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Radar and Navigation

12·1. Introduction

The term radar stands for Radio Detection And Ranging. It is basically a means of collecting information about distant objects or targets by sending electromagnetic waves to them and picking up the waves reflected back by these objects. It consists of a radar transmitter capable of transmitting a large UHF or microwave energy through a highly directional antenna. The energy reflected back by the object is now picked up by the same directional antenna and given to the receiver, which processes this signal and displays this information in a suitable manner. Generally, the same antenna is switched between transmitter and receiver.

Navigation is the art of directing the movement of a craft from one point to another along a desired path. The modern navigation uses different types of electronic navigational aids. These systems depend upon placing radio-transmitters and receivers at known locations on earth's surface and working in conjunction with transmitters/receivers placed in the craft. The system thus involves a dependence of the craft on radio installations on land and is not a self-contained system of navigation.

12·2. Basic Radar Systems

There are basically two radar systems : the pulsed radar and the CW radar. The *pulsed radar* consists of a transmitter which generates short rectangular pulses of energy in response to an internally generated trigger pulse. This pulse is fed to a *duplexer* which disconnects the receiver from the antenna and connects it to the transmitter. Thus, the antenna is switched between the transmitter and the receiver by the duplexer. The antenna is highly directional and moves around in a predetermined pattern, scanning the entire area around the radar. The scanning speed is mechanically high but it is small compared with the time taken by the pulses to retnrn

from a target. Thus, when a pulse is received back from a target, the antenna still points in the right direction to pick them up.

As the transmitted pulse terminates, the duplexer disconnects antenna from the transmitter and connects it to the receiver so that the pulses received back from the target by the antenna are passed on to the receiver. These pulses are amplified, demodulated and given to a device that displays them.

The radar gives the position of the target. The information about the *azimuth* (horizontal direction) and the *elevation* (vertical direction) are avaiable from the radar antenna. The distance of the target from the radar can be determined from the time taken by the pulse to travel from the radar to the target and back to the receiver. Since the velocity of electromagnetic wave is known (3×10^8 metres/sec) and also since the pulse travels twice the distance of the target, we can very easily say that corrersponding to a time of 1μ sec for the pulse to travel to and fro, the distance of the target is 150 metres.

The second type of radar is the *C.W. radar* which transmits continuous sinusoidal electromagenetic waves rather than pulses. These waves are reflected back by the target and picked up by a separate antenna which sends these pulses to the receiver for processing.

12·2·1. Radar Range. The maximum range of a radar is basically dependent upon the power in the received echo pulses and the miximum signal strength required by the receiver for satisfactory reception.

For an isotropic antenna with peak transimitted power P_T, the power density (p) at the target at a distance R from the antenna is given by equation 12·1.

$$(p)=\frac{P_T}{4\pi R^2} \qquad \text{..(12·1)}$$

Since the antenna is directional, it has a power gain G_T and power density at the target is

$$(p)=\frac{P_T \cdot G_T}{4\pi R^2} \qquad \text{...(12·2)}$$

Total power intercepted by the target depends upon its cross-sectional area. If this is (S), the power intercepted by the target is given by equation 12·3

$$P=\frac{P_T.G_T.S}{(4\pi R^2)^2} \qquad \text{...(12·2)}$$

As this energy travels back, it is picked up by the receiver antenna and the total energy picked up by this antenna is dependent upon its *capture area or aperture*. If this area is A_e, then receiver power P_R is given by equation 12·4.

$$P_R=\frac{P_T.G_T.S.A_e}{(4\pi R^2)^2} \qquad \text{...(12·4)}$$

Maximum radar range (R_{max}) may be determined from equation 12·4 and is given by equation 12·5.

Thus, $R_{max} = 4\sqrt{\dfrac{P_T.G_T.S.A_e}{16\pi^2 P_{R(min)}}}$ ...(12·5)

If same antenna is used for transmission and reception, then (G_T) and (A_e) are related as

$$G_T = \frac{4\pi A_e}{\lambda^2} \quad ...(12·6)$$

and

$$R_{max} = \left(\frac{4\pi A_e}{\lambda^2} \times \frac{P_T.S.A_e}{16\pi^2 P_{R(min)}}\right)^{\frac{1}{4}}$$

$$= \left[\frac{P_T.S A_e^2}{4\pi\lambda^2 P_{R(min)}}\right]^{\frac{1}{4}} \quad ...(12·7)$$

Alternatively

$$R_{max} = \left[\frac{P_T.G_T.\lambda^2 S}{(4\pi)^3 P_{R(min)}}\right]^{\frac{1}{4}} \quad ...(12·8)$$

12·2·2. Antenna Scanning. As already stated, the radar antennas are often made to scan the surrounding space. Some typical scanning patterns are shown in Fg. 12·1.

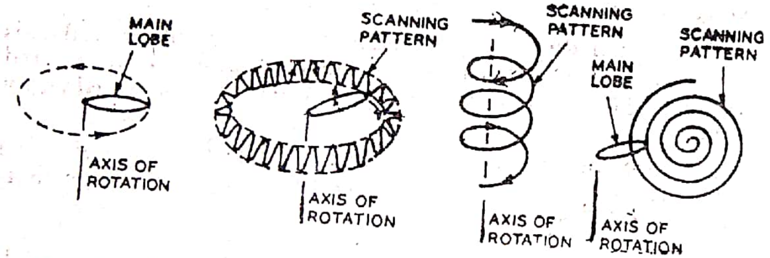

Fig. 12·1. Typical antenna scanning patterns (*a*) horizontal (*b*) nodding (*c*) helical (*d*) spiral.

The first method of scanning is shown in Fig. 12·1. (*a*). This is simplest and is used to scan the horizon. It is used in ship to ship radar. The scanning is done in the horizontal plane only. An extension of this method is to cause the scanning beam of Fig. 12·1. (*a*) to move in the vertical plane cyclically while it is scanning in the horizontal plane. The resultant scanning pattern is shown in Fig. 12·1 (*b*). This system is capable of scanning in both the planes and may be used to scan a limited sector or to cover the complete hemisphere. The scanning pattern of fig 12·1. (*c*) provides helical scanning. In this system, the height of the antenna is raised slowly while it is rotating in the horizontal direction. After the completion of scanning cycle, the antenna is quickly returned to its staring point. The spiral scanning is shown in Fig. 12·1. (*d*) and is useful when a limited area of more or less circular shape is to be scanned.

12·3. Pulsed Radar System

Fig. 12·2 shows the outlines of a typical high power pulsed radar. The triggering circuit provides trigger pulses to the modulator.

The modulator stage switches ON/OFF the supply voltage to the output tube. Thus, the output tube is switched ON/OFF and this

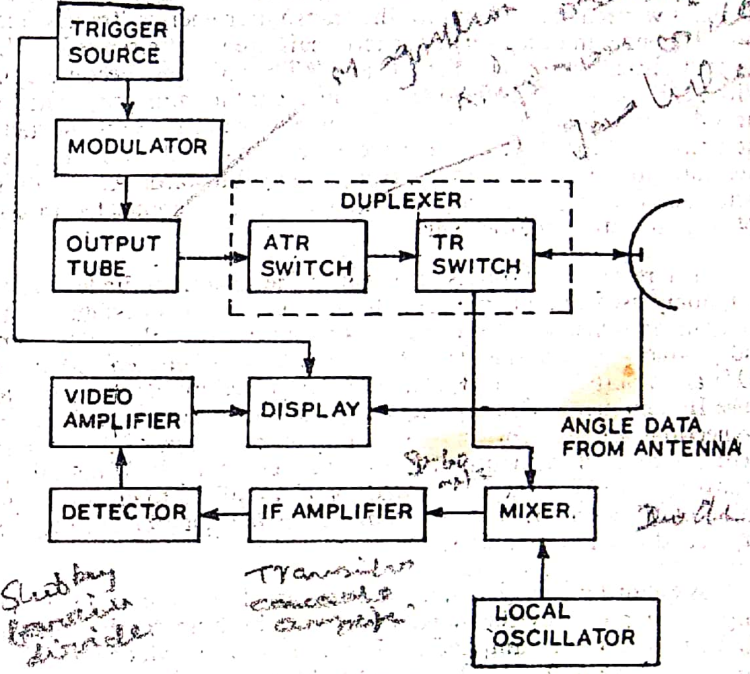

Fig. 12·2. Block diagram of a high power pulsed radar.

switching is carried out by the trigger source through modulator stage. The output tube is usually a magnetron oscillator, though in some cases a multicavity klystron or travelling wave tube may also be used. In the latter cases, a microwave source has to be used to supply input signal drive to these amplifier tubes. The high power pulse is given to the duplexer.

The duplexer switches the antenna between receiver and transmitter. It has two switches, the TR and ATR. (Fig. 12·31) These switches are so arranged that the transmitter and receiver are alternately connected to the antenna but they are never connected to each other. These switches are basically gas tubes which act as short-circuit when a voltage appears across them and remain open-circuit in the absence of voltage.

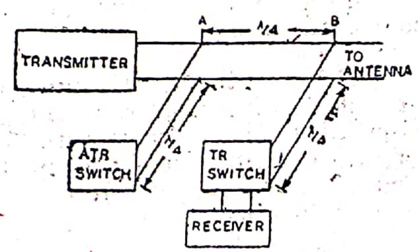

Fig. 12·3. Branch-type duplexer in a radar.

With the transmitter output pulse, both these switches become short-circuited. Thus the two $\lambda/4$ waveguide sections joining these switches to the main waveguide have short-circuited terminations and therefore offer infinite impedance at their junctions to the main waveguide. Therefore the transmitter energy travels freely to the antenna and receiver input terminals are short-circuited. When the transmitted pulse ends, the TR and ATR switches become open. With ATR switch offering open-circuit load, the input impedance of the $\lambda/4$ section becomes zero and thus the wave guide is shorted at the point A. Impedance of the waveguide at point B is infinite and therefore no energy can travel from point B towards A. With TR switch acting as open-circuit, the receiver is now connected through $\lambda/4$ section to the radar antenna.

The received echo-pulse is given to the mixer. A diode mixer is commonly used for this purpose, since it has a low noise figure. The mixer heterodynes the local oscillator output and the signal input and produces an intermediate frequency lying between 30 to 60 MHz at its output. The IF signal is amplified by a high gain low noise IF amplifier. Usually transistor amplifier stages with cascade connections are used for this purpose. An advantage of this arrangement is that need for neutralization in order to avoid *Miller effect* is removed. The IF stage is a broad band amplifier to ensure amplification of fairly narrow pulses. *Stagger tuning* may be used to meet large bandwith requirements.

A Schottky barrier divide is often used as a detector and its output is amplified by the video amplifier. This amplifier has the same band-width as the IF amplifier. The output of the video amplifier is fed to a display unit. CRT is commonly used for this purpose.

The output of a radar receiver may be displayed by one of the three ways. These are—

(*a*) deflection modulation of a CRT screen or A-Scope.

(*b*) intensity modulation of a CRT or plan-position indicator (PPI)

(*c*) feeding the signal to a computer.

Information regarding height, speed or velocity may be shown on separate meters.

12·3·1. A-Scope. The operation of this display is quite similar to that of an ordinary cathode ray oscilloscope. A linear sweep is applied to the horizontal deflection plates and moves the beam-form left to right. The frequency of the sweep waveform is made same as the *pulse repetition frequency* of the transmitted pulse. The flyback is blanked as usual.

In the absence of any target, there is no reflected pulse and the display is simply a horizontal line, but when a pulse is reflected from

a target, it is processed by the receiver and displayed by the CRT, as shown in Fig. 12·4. The receiver does not discriminate between a flying object like aeroplane or stationary objects, like tall buildings or hills etc and displays the received pulses, as shown in the Figure. While the position of the moving object displayed on the CRT screen will be changing from time to time, the stationary objects will be displayed at fixed positions. Since the time period of the sweep is fixed for a radar, the horizontal movement of the beam may be calibrated to give the range of the radar and marked in kilometers. Sometimes, a particular section of the scan may be expanded to give more accurate indication of a particular area. In some cases, marker pips are used for more accurate distance measurement.

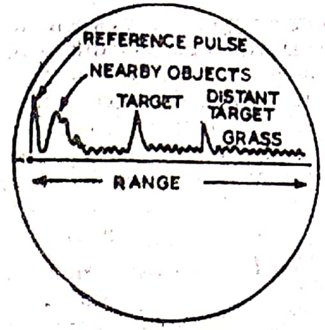

Fig. 12·4. A—Scope display.

A-Scope display is not suitable for search radars but may be used for tracking.

12·3·2. Plan-Position Indicator (PPI). This display shows a map of the target area. The signal output of the receiver is given to the control grid of the CRT so that the beam gets intensity modulated. The grid is biased beyond cut-off and thus screen areas corresponding to targets are brightened up. The deflection of the beam is achieved with application of saw-tooth current to horizontal and vertical deflection coils. The deflection yoke, which is similar to that of a deflection yoke of a TV picture, is rotated in synchronism with the radar antenna. As a result, the beam is not only deflected radially outwards, starting from the centre, but also rotates continuously across the CRT screen there by covering the entire screen. The presence of any object is indicated by a bright spot on the screen which shows the position of the object on the target area. The range is measured radially out from the centre to the brightened spots.

CRT employed for this radar display has a phosphor with long persistence. This ensures that the screen of the PPI display does not flicker because the scanning speed is quite low as compared to the TV field frequency of 52 Hz. The resolution of the display is dependent upon the beam-width of the transmitted energy, pulse width, the transmitted frequency and area of the CRT screen. For this reason, CRT's with large screens (39 to 40 cm) are employed.

The PPI is particularly suitable for search radars, especially when conical scanning is employed.

12·3·3. Search Radar. General outlines of a pulsed radar have already been given. When a radar is used to cover an all around area and search for an unknown target, it is called a search-radar. Such a radar should be capable of scanning a large volume of space to

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acquire a target. Thus scanning must be done rapidly. For this, an antenna with a beam-width which is not too narrow is used since a narrow beam would take a long time to scan the large volume of space. Once the target is approximately located, then a narrow beam of electromagnetic energy is sent to find its exact location. This can be done either by reducing the beam-width of the same transmitting antenna or by passing the information of the target from their radar to another radar which has a narrow beam-width. Such a radar is termed as *tracking radar*.

12·3·4. Tracking Radar. Once a target has been located by a search-radar, it may then be tracked. For this purpose, radars with pencil beam radiation are used. A radar that is used purely for tracking may employ conical scan or monopulse system. A radar that provides angular information of the target accurately is said to be *tracking in angle*. If it provides range information continuously and accurately, it is said to be *tracking in range*.

In ground and shipborne use, there is sufficient space available and separate search and tracking radars may be employed. In aeroplanes, the availability of space is limited and generally the same radar is used for search as well as tracking.

12·4. Moving Target Indicator (MTI)

In PPI display, there is a lot of *clutter* due to echoes corresponding to stationary targets. When it is desired to remove this *clutter* or grass from the display, MTI or *moving target indicator* may be employed. The MTI makes use of *Doppler effect* for its operation.

12·4·1. Doppler Effect. The apparent frequency of electromagnetic or sound waves is dependent upon the relative motion of the source and the observer. To understand this phenomenon, consider an observer standing on a platform approaching a fixed source of radiation with a relative velocity $+v_r$. If both the observer and the source of energy are stationary and the frequency of radiation is f_t, then he would note f_t crests of wave per second passing beyond him. If he is moving forward at a velocity v_r, he will come across more than f_t crests per second. The number of crests observed under this condition is given by

$$f_t+f_d=f_t\left(1+\frac{v_r}{v_c}\right) \qquad \ldots(12\cdot9)$$

where v_c is the velocity of the wave and f_d is the Doppler frequency difference or shift.

In radar, the signal undergoes the Doppler frequency shift when impinging upon a moving target. As this target reflects the waves, we may consider it as a moving source, transmitting energy towards a stationary observer. Thus we have another Dopper shift. Hence Doppler frequency in a radar is given as

$$f_d=2f_d'=\frac{2v_r \cdot f_t}{v_c} \qquad \ldots(12\cdot10)$$

$$=\frac{2v_r}{\lambda} \qquad \left(\because \frac{f_t}{v_c}=\lambda\right)$$

It should be noted that this Doppler frequency shift will take place only if the target moves radially and not in *tangential* motion.

The Doppler frequency shift may be used to determine the relative velocity of the target. Thus moving targets can be distinguished from stationary targets on the basis of Doppler frequency shift.

12·4·2. MTI Principle. In principle, a moving target indicator system compares a set of received echo pulses with those received during the previous sweep. The echoes belonging to the stationary targets cancel out while those corresponding to moving targets do not cancel and show only a phase change. Thus, the clutter is completely removed from the display and it reduces the time taken by the operator to observe the target. It allows easy detection of moving targets whose echoes are hundreds of times smaller than those of nearby stationary targets. This would not have been possible without the use of MTI. Block diagram of a MTI radar is shown in Fig. 12·5.

