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Principles of Satellite Communication

1.1. Evolution and Growth of Communication Satellites

The idea of communication through a satellite, in particular with a synchronous satellite was conceived by Arthur C. Clarke, a famous British science fiction writer in 1945[(1)]. Clarke had already pointed out that a satellite in a circular equatorial orbit with a radius of about 42,242 km would have an angular velocity that matched the earth's. Thus, it would always remain above the same spot on ground and it could receive and relay signals from most of a hemisphere. Three satellites spaced 120 degrees apart could cover the whole world with some overlap provided that messages could be relayed between satellites and thus reliable communication between any two points in the world was possible. Clarke had also stated that the electrical power for the satellite would be obtained by conversion of the sun's radiation by means of solar cells. Clarke's paper went almost totally unnoticed until man-made satellites became a reality with Sputnik (October 4, 1957). However, it may be noted that the synchronous orbit was not achieved until 1963.

The Russian launch of Sputnik I started 'space race between super powers (USA and USSR). USA launched SCORE on Dec 18, 1958[(2)]. It was a kind of Explorer satellite. On Aug. 12, 1960 ECHO I was launched by AT and T, USA. It was an orbiting balloon 100 ft in diameter which served as passive reflector. A similar ECHO II was launched by AT & T again on Jan 25, 1964. These provided communications between Bell Lab in New Jersey and JPL in California. However, the power and antenna requirements were severe and so it could not be used for communications between East and West Coast of USA. The TELSTAR I and II satellites of AT and T launched on July 10, 1962 and May 7, 1963 established the basis of modem technique of communication satellite. The TELSTAR I demonstrated for the first time a television link between the United States and Europe. The *Communications Satellite Corporation* (Comsat) was established in 1963 in USA and then SYNCOM series of communication satellites were launched. SYNCOM I was launched in the beginning of 1963. SYNCOM II was launched on July 26, 1963 and SYNCOM III was launched on July 19, 1964. The International Telecommunications Satellite Organisation (INTELSAT) was established in 1964. The INTELSAT I also called the *Early Bird* was launched on April 6, 1965. The same year Russian Communication satellite MOLNYA was also launched. Since these launches the INTELSAT organisation has grown to over 100 member nations and over 33 INTELSAT satellites have been launched(3) ranging from instruments with a small capacity (240 voice circuits or one television channel) to those with a huge capacity (12500 voice circuits and two television channels) and covering three regions-the Atlantic, Pacific and Indian Oceans. Thus a new era of Communication via satellite (satellite Communication) had begun and now over hundreds of geostationary satellites of different countries of the world are in the service. This is expected to grow in a very large number in near future(4,5).

1.2. Synchronous Satellites

As already mentioned the synchronous satellites also called the geostationary satellites go round the globe in 24 hours so they seem to us on earth to keep station some 36000 km vertically above the same point on the earth's surface. In fact a stationary satellite is a synchronous satellite that has sufficiently small values of orbital eccentricity and inclination to the Equator that the changes in its apparent direction relative to the rotating earth are negligible for practical purposes. The other advantages of synchronous altitude is that it is well above the high intensity inner radiation belt and above the most intense region of the considerably milder outer belt. Thus, adequate protection can be obtained with negligible weight. The stationary orbit is sunlit over 99% of the time (the infrequent eclipses can occur only at midnight at the meridian of the satellite, and then only at certain times of the year), simplifying the generation and storage of power and reducing the number of temperature cycles. The strength of the earth's magnetic field is only a hundredth of its value at lower altitudes, and spin-damping time constants are consequently 10,000 times as long-long enough to be neglected(6). The high altitude of the synchronous orbit makes such a satellite visible from 40% of the earth's surface. A single satellite may provide continuous coverage for the major portion of the world's communication market. The ground stations may be of sufficiently low cost that each country served by the system can readily afford to its own terminal, and the rf spectrum required for the system can be readily shared with other services. There are a few problems with these synchronous communication satellites, namely the time delay, in connection with telephony and the establishment of the synchronous orbit.

