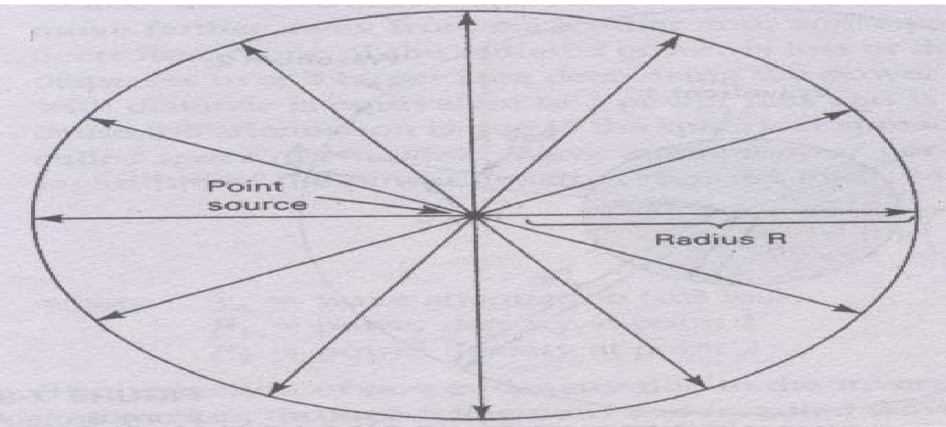


FIGURE 7-2 Wavefront from a point source

4-3. Describe *power density.*

Answer:- Power density:- The rate at which energy passes through a given surface area in free space is called *power density.* Therefore, power density is energy per Unit of time per unit of area and is usually given in watts per square meter. Mathematically, power density is

$$\mathcal{P} = \mathcal{E}\mathcal{H} \qquad (7\text{-}1)$$

where $\mathcal{P}$ = power density (watts per meter squared)

$\mathcal{E}$ = rms electric field intensity (volts per meter)

$\mathcal{H}$ = rms magnetic field intensity (ampere turns per meter)

4-4.* Describe a *spherical wavefront.

Answer:-

Spherical Wavefront: - An isotropic radiator produces a spherical wavefront with radius R. All points at distance R from the source lie on the surface of the sphere and have equal power densities. For example, in Figure 7-3, points A and B are an equal distance from the source. Therefore, the power densities at points A and B are equal. At any instant of time, the total power radiated, *P* watts, is uniformly distributed over the total surface of the sphere (assuming a lossless transmission medium). Therefore, the power density at any point on the sphere is the total radiated power divided by the total area of the sphere. Mathematically, the power density at any point on the surface of a spherical wavefront is

$$\mathcal{P} = \frac{P_{rad}}{4\pi R^2} \qquad (7\text{-}2)$$

Where $\mathcal{P}$ = power density at distance R from point source(watts per meter squared)

P_{rad} =total power radiated by point source(watts)

R= radius of the sphere (which is equal to the distance from any point on the surface of the sphere to the source

$4\pi R^2$=area of the sphere with radius R(square meters)

4-5. Explain the *inverse square law* and how it relates to electromagnetic waves.
Answer:-

Inverse *Square Law :-* From Equation 7-2,

$$\mathcal{P} = \frac{P_{rad}}{4\pi R^2} \quad \textbf{(7-2)}$$

it can be seen that the farther the wavefront moves from *the source,* the smaller the power density. The total power distributed over the surface of the sphere remains the same. However, because the area of the sphere increases in direct proportion to the distance from the source squared (i.e., the radius of the sphere squared). the power density is inversely proportional to the square of the distance from the source. This relationship is called the *inverse square law.*

4-6. Describe the difference between *wave attenuation* and *wave absorption.*
Answer:-

Wave attenuation* and *wave absorption:-Free space is a vacuum, so no loss of energy occurs as a wave propagates through it. However, as waves propagate through free space, they spread out, resulting in a reduction in power density. This is called *attenuation* and occurs in free space as well as the Earth's atmosphere. Since earth's atmosphere is not a vacuum, it contains particles that can absorb 1ectromagnetic energy. This type of reduction of power is called *absorption loss* and does not occur in waves traveling outside earth's atmosphere.

4-7. What are the *optical properties* of radio waves?
Answer:-

***Optical properties* of radio waves**:-In earth's atmosphere, ray-wavefront propagation may be altered from free-space behavior by optical effects such as *refraction reflection, diffraction,* and *interference .R*efraction can be thought of as bending, reflection as bouncing, diffract ion as scattering, and interference as colliding. Refraction, reflection, diffraction and interference are called *optical properties* because they were first observed in the science of optics, which is the behavior of light waves. Because light waves are high-frequency electromagnetic waves, optical properties will also apply to radio-wave propagation.

4-8. Describe the following terms and how they relate to radio-wave propagation: *refraction, reflection, diffraction,* and *interference.*
Answer:-
Refraction:- Electromagnetic *refraction* is the change in direction of an electromagnetic wave as it passes obliquely from one medium to another medium with a different density (refractive index). The

velocity at which an electromagnetic wave propagates is inversely proportional to the density of the medium in which it is propagating. Therefore, refraction occurs whenever a radio wave passes from one medium into another.