The radar transmitter frequency in the MTI system, shown in Fig. 12·5, is given by the sum of two oscillators produced at the out-

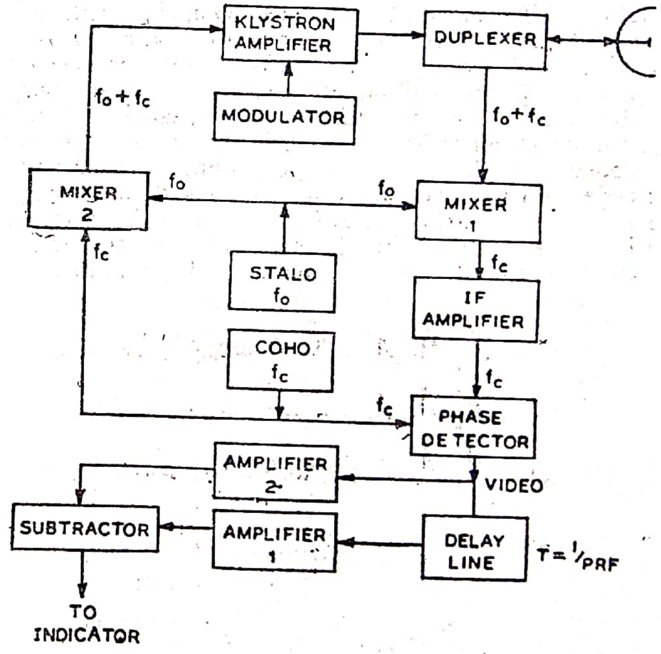

Fig. 12·5. Block diagram of MTI radar with klystron output tube.

put of mixer 2. The first of these oscillator is the *STALO* which stands for *stable local oscillator* and oscillates at a frequency f_0. The other oscillator is the *COHO* or *coherent oscillator*, oscillating at a frequency f_c. This frequency is the same as the intermediate frequency

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of the receiver and for this reason it is termed as the coherent frequency. The sum frequency (f_0+f_c) is given as input signal to the output tube which is a multicavity klystron amplifier in this case. This amplifier amplifies the signal and provides a high power pulse when modulator switches on this tube. The transmitter output pulse is passed on to the antenna through the duplexer

The transmitted pulse is received back by the radar antenna after its reflection from the target. In case of a moving target, the received pulse undergoes a doppler frequency shift. The received pulses are passed on to the mixer 1 of the receiver. The mixer heterodynes the received signal of frequency (f_0+f_c) with the output of the *STALO* at f_0 and gives the output at the difference frequency f_c. The stages Mixer 1 and Mixer 2 are similar in all respects except that the output frequencies are different. It is the difference frequency in Mixer 1 and sum freqnency in Mixer 2.

The difference frequency signal present at the output of Mixer amplified by the IF pmplifier and given to the phase sensitive detector, This detector compares this IF signal with the reference signal obtained from COHO stage and gives an output depending upon the phase difference between the two signals. Since all received signal pulses will have a phase difference compared with the transmitted pulse, phase deteceor gives output for stationary as well as moving targets. While the phase shifts for the stationary targets remain constant, for moving targets phase shifts are changing. This happens because of Doppler effect in moving targets. A change of half cycle in the doppler frequency shift would cause an output of opposite polarity in the phase detector output. Thus the output of the phase detector will have an output that has different magnitudes and polarities for successive pulses in case of a moving target whereas in fixed targets the magnitude and polarity of the output will remain the same for all transmitted pulses as shown in Fig. 12·6.

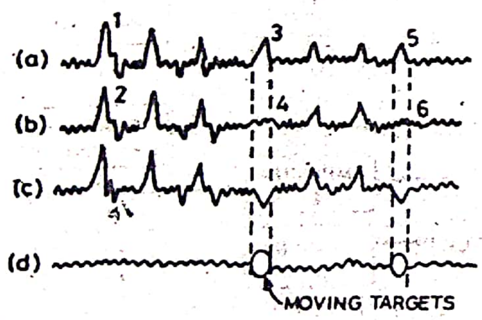

Fig. 12·6. (*a*) (*b*) and (*c*) Phase detector output for three successive pulses (*d*) subtractor output

The video output of the phase detector so obtained is applied to a delay line which has a delay time that exactly corresponds to the time period of the transmitted pulses. The delayed output is amplified by amplifier 1 and given to the *subtractor*. At the same time the undelayed video output of the detector is also amplified and given to the subtractor. For a stationary target signal pulse, such as

(1) in Fig. 12·6 (*a*), the delayed pulse at the subtractor input will be (2) of the Fig. 12·6 (*b*) and when subtracted these will cancel out each other, as shown in Fig. 12·6 (*d*). However for moving target pulses, as shown in Fig. 12·6 (*a*) (3 and 5), the delayed pulses and the following pulse will have different magnitude/phase and will not cancel each other when subtracted in the subtractor circuit. As a result, the subtractor output for moving targets is shown by the display, as given in Fig. 12·6 (*d*).

12·5. CW Doppler Radar

The radar systems discussed in the provions sections have their operations based upon transmission of pulses of high energy and reception of reflected pulses from the target. The CW radars, on the other hand, transmit electromagnetic waves continuously towards the target and there is a continuous reflection of these waves from the targets. It was possible to use a single antenna for transmission and reception in pulsed radars and this was acheived with the duplexer switch. In CW radars on the other hand the transmitted and reflected waves propagate simultaneously and, as such, separate antennae are required for transmission and reception.

The CW radar makes use of Doppler effect for speed measurements of targets. Fig 12·7 shows the block diagram of a CW Doppler radar.

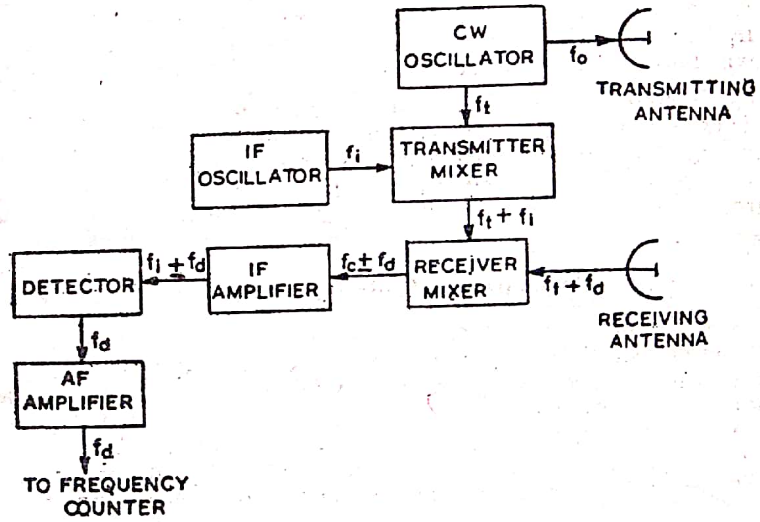

Fig. 12·7 Block diagram of a CW Doppler radar

The transmitter section is a low power microwave oscillator such as reflex klystron that generates sinusoidal signals in the microwave range. This signal is transmitted by the transmitting antenna. A small fraction of the transmitter signal is fed to the transmitter mixer, to which is also fed the IF signal generated by IF oscillator. Sum of the transmitter signal frequency (f_t) and the IF signal (f_c) is selected at the output of the transsmitter mixer.

The receiver antenna picks up the waves reflected from the target and for moving targets, the received signal frequency equals $f_t \pm f_d$. This signal is given to the receiver mixer where it mixes with the output of the transmitter mixer. At the output of the receiver mixer is obtained the difference frequency signal at $(f_c \pm f_d)$. This signal is amplified by the IF amplifier and given to the detector stage. The detector circuit recovers the Doppler frequency from the IF signal and passes it to the AF amplifier where it is amplified. The amplified signal is given to a frequency counter. Since the Doppler frequency shift f_d is proportional to the velocity of the target, the output of the counter gives an indication of the target speed. The frequency counter is so designed that at its output the target speed is displayed directly in Kilometre/hour rather than showing the Doppler frequency. However the display does not give indication as to whether the target is approaching or receding, because sign of the Doppler frequency shift is lost. The CW Doppler radar is not capable of giving the range of the target.

An important advantage of CW Doppler radar is that it uses low transmitting power, low power consumption, simple circuitry and small size. This makes it mobile. It can be used to give accurate measurement of relative velocity of the target and the reading obtained is unaffected by the presence of stationary objects. It is capable of measuring a large range of target velocities from a very low value to a high value quickly. The most common application of CW Doppler radars is in checking the speeds of vehicles and for this purpose it is widely used by Police. It is also used in aircraft navigation for speed measurement and as rate-of-climb meter.

In spite of these applications, it has certain drawbacks. Firstly, it is limited in the maximum power it transmits and this places a limit on its maximum range. Secondly, it is not capable of indicating the range of the target and can show its velocity only. Lastly, if a large number of targets are present, then it gets confused rather easily.

12·6. Frequency Modulated CW Radar

CW Doppler radar cannot give the range of a target, because the transmitted signal is unmodulated. As a result, the receiver cannot sense which particular cycle of oscillations is being received at a moment. If the transmitted carrier is frequency modulated, than it should be possible to eliminate this main drawback. Using frequency modulation will however increase the bandwidth and thus it is seen that for conveying more information, more bandwidth is required.

Fig 12.8 shows the block diagram of a *frequency modulated* CW radar used in aircrafts for measurement of their altitudes. For this reason, it is commonly named as *airborne altimeters*. Here a saw tooth wave is used for frequency modulating CW carrier. The other types of waveforms might also be used as modulating signal but the saw-tooth waveform gives the simplest circuit arrangement. Thus the frequency of the transmitted signal increases linearly with the increasing amplitude of the modulating signal. It this case the target is the Earth which is stationary with respect to the aircraft.

Since increase in the amplitude of modulating signal is uniform with time, therefore the rate of increase in frequency in the trans-

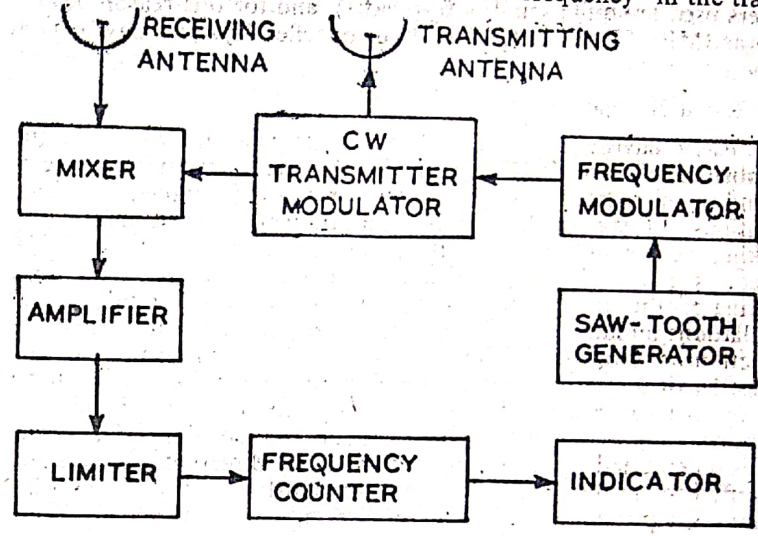

Fig 12.8. Block diagram of FM-CW radar

mitted signal brought by the modulating signal is also uniform with time. For a given height of aircraft, a known time will be required for the waves to travet from earth to the aircraft, thus during this time a definate change in signal frequency will take place. Viewing it the other way if we are able to measure the frequency change in the signal, it will give an indication of the height of the aircraft. Thus suppose we switch on a frequency counter just when the modulating signal has zero frequency *i.e.* the transmitted frequency equals (f_c). This signal frequency is picked up after its reflection from earth and may be used to switch-off the counter. The final reading of the counter will give an indication of the change in the frequency and hence about the height of the aircraft. This is indicated by the indicator connected in the receiver.

Now let us consider the case when the relative velocty of the aircraft and the earth is noth zero. This will produce another frequency stift due to the Doppler effect and this frequency shift will be supesimposed on the frequency difference discussed in the preceding paragraph. This frequency rhift can now be used to measure the relative velocty of the aircraft in the same way is in Doppler radar. However, the time difference between the transmission and reception of a particular cycle of the signal will be constant and hence the average frequency difference will also be constant. Therefore correct height measurement can still be made on the basis of average frequency difference.

The major application of FM-CW redar is as altimeter in aircrafts and because of short range involved, it is used in preference to pulsed radars. Another advantage is that it has quite a low power requirement as compared to pulsed radars. The size of this equipment is small and quite suitable for aircraft installations. Because

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reflection has to take place from earth which has a large size as compared to aircraft a small size can be used. The transmitting powers used are quite small (a few watts) and for this reason devices such as IMPATT diode, GUNN diode or reflex klystron may be used in the transmitter.

12.7 Radio Navigational Aids

Radio navigational aids utilize electromagnetic waves to find the position of an aircraft or a ship. All the navigational systems depend upon radio transmitters and or recivers installed at known loceations on the earth's surface and transmitters and or receivers working in conjunction with them in the aircraft or ship. The system is not self contained as it involves a dependence of the working of the radio equipments installed in the aircraft/ship or installations on land. All these systems depend upon the properties of rectilinear propagation and constant velocity of electromagnetic waves. Navigational parameters like direction, distance etc. by direct or indirect measurement of delay occuring between transmission and reception of waves. Information about the position of aircraft/ship is determined from the measurement of direction, distance and the difference in the distance of two transmitters. In the following sections, the principles underlying in a number of such systems are discussed.

12.8. Radio Direction Finding

Radio direction finding is the earliest method of electronic navigational aids and is even now widely used in ships and aircrafts. Electromagnetic waves travel along the great circle path and the direction finding helps to locate the transmitter along a great circle. A direction finder may be installed on ground or in an aircraft/ship. In the first case, the direction finder finds the bearing of the aircraft/ship and passes on the information to the vehicle concerned through a radio communication network. In the latter case, the position of the aircraft/ship is fixed after taking the bearing of two or more fixed transmitting stations.

Radio direction finding is used in LF/MF, HF and VHF ranges of frequency spectrum. In the present, the discussion shall be limited to direction finding using antenna and Adcock antenna.

12·8·1. The Loop Antenna. The loop antenna is used in direction finding in long and medium frequency ranges. To understand the action of loop antenna in direction-finding, consider a rectangular loop antenna having a length 'a' and width 'b' placed in a vertical plane, as shown in Fig 12·9. (a). The plane of the loop can be rotated about the vertical axis, so that it makes an angle θ with the east-west axis, as shown. Assume that a vertically polarized electromagnetic wave is incident on it from the eastwards direction. If the source of electromagnetic wave is far away from the loop, then a plane wavefront is incident at the loop. Since the wave is vertically polarized, it induces voltages in the vertical members of the loop only and there is no induced voltage the horizontal members. If 'ϵ' is the electric field magnitude, then voltage induced in AB and CD equals $a.\epsilon$ volts. The magnitude of the induced voltages across the two arms

is equal, but they have a phase difference. It the electric field at the centre of the loop is taken as reference, then voltage induced in arm CD leads the reference field by an angle ϕ, whereas the voltage induced in AB lags the reference field by an angle ϕ. The phase lag results due to the additional path length $\frac{1}{2}\,b\cos\theta$.

$$\phi=\frac{2\pi}{\lambda}\left(\frac{1}{2}b\cos\theta\right)$$

$$=\left(\frac{\pi}{\lambda}\,b\cos\right) \qquad \text{...(12·11)}$$

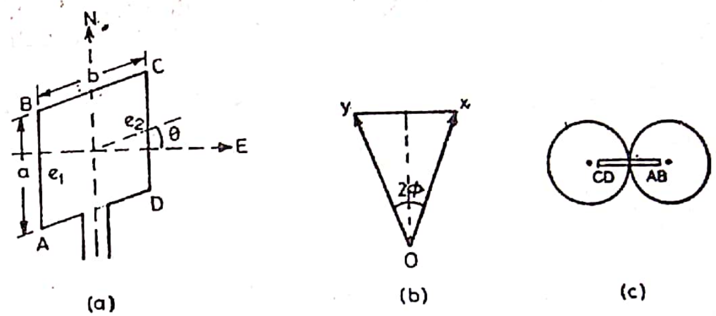

Fig. 12·9. (a) Rectangular loop antenna (b) phasor diagram and (c) polar diagram

If the electric field at the centre of the loop is $\epsilon\,(t)=\sqrt{2}\epsilon\cos\omega t$, then voltage induced in AB and CD is given by

$$e_1=\sqrt{2}\,a\epsilon\cos\left(\omega t-\frac{\pi}{\lambda}\,b\cos\theta\right)$$

and

$$e_2=\sqrt{2}\,a\omega\cos\left(\omega t+\frac{\pi}{\lambda}\,b\cos\theta\right) \qquad \text{...(12·12)}$$

The resultant voltage across the loop is the difference of e_1 and e_2

$$e_L=e_1-e_2=\sqrt{2}a\epsilon\left[\cos\left(\omega t-\frac{\pi}{\lambda}\,b\cos\theta\right)-\cos\left(\omega t+\frac{\pi}{\lambda}\,b\cos\theta\right)\right]$$

$$=\sqrt{2}\,a\epsilon\,2\sin\left(\frac{\pi}{\lambda}\,b\cos\theta\right)\sin\omega t \qquad \text{...(12·13)}$$

This voltage is represented by phasor XY in Fig. 12·9 (b). The voltage e_L is in phase quadrature with the reference electric field and its magnitude depends on angle θ. When θ is $\frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}\ldots$ $e_L=0$. If the width 'b' is very small compared with the wavelength λ, then

$$\text{Sin}\,\frac{b\pi}{\lambda}\cos\theta\approx\frac{\pi b}{\lambda}\cos\theta$$

and

$$e_L=\sqrt{2}\epsilon\,\frac{2\pi}{\lambda}\,ab\cos\theta\sin\omega t$$

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SATELLITE COMMUNICATIONS

13.1. Introduction

Communication plays an important role in economic and industrial development of a country. Today's world communication mostly depends on communication satellite which are a unique feature of space communication. The idea of satellite communication was desgined by great scientist Arthur C. Clarke in the year 1945. Communication through satellites is the strongest means of communication for cable communication, microwave communication, optical fibre communication, tropo-scatter communication, etc.