The synchronous satellites used for communication are widely called the *communication satellites*. These satellites are classified in terms of their territorial coverages-*e.g.* global, regional, or national (domestic)-or in terms of the type of services offered -*e.g.* fixed, mobile, maritime, aeronautical, etc or point to point, broadcasting, commercial, military, amateur, experimental etc. The global or international satellite communications is served primarily through the INTELSAT satellite system which serves over 100 nations interconnected through 200 Earth Stations. Another system, the Inter Sputnik satellite system primarily serves Eastern Block Communist Countries and Cuba. There are over 2 dozen countries including India which have their domestic satellite systems either operational or in advanced planning stages. These satellites have special shaped antenna beams to provide domestic overage and are employed for telephony, data and television distribution. Some regional satellites have also been developed such as those to serve Europe, the Arab states, portions of Africa, South America and Nordic regions. Such regional satellites have users and characteristics similar to domestic systems.

Military satellites are principally those of super powers. A Typical example is that of US's *Defence Satellite Communications System (DSCS)* which constitutes a series of satellites to provide worldwide military communications. The circuit capacities of military satellites are modest compared to international and domestic satellites. The broadcast satellites are used for domestic or regional coverage. These radiate a high powered TV signal down to a large number of small receiving antennas (one meter diameter of less). Special purpose satellites are those such as maritime satellite (MARISAT), remote sensing satellite and tracking and data relay satellite system etc. The experimental satellites are also a kind of special purpose satellites. Typical examples are NASA's application technology satellite (ATS), communication technology satellites (CTS), Lincoln Laboratories (LES), the European Space Agency Orbital test satellite (OTS) and the Japanese (ECS) etc. A variety of experiments concerning with communication technology and space propagation/communication at various frequency bands have been carried out by these experimental satellites.

1.3. International Regulation and Frequency Coordination

The International Telecommunication Union (ITU), a specialised agency of United Nations has developed a series of radio regulations for frequency allocations international wise for different purposes[7]. ITU carries out such activities through its tour permanent organs, namely the General Secretariat, International Frequency Registration Board (IFRB), International Radio Consultative Committee (CCIR) and the International Telegraph and Telephone Consultative Committee (CCITT). The General Secretariat is located in Geneva. It is responsible for the executive management and technical cooperation. The IFRB is responsible for recording frequencies and orbital positions and for advising member countries on operation of the maximum practical number of radio channels in portions of the spectrum where harmful interference may occur. The CCIR is responsible for studying technical and operational questions relating to radio communications which results in reports, recommendations, resolutions, and decisions published as a group in Green Books every 4 year following CCIR Planery Assemblies. The CCITT is responsible for studying technical, operational, and tariff questions relating to telegraphy and telephony and for adopting reports and recommendations.

The international radio conferences held under the auspices of ITU from time to time issue guidelines for frequencies etc. Such a conference widely known as World Administrative Radio Conference (WARC) was held in 1979 that allocated frequency bands for satellite communications. WARC described the various satellite services under 17 categories, namely the fixed, intersatellite, mobile, land mobile, maritime mobile, aeronautical mobile, broadcasting, earth exploration, space research, meteorological, space operation, amateur, radio determination, radio navigation, aeronautical radio navigation, maritime radio navigation and standard frequency and time signal. WARC also divided the globe into three geographic regions for the purposes of frequency allocations. These regions are: *Region 1*, including Europe, Africa, the USSR and Mongolia; *Region 2* including North and South America and Greenland ; and *Region 3* including Asia (except the USSR and Mongolia), Australia and the Southwest Pacific.

1.4. Satellite Frequency Allocations and Band Spectrum

There are six frequency bands that have been allocated for the use with satellite communications. Table 1.1 gives these bands. It may be noted that in addition to these bands given in Table 1.1, millimetre waves in the frequency ranges 40-300 GHz are also allocated for satellite communication purposes. Table 1.2 lists frequency allocations for fixed satellite service and broadcasting satellites. The frequency allocations for mobile satellite services are listed in Table 1.3. In addition to frequencies listed above there are allocations for meteorological satellites and for experimental and amateur use. Frequency ranges allocated for meteorological aids/meteorological satellites are in the band 1668.4-1670 MHz, 1670-1690 MHz, 1690-1700 MHz, 1700-1710 MHz, 7450-7550 MHz.

