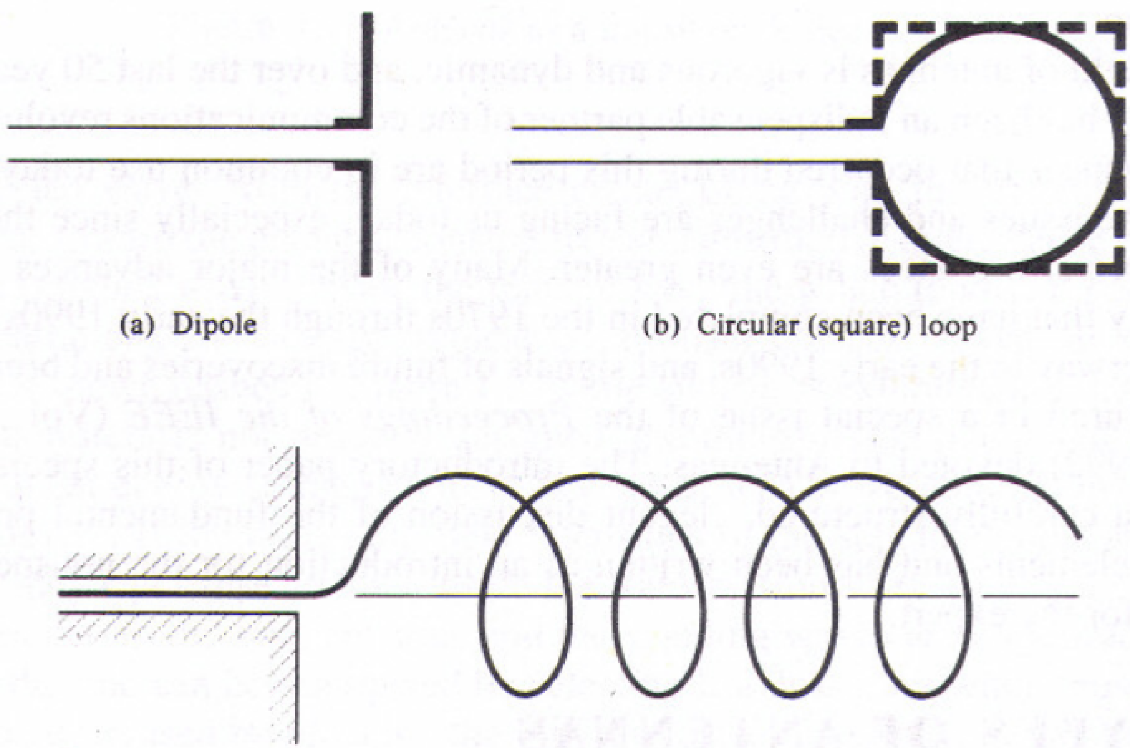
3. (a) Briefly describe all types of antennas with the aid of figures. (10 marks)

(b) Define radiation pattern, directive gain (dBi), directive gain (dBd), HPBW, FNBW, bandwidth and polarization of an antenna. (10 marks)

a)

1. Wire Antennas

Wire antennas are familiar to the layman because they are seen virtually everywhere—on automobiles, buildings, ships, aircraft, spacecraft, and so on. There are various shapes of wire antennas such as a straight wire (dipole), loop, and helix which are shown in Figure 1.3. Loop antennas need not only be circular. They may take the form of a rectangle, square, ellipse, or any other configuration. The circular loop is the most common because of its simplicity in construction. Dipoles are discussed in more detail in Chapter 4, loops in Chapter 5, and helices in Chapter 10.



