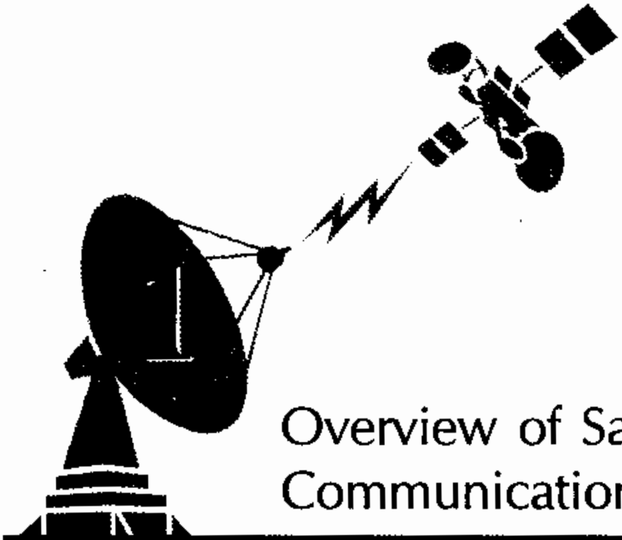

# 1 Overview of Satellite Communication

## 1.1 INTRODUCTION

The Satellite communication means communication through satellites. The advent of earth's artificial satellite has extended the range of line-of-sight propagation paths and made possible transoceanic transmission of microwaves with their potentiality for large bandwidths. Satellite forms an essential part of telecommunication systems worldwide carrying large amount of data (internet, e-mail) and telephone traffic in addition to TV signals. As satellite from its great height can see a large portion of the earth, it can be used as communication star point for net linking. Due to interference consideration, communication satellites must maintain a certain separation and thus only a limited number of satellites can be placed in geo-stationary orbit to provide communications for a region. In addition only certain radio frequency bands, assigned by international agreement, are available for commercial satellite communication. Later on efficiency of the satellite communication systems are being increased by using higher band of frequency, by increasing spectrum efficiency, developing high gain multiple spot beam antennas and frequency reusing technique. Apart from this, satellite communication has the following advantages over terrestrial link:

1. It is capable of transmitting signal long distances without using relay with higher capacity.
2. All the terrestrial relays are point to point whereas satellite relays are point to multipoint.

3. Satellite circuits can be installed rapidly.
4. The mobile communication can be easily achieved by satellite system as it has an unique degree of flexibility in interconnecting mobile vehicles.
5. The satellite costs are independent of distance.

Like any other system, satellite communication system has the following disadvantages:

1. As the distance between satellite transmitter and receiver is about 75,000 km and velocity of electromagnetic wave is $3 \times 10^5$ km/s, there is a delay of 1/4th second between the transmission and reception of signal. Thus between talks there is an elapses of half-second and one may feel it annoying.
2. Repairing any part of satellite after launching is very difficult.
3. To launch geo-stationary satellite in space more powerful launch vehicles are required and thus the high cost of launching can affect the total cost for communication.
4. High free space loss.

As advantages are much more than disadvantages, the satellite communication has become popular for long distance communication.

## 1.2 HISTORICAL BACKGROUND OF SATELLITE COMMUNICATION

The journey of satellite communication starts with a science fiction written by A.C. Clarke[1] in 1945. It was his proposal that a satellite at an altitude of 42,242 km from the centre of earth, rotates with same angular velocity of earth in the same direction, then its relative velocity with respect to earth is zero and it appears to be stationary on the top of the earth surface. Then the satellite can receive and relay signals from most of a hemisphere. He also suggested that by using three such satellities spaced 120° apart as shown in Figure 1.1 global communication is possible by relay process.

The space race then started between USA and USSR. On 4th October 1957 USSR launched a lower orbit satellite "Sputnik-I" and in the very next year on December 18th USA launched "SCORE" (Signal Communication by Orbiting Relay Equipment) having a period of 101 minutes. SCORE was an explorer satellite and first broadcast a tapped message from President Eisenhower. On August 12, 1960 ECHO-I and then on January 25, 1965 ECHO-II were launched by AT&T. These two satellities were orbiting balloons of 110 ft. diameter served as passive reflectors.