Table 1.1. Frequency Bands for Satellite Communication

Band	*Downward bands MHz*	*Uplink Bands MHz*
Uhf–Military	250–270 (Approx)	292–312 (Approx)
C Band–Commercial	3700–4200	5925–6425
X Band–Military	7250–7750	7900–8400
Ku Band–Commercial	11700–12200	14000–14500
Ka Band–Commercial	17,700–21200	27500–30,000
Ka Band–Military	20200–21200	43500–45500

Table 1.2. Frequency Allocations for Fixed Satellite Service and Broadcasting Satellites

Frequency	*Fixed Satellite Service*	*Broadcasting Satellites*
2500–2535 MHz	Down Region II and III	Down
2535–2655	Down Region II	Down
2655–2690	Up region II and III	Down
3400–3700	Down	
3700–4200	Down	
4500–4800	Down	
5725–5850	Up Region I	
5850–5925	Up	
5925–7075	Up	
7250–7450	Down	
7450–7550	Down	
7900–8025	Up	
8025–8400	Up	
10.7–11.7 GHz	Down	Up Region I
11.7–12.1	Down Region II	Down Region I and III
12.1–12.2	Down Region II	Down

(*Table contd...*)

Frequency	*Fixed Satellite Service*	*Broadcasting Satellites*
12.2–12.3	Down Region II	Down Region I & II
12.3–12.5		Down Region I & II
12.5–12.75	UP/Down	Down Region II
12.75–13.25	Up	
14.0–14.5	Up	
14.5–14.8		Up
17.3–17.7		Up
17.7–18.1		Up
18.1–18.6	Down	
18.6–18.8	Down	
18.8–20.2	Down	
20.2–21.2	Down	
22.5–23.0		Down Region II & III
27.0–27.5	Up Region II & III	
27.5–29.5		
29.5–31.0	Up	
37.5–39.5	Down	
39.5–40.5	Down	
40.5–42.5		Down
42.5–43.5	Up	Down
47.2–49.2		Up
49.2–50.2	Up	
50.4–51.4	Up	
71.0–75.5	Up	
81–84	Down	
84–86		Down
92–95	Up	
102–105	Down	
149–164	Down	
202–217	Up	
231–241	Down	
265–275	Up	

Table 1.3. Frequency Allocations for Mobile Satellite Service

Frequency	*Aeronautical Mobile*	*Maritime Mobile*	*General Mobile*
806–890 Mhz			Region II & III
1530–1535		Down, Shared	(limited use)
1535–1544		Down, Exclusive	
1544–1545			Down
1545–1559	Down, Exclusive		Down
1626.5–1645.5		Up, Exclusive	
1645.5–1646.5			Up

(*Table contd...*)

Frequency	*Aeronautical Mobile*	*Maritime Mobile*	*General Mobile*
1446.5–1660.5	Up, Exclusive		
1660–1660.5	Up, Shared		
19.7–21.2 GHz			Down
29.5–31.0			Up
39.5–40.5			Down
43.5–47			Up
66–71			Up/Down
71–74			Up/Down
81–84			Up/Down
95–100			Up/Down
134–142			Up/Down
190–200			Up/Down
252–265			Up/Down

1.5. General and Technical Characteristics of A Satellite Communication System

Fig. 1.1 indicates the general structure of a satellite communication system. This consists of a satellite in space that links many earth stations on the ground. The user is connected to the earth station through terrestrial network. This terrestrial network may be a telephone switch or a dedicated link to the earth station. The user generates the baseband signal that is processed and transmitted to the satellite at the earth station. Thus the satellite may be thought of a large repeater in space that receives the modulated rf carriers in its uplink (earth-to-space) frequency spectrum from all the earth stations in the network, amplifies these carriers and retransmits them back to the earth in the downlink (space-to-earth) frequency spectrum which is different from the uplink frequency spectrum in order to avoid the interference. The signal at the receiving earth station is processed to get back the baseband signal which is then sent to the user through a terrestrial network. Had there been no difference in the uplink and downlink frequencies, the satellite's transmitted signals would have blocked up the uplink received signals and so there would have been no isolation between the transmitter output and the receiver input.