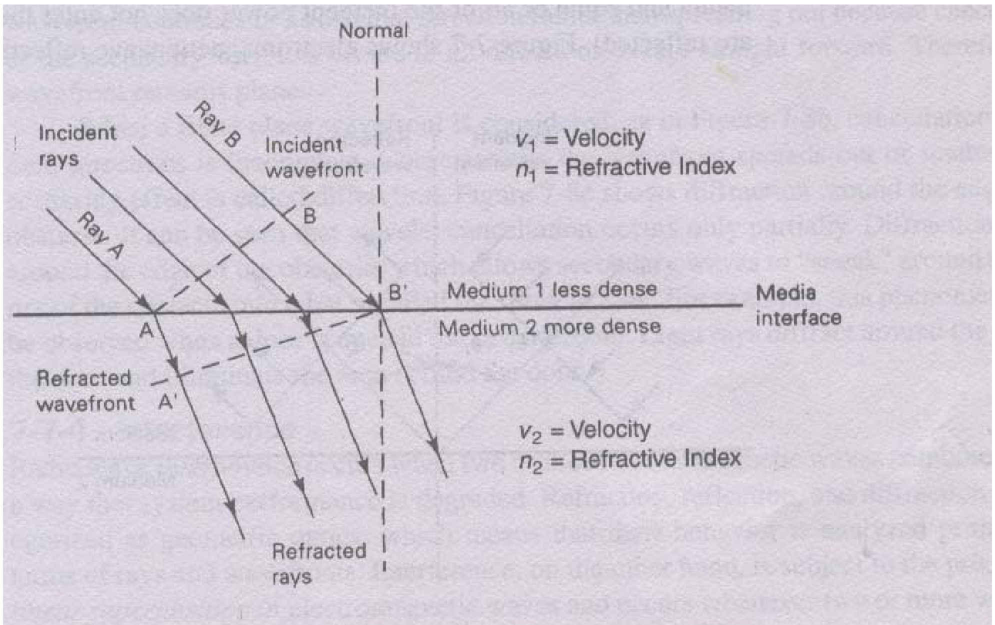


FIGURE 7-5 Refraction at a plane boundary between two media

Figure 7-5 shows refraction of a wavefront at a plane boundary between two media with different densities. For this example, medium 1 is less dense than medium 2 *($n_1 > n_2$, thus $v_1 > v_2$)*. It can be seen that ray A enters the more dense medium before ray B. Therefore, ray B propagates more rapidly than ray A and travels distance from B to B^1 during the same time that ray A travels the distance from A to A^1. Therefore, wavefront A^1B^1 is tilted or bent in a downward direction. Whenever a ray passes from a less dense to a more dense medium, it is effectively bent toward the normal (imaginary line drawn perpendicular to the interface at the point of incidence). Conversely, whenever a ray passes from a more dense to a less dense medium, it is effectively bent away from the normal. The *angle of incidence* is the angle formed between the incident wave and the normal, and the *angle of refraction* is the angle formed between the refracted wave and the normal.

As with optical frequencies, how an electromagnetic wave reacts when it meets the interface of two transmissive materials with different indexes of refraction can be explained with *Snell 's law.* Mathematically, Snell's law states,

$$sin\theta_1 \left(\frac{n_1}{n_2}\right) = sin\theta_2 \qquad (7\text{-}4)$$

where θ_1= angle of incidence (degrees)
θ_2= angle of refraction (degrees)
n_1 = refractive index of material 1 (unit less)
n_2= refractive index of material 2 (unit less)

Refraction also occurs when a wavefront propagates in a medium that has a density gradient that is perpendicular to the direction of propagation (i.e., parallel to the wavefront).

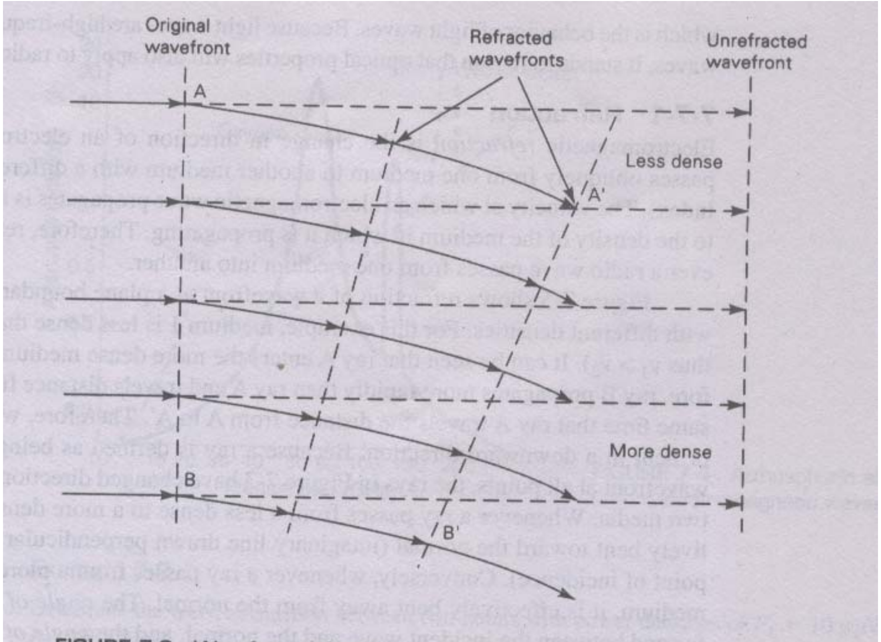


FIGURE 7-6 Wavefront refraction in a gradient medium

Figure 7-6 shows wavefront refraction in a transmission medium that has a gradient refractive index, such as earth's atmosphere. The medium is more dense near the bottom (close to earth's surface) and less dense near the top (in earth's upper atmosphere). Therefore, rays traveling in the upper layers of the atmosphere travel faster than rays traveling near earth's surface and, consequently, the wavefront tilts downward. The tilting occurs in a gradual fashion as the wave progresses. **Reflection :-**Electromagnetic wave *reflection* occurs when an incident wave strikes a boundary of two media and some or all of the incident power does not enter the second material (i.e., they are reflected).

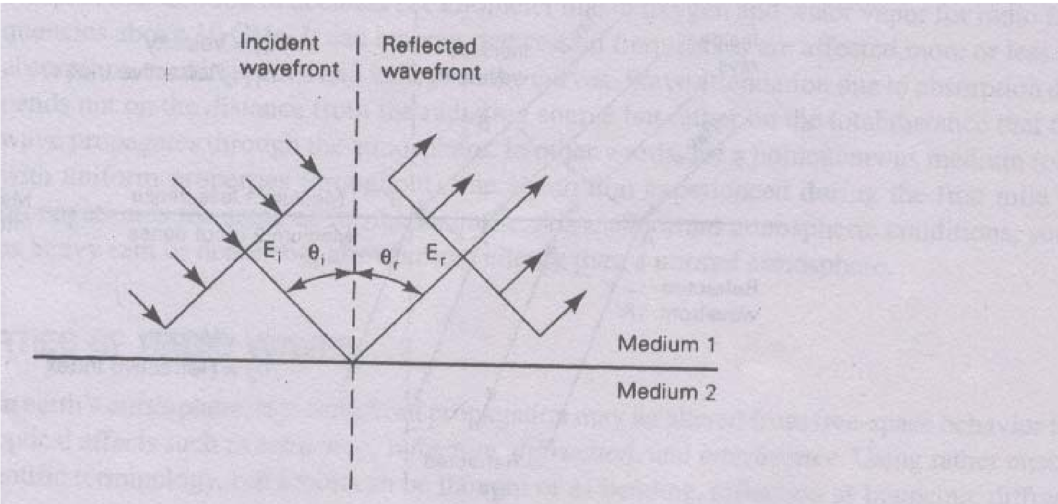


FIGURE 7-7 Electromagnetic reflection at a plane boundary of two media

Figure 7.7 shows electromagnetic wave reflection at a plane boundary between two media. Because all the reflected waves remain in medium 1, the velocities of the reflected and incident waves are equal. Consequently, the angle of reflection equals the angle of incidence($\theta_i = \theta_r$)**.** The ratio of the reflected to the incident power is f, expressed mathematically as

