Unit-1 Sat. Comm.

Satellite Communication – Overview/Introduction

In general terms, a **satellite** is a smaller object that revolves around a larger object in space. For example, moon is a natural satellite of earth.

We know that **Communication** refers to the exchange (sharing) of information between two or more entities, through any medium or channel. In other words, it is nothing but sending, receiving and processing of information.

If the communication takes place between any two earth stations through a satellite, then it is called as **satellite communication**. In this communication, electromagnetic waves are used as carrier signals. These signals carry the information such as voice, audio, video or any other data between ground and space and vice-versa.

Soviet Union had launched the world's first artificial satellite named, Sputnik 1 in 1957. Nearly after 18 years, India also launched the artificial satellite named, Aryabhata in 1975.

Need of Satellite Communication

The following two kinds of propagation are used earlier for communication up to some distance.

- **Ground wave propagation** – Ground wave propagation is suitable for frequencies up to 30MHz. This method of communication makes use of the troposphere conditions of the earth.
- **Sky wave propagation** – The suitable bandwidth for this type of communication is broadly between 30–40 MHz and it makes use of the ionosphere properties of the earth.

The maximum hop or the station distance is limited to 1500KM only in both ground wave propagation and sky wave propagation. Satellite communication overcomes this limitation. In this method, satellites provide **communication for long distances**, which is well beyond the line of sight.

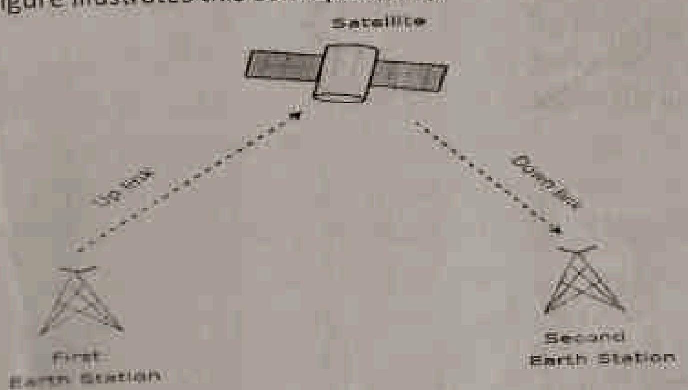
Since the satellites locate at certain height above earth, the communication takes place between any two earth stations easily via satellite. So, it overcomes the limitation of communication between two earth stations due to earth's curvature.

How a Satellite Works

A **satellite** is a body that moves around another body in a particular path. A communication satellite is nothing but a microwave repeater station in space. It is helpful in telecommunications, radio and television along with internet applications.

A **repeater** is a circuit, which increases the strength of the received signal and then transmits it. But, this repeater works as a **transponder**. That means, it changes the frequency band of the transmitted signal from the received one.

The frequency with which, the signal is sent into the space is called as **Uplink frequency**. Similarly, the frequency with which, the signal is sent by the transponder is called as **Downlink frequency**. The following figure illustrates this concept clearly.



The transmission of signal from first earth station to satellite through a channel is called as **uplink**. Similarly, the transmission of signal from satellite to second earth station through a channel is called as **downlink**. **Uplink frequency** is the frequency at which, the first earth station is communicating with satellite. The satellite transponder converts this signal into another frequency and sends it down to the second earth station. This frequency is called as **Downlink frequency**. In similar way, second earth station can also communicate with the first one.

The process of satellite communication begins at an earth station. Here, an installation is designed to transmit and receive signals from a satellite in an orbit around the earth. Earth stations send the information to satellites in the form of high powered, high frequency (GHz range) signals.

The satellites receive and retransmit the signals back to earth where they are received by other earth stations in the coverage area of the satellite. Satellite's **footprint** is the area which receives a signal of useful strength from the satellite.

Pros and Cons of Satellite Communication

In this section, let us have a look at the advantages and disadvantages of satellite communication.