Communication satellites can be divided into two types. The first type called *passive satellites* and the second types is called the *active satellites*. The passive satellites are like a balloon. Passive satellites do not have any type of equipments they do not use any kind of electrical energy. They act only as reflectors in space for reflecting the signals transmitted from ground stations. These reflection signals are received at various satellites ground stations. The first passive satellite was ECHO-1 launched in the year 1960. The biggest drawbacks of passive satellites was requirement of very high transmitting power of ground station. Passive satellites could not be found useful and after ECHO-2, they were never sent in space.

Now a days only active satellites are used. These active satellites are equipped with various microwave receiving and transmitting equipments. Active satellites need power for operating these equipments which is derived from the sun (solar energy). The solar cells are used as energy in these satellites. The solar cells converts the solar energy into electrical energy. Availability of solar fuels decides the life of a particular satellite.

13.1.1. Satellite Communication System. A communication satellite is basically a RF repeater (transponder) station which has made broadband long distance communication feasible and ensures a high quality service. Extension of radio relay systems to repeaters not located on earth's surface was demonstrated during Second World War. This can also be seen by remembering that by increasing the height of the transmitting and receiving antennae, range of a communication can be extended. If, therefore, a repeater is installed high above earth's surface, communication range could be considerably extended, since such a repeater will be able to transmit signals over the entire area seen by it. Clarke suggested that if a satellite was placed at a height of 35,880 km above equator, it would orbit the earth every 24 hours and would, therefore, appear to be stationary over a fixed point above the equator. Three such satellites could then cover the entire earth's surface, except small areas near north and south poles. The outlines of such a satellite network are shown in Fig. 13.1.

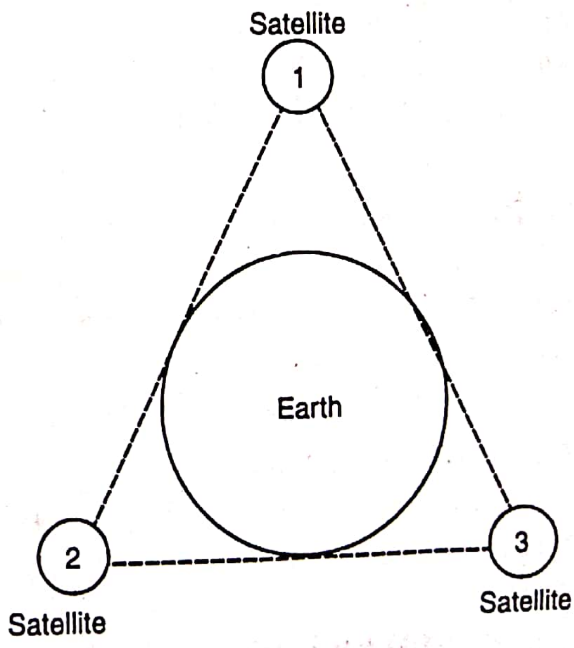

Fig. 13.1. Three synchronous satellites parked in such a way as to provide 100% earth coverage.

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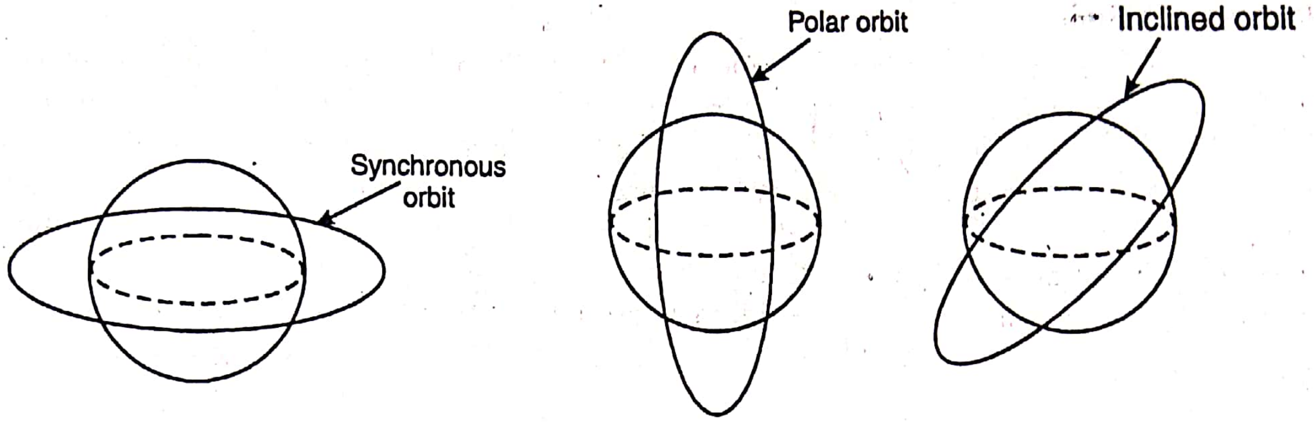
13.1.2. Satellite orbits. The paths along which satellites move in the space around earth are called orbits. The orbit of a satellite also determines the area which the satellite can serve and also the time period for which visibility of the satellite over the area is maintained.

A satellite can move in three types of orbits, these are synchronous orbits, polar orbits and inclined orbits. These orbits are illustrated in Fig. 13.2. The synchronous orbit is the most useful orbit for communications purposes. Every country of the world wants a slot in synchromus orbit.



(a) Synchronous orbit (a) Polar orbit (a) Inclined orbit

Fig. 13.2. Satellite orbits.

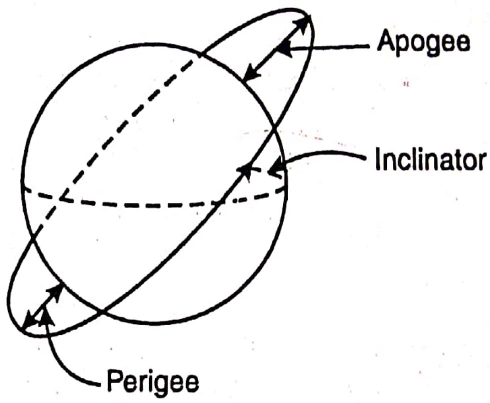


Fig. 13.3. Parameters of an orbit

It is in maximum demand, most of the satellites are placed in this orbit. Synchronous orbit lies in the equatorial plane of the earth. The other characteristics of the orbit are *Apogee, Perigee* and *Inclination*. These parameters of orbits are shown in Fig. 13.3. The Apogee is the farthest point on the orbit of a satellite from the earth. The Perigee is the nearest point on the orbit of a satellite from the earth. The inclination of the orbit is determined by the angle it makes with the equator. Sputnik I satellite had an orbit with apogee of 941 km and Perigee of 227 km.

The synchronous orbit is further classified into *Geostationary orbit* and *Geosynchronous orbit*.

Geostationary orbit

An orbit in which a satellite appears stationary relative to any point on earth is called geostationary orbit. This is achieved by synchronising the revolution of the satellite around the earth with the speed of earth's rotation about its own axis by placing the satellite into an equatorial orbit of about 3600 km above earth.

Geosynchronous orbit

A satellite whose period of resolution equals to period of rotation of earth about its axis. In this a satellite has 24-hours non-equatorial orbit. Both the synchronous orbits are circular in nature.

If a satellite is placed in a circular orbit at a height 'h' above earth, the time taken by the satellite for encircling the earth once is given by the expression

$$t = \frac{2\pi(r+h)}{V} \quad \text{... (13.1)}$$

where V is the velocity of the satellite.

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Now V is given by

$$V = r\sqrt{\frac{g}{r+h}} \quad \text{... (13.2)}$$

where g is the gravational acceleration, g = 980. 66 cm/sec and r is the radius of earth. If a satellite has a time period of 24 hours (geostationary) then height of the satellite above earth may be determined by the use of Eqs. 13.1 and 13.2. This height comes out to be about 35,800 km. This elementary approach assumes the earth to be circular. Geostationary equatorial orbit is most suitable and taking various factors that affect the satellite orbit, satellite height in this orbit comes out to be 36,000 km approximately. The satellite does not remain stationary even when placed at the correct height and also has to correct velocity, because of equatorial ellipticity and effect of the movements of sun and moon etc. Corrections to the height and velocity of the satellite are, therefore, done at regular intervals throughout the life of the satellite. This is termed as tracking. Merits and demerits of placing a satellite in this equatorial orbit are as under:

Merits

1. It requires a limited earth station antenna tracking, since the satellite remains fixed in its position relative to earth.
2. It is capable of providing continuous and uninterrupted communication over the desired area.
3. Satellite communication links are unaffected by Doppler frequency shift.

Demerits

1. A costly launch vehicle is required.
2. Regions near the north and south poles are not covered in the communication range of the satellite.
3. There is a time delay of about 300 m sec. Between a transmitted and received signal.
4. It requires increased EIRP (effective isotropically radiated power) as compared with low altitude systems.

13.1.3. Basic Components of Satellite Communication System. The basic components of satellite communication system has three main parts (see Fig. 13.4). (*i*) Earth station or ground

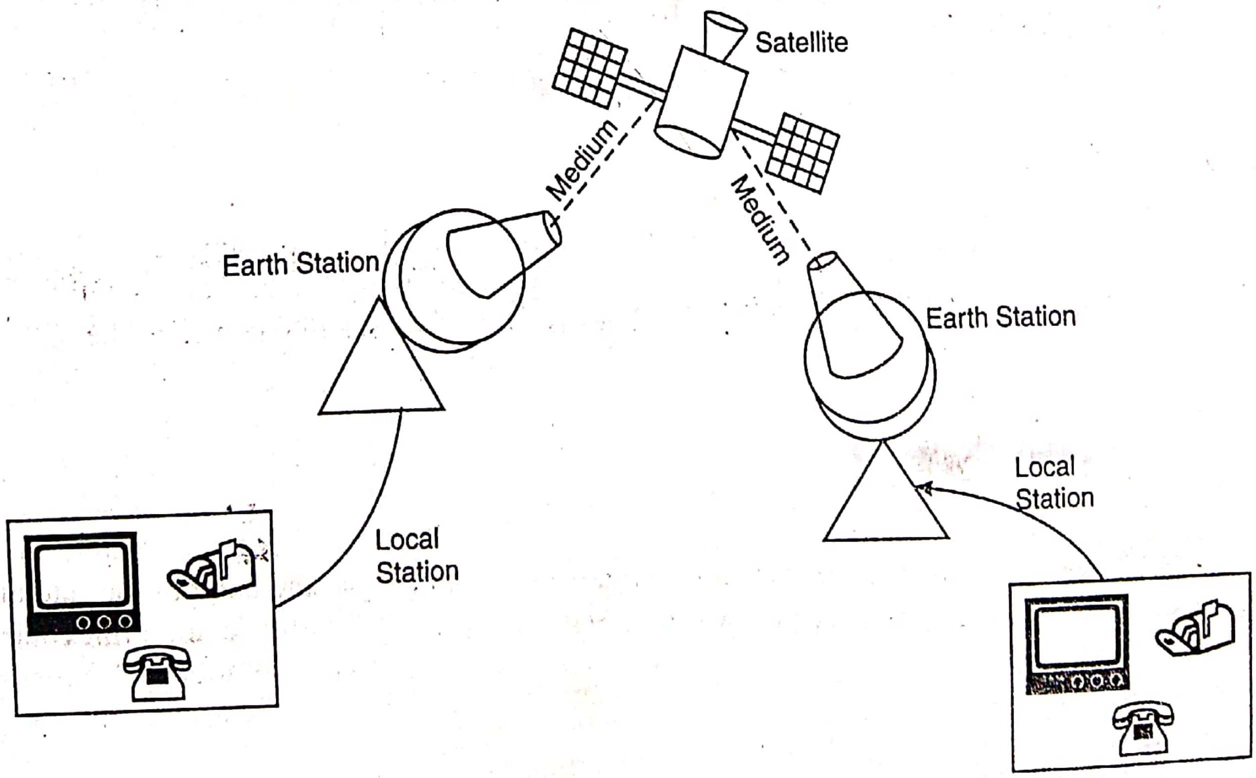

Fig. 13.4. Basic satellite communication systems.

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station or ground terminal (*ii*) Medium and (*iii*) Satellite itself. The earth stations are very important part of a satellite communication system. The earth station converts the local signals (like telephone, telex, Fax, TV signals etc.) to high frequency with the help of various earth station equipments. This high frequency signal is transmitted towards satellite by big parabolic antenna of earth station. Earth stations are of various types-these are big earth station, direct reception system (DRS) earth station, TV receive only (TVRO) earth station. Big earth stations of antenna diameter like 6.1 ms, 7.5 ms & 11 ms. are transmitting stations. They have both transmitting and receiving equipments at earth station. DRS earth station are only receive station. TVRO earth station are used for receiving TV programme from satellite and then the received programme is relayed through local TV transmitters. The quality of TVRO earth station for TV signals are better than DRS earth station.

The high frequency satellite earth station signal then travels through earth atmosphere medium upto few kilometers and then after that it is space environment which is vacuum. The medium also alternates the high frequencies signal which is then received by the satellite.

13.1.4. Constructional Features of Satellites. A satellite has many sub-systems, these sub-systems are responsible for various functions. These sub-systems are antenna, transponder, power generation and storage system, telemetry and tele command sub-system, attitude and orbit control sub-system, propulsion sub-system and thermal control sub-system.

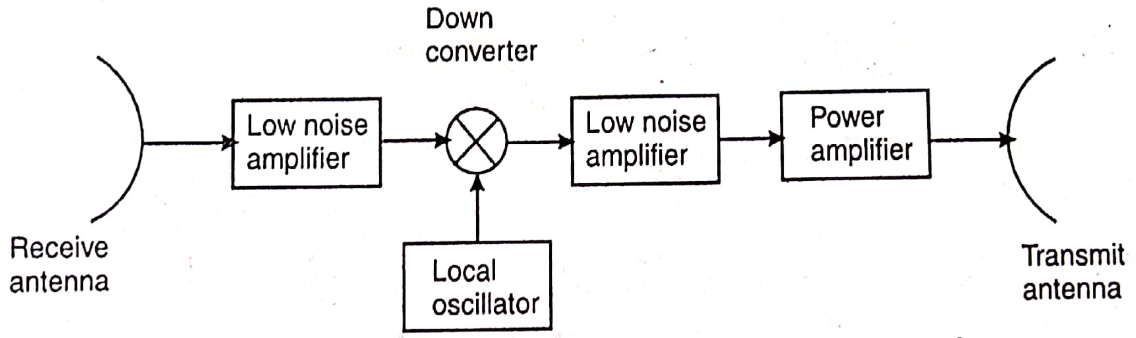

Fig. 13.5. Block diagram of a single conversion satellite transponder.

The satellite antenna is a parabolic reflector which receive signals from ground station. The same antenna is used for transmission. The transponder is the heart of a satellite. All operations related to communication take place inside the transponder. A block diagram of a single conversion satellite transponder is shown in Fig. 13.5. When the signal is received at satellite, it is amplified by a low noise amplifier, its frequency is down converted by down convertor and then it is radiated back by satellite towards the earth . All the earth station and dish antenna within the visible range of the satellite receive this down converted signal.

The power generation and storage sub-system consists of solar cells and storage batteries. The solar cells convert solar energy into electrical energy. This electrical energy is supplied to various equipments of the satellite for proper operation. In addition to solar cells, satellite also has storage batteries. The power from these batteries is used when satellite comes in the shadow zone of the earth. Telemetry and telecommand sub-system of the satellites gives the condition of the satellite. The telemetry is a system which gives information about the satellite. When a partial parameter of a satellite deviates from its signal value, then a particular signal is sent. This is called telcommand. If a satellite charges its position in its orbit, it needs some pushes and pulls to keep the satellite in its desired position in space. The propulsion sub-system keep the satellite in its desired location with the help of small hydrazine thrusters fitted around the body of the satellite. An exploded view of a communication satellite is shown in Fig. 13.6. Attitude and orbit control sub-system perform two functions. Firstly it keeps the satellite in its desired location and secondly, adjust the position of the satellite. The thermal control sub-system maintains the inside temperature of the satellite and other equipments. These temperature drop to as low as – 150°C when satellite comes in the shadow zone of the earth and shoot up very high when satellite faces the sun.