Then Bell system laboratory launched two more successful broadband real time transponder operated satellities TELSTER-I and II on Jully 10, 1962 and May 7, 1963 with a period of 158 minutes and 225 minutes respectively. TELSTER-I successfully established an FM link for Television signal between USA and Europe using 6389.5 MHz as uplink and 4169.7 MHz as downlink frequency.

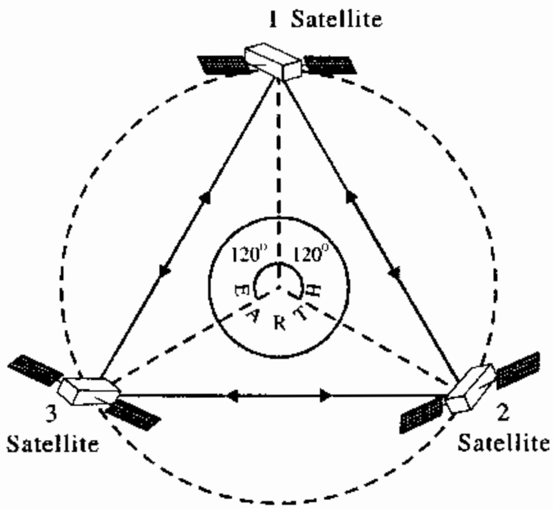


**FIGURE 1.1** Global communication with three geostationary satellites.

Then SYNCOM series of communication satellites were launched in between 1963 and 1964 by NASA. These were the first successful geo-synchronous communication satellite with FM and PSK transponders and could support two carriers at a time for full duplex operation.

On 6th April, 1965 INTELSAT-I was the early bird in the history of commercial geo-synchronous commnication satellite launched by USA and a routine commercial satellite communication started on 28th June, 1965 between USA and Europe. This satellite had two 25 MHz bandwidth transponders. In the same year USSR also launched another communication satellite, MOLNYA. But in the meantime INTELSAT organization had launched 33 INTELSAT satellites and connected 200 earth stations of 100 nations. Also different satellites were developed by different countries, either for their defense people or for a special purpose such as MARISAT, CTS, ATS, OTS, ECS, etc.

The history of Indian satellite communication starts with the launching of 'Aryabhatta' on 19th April, 1975. It was an experimental satellite developed by Indian Space Research Organization (ISRO) under Department of Space, Govt. of India. Indian space research is discussed in detail in Chapter 12 of the book. The space research in India started on 21st Nov, 1963 with the launching of a sounding rocket by Indian National Committee for Space Research (INCOSPAR). 'Bhaskara-1' was the first experimental satellite launched on 7th June, 1979 for earth observation. On and from 1982, works on INSAT and SLV series of communication satellite started. In 2002, INSAT 3C so far the last satellite of INSAT series was launched, which had 24 C-band transponders. With the development of satellite communication, some international laws, regulations are also developed side by side along with some legal committees.

## 1.3 ACTIVE AND PASSIVE SATELLITES

When the reflector of the relay system (satellite) is a passive one, i.e. a metal coated plastic spherical balloon, the satellite is called a passive one. In passive satellite the transmitter of the ground station requires large power and the receiving station receives a fraction of that power and then it is amplified by active electronic means. Passive system may have sufficient advantages for military systems because of invulnerability of the satellite. ECHO-I was the world's best known passive communication satellite, which was launched in 1960 into an 870 nautical mile orbit with an inclination of 47.3° with respect to the equator. It was basically a spherical balloon with diameter 100 ft. of Mylar coated on the outside with alumina. On the other hand with time, these balloons gradually lost their reflectivity while these are coasting through space. Once the inflating gases leaked out, these balloons became prune-faced and reflectes radio waves inefficiently.

A later version of ECHO-II was semi-irigidized, that it was designed to remain spherical in space even after it lost all of its gases. This was accomplished by coating it on the outside and inside with the layers of aluminium and over stressing the Mylar inside the sandwich during its inflation. ECHO-II was a balloon of 135 ft. in diameter.

In active satellite system on board transponder is used by which the signal of earth station is received, amplified, downconverted and retransmitted for another earth station. Thus the required power of the transmitting earth station is low. As mentioned earlier 'SCORE' was the first active satellite, which was launched by USA.