Following are the **advantages** of using satellite communication:

- Area of coverage is more than that of terrestrial systems
- Each and every corner of the earth can be covered
- Transmission cost is independent of coverage area
- More bandwidth and broadcasting possibilities

Following are the **disadvantages** of using satellite communication –

- Launching of satellites into orbits is a costly process.
- Propagation delay of satellite systems is more than that of conventional terrestrial systems.
- Difficult to provide repairing activities if any problem occurs in a satellite system.
- Free space loss is more
- There can be congestion of frequencies.

Applications of Satellite Communication

Satellite communication plays a vital role in our daily life. Following are the applications of satellite communication –

- Radio broadcasting and voice communications
- TV broadcasting such as Direct To Home (DTH)
- Internet applications such as providing Internet connection for data transfer, GPS applications, Internet surfing, etc.
- Military applications and navigations
- Remote sensing applications
- Weather condition monitoring & Forecasting

GEO, MEO and LEO satellite system

Satellite communications are used in telephone, radio, television, internet and military applications. Believe it or not, there are more than 2000 artificial satellites hurtling around in space right above your heads.

These satellites all have different purposes, and they're all at different orbits. Orbit, in this case, is the path that a satellite follows while revolving around a planet. Let's take a better look at the types of orbits.

- **Low Earth Orbit (LEO)**

Low Earth Orbit is usually a circular orbit at a height of 160 to 2000 km above the surface. Due to a low height and a circular orbit, they are able to revolve around the Earth in about 90 minutes. The line of sight of such a satellite is about 1000 km, and they are travelling at enormous speeds, (Around the World in 90 minutes!!). So for a station on Earth to have continuous connectivity, you need numerous Low Earth Orbit satellites. Such satellites though are very easy to launch and because they are close to the ground, Low Earth Orbit satellites do not require high signal strength which is an enormous advantage. Low earth orbit satellites can also form a satellite constellation, which is making and maintaining a specific arrangement with respect to other satellites.

- **Medium Earth Orbit (MEO)**

Medium Earth Orbit satellite is a satellite in orbit around the earth somewhere between 2000 and 35786 km above the surface. These satellites take quite a bit longer than the ones in Low Earth orbit to go around the Earth and hence they are visible for longer durations. They make one revolution in about 3-12 hours. Also, since they are higher up than LEO, MEO Satellites have better coverage of the Earth's surface. The disadvantage is that an MEO satellite is higher up which results in a long time for communication and weaker signal.

- **Geostationary Orbit (GEO)**

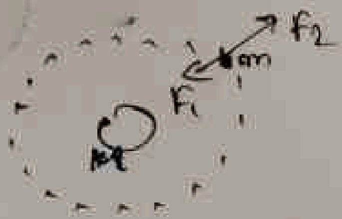
To a viewer on the ground, a satellite revolving around the Earth in a geostationary orbit at a height of 35786 km, would appear fixed in the sky. This is because the angular velocity of the satellite is synced with that of the Earth's. Both the earth and the satellite cover 360° in 24 hours. Having a satellite fixed in space helps because you don't have to track the satellite. You just point your equipment to the satellite once and you don't have to bother again. Admittedly getting a satellite to the geostationary orbit is hugely expensive and the equipment is complex but in applications like television DTH service, the transmission can be scaled to a lot of people and the reception equipment is cheap.

Orbital Mechanics : Orbital eq^n

→ force acting on satellite

A satellite when revolves around the earth, it gets pulling force from earth due to grav. force this is called centripetal force (F_1)

$$F_1 = \frac{GMm}{r^2}$$



$G \rightarrow$ universal gravitational f. $6.673 \times 10^{-11}\ N \cdot m^2/kg^2$

$M \rightarrow$ mass of earth $5.98 \times 10^{24}\ kg$.

$m \rightarrow$ mass of satellite

$r \rightarrow$ dis. of satellite from centre of earth

A satellite when revolve around earth, it undergo pulling force sun and moon due to grav. force this force is called centrifugal force (F_2). this tend satellite away from earth.

$$F_2 = \frac{mv^2}{r}$$

$v \rightarrow$ orbital velocity of satellite.