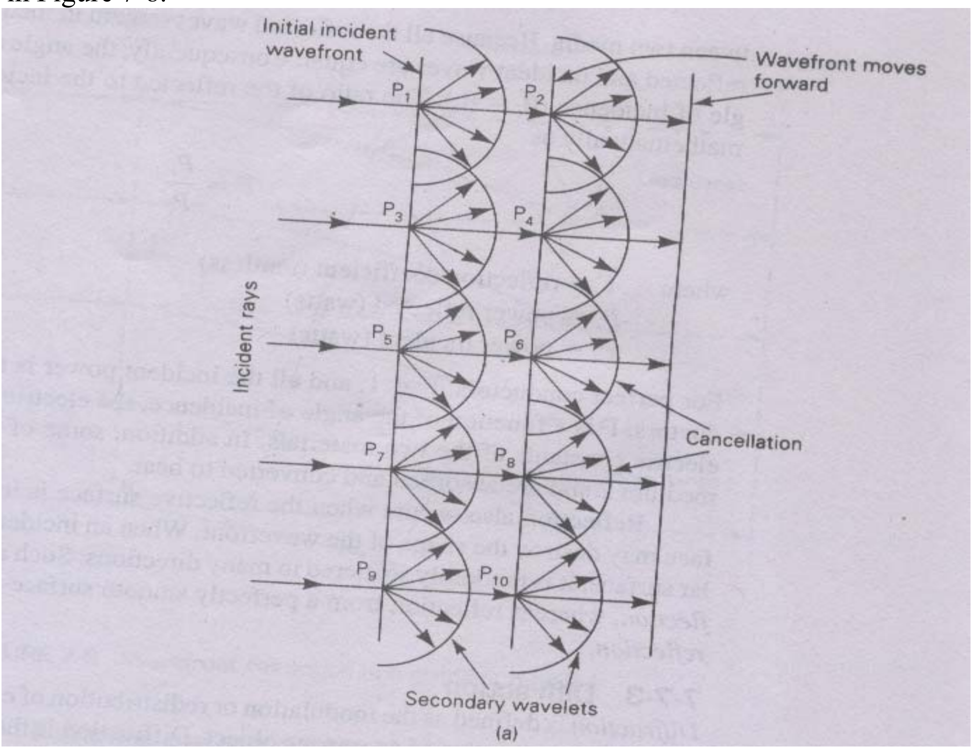
$$r = P_r/P_i \qquad (7\text{-}5)$$

where r= reflection coefficient (unit less)
P_r= power reflected (watts)
P_i = power incident (watts)

For perfect conductors, r = 1**,** and all the incident power is reflected. For imperfect conductors, r is a function of the angle of incidence, the electric field orientation, and the dielectric constants of the two materials. In addition, some of the incident waves penetrate medium 2 and are absorbed and converted to heat.

Reflection also occurs when the reflective surface is irregular; however, such a surf ace may destroy the shape of the wavefront. When an incident wavefront strikes an irregular surface, it is randomly scattered in many directions. Such a condition is called *diffuse* ref*lection,* whereas reflection from a perfectly smooth surface is called *specular* (mirror like) *reflection.*

Diffraction :- *Diffraction* is defined as the modulation or redistribution of energy within a wavefront when a density it passes near the edge of an opaque object. Diffraction is the phenomenon that allows light or radio waves to propagate (peek) around corners. The previous discussions on refraction and reflection assumed that the dimensions of the refracting and reflecting surfaces were large with respect to a wavelength. However, when a wavefront passes near an obstacle or discontinuity with dimensions comparable in size to a wavelength, simple geometric analysis cannot be used to explain the results. In these cases, ***Huygen 's*** *principle* is necessary. Huygen's principle states that every point on a given spherical wavefront can be considered as a secondary point source of electromagnetic waves from which other secondary waves (wavelets) are radiated outward. Huygen's principle is illustrated in Figure 7-8.



(a)

Normal wave propagation considering an infinite plane is shown in Figure 7-8a. Each secondary point source *(P_1, P_2* and so on) radiates energy outward in all directions. However, the wavefront continues in its original direction rather than spreading out because cancellation of the secondary wavelets occurs in all directions except straight forward. Therefore, the wavefront remains plane. When a finite plane wavefront is considered, as in Figure 7-8b, cancellation in random directions is incomplete.

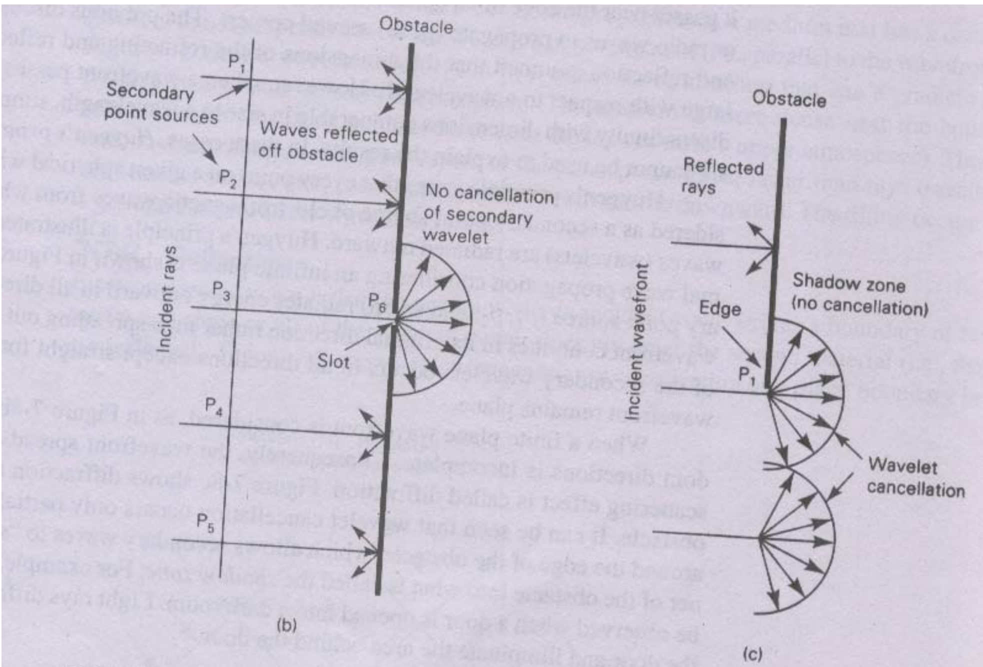


FIGURE 7-8 Electromagnetic wave diffraction: (a) Huygen's principle for a plane wavefront; (b) finite wavefront through a slot; (c) around an edge

Consequently, the wavefront spreads out or scatters. This scattering effect is called diffraction. Figure 7-8c shows diffraction around the edge of an obstacle. It can be seen that wavelet cancellation occurs only partially. Diffraction occurs around the edge of the obstacle, which allows secondary waves to "sneak" around the corner of the obstacle into what is called the *shadow zone*. For example, this phenomenon can be observed when a door is opened into a dark room. Light rays diffract around the edge of the door and illuminate the area behind the door.