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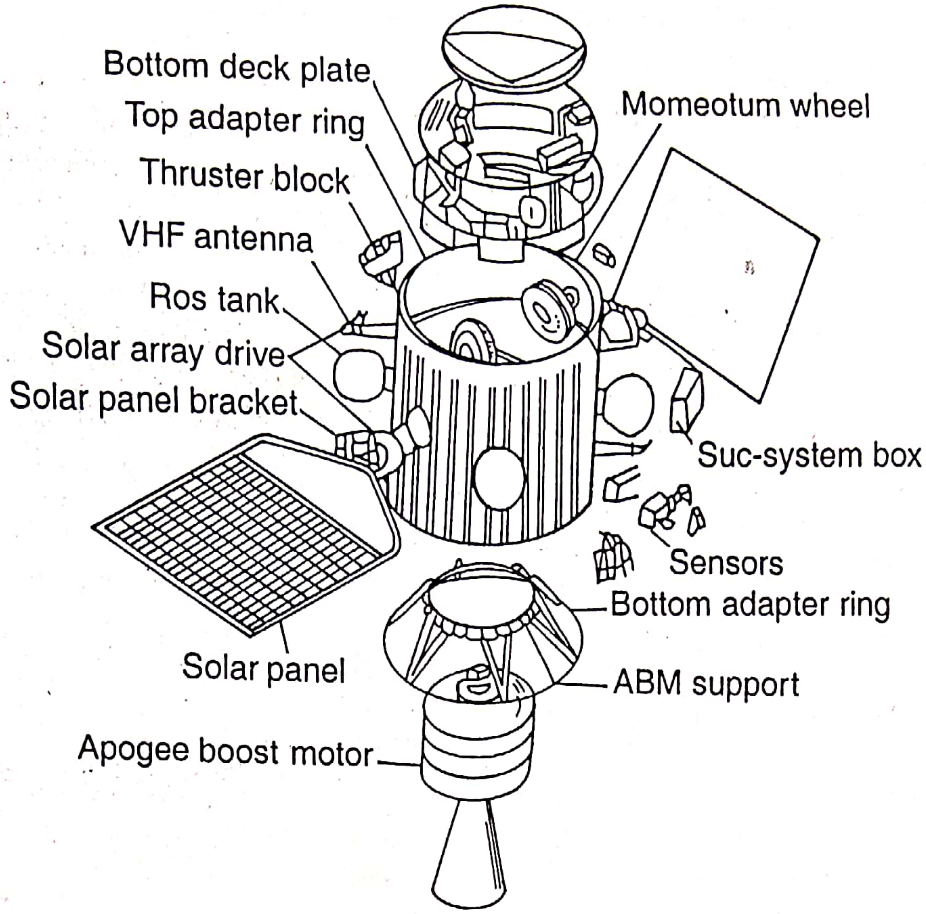

Fig. 13.6. Exploded view of a communication satellite.

13.1.5. Commonly Used Frequency in Satellite Communication. Satellite communication uses three types of frequency bands. These are C band, K_u band and K_a band. In addition to this L and S band frequencies are also in use in satellite communication. C band ranges from 5.925 GH_Z, to 6.425 GH_Z as uplink frequency and 3.7 GH_Z to 4.2 GH_2. KU band frequency 14 to 14.5 GH_Z as uplink and 11.7 GH_Z to 12.2 GH_Z as down link. Ka bond frequencie 27.5 GH_Z to 31 GH_Z for uplink and 17.07 GH_Z to 21.2 GH_Z for down link. In satellite communication uplink frequency is always higher then down link frequency. The reason for this is that high power uplink signal is transmitted to satellite and weak signal is received at ground station from satellite. Also noise picked up by down link frequency is lower than the uplink frequency. Down link weak signal can be easily amplified by the earth station.

13.2. Multiple Access. By the term multiple access is meant the manner by which a number of earth stations may use the satellite repeater simultaneously. There are two basic methods in common use that permit the simultaneous multi-usage of satellite's repeaters. First method allows multiple access in the frequency domain and is, therefore, termed as Frequency Division Multiple Access. The second method TDMA (Time Division Multiple Access) permits multiple access in time domain.

FDMA. In frequency division multiple access system, each earth station is assigned a segment of the satellite usable banwidth. To ensure interference free communication, sufficient guard band is provided between these segments. Figure 13.7 shows the outlines of an FDMA system.

The Station A Transmits FDM. FM signals in a frequency segment of (5930 – 5950) MHz to the satellite repeater which receives these signals and converts them to a frequency range 3705 – 3725 MHz by mixing it with a carrier frequency of 2225 MHz generated by the local oscillator of the satellite repeater. Similarly, signals transmitted to the satellite by stations B and C are converted to lower frequencies in the satellite repeater and retransmitted to their destinations.

Station B UP–Signal	= 5990 – 6010 MHz
Retransmitted signal frequency	= 3765 – 3785 MHz
Station C UP–Signal	= 6220 – 6240 MHz
Retransmitted signal frequency	= 3995 – 4015 MHz

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Thus it can be seen that signals transmitted in the up direction (to satellite) lie in the band 5925 to 6425 MHz while the down signals (transmitted by the satellite) lie in the frequency band 3700 – 4200 MHz. Salient features of the FDMA system described briefly in the preceding paragraphs are :

(*a*) Each earth station can transmit one carrier up towards the satellite. The signal frequency is changed by the satellite and the signal is reradiated omni- directionally.

(*b*) The reradiated signal can be received by any of the earth- stations.

(*c*) Satellite repeater is capable of receiving simultaneously signals from different earth-stations and reradiating them at new frequencies.

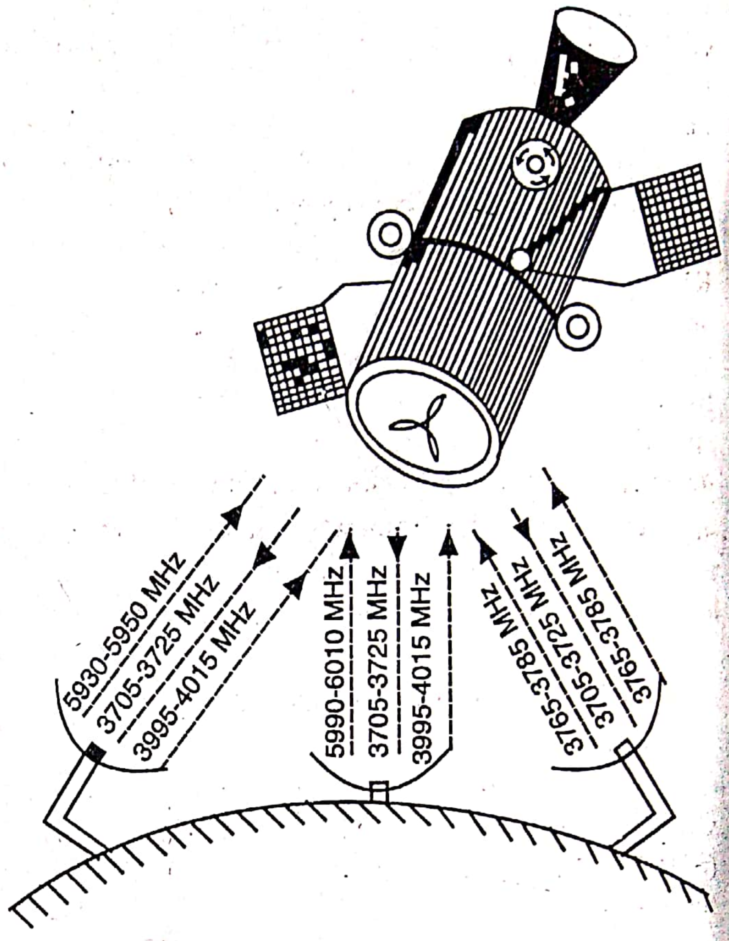

Fig. 13.7. Outline of a FDMA system.

It should be remembered that 20 MHz frequency segments transmitted by diferent earth stations contain a baseband of 120 telephone channels frequency division multiplexed, which frequency modulates the UHF carrier.

TDMA. In time division multiple access system, satellite transponder is used only by one earth-station at a given instant of time. This system has the advantage of limiting the producing of inter-modulation products resulting due to multiple carrier frequencies as in FDMA. Here the telephone signals are sampled and converted into PCM at a sampling frequency of 8,000 Hz. Each earth-station, therefore, produces a PCM digit stream, the speed of which is dependent upon the number of telephone channels handled by that station. The PCM signals from each station are interleaved in time. The combined signal at the satellite input is amplified by a single wideband amplifier. Signals from each earth station are retimed and reradiated as a single burst per frame period. Figure 13.8 shows signals at different points in the UP and DOWN direction.

TDMA system requires stable timing to be maintained between different earth stations. Since the transmission path involved is long, it is extremely difficult to achieve accurate timing.

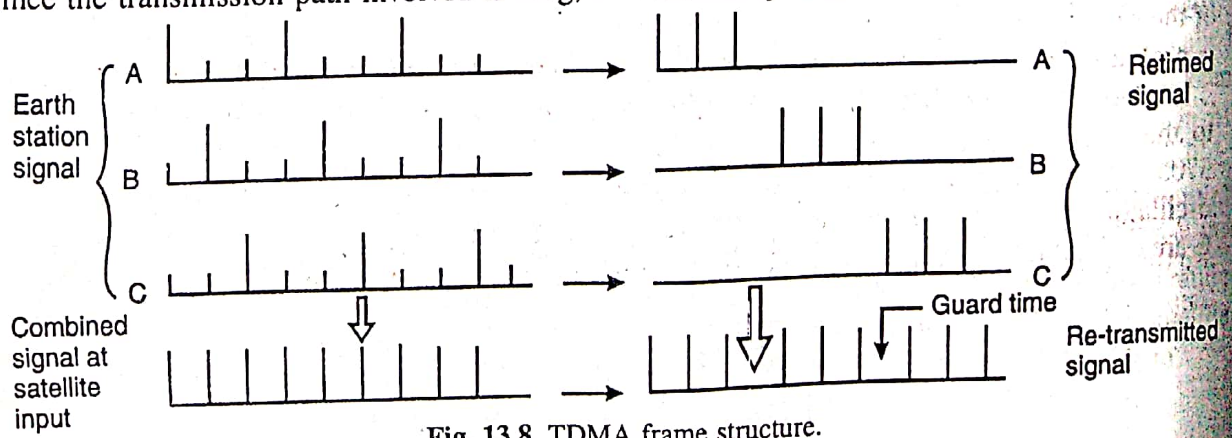

Fig. 13.8. TDMA frame structure.

To overcome this difficulty, an alternate method of providing a guard time between signals corresponding to different earth-stations is employed. However, this method has a drawback that it requires storage and retiming of the bit stream before and after transmission. It is to be noticed that TDMA technique is not yet fully exploited commercially.

SPADE (Single Channel Per Carrier Multiple Access Damped Assignment Equipment). A third form of multiple access which in reality is a form of FDMA is now in use. In this system, a single voice channel is used to modulate a RF carrier producing a frequency modulated slot 45 KHz wide. A pool of 800-voice channel slots occupies a band of 36 MHz. This baseband is then used to frequency modulate the UHF carrier which is then transmitted to satellite. Remaining system is comparable to FDMA described in previous paragraphs. The system, however, differs from FDMA / FM in the fact that neither end of a channel is permanently associated with a specific earth-station. The voice channels are paired to form a combination as required within the demand assignment pool. Important merits of the SPADE are :

(*a*) It establishes communication links between any two stations whether or not these links are economically justified.

(*b*) The number of carriers is reduced in comparison to that used in FDM/FM (FDMA) with associated reduction of earth-station down chains.

(*c*) Number of frequency plan revision to accommodate new uses is reduced.

(*d*) The system allows growth on the basis of traffic at nominal expense.

Apart from the multiple access techniques described above techniques like DCMA (DIGITAL COMMUNICATION MULTIPLE ACCESS), TVMA (TV WITH MULTIPLE AUDIO) and SSMA (SPREAD SPECTRUM MULTIPLE ACCESS) are also sometimes used. TVMA is very important for use in multilingual countries like India where this technique allows TV programmes of national importance to be transmitted to different regions of the country dubbed in their own language.

A communication satellite comprises of various subsystems. The communication package, which usually contains a straight forward repeater and occupies only about 20% of the total weight of the spacecraft is the heart of the satellite. The other subsystems include the power system deriving primary power from solar cells, the altitude and orbit control subsystems that control and periodically correct the satellite position relative to earth, the telemetry and telecommand subsystems which monitor the performance of the communication package and carry out changes in satellite operations on receiving commands from earth-control stations. Figure 11.20 shows the exploded view of a communication statellite and lists its major parts.

13.2.1. Communication Package. Satellite communication package is basically a wide band RF repeater. Each satellite has a number of transponders on board, that receive signals from earth stations and retransmit them. These transponders not only transmit video, but also mono and stereo audio, telephone signals, data and news reports etc. Uplink transmission frequencies employed range from 5.9 GHz to 6.4 GHz, as can be seen from Fig. 11. 18. In the satellite, the signals are down converted to a frequency range of 3.7 GHz to 4.2 GHz and retransmitted towards earth. This gives a bandwidth of 500 MHz.

This bandwidth of 500 MHz is often divided into 12 channels, each of 40 MHz bandwidth. Each channel can be used for one TV signal 1500 one way telephone signals or 60 million bits/second of digital data.

Every channel has its own transponder. The number of channels may be increased by using two satellites with a sufficient distance between them. A 4-degree spacing (2950 kms approx.) is usually kept between adjacent satellites. Alternately, a satellite may be equipped with 24 transponders—12 transponders transmitting vertically polarized waves and the remaining 12 transponders transmitting horizontally polarized waves.

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13.2.2. Antenna. Modern communication satellites are spin stabilized and the antennae are so arranged as to spin in the opposite direction at the same speed. As a result, these antennae always face the earth in the desired direction. Their position is properly maintained by control circuits. The platform on which electronic equipment is mounted is also despun to avoid rotating join in the antenna RF feed.

13.2.3. Power Source. Power requirements of the satellites are met by solar cells and large solar panels are built in the form of large paddles which are oriented to be always looking towards sun. Solar cell panels are capable of providing a power of about 5 kW while the usual power requirement of present satellites is of the order of 1 kW.

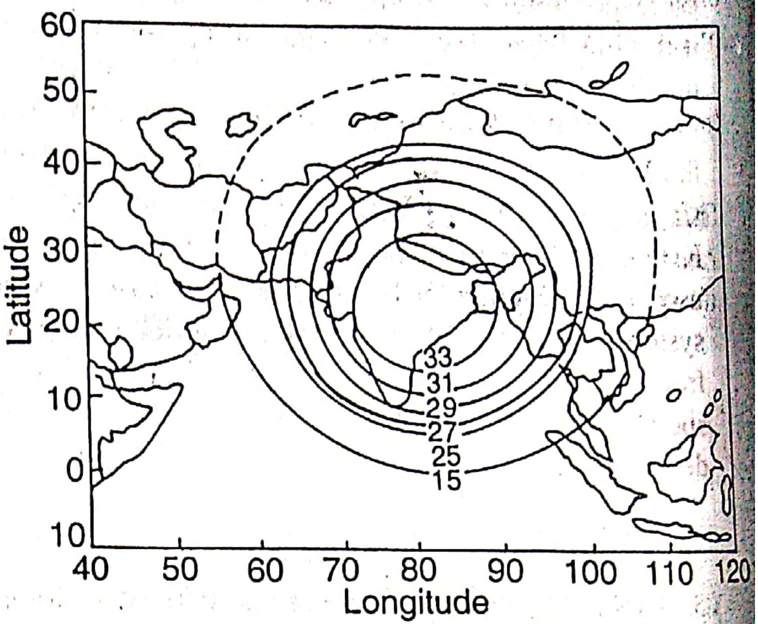

Fig. 13.9. The footprint of INSAT-2B

13.2.4. Satellite Foot Prints. The area over which satellite signals can be received, depends upon the radiation pattern of satellite transmitting antenna. This radation pattern, when superimposed on the map of a region display the *effective isotropic radiated power* (EIRP) of the satellite for each part of the region and is called the *satellite footprint.*

The footprint displays the vertical and horizontal radiation patterns on a single map. Figure 13.9 shows a typical satellite footprint.

13.3. Satellite Communication in India. In India space research is carried out by a body known as ISRO (INDIAN SPACE RESEARCH ORGANISATION). India's first experimental telecommuni-cation satellite was launched into space on June 19, 1981.

After this successful experiment, India launched INSAT-1A (built in USA) in 1982 for broadcasting programmes to rural areas. INSAT-1A failed after 147 days and was replaced by INSAT-1B in 1983. This satellite provided services for 5 years and was replaced by INSAT-1C in July 1988. This satellite had a short life span and lost earth lock in November 1989. INSAT-1D was launched in 1990 to replace INSAT-1C and has been working satisfactorily since then.

India moved to INSAT-II series by launching its INSAT-2A in July 1992. It contained 12 C-band, 6 extended C-band and 2 S-band transponders: INSAT-2B launched in 1993 contains 18C-band, 6 extended C-band and two S-band transponders.