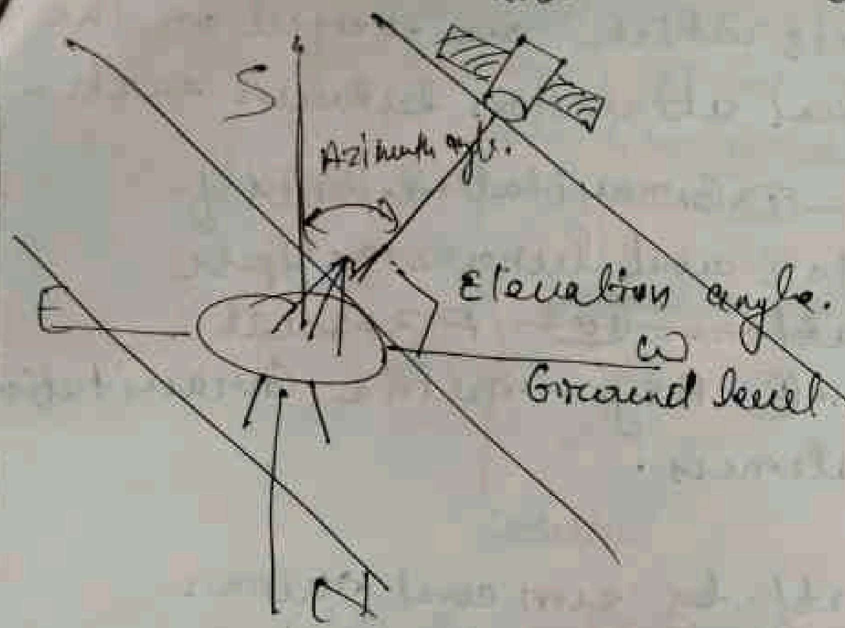
$$F_1 = F_2 \Rightarrow \frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow v^2 = \frac{GM}{r}$$

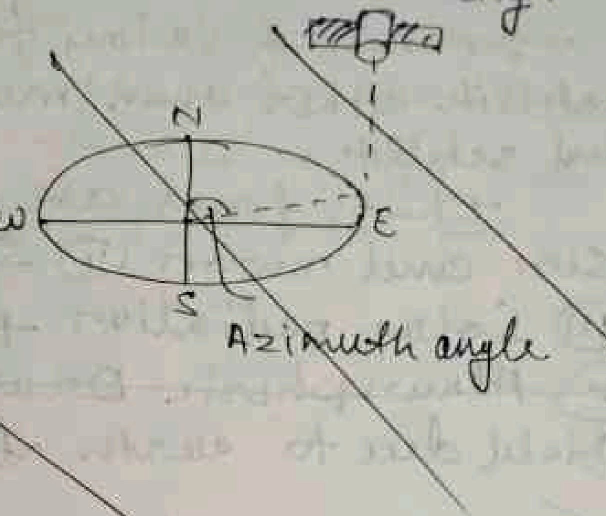
$$\Rightarrow v = \sqrt{\frac{GM}{r}}$$

$$\boxed{v = \sqrt{\frac{GM}{r}}}$$

Look Angle

earth antenna — look at ⟶ satellite directly.





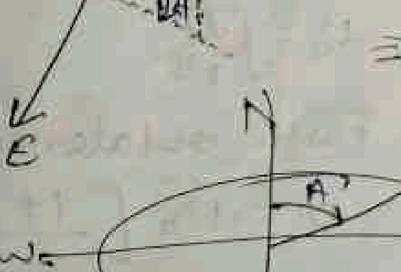
2 look angle needed ⟶ (I) Azimuth A
(II) Elevation A.

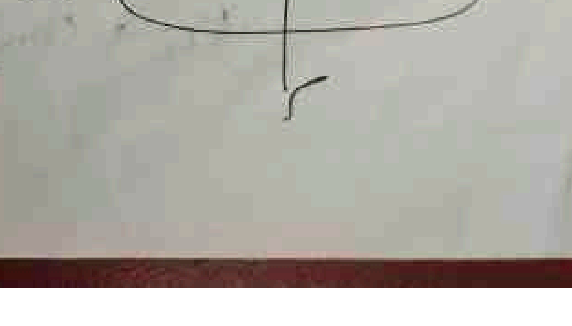
→ look angles are required such that the earth station antenna points or 'look at' the satellite directly.