On the guidelines of WARC - 1979 commercial communication satellites use a frequency band of 500 MHz bandwidth near 6 GHz for up-link transmissions and another 500 MHz bandwidth near 4 GHz for downlink transmission. Infact an uplink of 5.725 to 7.075 GHz and a downlink of 3.4 to 4.8 GHz is used. It may be noted that this 6/4 GHz band is also used in many countries for terrestrial communications (microwave links) and so the problem of mutual interference is seriously to be looked into. The 500 MHz allocation is usually divided into 12 channels of approximately 40 MHz each and the level of transmit power per 40 MHz channel is typically of the order of 5 to 10 W. This allows each of up to the 12 transponders to carry one TV channel or about 1500 analog FM voice circuits. If digital modulation is used, transponder data rates from 50 to 100 Mb are achieveable. With the use of single side band (SSB) modulation technique about 10,000 voice circuits could be carried over a single satellite transponder. Modern communication satellites also employ frequency reuse to increase the number of transponders in the 500 MHz allocated to them.

It should be of importance to note that 6/4 bands have been the most popular because they offer the fewest propagation problems and historically RF components for these bands have been readily available. Rain attenuation is also not much serious at these bands. Sky noise is also low at 4 GHz and so it is possible to build receiving systems with lower noise temperatures at 4 GHz. With the overcrowding of geostationary satellites at 6/4 GHz band, 14/12 GHz band is also being used in commercial communication satellites. Here uplink is of 12.75 to 14.8 GHz and downlink of either 10.7 to 12.3 GHz or 12.5 to 12.7 GHz. This frequency band is not yet congested and is hoped to be used extensively in future. Rain attenuation is a problem at this frequency band. A third band where extremely high capacities are potentially available is the 20/30 GHz band where 2.5 GHz bandwidth has been allocated. Here the uplink is of 27.5 to 31 GHz and downlink is of 18.1 to 21.2 GHz. The future advanced technology of satellite communication has been focussed on these bands. Equipments on these frequency bands are in progress and experimental stage.

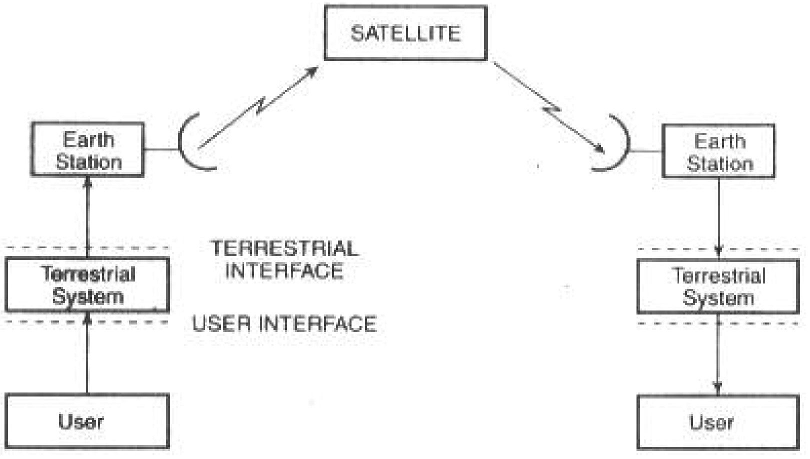

Fig. 1.1. General Structure of A Satellite Communication System.

The basic block diagram of an earth station that transmits to and receives information from a satellite is shown in Fig. 1.2. The baseband signal from the terrestrial network enters the earth station at the transmitter after having processed (buffered, multiplexed, formatted, etc.) by the baseband equipment. After the encoder and modulator have acted upon the baseband signal, it is converted to the uplink frequency. Then it is amplified and directed to the appropriate polarization port of the antenna feed. The signal received from the satellite is amplified in an LNA first and is then downconverted from the downlink frequency. It is then demodulated and decoded and then the original baseband signal is obtained. Critical components will often be installed redundantly with automatic switch over in the event of failure so that uninterrupted operation is maintained. The isolation of low noise receiver from the high power transmitter is of much concern in the design considerations of earth station. There may also be satellite/earth terminal mutual interference effects. These effects include the interference caused by sidelobes if antenna interferes with an adjacent satellite or earth terminal equipment. Other sources of interference include ground microwave relay links, sun transit effects and intermodulation products generated in the transponder or earth terminal. It would be of importance to mention here that before 1983 the spacing between two geostationary satellites was established at 4° of the equatorial arc and the smallest earth station antenna for the simultaneous transmit-receive operation was 5m in diameter. Now a days the spacing allowed between two adjacent satellites in sapce is 2° along the equatorial arc instead of 4°. The closer spacing has allowed twice as many satellites to occupy the same orbital arc and therefore now all the earth station antennas are designed to accommodate this spacing of 2°.