C-band transponders are used for communications and the S-band transponders are used for TV and broadcast. It also has a very high resolution radiometer (VHRR) for meterology purposes and search and rescue payloads to pick up distress signals. The combination of VHRRs in INSAT-2A and INSAT-2B provides stereoscopic images of clouds which gives good estimate of cloud height.

INSAT-2C and D were launched in 1995 and 1997 respectively and provide facilities like teleconferencing, computer to computer and voice communications.

Indian third generation satellite INSAT-3B was launched on 22nd March 2000. This satellite is intendced for business development and mobile communication. It has boosted the country space programme and VSAT (very small aperture terminal) services. The major users of VSAT's are banks, financial institution, stock market, fast moving goods sector and medium and heavy engineering company. INSAT-3B has 12 extended C-band channel each having a bandwidth of 36 MHZ. It was placed in the geostationery orbit with a perigee of 560 km and apogee of 35,770 km.

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1.5 TYPES OF SATELLITES (BASED ON ORBITS)

1.5.1) Geostationary or geosynchronous earth orbit (GEO)

- GEO satellites are synchronous with respect to earth. Looking from a fixed point from Earth, these satellites appear to be stationary. These satellites are placed in the space in such a way that only three satellites are sufficient to provide connection throughout the surface of the Earth (that is; their footprint is covering almost 1/3rd of the Earth). The orbit of these satellites is circular.

- There are three conditions which lead to geostationary satellites. Lifetime expectancy of these satellites is 15 years.
  1) The satellite should be placed 37,,786 kms (approximated to 36,000 kms) above the surface of the earth.
  2) These satellites must travel in the rotational speed of earth, and in the direction of motion of earth, that is eastward.
  3) The inclination of satellite with respect to earth must be 0^0.
- Geostationary satellite in practical is termed as geosynchronous as there are multiple factors which make these satellites shift from the ideal geostationary condition.

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- These satellites are mainly used in remote sensing an providing mobile communication services (due to lower latency).

- Disadvantages: The biggest problem of the LEO concept is the need for many satellites if global coverage is to be reached. Several concepts involve 50–200 or even more satellites in orbit. The short time of visibility with a high elevation requires additional mechanisms for connection handover between different satellites. The high number of satellites combined with the fast movements resulting in a high complexity of the whole satellite system. One general problem of LEOs is the short lifetime of about five to eight years due to atmospheric drag and radiation from the inner Van Allen belt1. Assuming 48 satellites and a lifetime of eight years, a new satellite would be needed every two months. The low latency via a single LEO is only half of the story. Other factors are the need for routing of data packets from satellite to if a user wants to communicate around the world. Due to the large footprint, a GEO typically does not need this type of routing, as senders and receivers are most likely in the same footprint.

1.5.3) Medium Earth Orbit (MEO) satellites:

- MEOs can be positioned somewhere between LEOs and GEOs, both in terms of their orbit and due to their advantages and disadvantages. Using orbits around 10,000 km, the system only requires a dozen satellites which is more than a GEO system, but much less than a LEO system. These satellites move more slowly relative to the earth's rotation allowing a simpler system design (satellite periods are about six hours). Depending on the inclination, a MEO can cover larger populations, so requiring fewer handovers.

- Disadvantages: Again, due to the larger distance to the earth, delay increases to about 70–80 ms. the satellites need higher transmit power and special antennas for smaller footprints.

The above three are the major three categories of satellites, apart from these, the satellites are also classified based on the following types of orbits:

1.5.4) Sun- Synchronous Orbits satellites:

- These satellites rise and set with the sun. Their orbit is defined in such a way that they are always facing the sun and hence they never go through an eclipse.
- For these satellites, the surface illumination angle will be nearly the same every time.
  (Surface illumination angle: The illumination angle is the angle between the inward surface normal and the direction

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1) Gravitational pull of sun and moon makes these satellites deviate from their orbit. Over the period of time, they go through a drag. (Earth's gravitational force has no effect on these satellites due to their distance from the surface of the Earth.)
2) These satellites experience the centrifugal force due to the rotation of Earth, making them deviate from their orbit.
3) The non-circular shape of the earth leads to continuous adjustment of speed of satellite from the earth station.

- These satellites are used for TV and radio broadcast, weather forecast and also, these satellites are operating as backbones for the telephone networks.

- Disadvantages of GEO: Northern or southern regions of the Earth (poles) have more problems receiving these satellites due to the low elevation above a latitude of 60°, i.e., larger antennas are needed in this case. Shading of the signals is seen in cities due to high buildings and the low elevation further away from the equator limit transmission quality. The transmit power needed is relatively high which causes problems for battery powered devices. These satellites cannot be used for small mobile phones. The biggest problem for voice and also data communication is the high latency as without having any handovers, the signal has to at least travel 72,000 kms. Due to the large footprint, either frequencies cannot be reused or the GEO satellite needs special antennas focusing on a smaller footprint. Transferring a GEO into orbit is very expensive.

1.5.2) Low Earth Orbit (LEO) satellites:

- These satellites are placed 500-1500 kms above the surface of the earth. As LEOs circulate on a lower orbit, hence they exhibit a much shorter period that is 95 to 120 minutes. LEO systems try to ensure a high elevation for every spot on earth to provide a high quality communication link. Each LEO satellite will only be visible from the earth for around ten minutes.

- Using advanced compression schemes, transmission rates of about 2,400 bit/s can be enough for voice communication. LEOs even provide this bandwidth for mobile terminals with Omni-directional antennas using low transmit power in the range of 1W. The delay for packets delivered via a LEO is relatively low (approx 10 ms). The delay is comparable to long-distance wired connections (about 5–10 ms). Smaller footprints of LEOs allow for better frequency reuse, similar to the concepts used for cellular networks. LEOs can provide a much higher elevation in Polar Regions and so better global coverage.

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of light. This means that the illumination angle of a certain point of the Earth's surface is zero if the Sun is precisely overhead and that it is 90 degrees at sunset and at sunrise.)

- Special cases of the sun-synchronous orbit are the noon/midnight orbit, where the local mean solar time of passage for equatorial longitudes is around noon or midnight, and the dawn/dusk orbit, where the local mean solar time of passage for equatorial longitudes is around sunrise or sunset, so that the satellite rides the terminator between day and night.

1.5.5) Hohmann Transfer Orbit:

This is an intermediate orbit having a highly elliptical shape. It is used by GEO satellites to reach their final destination orbits. This orbit is connected to the LEO orbit at the point of perigee forming a tangent and is connected to the GEO orbit at the point of apogee again forming a tangent.

1.5.6) Prograde orbit:

This orbit is with an inclination of less than 90°. Its direction is the same as the direction as the rotation of the primary (planet).

1.5.7) Retrograde orbit:

This orbit is with an inclination of more than 90°. Its direction is counter to the direction of rotation of the planet. Only few satellites are launched into retrograde orbit because the quantity of fuel required to launch them is much greater than for a prograde orbit. This is because when the rocket starts out on the ground, it already has an eastward component of velocity equal to the rotational velocity of the planet at its launch latitude.

1.5.8) Polar Orbits

This orbit passes above or nearly above both poles (north and south pole) of the planet on each of its revolutions. Therefore it has an inclination of (or very close to) 90 degrees. These orbits are highly inclined in shape.

1.6 EXAMPLES

1.6.1) INTELSAT

- International Telecommunication Satellite:
- Created in 1964
- Over 140 member countries
- More than 40 investing entities
- Early Bird satellite in 1965
- Six (6) evolutions of INTELSAT satellites between 1965-87
- Geostationary orbit
- Covers 3 regions:

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- Atlantic Ocean Region (AOR),
- Indian Ocean Region (IOR), and
- Pacific Ocean Region (POR)

1.6.2) U.S DOMSATS

Domestic Satellite:

- In geostationary orbit
- Over 140 member countries
- Direct-to-home TV service
- Three (3) categories of U. S. DBS system: high power, medium, and low power.
- Measure in equivalent isotropic radiated power (EIRP).
- The upper limit of EIRP:
    - High power (60 dBW),
    - Medium (48 dBW), and
    - Low power (37 dBW).

1.6.3) Polar Orbiting Satellites

These satellites follow the Polar Orbits. An infinite number of polar orbits cover north and south polar regions.

- Weather (ultraviolet sensor also measure ozone level) satellites between 800 and 900 km
- National Oceanic and Atmospheric Administration (NOAA) operate a weather satellite system
- Satellite period is 102 minutes and earth rotated 25 degree.
- Estimate the sub-satellite point at the following times after the equator 90 degree E North-South crossing:
    - a) 10 minutes, 87.5 degree E and 36 degree S;
    - b) 102 minutes, 65 degree E and equator;
    - c) 120 minutes, 60 degree E and 72 degree S.
- The system uses both geostationary operational environment satellite (GOES) and polar operational environment satellite (POES)
    - Sun synchronous: they across the equator at the same local time each day
    - The morning orbit, at an altitude of 830 km, crosses the equator from south to north at 7:30 AM, and the afternoon orbit, at an altitude of 870 km, at 1:40 PM.
- Search and rescue (SAR) satellite: Cospas-Sarsat.

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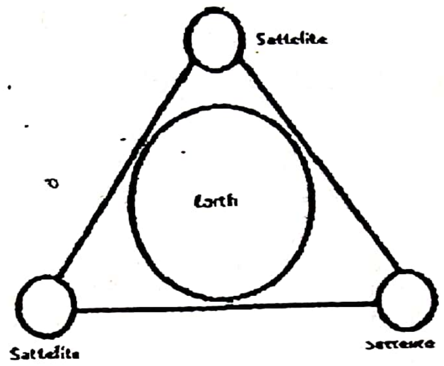
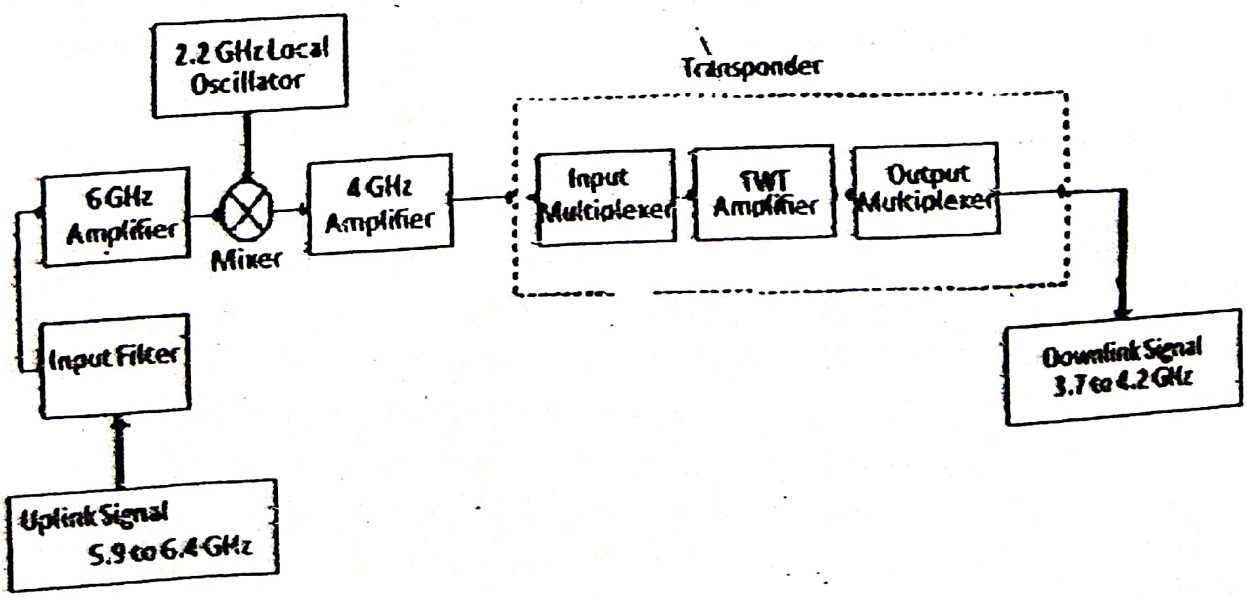
Introduction to Satellite communication

Satellite is powerful long distance and point to multi point communication system. A communication satellite is an R.F (Radio Frequency) repeater. To overcome disadvantage of Line of sight communication which is only 45 55 km, the transmitting antenna is placed on the satellite and the satellite is placed in the orbit high above the earth. The function of satellite is to communicate between different earth stations around the earth, thus with the help of satellite, it is easy to communicate over thousands of km, a com satellite is a combination of ROCKET to put the satellite in the orbit, micro wave electronic devices for the communication, solar cells are used to convert the solar energy into a power supply (ELECTRICAL ENERGY) for the electronic equipment.



The satellite placed in GEOSTATIONARY and placed at an altitude of 22300 miles or 35900 km above the ground level. The satellite travels at the same speed at which the earth rotates around the sun. The rotation of satellite is synchronized with earth rotation as a result satellite appears to be stationary in the sky w.r.t the earth station is constant. There are 3 satellites are placed at angle 120° in GEOSTATIONARY orbit, they provide 100% coverage from one earth station to anywhere on the earth.

Block Diagram of Satellite Communication System



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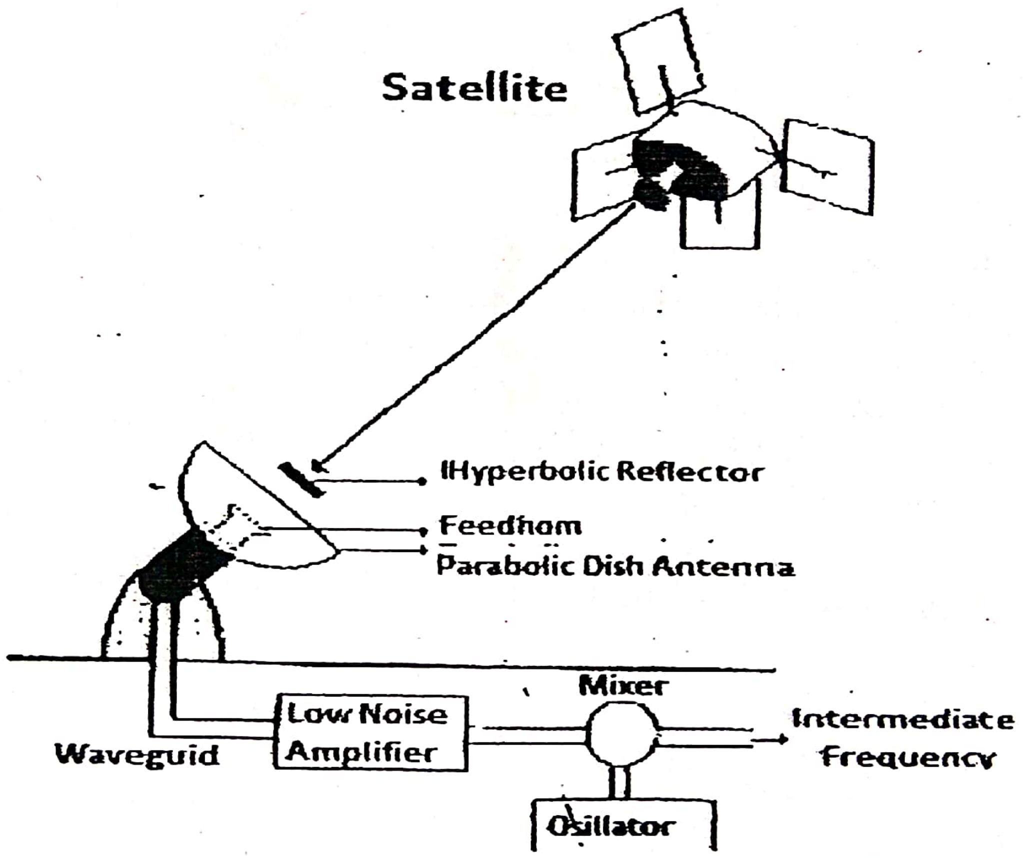
The uplink frequencies (5.96.4 GHZ) are used for T/N from the earth station to the satellite and down link frequencies (3.7—4.2GHZ). The above frequencies are used for T/N from the satellite to the earth station , the uplink frequencies are converted to lower frequencies by the mixer and local Osc, the com satellite acts as a repeater station it receives the signal, amplifiers it and then transmitted over a next frequencies to avoid interference between the uplink signal and down link , the two way communication is established with the help of transponder , a com satellite has multi transponder per satellite has increased over the year ,a satellite with 2 transponder can support a signal T.V channel or 240 telephone lines , a satellite with 48 transponder can accommodate 4000T.P CKTS and 2 T.V channels nowadays in satellite using a digital tech , due to which One satellite can handle 120,000 T.P4 channels and more than 500 T.V channels.

Satellite Communication Earth Station



The equipment used in satellite earth station are shown in fig , the earth station consist of a dish antenna transmitter which can transmit a high frequencies (5.9—6.4GHZ) micro wave signals, some earth stations also called ground station , which can transmit and receive the signals while others can only receive signals. A high directive and a high gain antenna is necessary at the earth station , because the losses over the long T/N path is very high , the signals power reaching back to the earth station from satellite is very small . therefore at receiving end a parabolic dish antenna with 61m diameter provides a high gain and thus amplify the signal power , it is important to have a low noise amplifier before the mixer stage in the receiver C,K,T at the satellite earth terminal.