Interference:- Radio wave *interference* occurs when two or more electromagnetic waves combine in such a way that system performance is degraded. Refraction, reflection, and diffraction are categorized as geometric optics, which means that their behavior is analyzed primarily in terms of rays and wavefronts. Interference, on the other hand, is subject to the principle of *linear superposition* of electromagnetic waves and occurs whenever two or more waves simultaneously occupy the same point in space. Figure 7-9 shows the linear addition of two instantaneous voltage vectors whose phase angles differ by angle 0. It can be seen that the total voltage is not simply the sum of the two vector magnitudes but rather the phasor addition of the two. Depending on the phase angles of the two vectors, either addition or subtraction can occur.

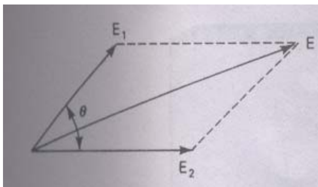


FIGURE 7-9 Linear addition of two vectors with differing phase angles

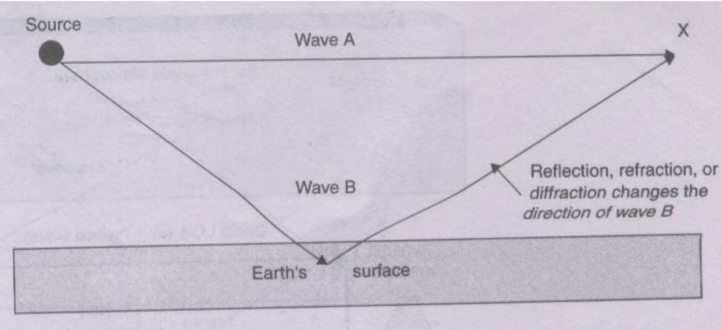


FIGURE 7-10 Electromagnetic wave interference

Figure 7-10 shows interference between two electromagnetic waves in free space. It can be seen that at point X the two waves occupy the same area in space. However, wave B has traveled a different path than wave A and, therefore, their relative phase angles may be different. If the difference in distance traveled is an odd-integral multiple of one-half wavelength, reinforcement takes place. If the difference is an even-integral multiple of one- half wavelength, total cancellation occurs. More than likely, the difference in distance falls somewhere between the two, and partial cancellation occurs.

4-9.* Describe *ground wave propagation, space wave propagation,* and *sky wave propagation.
Answer:-

Ground Wave Propagation:- *Ground waves* are electromagnetic waves that travel along the surface of earth. Therefore, ground waves are sometimes called *surface waves.* Ground waves must be vertically polarized because the electric field in a horizontally polarized wave is parallel to earth's surf ace and short-circuited by the conductivity of the ground. With ground waves, the changing electric field induces voltages in earth's surface, which cause currents to flow that are very similar to those in a transmission line. Earth's surface also has resistance and dielectric losses. Therefore, ground waves are attenuated as they propagate. Ground waves propagate best over a surface that is a good conductor, such as salt water, and poorly over dry desert areas. Ground wave losses increase rapidly with frequency; therefore, ground wave propagation is generally limited to frequencies below 2 MHz.

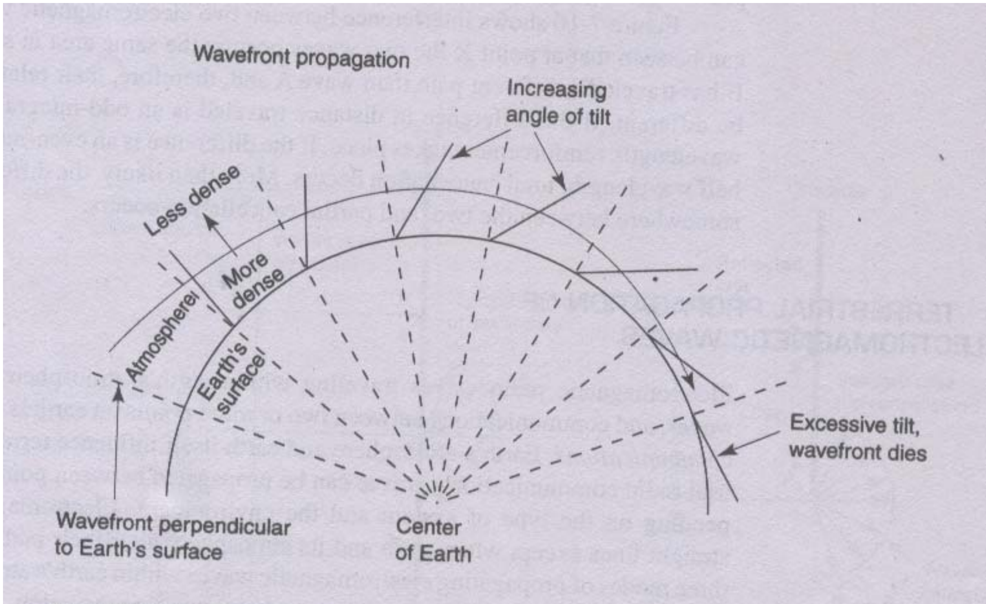


FIGURE 7-12 Surface (ground) wave propagation

Figure 7-12 shows ground wave propagation. Earth's atmosphere has a gradient density (i.e., the density decreases gradually with distance from earth's surface), which causes the wavefront to tilt progressively forward. Therefore, the ground wave propagates around earth, remaining close to its surface, and if enough power is transmitted, the wavefront could propagate beyond the horizon or even around the entire circumference of earth. However, care must be taken when selecting the frequency and the terrain over which the ground wave will propagate to ensure that the wavefront does not tilt excessively and simply turn over, lie flat on the ground, and cease to propagate. Ground wave propagation is commonly used for ship-to-ship and ship-to-shore communications, for radio navigations and for maritime mobile communications.

Space Wave Propagation: Space wave propagation of electromagnetic energy includes radiated energy that travels in the lower few miles of earth's atmosphere. Space waves include both direct and ground- reflected waves (see Figure 7-13). Direct waves travel essentially in a straight line between transmits and receive antennas. Space wave propagation with direct waves is commonly called *line-of-sight* (LOS) *transmission.* Therefore, direct space wave propagation is limited by the curvature of the earth. *Ground-reflected waves* are waves reflected by earth's surface as they propagate between transmit and receive antennas.