1.6. Advantages of Satellite Communication

Communication through satellite has several advantages and disadvantages. Until the advent of communication satellites, the long distance communication through space could be done by using cascaded radio relays, very low frequency radio (below 30 kHz) and high frequency or short wave radio (3-30 MHz). The latter two are inherently low capacity media suitable only for specialized applications and the cascaded radio relays were limited to overland spans. Thus the satellite has filled a huge void in the sense that has been capable of transmitting high capacities over long distances, either overland or water. Also, because of its unique geometry, it is inherently a broadcast medium with a natural ability to transmit simultaneously from one pint to an arbitrary number of other points within its coverage area.

Some of the typical advantages of satellite communication are automatically derived when compared it with other kind of signal relay systems. Firstly the satellite relays are inherently wide-area broadcast, *i.e.* the *point-to-multipoint* whereas all the terrestrial

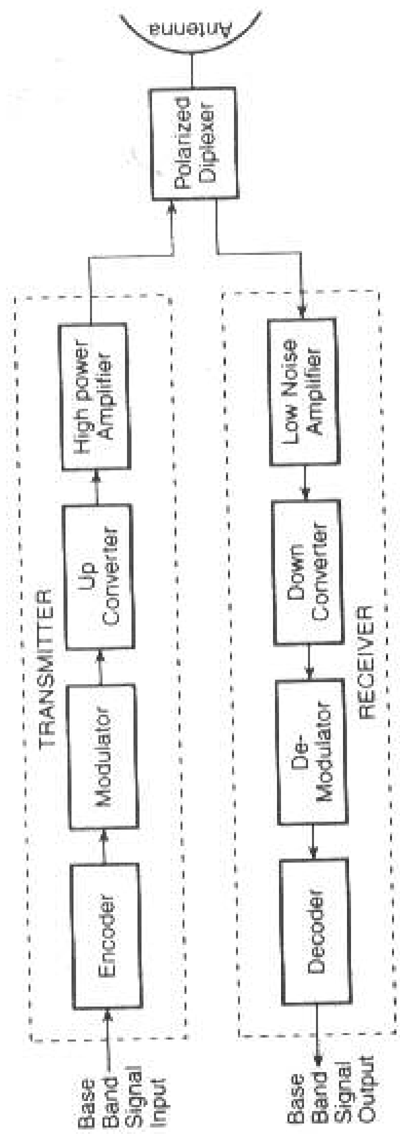

Fig. 1.2. Basic Block Diagram of an Earth Station.

relays are point-to-point. Secondly the satellite circuits can be installed rapidly. Once the satellite is in position, the earth stations can be installed and communication may be established in days or even hours. Thus a station may be removed relatively quickly from one location and reinstalled elsewhere. The terrestrial circuits of any kind would require a time consuming installations. The third advantage is that the mobile communication can be easily achieved by satellite communications as it has a unique degree of flexibility in interconnecting mobile vehicles. Thus the satellite has become an alternative to short wave radio in this specialised area and has significant reliability advantages (terrestrial networks may interconnect mobile vehicles by cellular radios).

The satellite communications has certain disadvantages as well. With the satellite in position the communication path between the terrestrial transmitter and the receiver is approximately 75000 km long. Since the velocity of em waves is 3×10^5 km/s, there is a delay of 1/4 second between the transmission and reception of a signal. Thus between talks there is an elapse of 1/2 second and one may feel it annoying. The delay exacerbates *echo* which actually is caused by an imperfect impedance matching. Thus there is an audible reflection with 1/2 second delay. Though a variety of echo suppressors have been deployed in satellite communications, one may still feel the echo. The above time delay of 1/2 second also reduces the efficiency of satellite in data transmission and long file transfers when carried out over the satellites.

Satellite communication, however, has the economical advantages. The satellite costs are independent of distance whereas the terrestrial network costs are proportional to the distance. The cross over distance at which the costs are equal is relatively much better with the satellite. However, if needed repair is nearly impossible after launching the satellite and also the equipments are subject to extreme environmental stresses. As compared to the fibre optic cable, the satellite communication has the advantage that the quality of transmitted signal and the locations of stations sending and receiving information are independent of distance. So long as two stations fall within the geographic coverage area of the satellite antenna pattern, those two stations maintain the same quality of information transfer whether they are 60 km or 2000 km apart.