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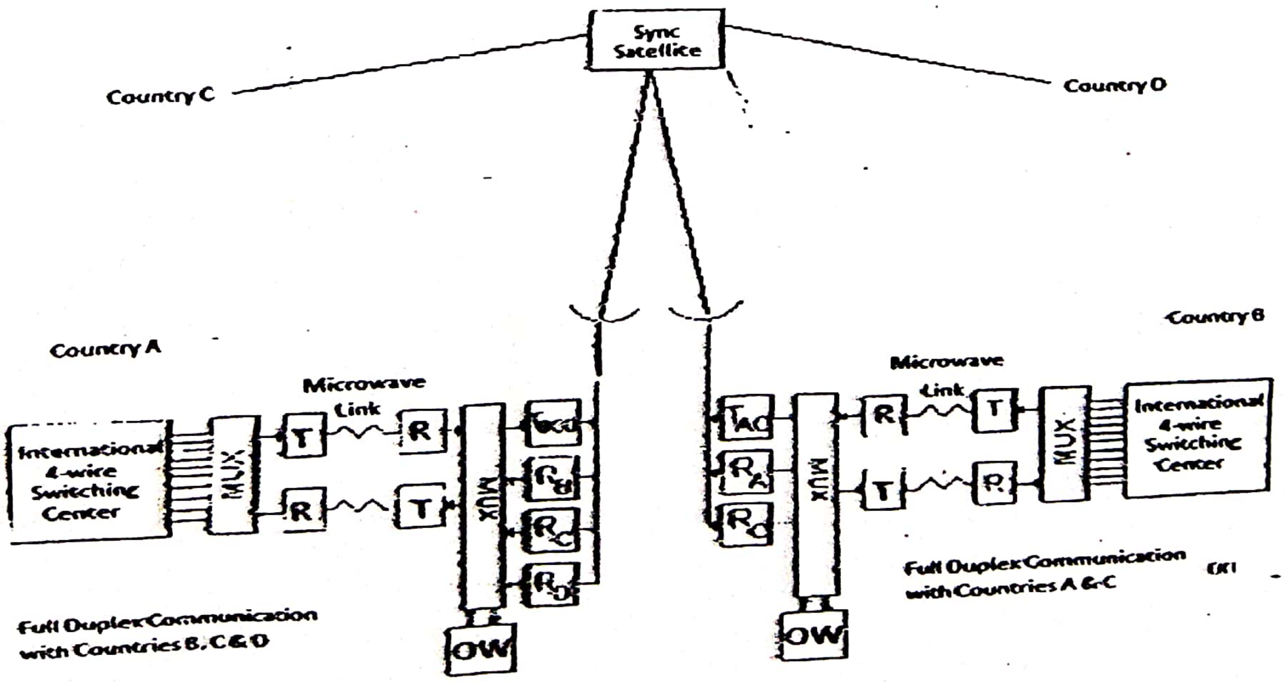
Geostationary Satellite

The satellites were placed in low earth orbit. as a result the satellite at a such high speed that it visible to the ground only for a short time at each day , the satellite appeared below the horizon and dies appear below the opposite horizon , the ground station was cut off for long time in day , to maintain the communication link another station had to be activated , this problem was solved by placing the satellite in circular orbit of approximately 22300 miles or 35900 km radius, as the satellite height increases from the earth surface , the speed of satellite decreases by the same manner , at that height the angular velocity of satellite will be proportional to the angular velocity of earth , the satellite rotates with the same speed as that of the earth due to which the satellite will always be at the same place where it has been fixed , this type of satellite is called geo stationary satellite

Telephone Link via Satellite

The satellite communication can be used for Telephone telecom. Around the world, the block diagram of such a system is shown in fig. The block diagram of earth station working with three satellites here, the national long distance Telephone network of a 4 countries (A,B,C,D,) through international switching centre are connected, consider country "A" the 0/p of the Telephone exchange is applied to the MUX, the multiplexed signal is send to the microwave station and from there to the satellite earth station , at the earth station the signal is multiplexed and directly applied to the modulator stage of earth station where it demodulated with a high frequency signal and transmitted towards the satellite as uplink , in other case the earth station "A" receive three down link signal , the 3 carriers are demodulated and then transmitted toward the microwave station and from there international switching centre. Many earth stations are designed to transmit several carriers from direct communication with other station through one satellite; the other wire (OW) facilities are transmitted for message carriers from the band of 300HZ-12KHZ.



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Merits and Demerits of the Satellite Communication

Following are the merits and demerits of satellite communication system:

Merits

1. No tracking is required by Geostationary Satellites.
2. Multiple access points are available in Satellite communication
3. 24 hour communication can be achieved with the help of satellite.
4. The signal quality of Satellite communication is higher.
5. To put more information on the carrier a broad band can be used.
6. Satellite Communication is used for long distance communication or across oceans.
7. low transmitting Power and low receiver sensitivity is required by the Satellite in close elliptical orbits.

Demerits

1. The transmitter and receiver used in satellite communication requires high power, most sensitive transmitters and large diameter antenna's.
2. Satellite communication is disturbed by solar activities and cyclones in the space.
3. Due to ageing effect the efficiency of Satellite components decreases.
4. The longer propagation times (APPOX,300 ms) is one of a disadvantage of satellite communication.
5. The cost for Initial design and launching of the satellite in the orbit results in extremely high

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CELLULAR MOBILE COMMUNICATIONS

20.1 Introduction

The beginning of the mobile communications started in Germany in the year 1926. An attempt was made to call the public telephone exchange from the train on the Hamburg-Bestin route. A further development was made after the Second World War. The first civil mobile communication services were made available in the USA in the year 1946. The first radio-phone network originated in Europe in the fifties. The mobile network comprised of fixed radio stations with a few sending and receiving channels, which were connected to the public telephone exchange.

In early sixties the mobile networks of Germany further developed the A-network. In these the land networks were grouped together to form the first public mobile communication network of Germany. The connection between the mobile subscribers and the subscribers of the public telephone exchange was established manually. It was further developed as B-network. In this the manual switching was substituted by a self-selection from the subscriber in the B-network. In B-network if one subscriber wanted to call a mobile subscriber, his geographical location had to be known approximately with a cell to the respective exchange and the concerned radio station connected to it. The B-network comprises of 74 duplex channels and had about 27,000 subscribers.

Only after the advent of the computers the electronic telephone exchanges services became available, then development of "cellular mobile communication systems" started. The first cellular networks were created in 1981. The C-network in Germany was inaugurated in 1985. The C-networks today is the most modern among the cellular mobile networks.

20.1.1 The Concept of cell

A cellular system consists of many small 'cells'. Each cell in a cell phone system represents the area served by one cell phone tower. In this cells are placed fairly close to each other. These hexagon shaped cells provide complete signal coverage over the entire area. At the centre of each cell is a relatively low-powered transmitter base station and different cells are assigned different grouping of channels. These cells are grouped by letters *A*, *B*, *C* and so on. Different cells are shown in fig 20.1.

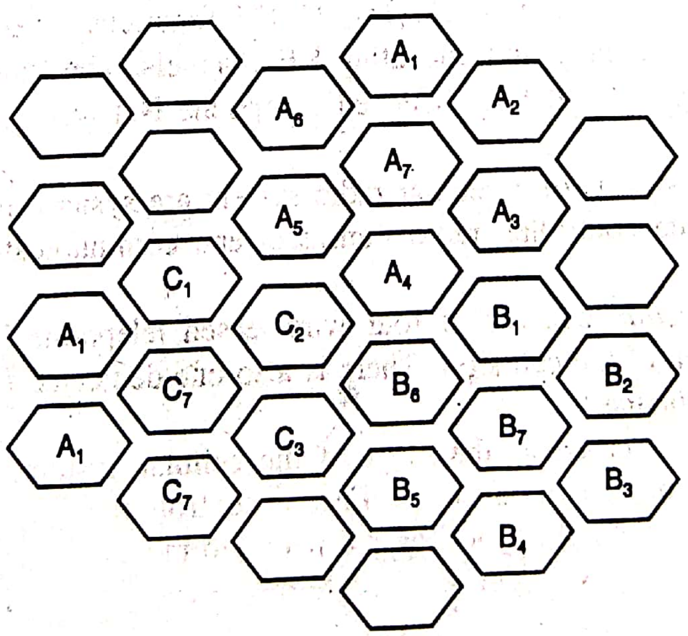

Fig. 20.1. The cell Structure.

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These cells are organised into clusters with most cellular system using seven cells per cluster. The radio channels are allocated across the seven channels. These cells clusters repeats again and again to cover the entire geographical area served by the mobile system.

The cellular system permit the 'frequency reuse' in non-adjacent cells. By frequency reuse means the same frequency channels can be used in different cells which are separated by a sufficient distance, without interference.

20.1.2 Basic cellular mobile radio system.

A basic cellular mobile system consists of a mobile Telephone switching office (MTSO) which acts as a central office and a base station. An outline of basic cellular system is shown in fig 20.2

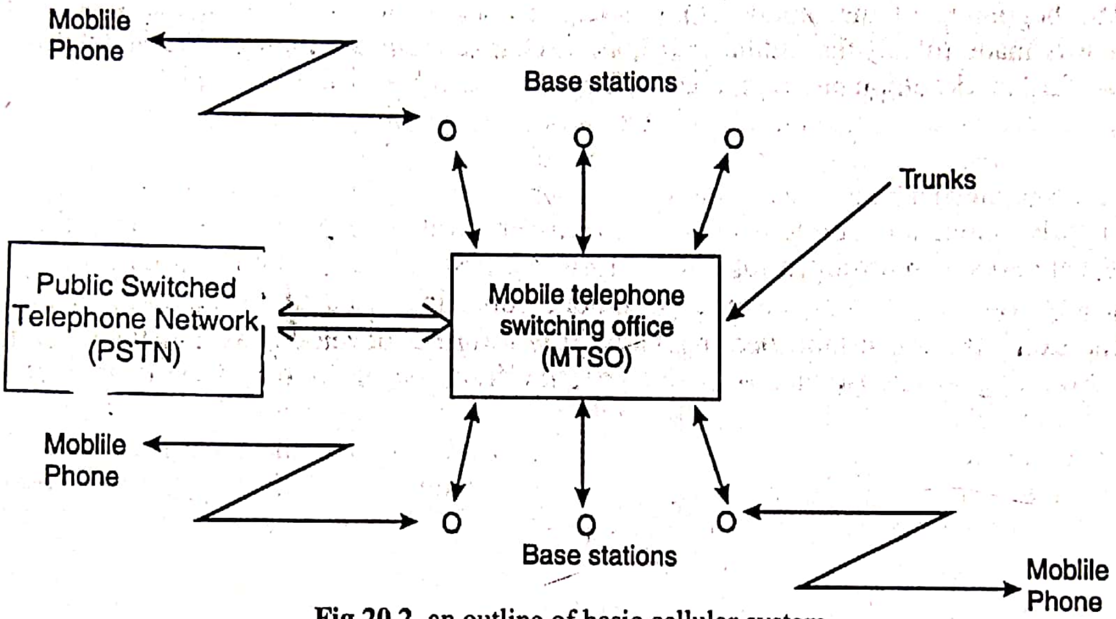

Fig 20.2. an outline of basic cellular system.

A base station is comprised of low-power FM transreceiver power amplifier, control unit and other hardware depending on the system configuration. A base station serves as a central control for all user within that cell. Mobile units communicate directly with the base station, and the base station serves as high power relay station. The base station rebroadcast at a higher power. The base stations are directly connected to the mobile telephone switching office (MTSO). The base station is the interface between cellular mobile units and the MTSO. It communicate with the MTSO over the dedicated data links. The MTSO provides a centralised administration and maintenance point for the entire network. The MTSO functions is to control call processing, signalling, supervision switching and allocating RF channels. The mobile telephone switching office (MTSO) interfaces with Public Switched Telephone Networks (PSTN) and other trunks lines.

The primary components of a cellular radio system are system interconnection, electronic switching centre, cell-site controller, radio transreceivers, communication protocol and mobile telephone units.

System interconnection consists of four wire leased telephone lines which connects the switching centres to each of the cell sites. There is also one dedicated four-wire trunk circuit for each of the cell's user channel.

Electronic switching centre is the heart of the cellular system. It is a digital telephone exchange and performs basic two functions. First it controls the switching between the public telephone network and the cell sites for all fixed phone to mobile, mobile to fixed and mobile to mobile calls. Second it processes data received from the cell-site controllers concerning mobile unit status, diagnostic data and bill-compiling information.

Each cell contains one *cell-site controller*. The cell-site controller operates under the direction of the switching centre. It manages each of the radio channels at the site, supervises calls, turns

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the radio transreceiver on and off, injects data on to the control and user channels. It also performs diagnostic tests on the cell-site equipment.

Radio transreceiver is narrow band FM transreceiver. The audio range is 300 Hz to 3 KHz with 100% modulation and frequency deviation of ± 12 kHz which gives bandwidth of 30 KHz. Each cell contains two radio receiver and one transmitters. When signal is received, the strongest signal is detected out of the two receiver.

Different *communication protocol* is adopted by a different countries. It differs between countries to countries. In USA the Advanced Mobile Phone Service (AMPS) standard is used, whereas in Canada the AURORA 800 standards are used. The communication protocol governs the way a telephone call is established.

Mobile telephone unit consists of a control unit, a radio transreceiver, a logic unit and an antenna. The control unit houses all the user interfaces, including a hanset with antenna. The logic unit interrupts subscriber actions and system commands. The transreceivers make use of frequency synthesizer to tune into any designated cellular system channel.

20.1.3 The cellphone

The cellphone is a compact and small piece which can be easily handled by a user.

Fig 20.3 shows an outline of a cell phone. The cell phone is a full duplex system which contains complete circuitry for receive and transmit channels. The inside can be broadly divided into three units. One is the transreceiver unit, second is the frequency synthesizer and third a system microprocessor unit alongwith keypad and display system. Fig 20.4 shows the block diagram of a cellphone handset.

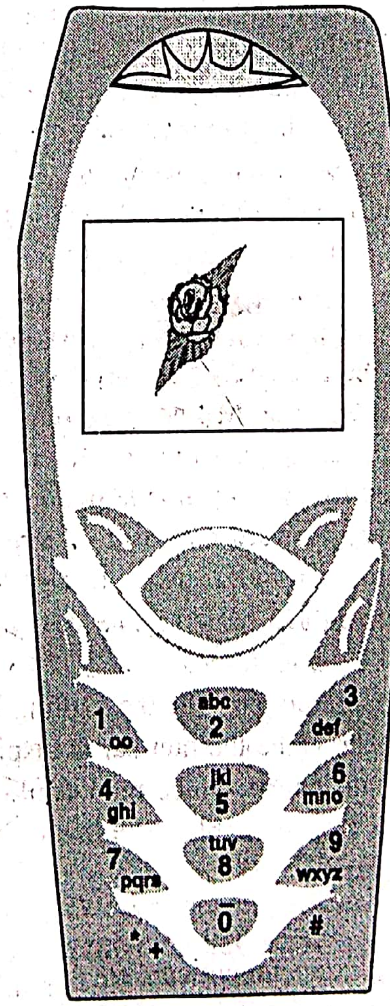

Fig 20.3 Outline of a cellphone

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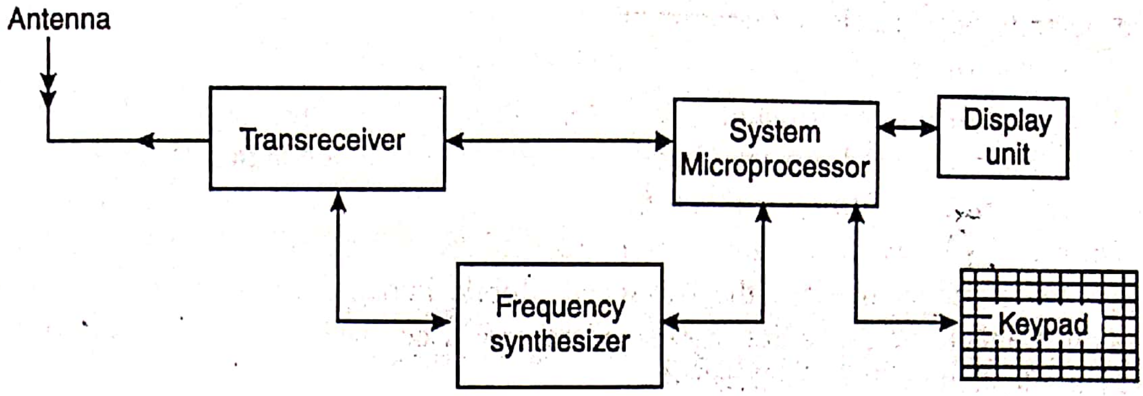

Fig 20.4 Block diagram of a cellphone

The heart of the cellphone is the Subscriber Identity Module (SIM) Card. It is directly associated with the system microprocessor.