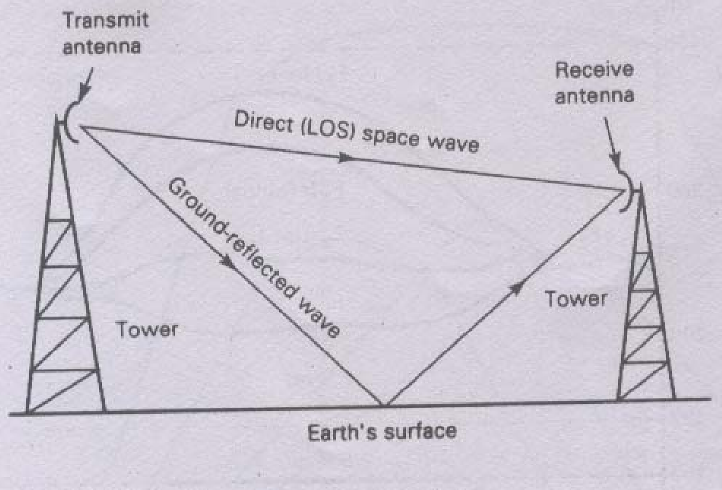


FIGURE 7-13 Space wave propagation

Figure 7-13 shows space wave propagation between two antennas. It can be seen that the field intensity at the receive antenna depends on the distance between the two antennas (attenuation and absorption) and whether the direct and ground-reflected waves are in phase (interference). The curvature of earth presents a horizon to space wave propagation commonly called the *radio horizon.* Because of atmospheric refraction, the radio horizon extends beyond the optical horizon for the common standard atmosphere. The radio horizon is approximately four-thirds that of the optical horizon. Refraction is caused by the troposphere because of changes in its density, temperature, water vapor content, and relative conductivity. The radio horizon can be lengthened by simply elevating the transmit or receive antennas (or both) above earth's surface with towers or by placing the antennas on top of mountains or tall buildings.

Because the conditions in earth's lower atmosphere are subject to change, the degree of refraction can vary with time. A special condition called *duct propagation* occurs when the density of the lower atmosphere is such that electromagnetic waves can propagate within the duct for great distances, causing them to propagate around earth following its natural curvature.

Sky Wave Propagation:- Electromagnetic waves that are directed above the horizon level are called *sky waves.* Typically, sky waves are radiated in a direction that produces a relatively large angle with reference to earth. Sky waves are radiated toward the sky, where they are either reflected or refracted back to earth by the *ionosphere.* Because of this, sky wave propagation is sometimes called *ionospheric propagation.* The ionosphere is the region of space located approximately 50km to 400 km (31 mi to 248 mi) above earth's surface.

The ionosphere is the upper portion of earth's atmosphere. Therefore, it absorbs large quantities of the sun's radiant energy, which ionizes the air molecules. The upper atmosphere has a higher percentage of ionized molecules than the lower atmosphere. The higher the ion density, the more the refraction. Also, because of the ionosphere's non uniform composition and its temperature and density variations, it is *stratified.* Essentially, three layers make up the ionosphere (the D, E, and F layers) and are shown in Figure 7-14.

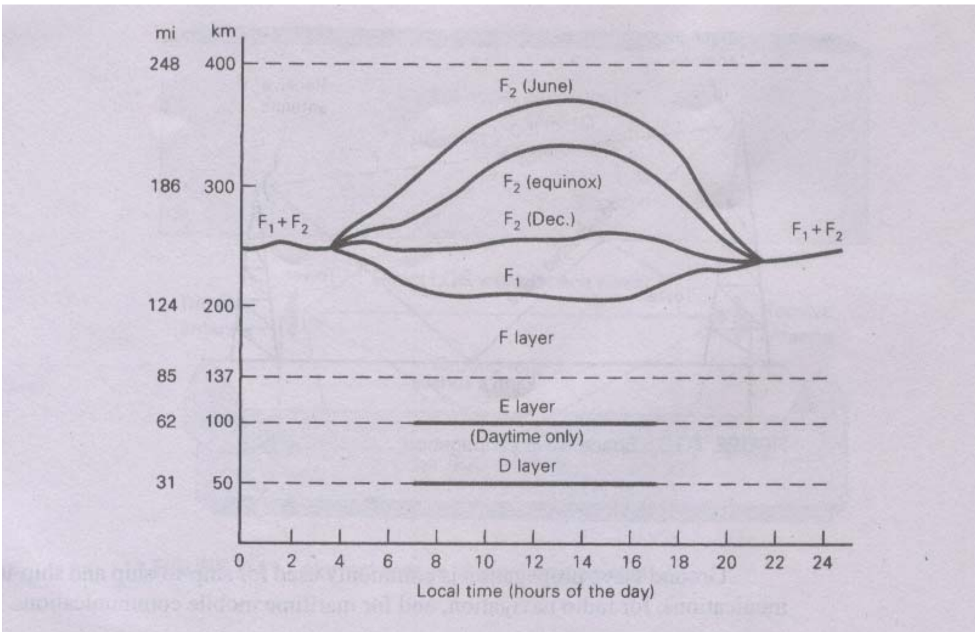


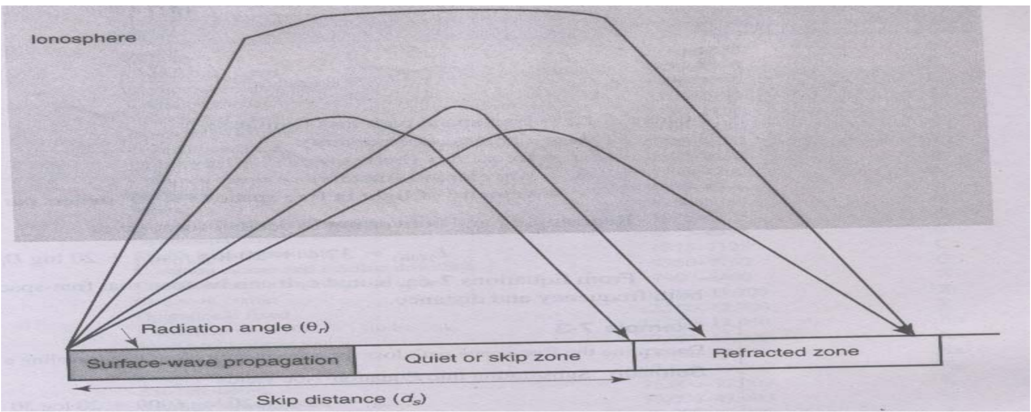
FIGURE 7-14 Ionospheric layers

It can be seen that all three layers of the ionosphere vary in location and in *ionization density* with the time of day. They also fluctuate in a cyclic pattern throughout the year and in accordance with the 11-year *sunspot cycle.* The ionosphere is most dense during times of maxim um sunlight (i.e., during the daylight hours in the summer). Because the density and location of the ionosphere vary over time, the effects it has on electromagnetic radio wave propagation also vary.