It would be of importance to note that undersea copper cables have relatively limited capacities and when the undersea optical cable makes its first appearance it will provide for the first time an alternative way of transmitting wide-bandwidth signals across the ocean. For thin route remote area communications in the plains as well as hilly terrains like India's N-E region, Himachal Pradesh, Ladakh, Sikkim and communications between the Islands and the mainland satellite communication is the only cost-effective option. Similarly for search, rescue and navigation efforts satellites offer the advantages which no other systems can offer.

1.7. Active and Passive Satellites

The difference between a passive and an active communication satellite arises from the fact whether the communication relay (here satellite) involves passive reflection or an active electronics system. As mentioned in Section 1.1, the early project ECHO was a passive reflector (satellite) that consisted of a large reflector such as a spherical balloon. In the passive satellite system the ground transmitting system beams power at the reflector. The receiving ground system receives a fraction of the power that has been intercepted by the reflector and reradiated. In active satellite, the satellite receives a fraction of the energy beamed toward it by the ground transmitting system and the received power is amplified by active electronic means, usually in conjuction with frequency shifting. The power received by the ground receiving system is determined by the power level of the space craft transmitter.

The most important comparison of the communication capability of active and passive satellites is the amount of power radiated toward the receiving ground stations by the satellite. Actually the communication capability of active systems with directional antennas rapidly becomes much greater than that of the passive systems as the altitude is increased. Passive systems are incapable of competing with active systems with respect to communication capability except at low altitudes. Passive systems may have significant advantages for military systems because of the relative invulnerability of the satellites. However, the principal interest in the society is on systems that are capable of providing appreciable communication capability and hence the modern communication satellites are active satellite systems. Now a days space qualified reliable, long life electronic equipment are available and these have enhanced the capability of active satellite system.

1.8. From Analog to Digital Satellite Communication

For the first 20 years of satellite communications, analog signals were widely used, with most links employing frequency modulation (FM). Wideband FM can operate at low carrier-to-noise ratios (C/N) in the 5 to 15 dB range, but adds a signal-to-noise improvement so that video and telephone signals can be delivered with signal-to-noise ratios (S/N) of 50 dB. The penalty for the improvement is that the radio frequency (RF) signal occupies a much larger bandwidth than the baseband signal. In satellite links, this penalty is because signals are always weak and the improvement in signal-to-noise ratio is essential.

However, the rapid change in technology over the past fifteen years has been the transition from analog to digital transmission techniques. The move towards digital communications in terrestrial telephone and data transmission has been seen in a similar move towards digital transmission over satellite links. Thus, digital modulation is the obvious choice for satellite transmission of signals that originate in digital form and that are used by digital devices. In digital transmission, analog signals that are transmitted digitally can share channels with digital data, since all digital signals are handled in the same way, and their content is immaterial. Thus a digital satellite link can carry a mix of telephone and data signals that varies with traffic demand.

Today, virtually all signals sent via satellites are now digital. Familiar examples are data transmissions to and from the Internet, communication between remote terminals and computers, digital telephone, and TV signals in digital form, such as HDTV and DBS-TV. More importantly, dual standards permitting the transmission of not only digital TV but also high definition TV (HDTV), is eventually making analog TV obsolete. Even cable TV stations are switching over to digital receivers that allow many TV signals to be sent though use of single Ku-band. In addition, all LEO (low-earth orbit) and MEO (medium-earth orbit) mobile communication systems are digital, taking advantage of voice compression techniques that allow digital voice signal to be compressed into a bit stream at 4.8 kbits/sec (kbps). Similarly, MPEG-2 (Moving Picture Coding Expert Group) and other video compression techniques allow video signals to be transmitted in full fidelity at rates less than 6.2 kbps.

The advent of personal communication via LEO satellites and of direct broadcasting from satellites using digital transmission has resulted in the development of very small aperature terminal (VSAT) systems. The Global Positioning System (GPS) has become the dominate radio navigation aid and digital and mobile telephony. Domestic satellites now carry video signals for distribution to cable TV companies or direct to homes and serve networks of VSAT stations linked to central hubs in major cities. The development of direct to home satellite broadcast television (DBS-TV) has had a major impact on the market place. It is estimated that the worldwide revenue from all satellite communication services will increase from about 100 billion US dollars in 1990 to 200 billion US dollars in 2010.