→ The coordinates to which an earth station must be pointed to communicate with satellite are called look angle.

(I) measure from N to E to projection of satellite path onto horizontal plane

(II) the angle measure from horizontal plane to the orbit plane





Orbital Perturbation

→ result of various forces which are exerted on the satellite other than mutual attraction between earth and satellite.

That forces are — (I) Gravitation forces of sun and moon (II) Solar and lunar eclipse (III) Solar radiation ~~pattern~~ (IV) pressure ~~(IV) Atmospheric Drag~~ (V) Asymmetric Gravitation field due to earth oblateness.

Effect of sun and moon

Gravitation att. by sun and moon causes orbital inclination of the satellite which change with time.

These forces will result in increase in the orbital inclination from an initial 0° at launch to 14.67° in 26.6 yr.

The life of commercial satellite is not more than 26 yr.

Effect of earth oblateness

– earth is not perfectly spherical, there is an equatorial bulge and flattering at the poles. This shape is oblate spheroid.

A/c to Kepler's law, the mean motion

$$v_0 = \sqrt{\frac{\mu}{r^3}}$$

if earth oblateness is taken

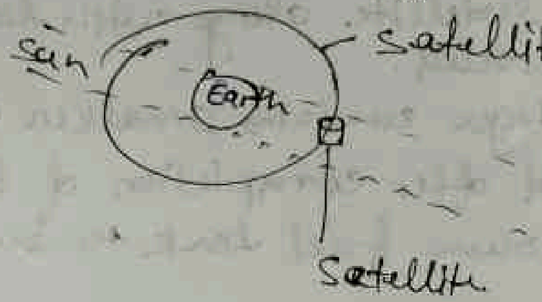
$$v = v_0 \left[\frac{1 + K_1 (1 - 1.5 \sin^2 i)}{a r^2 (1 - e^2)^{1.5}} \right]$$

$K_1 \rightarrow$ Const.

Solar and lunar eclipse

A satellite is said to be eclipse when earth or moon prevent sunlight from reaching it.

A satellite draws electrical energy from its house keeping with the help of solar panel.



Solar radiation Pressure

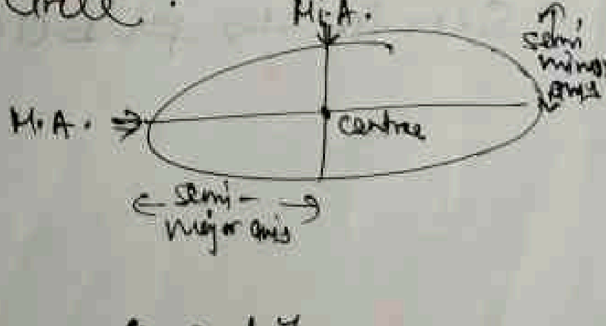
- It disturb satellite orbit and satellite exp. changes in eccentricity of orbit
- eccentricity builds up for 1st 6 month and then shrinks during next 6 months.
- small variation in shape of orbit may be tolerated.

$e = 0.5$

$e = 0.75$

eccentricity → fixes the shape of satellite orbit.

- this parameter indicates deviation of orbits shape from perfect circle.



length of semi major axis → a.

" " " minor axis → b

$$e = \frac{\sqrt{a^2 - b^2}}{a}$$

e → for circle → 0 $(a = b)$

e → for eclipse → lies between 0 and 1.

Launching of satellite

- The process of placing the satellite in a proper orbit is known as launching process.
- there are four stages —

(I) First stage — the first stage contains rockets and fuel for lifting the satellite along with launching vehicle from ground.

(II) Second stage - The second stage contains smaller rocket these are ignited after completion of 1st stage they have their own fuel tank to send satellite in space.

(III) third stage — It is connected to satellite fairing. this is metal shield which contain satellite and it protect the satellite.

(IV) Fourth stage — Satellite get separated from upper stage of launch vehicle, when it has been reached out of earth atmosphere. Then satellite will go to "transfer orbit". This orbit send satellite higher into space

when satellite reach to desired height of orbit its subsystem solar panel and comm. antenna get unfurled. Now satellite is ready to provide Service to public