4-10. Describe what is meant by the term *skip distance?*

Answer:-

Skip distance is the minimum distance from a transmit antenna that a sky wave of given frequency will be returned to earth. Figure shows several rays with different elevation angles being radiated from the same point on earth. It can be seen that the location where the wave is returned to earth moves closer to the transmitter as the elevation angle (φ) increases. Eventually, the angle of elevation is sufficiently high that the wave penetrates the ionosphere and continues into space totally escaping earth's atmosphere.



4-11. Describe *free-space path loss.*

Answer:-

Free-space path loss is often defined as the loss incurred by an electromagnetic wave as it propagates in a straight line through a vacuum with no absorption or reflection of energy from nearby objects. This is a misstated and often misleading definition. Free-space path loss is a fabricated engineering quantity that evolved from manipulating communications system link budget equations into a particular format. With free-space path loss, no electromagnetic energy is actually lost—it merely spreads out as it propagates away from the source resulting in a lower power density.

4-12. What is the approximate range for microwave frequencies?
Answer:-Microwaves are generally described as electromagnetic waves with frequencies that range from approximately 500 MHz to 300 GHz.

4-13. List the advantages and disadvantages of *microwave radio communications* over *cable transmission facilities.*

Answer:-

The advantages of microwave radio systems over cable facilities include the following:

1. Radio systems do not require a right-of-way acquisition between stations.

2. Each station requires the purchase or lease of only a small area of land.

3. Because of their high operating frequencies, microwave radio systems can carry large quantities of information.
4. High frequencies mean short wavelengths, which require relatively small antenna

5. Radio signals are more easily propagated around physical obstacles, such as water and high mountains.

6. Microwave Systems require fewer repeaters for amplification.

7. Distances between switching centers are less.

8. Underground facilities are minimized.

9. Minimum delay times are introduced.

10. Minimal crosstalk exists between voice channels.

Microwave radio systems also have several disadvantages, including the following

1. The electronic circuits used with microwave frequencies are more difficult to analyze.

2. Conventional components, such as resistors, inductors, and capacitors, are more difficult to manufacture and implement at microwave frequencies.

3. Microwave components are more expensive.

4. Transistor transit time is a problem with microwave devices.

5. Signal amplification is more difficult with microwave frequencies.

4-14. What is the difference between a *terminal station* and a *repeater station?*
Answer:-

A simplified block diagram for a microwave repeater is shown in Figure 7-18. The repeater station receives a signal, amplifies and reshapes it, and then retransmits it to the next repeater or terminal station down line from it. A terminal station is simply a station at the end of a microwave system where information signals originate and terminate.

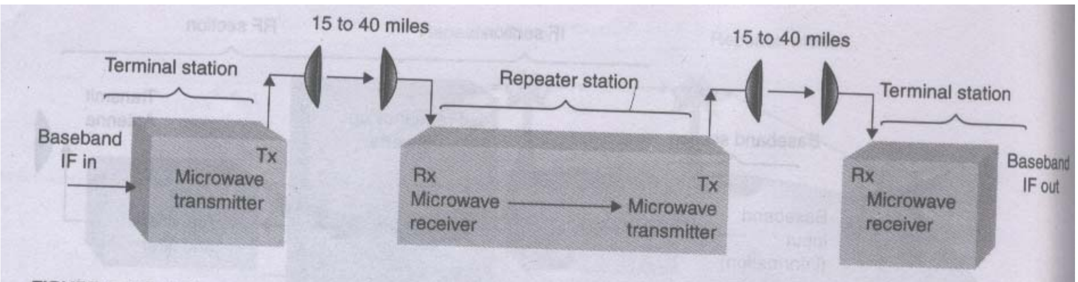


FIGURE 7-18 Microwave repeater

4-15. List and give examples of the three *satellite elevation categories.*
Answer:-

Satellites are generally classified as having a low earth orbit (LEO), medium earth orbit (MEO), or geosynchronous earth orbit (GEO). Motorola's satellite-based mobile telephone system, Iridium, is an LEO system utilizing a 67-satellite constellation orbiting approximately 480 miles above earth's surface. The Department of Defense's satellite- based global positioning system, NAVSTAR, is a MEO system with a constellation of 21 working satellites and six or more spares orbiting approximately 9500 miles above earth.

4-16. List and describe the three *orbital patterns* used by satellites.
Answer:-

Figure 7-21 shows three paths a satellite can follow as it rotates around earth: inclined, equatorial, or polar. All satellites rotate around earth in an orb it that forms a plane that passes through the center of gravity of earth called the *geocenter*. *Inclined* orbits are virtually all orbits except those that travel directly above the equator or directly above the North and South Poles. Angles of inclination vary between 0 degrees and 90 degrees.

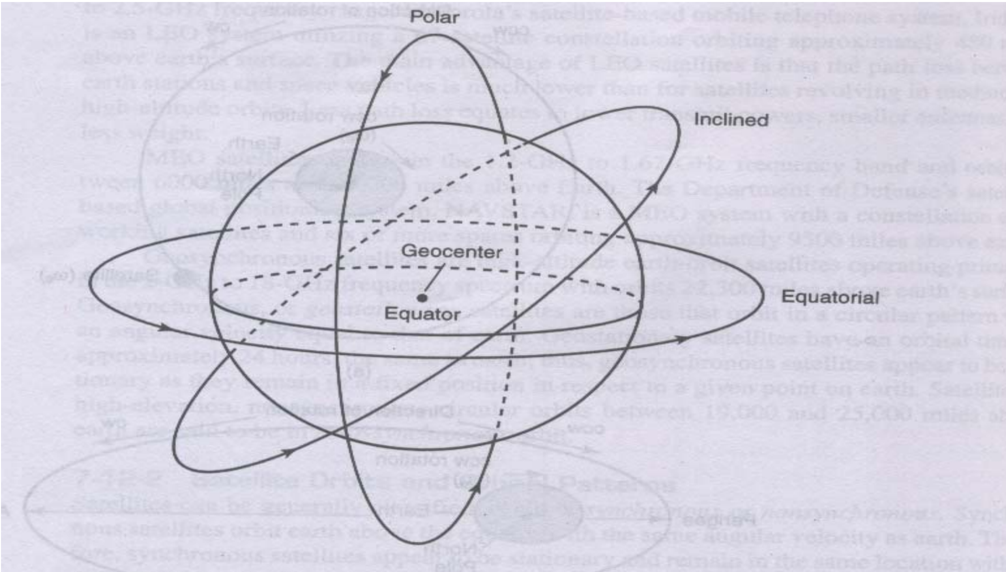


FIGURE 7-21 Satellite orbital patterns

An *equatorial orbit* is when the satellite rotates in an orbit directly above the equator, usually in a circular path. With an equatorial orbit, the angle of inclination is 0 degrees. A *polar orbit* is when the satellite rotates in a path that takes it over the North and South Poles in an orbital pattern that is perpendicular to the equatorial plane. The angle of inclination of a satellite in a polar orbit is nearly 90 degrees. 100% of earth's surface can be covered with a single satellite in a polar orbit. Satellites in polar orbits rotate around earth in a longitudinal orbit while earth is rotating on its axis in a latitudinal rotation.