The high capacity of digital satellites results from the use of high-power terrestrial transmitters and relatively high gain earth station antennas. Satellite communication systems are dominated by the need to receive very weak signals. In the early days, very large receiving antennas, with diameters up to 30m, were needed to collect sufficient signal power to drive video signals or multiplexed telephone channels. As satellites have become larger, heavier, and more powerful, smaller earth antennas have become feasible, and Direct Broadcast Satellite TV (DBS-TV) receiving systems can use dish antennas as small as 0.5 m in diameter. High earth station antenna gain now translates directly into communication capacity, and therefore into revenue. Increased capacity lowers the delivery cost per bit for a customer. Systems with fixed directional antennas can deliver bits at a significantly lower cost than system using low gain antennas, such as those designed for use by mobile users.

Satellite communication systems started in C band, with an allocation of 500 MHz, shared with terrestrial microwave links. As the GEO orbit filled up with satellites operating at C band, satellites were built for the next available frequency band, Ku band. There is a continuing demand for ever more spectrum to allow satellites to provide new services, with high speed access to the Internet forcing a move to Ka-band and even higher frequencies. Access to the Internet from small transmitting Ka-band earth stations located at the home offers a way to bypass the terrestrial telephone network with the Astra-K satellite, and the next generation of Ka-band satellites in the United States will offer similar services.

The World Radio Conferences of the International Telecommunication Union (ITU) have allocated new frequency bands for commercial satellite services that now include, L, S, C, Ku, K, Ka, V, and Q bands. Mobile satellite systems use VHF, UHF, L, and S band with carrier frequencies from 137 to 2500 MHz, and GEO satellites use frequency bands extending from 3.2 to 50 GHz.

Despite the growth of fiber-optic links with very high capacity, the demand for satellite systems continues to increase. Satellites have also become integrated into complex communications architectures that use each element of the network to its best advantage. Examples are VSAT/WLL (very small aperture/terminals local loop) in countries where the communications infrastructure is not yet mature and GEO/LMDS (local multipoint distribution systems) for the urban fringes of development nations where the build-out of fiber has yet to be an economic proposition.

With the fast development in digital electronics technology, access techniques and possibility of expanded communication network, digital signalling techniques have been introduced in communication by satellites. The advantages of digital signal transmission are now very well established and can be easily numbered as[8] (*i*) the ease and efficiency of multiplexing multiple signals or handling digital messages in 'packets' for convenient switching ; (*ii*) the relative insensitivity of digital circuits to retransmission noise, commonly a problem with analog systems, (*iii*) potential for extremely low error rates and high fidelity through error detection and correction, (*iv*) communications privacy and (*v*) the flexibility of digital hardware implementation, which permits the use of microprocessors and miniprocessors, digital switching and the use of large scale integrated circuits (LSI). Thus the digital transmission techniques have gained increased usage for satellite communication, microwave relay, and cable or waveguide transmission. In laser satellite communication too digital techniques have been successfully utilised.

Though the various digital modulation techniques will be discussed in later chapter, it may be mentioned here that in analog communication systems, frequency division multiplexing-frequency modulation-frequency division multiple access (FDM-FM-FDMA) has been widely used and it provided good quality satellite links. But here the number of earth stations is limited. A digital satellite system such as that using 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. Further the system can quickly respond to traffic variations. A further increase in efficiency can be easily obtained by using the techniques known as demand assignment and digital speech interpolation. The advanced satellite systems that use onboard switching and processing, multiple spot beams and beam hopping use the digital communication techniques and such digital systems are capable of serving a mixture of large, medium and small earth stations with high efficiency. The recent technique of code division multiple access has allowed to employ micro earth stations (0.5 m antenna) at an extremely low cost ($ 3000) with a good quality service. ISDN systems will further enhance the importance of digital communication networking with satellites.

1.9. Modem and Codec

The equipment that carries out modulation (MOD) and demodulation (DEMOD) is called *modem*. Similarly the equipment responsible for carrying out coding and decoding is termed *codec*. These two devices are widely used in digital satellite communication. Modem is used as an interface between analog and digital systems. These play an important role in computer communication networks and ISDN systems. Codecs are used in digital television systems and normally consists of a pair of A/D converter and D/A converter. It is a kind of black box digital device as shown in Fig 1.3.