The SIM card is a credit card-sized plastic module which fits into the cellphone. The SIM card is a 'smart card' which contains all the subscriber related information like cellular identification number and other related functions. It also stores messages and phone numbers. A SIM card is shown in fig 20.5.

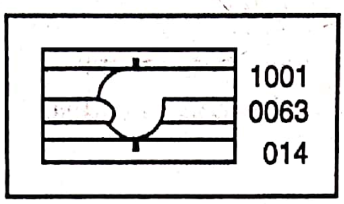

Fig. 20.5. A SIM card

When a user dial a number on the keypad of the cell phone. The called number is placed into the originating register in the cell, and checks to see that the number is correct and pushes the 'send button'. The handset transmits the digits through the built in radio receiver, to a nearby cell site. The nearby cell site receives it and selects the best directive antenna for the voice channel and send the request to the mobile telephone switching office (MTSO).

The MTSO selects an appropriate voice channel for the call, and the cell site acts on it through the best directive antenna to link the cell phone. All the switching functions within a group special mobile (GSM) are handled by MTSO. Once the requested is forwarded to the MTSO, it determines how to route the call and set up the required link to enable the conversation. If the call is destined for a fixed line phone then network sends it to public telephone exchange, over a leased line, which then switches the call to the desired telephone.

However if the call is destined for another mobile phone, then MTSO has to find out where the desired mobile phone is, and then forward the call to the nearest radio base station (or cell).

Cellular phones uses frequencies from 825 MHz to 890 MHz (UHF TV Channels 73-83). The transmit band frequencies are from 825 MHz to 840 MHz and receive band frequencies from 870 MHz to 890 MHz.

Now a days all the cellular operators provide the Calling Line Identification service which displays the incoming caller's number. Once the number is displayed the user can decide if he or she want to take the call on their cell phone. Voice mail facility is also available in cell phone. The Short Message service (SMS) is also available, with this the users send or receive the message upto 160 characters on their cell phones.

20.2 Facsimile (FAX)

A Facsimile or FAX system is a document carrier, with the help of a Fax machine one can send an image on a sheet of paper to another fax machine over regular telephone lines. An outline of a Fax machine is shown in fig 20.5.

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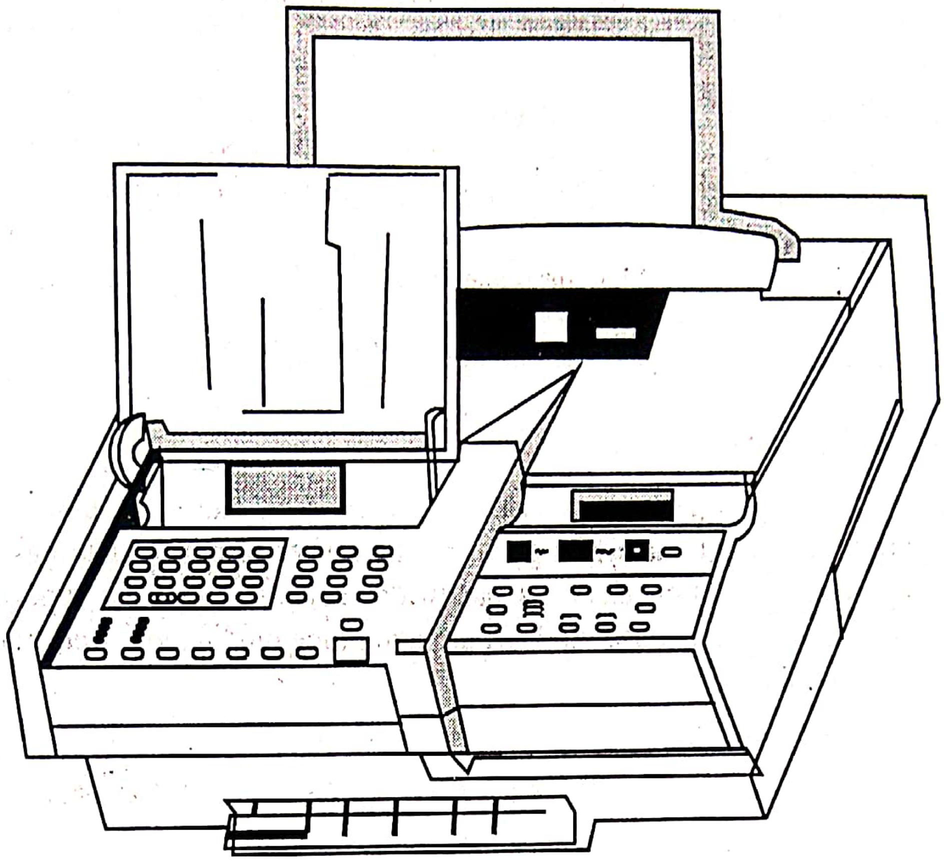

Fig. 20.5. Outline of Fax machine

The document with message written on it is inserted in the Fax machine at the input of the machine. The document is scanned by the electronic scanner, line by line and from top to bottom using light and mirror. The electronic scanner uses a photo cell which senses the light reflected from the document. Whenever there is mark (typing or figure) on this, the photo cell output voltage is very small or binary 0 is generated. If there is no mark, the voltage generated is very large and binary 1 is generated. As line by line is scanned series of 1'S and 0'S are generated.

Each scan line is divided into 200 points per inch, so $8\frac{1}{2}$" wide paper produces 1700 bits/line. These 1's and 0's are further represented by two frequency tones when sent over the telephone line. A block diagram of facsimile system is shown in fig 20.6.

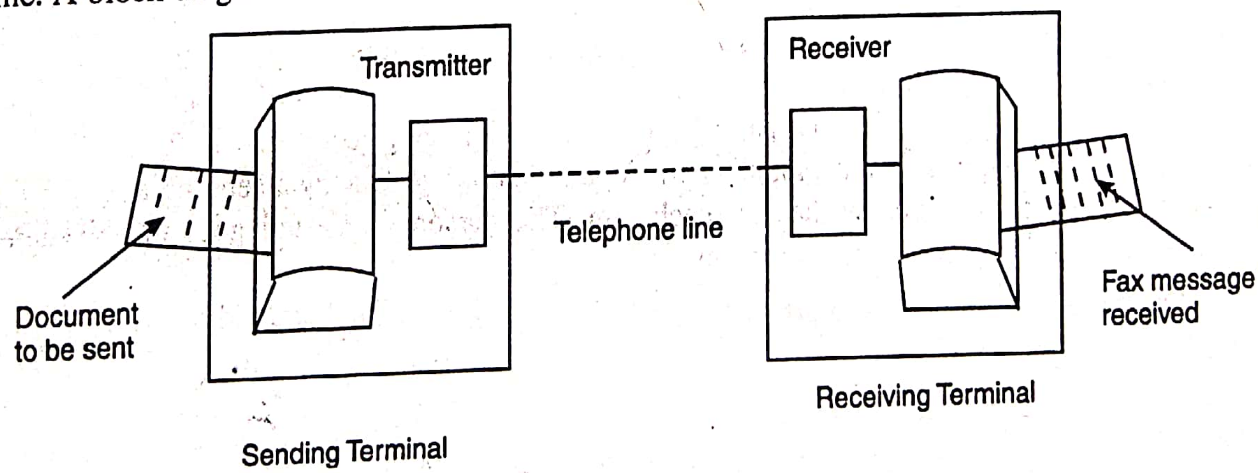

Fig 20.6 Block diagram of Facsimile system.

At the receiving terminal, beam of light scan a specially treated drum surface in synchronization with the scan of the sending unit. As series of 1's and 0's are received, the beam of light is turn on and off and drum turns at the end of each line. The drum carries electrical charges on its surface that have the complete image like photo-graphic negative, and then uses

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these charges to transfer toner ink to a piece of paper. The reproduced image is the exact replica of the sending unit.

20.2.1 Important Features of Fax Machines

There are various features of Fax machines, which decides its resolution and speed. These features directly affect the bandwidth. The various parameters of Fax machine are; scan rate in line per second; Length of scan line; resolution in lines per inch. The scan rate of lines per second and resolution, also paper width decides the pulse frequency. If a Fax system uses a line rate of 3 lines per second and resolution of 100 lines per inch and a paper width of $8\frac{1}{2}$ inches, will give a pulse frequency of $\left(100 \times 8.5 \times \frac{3}{2}\right) = 1275\,\text{Hz}$.

If the resolution in lines per inch is increased or the scan rate is increased, the maximum bandwidth will increase proportionately as given by the earlier formulae. The Fax system signal bandwidth and the communication channels bandwidth depends upon the type of modulation used. The basic modulation system used in FAX are amplitude modulation, frequency modulation and pulse code modulation.

20.2.2 Application of Facsimile

1. The main application of facsimile system are transmission of documents, maps and weather etc.

2. Transmission of photographs.

3. Transmission of languages texts *i.e.,* other languages which are other than English or Hindi can be transmitted without translation.

20.3 VSAT (Very small aperture terminals)

The very small aperture terminal (VSAT) can provide Voice, data, Video Communication and Fax services. The VSAT uses a small (120 cm or 60 cm) dish antenna which communicate with the central hub satellite station. VSAT uses time communication (TDM) over a distributed organisation, without using costly high-power antenna. The VSAT provides two-ways direct communication for all purposes like Video, data and Voice. Now a days the main users of VSAT are ONGC, BHEL, Mother Dairy NTPC etc. Now a days all VSAT systems are based on IP, with a very broad spectrum of applications.

20.4 Radio Paging System

A radio paging system means to summon somebody by sending a page. It is a one-way personal selective calling system which makes use of public switching telephone network (PSTN). The page transmission is from a fixed paging transmitter to a paging receiver. The Paging receiver is a small box, usually, tied on a personal's belt. A pager alerts the user by a sending a beep along with a message that someone wishes to reach him. The person so alerted goes to the nearest telephone hand set and calls a prescribed number.

The pager system operates in VHF and UHF bands with a 3 KHz bandwidth and transmitter power of 1.5 watts, and paging receiver has sensitivity in the range of $10 - 100\ \mu\text{v/m}$.

There are narrow, mid and wide area pager also known as local regional and national pager. The local or narrow area paging system operates only within a building complex. The regional or mid area pager covers an area of several square kilometers, whereas national or wide area pagers operates worldwide. The widely used pagers are mid area pagers, with one centrally located high power transmitter covers an area of 10 to 25 km in diameter. The simplified block diagram of a paging system is shown in Fig. 20.7. Generally the paging system is simplex.

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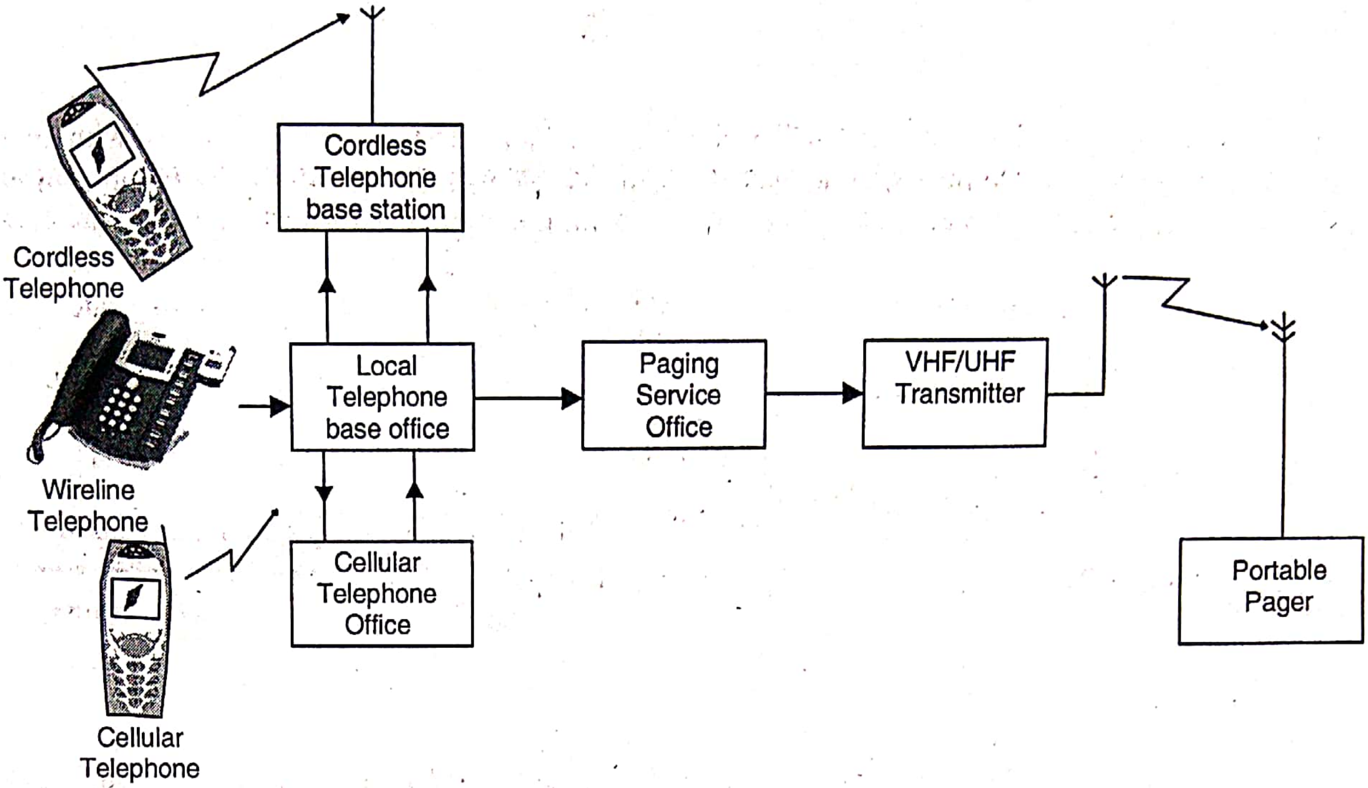

Fig. 20.7. Block diagram of a paging system

To contact a person carrying pager, the telephone number of assigned pager is dialed either from wireline telephone or cellular, telephone or cordless telephone. The paging service office receive the call through local telephone exchange. At the paging service office. The caller number which is usually with the sign is converted into digital code and transmits in the form of a digitally encoded signal by VHF/UHF transmitter over the wireless communication system to the assigned pager. If the paged person is within range of a broadcast transmitter the targeted pager will receive the message either with an audible beep or causes the pager to vibrate and the number of the called person is displayed on the alphanumeric display screen of the pager. Now a days the latest models of pager are capable of displaying message as well as the telephone number of the called person.

20.4.1 Advantages of Paging

A paging system improve efficiency. It reduces the risk of miscommunication. In case of personal emergencies, immediate advice is available. Person with, pagers unit are free to move about the paging zone without disclosing identity.

There are two types of standards for paging transmission : 1. Post office code standard advisory group (POCSAG) and second Radio data system. (RDS). The All India Radio has adopted RDS paging with FM radio frequency carrier. The RDS paging system can be classified into two groups. On sight paging (ONSP) and off-time paging system. The ONSP system is realised through the dedicated transmission system. It is costly but communication is uninterrupted and easier.

20.5 Modem

A modem is a hardware device which is connected to the computer for connecting to the internet. A modem can be as a card inside the computer or as an external device, that is connected to the computer. The word modem is derived from the words modulator and demodulator.

A modem is connected between computer and the telephone line. At the other end, there is another modem, which is connected between Internet Service Provider (ISP) computer and the telephone line. An internet service provider is a group or company which provide access to user over a dedicated connection to the Internet. Any data to be sent by the computer over the telephone line is converted to analogue signal by the modem. At the other end ISP's modem reconverts this

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analogue signal to digital data which is accepted by the ISP's computer.

A modem is a basically a repeater that converts electrical signal received in digital form to electrical signals in analogue form and vice versa. A modem does not change the information contained in the data, it simply repeats or retransmits data. Modems work in pairs with one located at each end of a data communication circuit. A block diagram of data communication modems is shown in Fig. 20.8. A serial interface such as RS. 232 is used in digital computer for

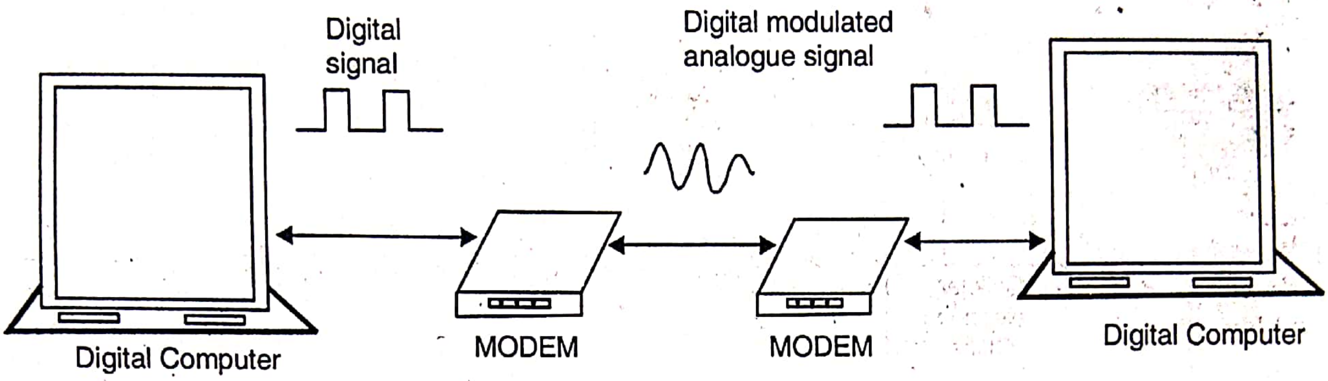

Fig. 20.8. Block diagram data communication modem

connecting to the modems. Then modem converts the digital pulses to analogue signal, the modem transmitter is a digital to analogue converter (DAC). This digitally modulated analogue signal is sent over the telephone lines to the distant receiver. At the destination end of a data communication system the modem receiver converts the analogue signal to digital signal, infact modem receiver is a analogue to digital converters (ADC). Then these pulses are computed inside the computer through several digital interface (RS 232). The speed of the modem is expressed in bits per second (bps). For TCP/IP (Transmission control Protocol Internet protocol/account a modem should preferably have a speed of at least 28.8 kbps (kilo bits per second).