## 1.4 SATELLITE ORBITS

The path in which satellite goes round the earth is called orbit path and the distance from the centre of the earth to the satellite is called orbit radius. An orbit is characterized by the attributes—altitude and inclination. The height of the satellite from the surface of the earth is called altitude and at any point in the orbit the angle of rotation of the satellite with horizon is known as inclination. At altitudes of 2000–5000 km and 15,000–30,000 km, there are belts of ionized particles known as 'inner Van Allen belt' and 'outer Van Allen belt' respectively. Satellite orbits are impossible in these ranges as communication would be impossible. In case of eccentric orbits, the radius varies, while in circular orbits it is constant. Satellite can be classified in terms of altitude as follows:

1. Low Earth Orbit (LEO) satellite
2. Middle Earth Orbit (MEO) satellite
3. Geo-stationary Earth Orbit (GEO) satellite
4. Highly Eccentric Orbit (HEO) satellite

Table 1.1 below shows the altitude, rotational period, time in sight, example and use of each of these four types of satellite.

**TABLE 1.1** Performance characteristics of different altitude satellites

| *Types of satellite* | *LEO* | *MEO* | *GEO* | *HEO* |
|---|---|---|---|---|
| Altitude | 500–1500 km | 5000–10,000 km | 36,000 km | 15,000–30,000 km |
| Rotation period | 90 minutes | 5–12 hours | 24 hours | Less than 24 hours |
| Time in sight | 15 minutes | 2–4 hours | Always | 8 hours |
| Example | Iridium | GPS | VSAT | Molnya |
| Uses | Mobile communication and for surveying. | Global communications on such as e-mail, FAX, telephony | Global communication on such as TV and radio transmission, data transmission. | Communication amongst the polar countries. |

## 1.5 GENERAL STRUCTURE OF SATELLITE COMMUNICATION

The block diagram of the general structure of a satellite communication system is as shown in Figure 1.2. On the guidelines of WARC-1979 commercial communication satellites use a frequency band of 500 MHz bandwidth, near 6 GHz for uplink and another 500 MHz bandwidth near 4 GHz for downlink transmission. The 500 MHz allocation is usually divided into 12 channels of approximately 40 MHz each and each channel transmits power of typically 5–10 watts. For these 12 channels, 12 transponders are used to carry one TV channel or about 1500 analog voice signals. If digital modulation is used, transponder data

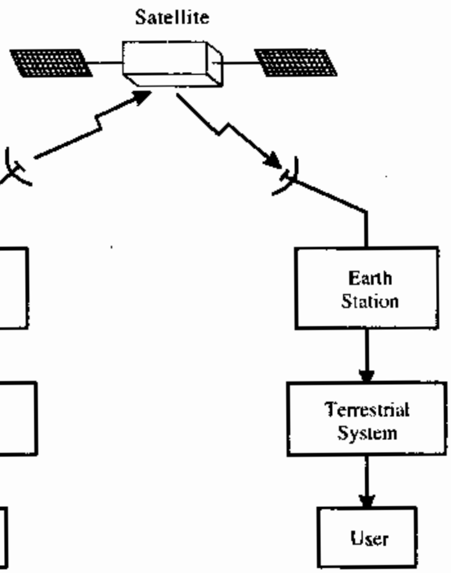


**FIGURE 1.2** Structure of a satellite communication.

rate of 50 to 100 MB are achievable. With the use of SSB modulation technique, about 10,000 voice channels could be carried over a single satellite transponder.

In general there are three types of satellite systems, such as (a) ground to ground, (b) ground cross link ground, (c) ground to relay platform.

## 1.6 IRIDIUM

Motorola's Satellite Communication Division introduced the Iridium concept in 1987. As per periodic table material Iridium has 77 orbital electrons and similarly here the system consisting of 77 low earth orbit (LEO) satellites.