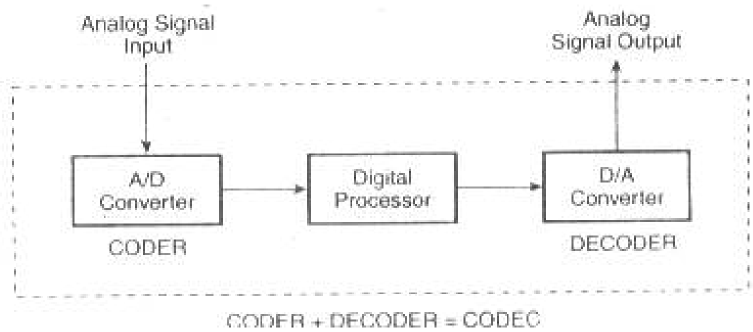

Fig. 1.3. Basic Block Diagram of Codec.

1.10. Review Questions

1. What is a satellite and how does a communication satellite differ from a communication relay ?
2. Explain the basic differences between an active and passive satellite systems. Discuss their merits and demerits.
3. Prove that for covering the globe three communication satellites would be sufficient.
4. What is the difference between a geostationary satellite and a low altitude satellite ? Can a low altitude satellite be also used for communication purposes ? If not why?
5. List various frequency bands being used in satellite communication. Compare the advantages and disadvantages of different bands considering the effects of propagation media.
6. Give the reasons as to why the uplink frequency is different than the down link frequency. Also mention the reasons for keeping uplink frequency higher than the downlink frequency.
7. What are the elements of satellite communication system ? Explain each with a suitable block diagram.
8. List various advantages and disadvantages of satellite communication. Give the reasons that optical fibres inspite of being high bandwidth channel, satellite communication has an edge over it.
9. What are the advantages of a communication system that uses digital signal transmission ? Explain as to how the digital satellite communication has reduced the size of earth station?

10. What are Modem and Codec ? Both are A/D and D/A converters but what makes the difference between the two? Mention the areas of their applications.

1.11. References

1. Clarke, A.C., Extraterrestrial Relays, Wireless World, 51 (1945), 305-308.
2. Pratt, T. and Bostian, C.W., Satellite Communication, John Wiley and Sons, NY, 1986.
3. Ha, T.T., Digital Satellite Communication, H.W. Sams & Co., NY, 1986.
4. Feher, K., Advanced Digital Communications, Prentice- Hall Inc., 1987.
5. Morgan, W.L., Satellite Locations-1984, Proc IEEE, Vol 72, No 11, Nov 1984, pp 1434-1444.
6. Williams, D.D., Synchronous Satellite Communication Systems, in Advances in Communication Systems, Theory and Applications, Ed. A.V. Balkrishnan, Vol 2, p. 151-171, Academic Press, NY, 1966.
7. Jordan, E.C. (Ed). Reference Data for Engineers, Radio, Electronics, Computers and Communication, H.W. Sams and Co., Indianapolis,USA, 1986.
8. Spilker, J.J., Digital Communication by Satellites, Prentice Hall Inc., NJ, 1977.

Other Suggested References

1. Bharagava, V.K., Haccoun, D., Matyas, R. and Nuspe, P.P., Digital Communications by Satellite, Wiley Interscience Publication, NY, 1981.
2. Lebow, I.L., Satellite Communications, in Digital Communications (Ed Bartree, T.C.). H.W. Sams & Co., 1986.
3. Maral, G. and Bousquet, M., Satellite Communications Systems, John Wiley & Sons, 1986.
4. Yuen, J.H. (Ed). Deep Space Telecommunications Systems Engineering, Plenum Press, NY, 1983.
5. Jefferis, D. Watts, Satellites, USA, 1987.
6. Elbert, V.B.R. Introduction to Satellite Communication, Artech House, 1987.
7. Lewis, G.E. Communications *via* Satellites, Blackwell Scientific, 1988.
8. Jansky, D.M. and Jeruchim, M.C., Communication Satellites in the Geostationary Orbit, Artech House, Inc., 1987.
9. Wu, W.M., Elements of Digital Satellite Communications, Computer Science Press, NY, 1984.
10. Gagliardi, R.M. Satellite Communication, Van Nostrand Reinhold, 1987.