20.6 Video-on Demand (VOD)

Video-on-demand technology is getting popularity day by day. It is a service designed to provide the viewer access to large number of programme or movies. The customer by means of a set-top-box (STB) can access any movie or programme. The set-top-box is fitted with the television set. The STB decodes the digital signal into analogue form and provide menu and control function to access list of programme or movie titles. For this the service provider needs a large server. The viewer can have control over an individual movie from the movie titles. To store the large data, the video is digitally compressed which requires less storage. For this the server uses digital video compression technology, which require cable-quality video in a 4 to 6 Mbits/s bandwidth. The video on demand requires costly server.

A new services has been proposed which requires less costly server and less storage, the service has been named as Near-Video-on-Demand (NVOD). The film is divided into six transmission access instead of several thousand copies. If the viewer switch of the TV set or leave for few minutes, and rejoin after sometimes, he or she would need to wait 10 minutes at the most to return to the point at which the film was stopped. The set-top-box menu/titeles would automatically determine where to rejoin the film out of the six transmission to access. The NVOD or VOD requires two-way communication with the service provider (IPTV/cable company). In this two-way communication, when the user control video/select video then this is called *upstream*. The video transmission by the service provider is called *downstream*. The bandwidth requirement of downstream is much larger than the down stream direction. The VOD services are asymmetric. The video on demand services works on broadband switching.

20.7 IPTV (Internet Protocol Television)

IPTV means video over telephone lines. To use IPTV services broadband connection is necessary. In this service the customer can view TV programme without cable connection or DTH

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services To use IPTV services *set-top box* (STB) is necessary. The IPTV services works without internet connection and without computer, for this only STB and television set is required. IPTV service is better than DTH (direct to home) service, no microwave dish is required for IPTV service. There is no need of cable, already existing telephone line is used for IPTV services. In DTH all the viewer see the same film at a particular time; whereas in IPTV different movie/ programme can be viewed by the different user at the same time. Some of the sailent features of IPTV are listed below :

1. Video on demand (VOD)
2. Time-shift TV (TSTV)
3. Video Calling
4. Video games
5. E-shopping
6. E-Ticketing
7. Stock-exchange
8. T-commerce

IPTV is a value-added service (VAS). It is video on demand. In time-shift TV, the viewer can view 10 days ald programme on demand. If the IPTV user has missed the programme, he can demand the same programme/movie after few days.

The IPTV has facility of video calling. In video calling a web camera is required. The web camera is connected around the TV receiver. The viewer can view the distant relative/friend picture on TV and can talk. In video calling facility, a tutor can teach thousands of students at a time. Those students having IPTV connection with broadband can watch the lecture sitting at home and ask question over the web camera and gets solutions of their problem.

IPTV has the facility of playing video games. Different video games can be played without any extra charges however few video games requires some charges that can be paid at a later date.

Under T-commerce, IPTV has the facility to watch advertisement of different products. If the viewer wants to purchase a TV set then he can select from the advertisement of TV sets of different company than he can select the TV sets out of various models.

The T-commerce facility of IPTV has the advantage of booking rail/airways tickets. The viewer can do the E-shopping.

At present MTNL is the only company which is providing IPTV services; other companies are also trying to get IPTV service. The IPTV service charges are less as compared to Cable/DTH services.

20.8 WI-FI

Wi-Fi is a Wireless internet connection. In wi-fi system, the wireless router is plugged to an electricity socket, when Wi-Fi is turned on it broadcast signals to the wi-fi enabled computer so that laptop or computer is connected to the internet. The wi-fi works upto a radius of 50 metres, depending on the strength and quality of the connection. In a house it works upto two floors in both directions. The safe and secure method to use wi-fi is to use user name and password.

20.9. What is 3G

3G is the *Third Generation* of mobile technology. It enables mobile operators to offer a range of advanced services to the mobile users. At present all mobile operate on 2G (second generation) frequencies. The 3G technology will transfer date at speeds between 2 mbs and 348 kbs, depending upon whether the person is stationary or mobile. According to the sanctioned bank width, the 3G mobile will help user to down load voice, sound, photo and video at much faster speed. The 3G services will enables, wi-fi facility, the video comferencing and voice data transfer using skype. Like internet the user can talk free on the 3G mobile. The mobile manufacturer such as Nokia, Samsung, Sony Ericsson and Motorola will provides 3-G enabled models. By the end of the year 2012 every fifth handset in India will be 3G enabled mobilephone.

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- System performance is independent of the carrier frequency.
- Beam width and λ/D ratio are constant.
- Satellite antenna gain is constant.
- For a given HPA output, satellite EIRP remains constant.
- For a given earth - station antenna size and fixed EIRP, the received power at the earth station is independent of frequency.

6.4.6 Drawbacks of VSAT Systems

(i) High initial costs

(ii) The tendency towards optimizing systems for large networks (>500 VSATs)

(iii) No direct VSAT-to-VSAT links are available.

6.5 INTRODUCTION - Mobile Satellite Services

Three geostationary satellites situated at appropriate places could provide communications coverage for the whole earth. In addition to geostationary orbits, non geostationary orbits are also used, especially low earth orbits (LEOs) and medium earth orbits (MEOs).

Even though there is development in larger satellites, small satellites also play an important role. Still there are large areas and population groups that have very limited access to telecommunications services. This is the main reason for the development of satellite mobile services.

6.6 GSM – GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS

– GSM stands for Global System for Mobile Communications. It is a digital cellular technology used for transmitting mobile voice and data services.

– Originally known as ***Group especial Mobile***, is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile phones.

– It was established in 1982 and as of 2014 it has become the default global standard for mobile communications.

– According to GSM World, there are now more than 2 billion GSM mobile phone users in more than 210 countries throughout the world.

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6.6.1 Features

- GSM supports voice calls and data transfer speeds of up to 9.6 kbps, together with the transmission of SMS (Short Message Service).
- GSM was developed using digital technology. It has an ability to carry 64 kbps to 120 Mbps of data rates.
- GSM makes use of narrowband Time Division Multiple Access (TDMA) technique for transmitting signals.
- The ***uplink*** frequency range specified for GSM is 933 - 960 MHz and the ***downlink*** frequency band is 890 - 915 MHz .
- ***Channel spacing*** indicates the spacing between adjacent carrier frequencies. For GSM, it is 200 kHz.
- GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1800 MHz frequency band.
- Terrestrial GSM networks now cover more than 90% of the world's population. It operates in over 219 countries and territories

6.6.2 Architecture

GSM network comprises of many functional units. The GSM network can be broadly divided into:

(1)The Mobile Station (MS)

(2)The Base Station Subsystem (BSS)

(3)The Network Switching Subsystem (NSS)

(4)The Operation Support Subsystem (OSS)

(1) The Mobile Station (MS)

The MS consists of the physical equipment, such as the radio transceiver, display and digital signal processors, and the SIM card. It provides the air interface to the user in GSM networks.

(2) The Base Station Subsystem (BSS)

The BSS is composed of two parts:

- The Base Transceiver Station (BTS)
- The Base Station Controller (BSC)

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The BTS and the BSC communicate across the specified Abis interface, enabling operations between components that are made by different suppliers.

A simple pictorial view of the GSM architecture is shown in fig.6.5.

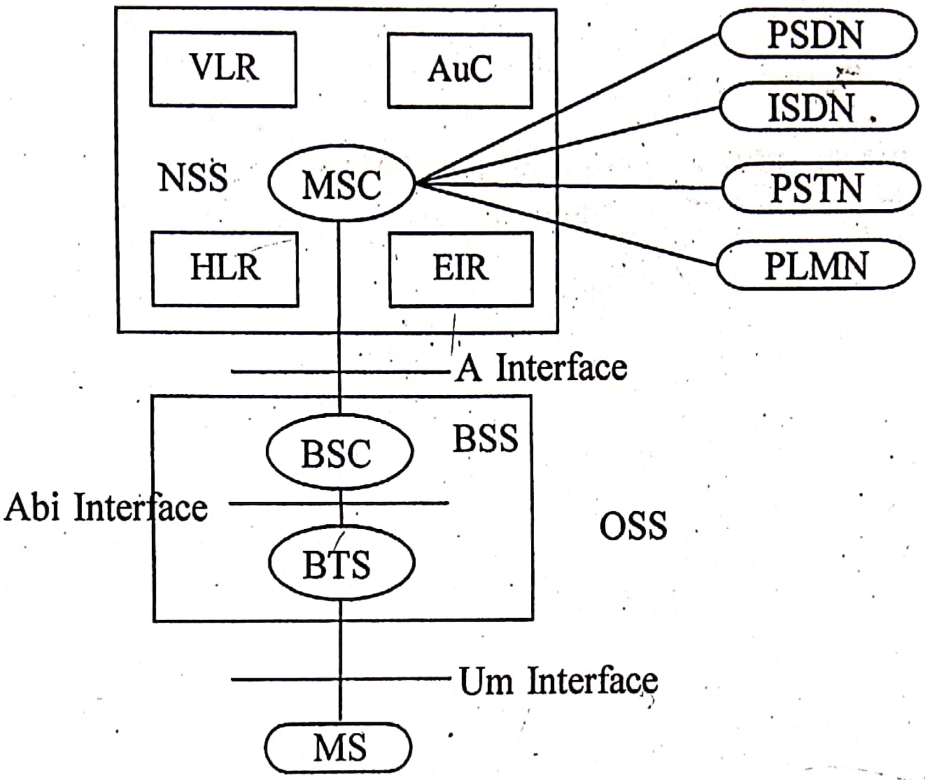

Figure 6.5 The GSM Functional Units

(3) The Network Switching Subsystem (NSS)

The Network switching system (NSS), the main part of which is the Mobile Switching Center (MSC), performs the switching of calls between the mobile and other fixed or mobile network users, as well as the management of mobile services such as authentication.The switching system includes the following functional elements:

(a) Home Location Register (HLR)

The HLR is a database used for storage and management of subscriptions.

(b) Mobile Services Switching Center (MSC)

The central component of the Network Subsystem is the MSC. The MSC performs the switching of calls between the mobile and other fixed or mobile network users, as well as the management of mobile services such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber.

(c) Visitor Location Register (VLR)

The VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers.

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(d) Authentication Center (AUC)

The Authentication Center is a protected database that stores a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and ciphering of the radio channel. The AUC protects network operators from different types of fraud found in today's cellular world.

(e) Equipment Identity Register (*EIR*)

The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where its International Mobile Equipment Identity (IMEI) identifies each MS. An IMEI is marked as invalid if it has been reported stolen or is not type approved.

(4) The Operation Support Subsystem (OSS)

The operations and maintenance center (OMC) is connected to all equipment in the switching system and to the BSC. The implementation of OMC is called the operation and support system (OSS).

Here are some of the OMC ***functions***:

- Administration and commercial operation (subscription, end terminals, charging and statistics).
- Security Management.
- Network configuration, Operation and Performance Management.
- Maintenance Tasks.

The MS and the BSS communicate across the ***Uminterface***. It is also known as the *air interface* or the *radio link*. The BSS communicates with the Network Service Switching (NSS) center across the ***A interface***.

6.6.3 GSM Network Areas

In a GSM network, the following areas are defined:

- ***Cell*** **:** Cell is the basic service area; one BTS covers one cell. Each cell is given an unique number to identify that cell, called the Cell Global Identity (CGI).
- ***Location Area*** : A group of cells form a Location Area (LA). This is the area that is paged when a subscriber gets an incoming call. Each LA is assigned a Location Area Identity (LAI). Each LA is served by one or more BSCs.
- ***MSC/VLR Service Area*** : The area covered by one MSC is called the MSC/VLR service area.
- ***PLMN*** : The area covered by one network operator is called the Public Land Mobile Network (PLMN). A PLMN can contain one or more MSCs.

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GSM treats the users and the equipment in different ways, Phone numbers, subscribers, and equipment identifiers are some of them.

Cell Sizes

GSM is a cellular network, which means that cell phones connect to it by searching for cells in the immediate vicinity.

There are five different cell sizes in a GSM network—*macro, micro, pico, femto, and umbrella cells.* The coverage area of each cell varies according to the implementation environment.

- ***Macro cells*** can be regarded as cells where the base station antenna is installed on a mast or a building above average rooftop level.
- ***Micro cells*** are cells whose antenna height is under average rooftop level; they are typically used in urban areas.
- ***Pico cells*** are small cells whose coverage diameter is a few dozen meters; they are mainly used indoors.
- ***Femto cells*** are cells designed for use in residential or small business environments and connect to the service provider's network via a broadband internet connection.
- ***Umbrella cells*** are used to cover shadowed regions of smaller cells and fill in gaps in coverage between those cells.

6.6.4 Subscriber Identity Module (SIM)

One of the key features of GSM is the Subscriber Identity Module, commonly known as a ***SIM card***. The SIM is a detachable smart card containing the user's subscription information and phone book.

The SIM provides personal mobility so that the user can have access to all subscribed services irrespective of both the location of the terminal and the use of a specific terminal. This allows the user to retain his or her information after switching handsets. Alternatively, the user can also change operators while retaining the handset simply by changing the SIM.

Some operators will block this by allowing the phone to use only a single SIM, or only a SIM issued by them. It is implemented by a software feature of the phone. This practice is known as ***SIM locking***.

6.6.5 Roaming

Roaming is the ability to use your GSM phone number in another GSM network.

GSM satellite roaming has also extended service access to areas where terrestrial coverage is not available.

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Since many GSM network operators have roaming agreements with foreign operators, users can often continue to use their mobile phones when they travel to other countries. SIM cards (Subscriber Identity Module) holding home network access configurations may be switched to those will metered local access, significantly reducing roaming costs while experiencing no reductions in service.

6.6.6 GSM Security

GSM is the most secured cellular telecommunications system available today. GSM has its security methods standardized. GSM maintains end-to-end security by retaining the confidentiality of calls and anonymity of the GSM subscriber.

Temporary identification numbers are assigned to the subscriber's number to maintain the privacy of the user. The privacy of the communication is maintained by applying encryption algorithms and frequency hopping that can be enabled using digital systems and signalling.

6.6.7 Service Provided

GSM offers three basic types of services:

(i)Telephony services or teleservices

(ii)Data services or bearer services

(iii)Supplementary services

(i) Teleservices

The abilities of a Bearer Service are used by a Teleservice to transport data. These services are further transited in the following ways:

- Voice Calls
- Videotext and Facsmile
- Short Text Messages: *Short Messaging Service* (*SMS*) service is a text messaging service that allows sending and receiving text messages on the GSM mobile phone.

(ii) *Bearer Services*

Data services or Bearer Services are used through a GSM phone to receive and send data. It is the essential service leads to widespread mobile Internet access and mobile data transfer. GSM currently has a data transfer rate of 9.6k.

(iii) Supplementary Services

Supplementary services are additional services that are provided in addition to teleservices and bearer services. These services include:

- caller identification,

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- call forwarding,
- call waiting and call holding,
- multi-party conversations,
- barring of outgoing (international) calls
- *Conferencing* : It allows a mobile subscriber to establish a multiparty conversation, i.e., a simultaneous conversation between three or more subscribers to setup a conference call.
- *GPRS Services:* Using GPRS service, subscriber can browse, play games on the Internet, and download movies. So a service provider will charge the subscriber based on the data uploaded as well as data downloaded on the mobile phone.

6.6.8 Advantages of GSM

Listed below are the features of GSM that account for its popularity and wide acceptance.

i) Improved spectrum efficiency

ii) International roaming

iii) Low-cost mobile sets and base stations (BSs)

iv) High-quality speech

v) Compatibility with Integrated Services Digital Network (ISDN) and other telephone company services

vi) Support for new services

6.7 GPS – GLOBAL POSITIONING SYSTEM

Global Positioning System (GPS) was created and realized by the US department of defense (USDOD). GPS is a space-based global navigation satellite (GNSS) that provides reliable ***location and time information***.

It works in all weather conditions and at all times and day where on or near the earth. There are no subscription fee or setup charges to use GPS.

GPS has become a widely deployed and useful tool for commerce, scientific uses, tracking and surveillance.

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