In this system 66 satellites are grouped in six orbital planes, each containing 11 active satellites. The orbits are circular and a height of 783 km from the surface of earth. The 11-satellites of each plane are uniformly spaced, the nominal spacing being 32.7° and thus covers the globe along the plane. These satellites travel up one side of the earth, cross over near the north pole, and travel down the other side, thus both sides of the earth are covered continuously. The polar view of the iridium satellite orbits is as shown in Figure 1.3. When satellite of one orbit crosses the other orbit at poles then there is a chance of collision between them. But collision avoidance is built into the orbital planning and the closest approach between satellites in planes 1, 3 and 5 cross the equator in synchronism while satellites in planes 2, 4, 6 also cross the equator but out of phase with those of planes 1, 3 and 5. Again the separation between rotating planes is 31.6°. Here each satellite is not only connected with two earth stations but also its nearest neighbours ahead and front, and to the satellites in the adjacent planes.

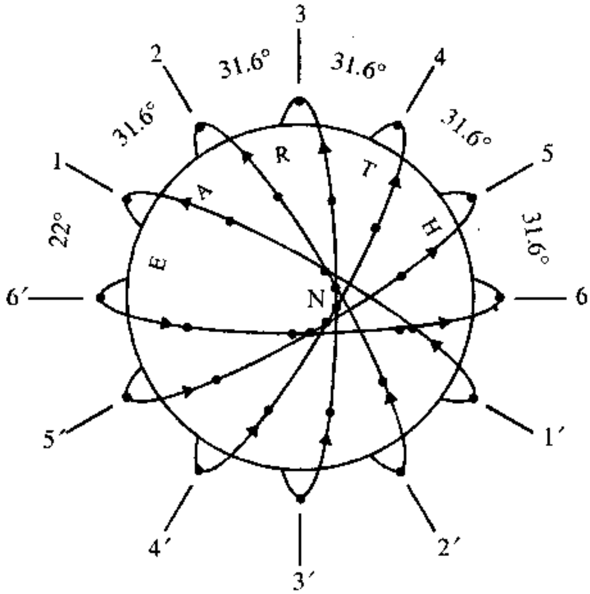


FIGURE 1.3 A polar view of the Iridium satellite orbits.

The uplink/downlink between subscriber and satellite takes place in the L-band, whereas inter-satellite links and up/down links between satellites and gateway stations, operate in the Ka-band. The link between the Iridium system control station and the satellite is also in the Ka-band. Circular polarization is used in all the links. The multiple access utilizes a combination of TDMA and FDMA. Each subscriber unit operates in a burst mode using a single carrier transmission. Here the beam switching system is very much similar to the cell management of cellular mobile telephony. Iridium system is not a replacement for existing cellular system but rather an extension of wireless telephony. Iridium system is less likely to be disabled in the disaster situations and be able to provide mobile services in remote and sparsely populated areas. Also Iridium will be able to offer more channels with shorter delays.

## 1.7 IMPORTANCE OF 6/4 GHz SYSTEM

In general the 6/4 GHz system is most popular due to the following reasons:

1. Rain attenuation is not much serious at these bands.
2. Sky noise is also low at 4 GHz and so it is possible to built receiving system with lower noise temperature.
3. Also, cost of equipment at these frequencies is less.

To avoid the overcrowding of geo-stationary satellite at 6/4 GHz band, 14/12 GHz band is also being used in commercial communication satellite.

## 1.8 SATELLITE APPLICATIONS

Applications are innumerous but can be broadly classified as:

1. In communication such as T.V., telephony, data transfer such as e-mail and internet etc. are mostly done through different communication satellite these days.
2. Remote sensing and earth observation can be done with the help of lower earth orbit satellite.
3. Meteorological applications such weather survey, to study different layer and amount of ozone contents in the atmosphere.
4. Military applications like short distance local communication from one camp to another, to study the location of the enemy, etc.

## 1.9 SATELLITE FREQUENCY ALLOCATION AND BAND SPECTRUM

In the lower frequency range, six frequency bands have been allocated for satellite communication as described in Table 1.2.