4-17. Describe a *geosynchronous satellite.*

Answer:-

Geosynchronous Satellites :- Since geosynchronous satellites orbit earth above the equator with the same angular velocity as earth, they appear to remain in a fixed location above one spot on earth's surface. Therefore, no special antenna tracking equipment is necessary—earth station antennas are simply pointed at the satellite. A single high-altitude geosynchronous satellite can provide reliable communications to approximately 40% of the earth's surface. Geosynchronous orbits are circular; therefore, the speed of rotation is constant throughout the orbit. There is only one geosynchronous earth orbit, and this orbit is occupied by a large number of satellites. In fact, geosynchronous orbits are the most widely used earth orbit.

4-18. What is the *Clarke orbit?*
Answer:-

Clarke orbit:- A geosynchronous earth orbit is sometimes referred to as the *Clarke orbit* or *Clarke belt,* after Arthur C. Clarke, who first suggested its existence in 1945 and proposed its use for communications satellites. Clarke orbit meets the concise setoff specifications for geosynchronous satellite orbits: (1) be located directly above the equator, (2) travel in the same direct ion as earth's rotation with a velocity of 6840 miles per hour, (3) have an altitude of 22,300 miles above earth, and *(4)* complete one revolution in 24 hours. As shown in Figure 7-23, three satellites in Clarke orbits separated by 120 degrees in longitude can provide communications over the entire globe except the polar regions.

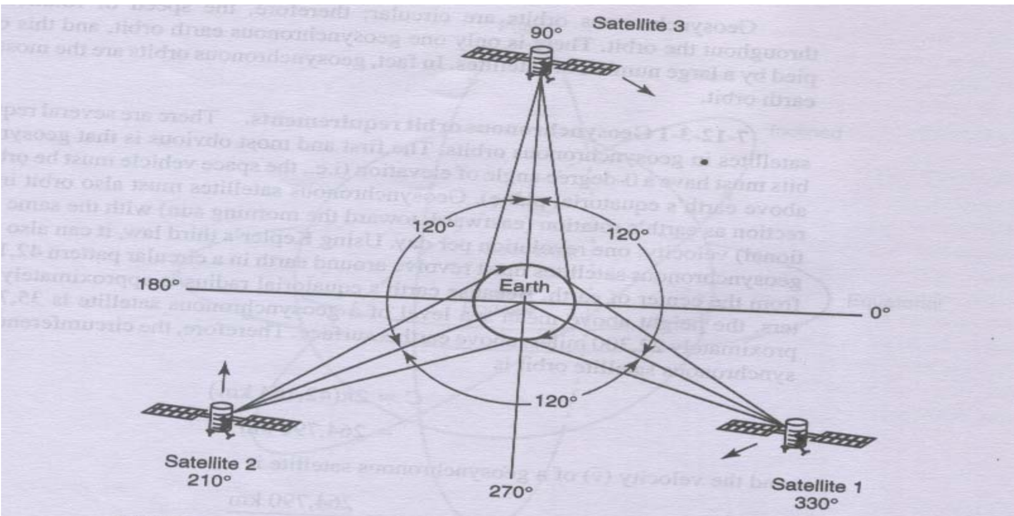


FIGURE 7-23 Three geosynchronous satellites in Clarke orbits

4-19. List the advantages and disadvantages of *geosynchronous satellites.*
Answer:-

Advantages:

-

1. Geosynchronous satellites remain almost stationary in respect to a given earth stat ion; therefore, expensive tracking equipment is not required at the earth stations.

2. Geosynchronous satellites are available to all earth stations within their *shadow* 100% of the time. The shadow of a satellite includes all the earth stations that have a line-of-sight path to the satellite.

3. Switching from one geosynchronous satellite to another as they orbit overhead is not necessary. Consequently, there are no transmission breaks due to switching times.

Disadvantages: -

1. An obvious disadvantage of geosynchronous satellites is they require sophistic ated and heavy propulsion devices on board to keep them in a fixed orbit.

2. High-altitude geosynchronous satellites introduce much longer propagation delays. The round-trip propagation delay between two earth stations through a geosynchronous satellite is typical]y between 500 ms and 600 ms.

3. Geosyncj08 satellites require higher transmit power levels and more sensitive receivers because of the longer distances and greater path losses.

4-20. What is meant by the term *look angles?*
Answer:-

To optimize the performance of a satellite communication system, an earth station antenna must be pointed directly at the satellite. To ensure that the earth station antenna is aligned, two angles must be determined: the *azimuth* and the *elevation angle.* Azimuth and elevation angle are jointly referred to as the *look angles.* With geosynchronous satellites, the look angles of earth station antennas need to be adjusted only once, as the satellite will remain in a given position permanently except for minor variations.

4-21. Describe a *satellite footprint.*
Answer:-

The geographical representation of the area on earth illuminated by the radiation from a satellite's antenna is called a *footprint* or sometimes a *footprint map.* In essence, a footprint of a satellite is the area on earth's surface that the satellite can receive from or transmit to. The shape of a satellite's footprint depends on the satellite's orbital path, height, and the type of antenna used. The higher the satellite, the more of the earth's surface it can cover. A typical satellite footprint is shown in Figure 7-26. The contour lines represent limits of equal receive power density.

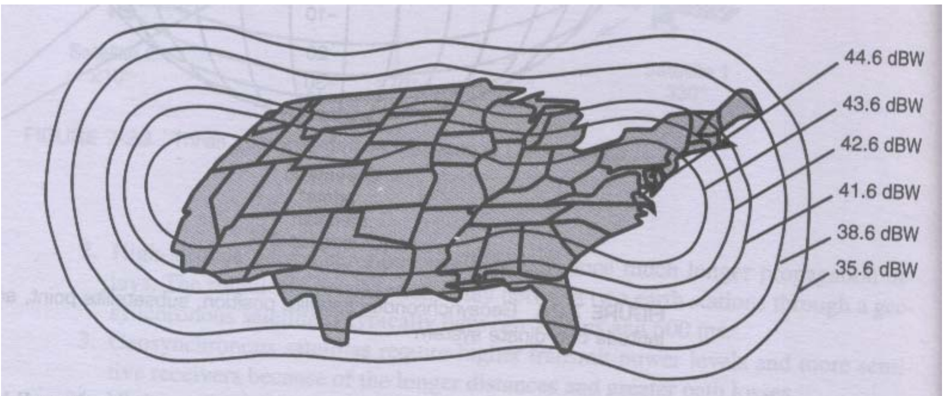


FIGURE 7-26 Satellite antenna radiation patterns (footprints)

4-22. What is a *satellite multiple-accessing arrangement?*
Answer:-

Satellite *multiple accessing* (sometimes called *multiple destination)* implies that more than one user has access to one or more transponders within a satellite's bandwidth allocation. Transponders are typically leased from a common carrier for the purpose of providing voice or data transmission to a multitude of users. The method by which a satellite transponders bandwidth is used or accessed depends on the multiple-accessing method utilized.

