial system.
* Transmitter and receiver used in satellite communication requires high power and large diameter antennas.
* Due to aging effect the efficiency of satellite components decreases.
* Free space loss is more.

**What is Microwave Transmission?**

**Sending and receiving information using a microwave is known as microwave transmission. It is the Transmission of information (voice, data, television, telephony, radio signals)by microwave signals. Microwaves are widely used for point-to-point communications.**

**Properties of Microwaves**

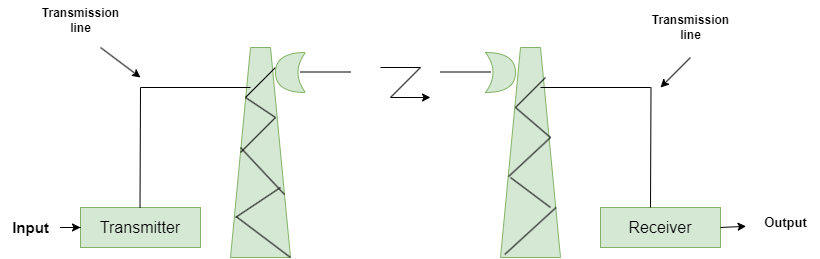
* It is the wave that radiates electromagnetic energy with a shorter wavelength.
* Microwave links consist of a Transmitting station (Tx), a Relay station or Repeaters (RPT), and a Receiving station (Rx).
* Microwaves travel in straight lines, so stations should be aligned to each other.
* Microwave links require clear LOS (line of sight ), so antennas are installed high up to avoid the interference of obstacles in their path.
* They do not pass through buildings, thus reducing the efficiency of inside receivers.
* They are unidirectional and allow multiple receivers.
* Receivers are added to boost the power of the signal so that it can travel a longer distance.
* They are also refracted by atmospheric layers thus refracted rays take more time to reach the destination than direct rays.

**Characteristics of Microwave Transmission**

* Microwaves are unidirectional.
* Microwave transmission Involves line-of-sight (LOS) communication technology.
* Affected greatly by environmental factors like rain fading.
* Microwaves cannot penetrate through obstacles such as hills, buildings, and trees due to their high frequency.
* Signals can be degraded during Solar proton events.
* Atmospheric disturbances such as rain and snow can scatter microwave signals.

**Applications of Microwaves**

* Bluetooth: In Bluetooth, Communication is done through Ultra high frequency (UHF) radio waves .
* Wi-Fi: In Wi-fi , data is transferred using microwave.
* Direct broadcast satellites: Since microwaves are able to pass through the atmosphere layer so communication is done through satellites
* GPS: In order to locate the positions, microwaves are used.
* FM Radio: Microwave transmitter and receiver is used to transfer information through a line to other and so form radio connection.
* Satellite T.V: Since microwaves are able to pass through the atmosphere layer so the information passes from Tv to satellite and vice versa.

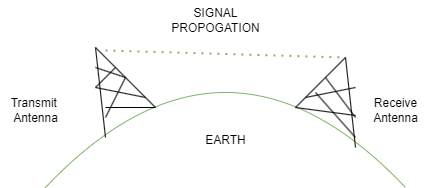


*Microwave Transmission Link*

**Types of Microwave Data Transmission System**

1. **Terrestrial Transmission**

* They cannot pass through any obstacle.
* They Use directional Parabolic Antenna.
* Signals are highly focused.
* Line of Sight Transmission is needed i.e. their path should be free of any sort of obstacle.
* For long-distance transmission signal strength weakens.
* Repeaters are used for every 35-40 km as such.



1. **Satellite Transmission**

* Microwave Relay station is placed in outer space.
* A satellite is launched by a rocket or space shuttle.
* Satellite is precisely positioned 360000 km above.
* Orbit speed matches Earth’s rotation speed.
* A satellite is stationary relative to Earth.