TABLE 1.2 Frequency Bands for Satellite Communication

| *Band* | *User* | *Downlink bands* (in GHz) | *Uplink bands* (in GHz) |
|---|---|---|---|
| UHF | Military | 0.25 to 0.27 | 0.29 to 0.31 |
| C-band | Commercial | 3.7 to 4.2 | 5.9 to 6.4 |
| X-band | Military | 7.2 to 7.7 | 7.9 to 8.4 |
| Ku-band | Commercial | 11.7 to 12.2 | 14.0 to 14.5 |
| K-band | Commercial | 17.7 to 21.2 | 27.5 to 30.0 |
| Ka-band | Military | 20.2 to 21.2 | 43.5 to 45.5 |

In addition to the frequency listed above, a few bands within the frequency range 0.8–265 GHz are used for aeronautical, maritime and general mobile system. Also some bands within the frequency range 2.5–275 GHz are used for fixed satellite services (FSS) and Broadcasting Satellite Services (BSS). Frequency ranges allocated for meteorological satellites are in the band 1.66–1.67 GHz, 1.67–1.69 GHz and 1.70–1.71 GHz.

## 1.10 ADVANTAGES OF MICROWAVE AND MILLIMETER WAVE IN SATELLITE COMMUNICATION

**High directivity:** Microwave and millimeter wave beams are highly directive and very sharp. With the increase of frequency, beam width decreases and directivity increases. The relation between beam width ($B$) and directivity ($D$) is

$$B = \frac{140\lambda}{D} \tag{1.1}$$

where $\lambda$ is the wavelength of electromagnetic wave.

**Improved bandwidth availability:** Large bandwidth (because of very high centre frequency of 3 to few hundred GHz) of microwave and millimeter wave can accommodate more number of information channels for TV networks, telephone network, space communication, defense application, etc. with a small percentage variation of carrier frequency.

**Fading effect and reliability:** At high frequency fading effect is less and hence microwave and millimeter wave satellite communication is more reliable.

**Transparency property of microwave:** Microwave can freely propagate through different ionized layer as well as through the atmosphere. Millimeter waves can freely propagate through various window frequencies through atmosphere.

## 1.11 DIGITAL SATELLITE COMMUNICATION

The following advantages of digital signal processing over its analog counterpart make it popular also in satellite communication:

1. Extremely low error rate, high fidelity through error detection and correction.
2. It is easy to multiplex multiple signals and handling digital signals in the form of packets.
3. Use of microprocessor, digital integrated circuit and digital switching makes the communication system compact and small.
4. Communication privacy.

Unlike FDM-FM-FDMA of analog communication system, the use of quaternary phase shift keying—time division multiple access (QPSK—TDMA) can accommodate a large number of earth stations with a small loss in transponder capacity. Also, use of demand assignment and digital speech interpolation techniques increases its efficiency. Code Division Multiple Access (CDMA) offers good quality service at a lower cost to small earth stations.

## 1.12 SATELLITE MOBILE COMMUNICATION SYSTEM

It is particularly significant for long distance travelers of any part of the world, who cannot be connected by conventional land based communication system. This system greatly improves navigational problem, air traffic control and rescue operation over transoceanic crossings. For this purpose the first satellite INMARSAT was launched by International Maritime Satellite Organization in 1979. INMARSAT space communication system provides data services for aircraft crew, cockpit voice communication and passenger telephony. On the other hand, INMARSAT maritime communication system is basically an analog communication system, which provides telex and telephone services. After that INMARSAT was further developed for additional services and ISDN services.

In 1988 the first domestic satellite system Geo-star's Radio Determination Satellite System (RDSS) stared it operation and provided regular service to mobile user in USA. In the very next year Omni Tracs system stared it operation and provided a two way mobile satellite communication around USA and Europe. The Australian MOBILESAT system provided circuit-switched voice and data services for land, aeronautical and maritime users.

Lower Earth Orbit (LEO) mobile satellite communication can offer a cost efficient solution for cellular services like mobile voice and data users, as well as for emerging Personal Communication Services (PCS).

## SUMMARY

In this chapter we have discussed the basic concept of satellite communication, and its advantages and disadvantages. Also, different allocated frequency bands for satellite communication and some of the applications of satellite are mentioned. Since the launching of the first satellite in the early 1960s, the developments have taken place in the areas of space-craft capacity and power. We may conclude by saying that for long distance transmission, satellite is the best mean and with the help of only three geo-stationary satellites, global communication is possible. Advantages and disadvantages of satellite