4-23. List and describe the three forms of *satellite multiple-accessing arrangements.*

Answer:-

Figure 7-28 illustrates the three most commonly used multiple-accessing arrange ments: *frequencydiyjsj0 multiple accessing* (FDM), *time-division multiple accessing* (TDMA), and *code-division multiple accessing* (CDMA).

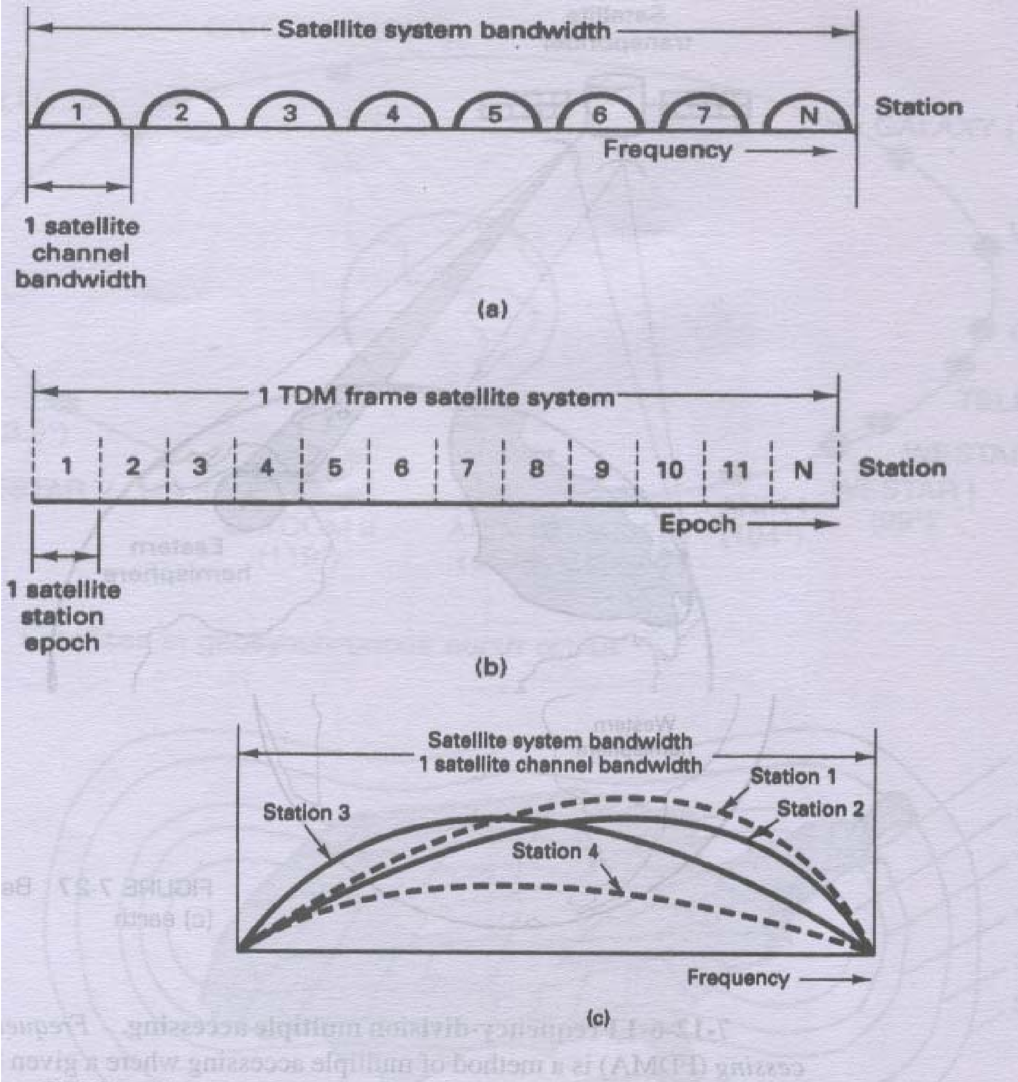


FIGURE 7-28 Multiple-accessing arrangements: (a) FDMA; (b) TDMA; (c) CDMA

Frequency-division multiple accessing:- *Frequency-division multiple accessing* (FDMA) is a method of multiple accessing where a given RF bandwidth is divided into smaller frequency bands called *subdivisions.* Consequently, FDMA transmissions are separated in the frequency domain and, therefore, must share the total available transponder bandwidth as well as the total transponder power. A control mechanism is used to ensure that two or more earth stations do not transmit in the same subdivision at the same time. Essentially, the control mechanism designates a receive station for each of the subdivisions. Thus, with FDMA, transmission can occur from more than one station at the same time, but the transmitting stations must share the allocated power, and no two stations can utilize the same bandwidth.

Time-division multiple accessing:- *Time-division multiple accessing* (TDMA) is the predominant multiple-accessing method used today. TDMA is a method of time-division multiplexing digitally modulated carriers between participating earth stations within a satellite network using a common satellite transponder. With TDMA, each earth stat ion transmits a short burst of information during a specific time slot within a TDMA frame. The bursts must be synchronized so that each station's burst arrives at the satellite at a different time, thus avoiding a collision with another station's carrier.

TDMA transmissions are separated in the tune domain, and with TDMA, the entire transponder bandwidth and power are used for each transmission but for only a prescribed interval of time. Thus, with TDMA, transmission cannot occur from more than one station at the same time. However, the transmitting station can use all the allocated power and the entire bandwidth during its assigned time slot.

Code-division multiple accessing:- With *code-division multiple accessing* (CDMA), there are no restrictions on time or bandwidth. Because there are no limitations on bandwidth, CDMA is sometimes referred to as *spread-spectrum multiple accessing* (SSMA). With CDMA, all earth stations transmit within the same frequency band and, for all practical purposes, have no limitations on when they may transmit or on which carrier frequency. Thus, with CDMA, the entire satellite transponder bandwidth is used by all stations on a continuous basis. Signal separation is accomplished with envelope encryption/decryption techniques.