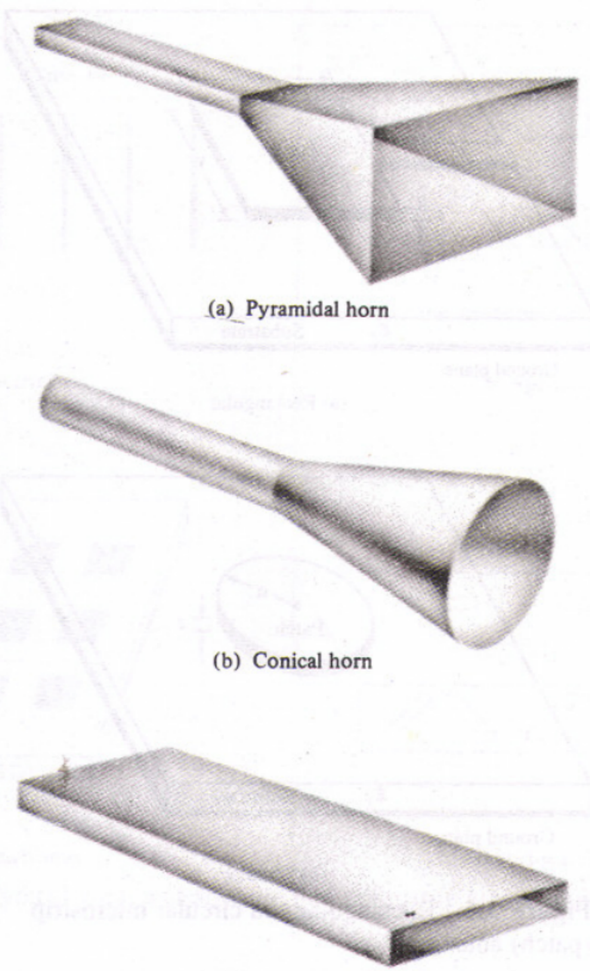
(a) Dipole (b) Circular (square) loop

(c) Helix

Figure 1.3 Wire antenna configurations.

2. Aperture Antennas

Aperture antennas may be more familiar to the layman today than in the past because of the increasing demand for more sophisticated forms of antennas and the utilization of higher frequencies. Some forms of aperture antennas are shown in Figure 1.4. Antennas of this type are very useful for aircraft and spacecraft applications, because they can be very conveniently flush-mounted on the skin of the aircraft or spacecraft. In addition, they can be covered with a dielectric material to protect them from hazardous conditions of the environment. Waveguide apertures are discussed in more detail in Chapter 12 while horns are examined in Chapter 13.



(a) Pyramidal horn

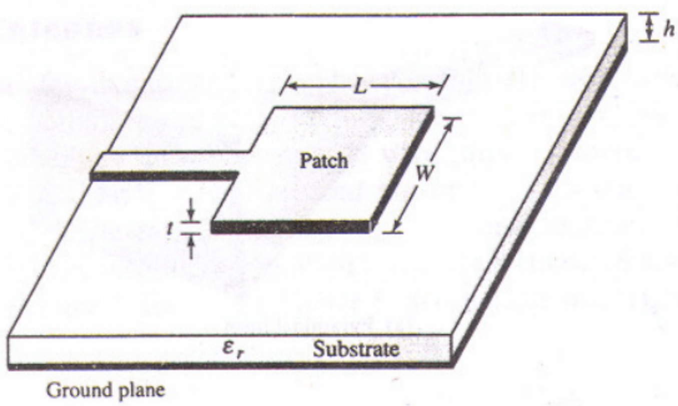
(b) Conical horn

(c) Rectangular waveguide

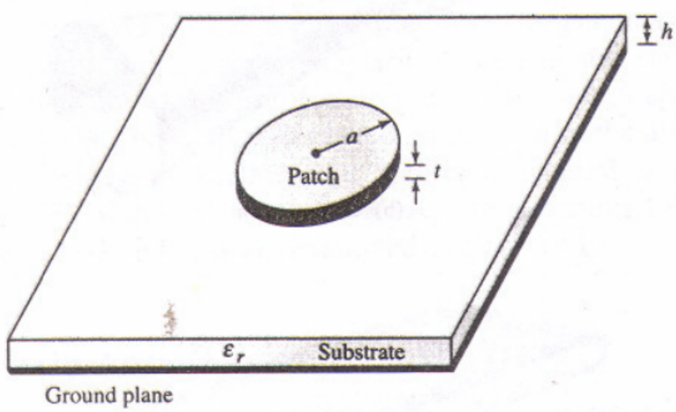
Figure 1.4 Aperture antenna configurations.

3. Microstrip Antennas

Microstrip antennas became very popular in the 1970s primarily for spaceborne applications. Today they are used for government and commercial applications. These antennas consist of a metallic patch on a grounded substrate. The metallic patch can take many different configurations, as shown in Figure 14.2. However, the rectangular and circular patches, shown in Figure 1.5, are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. The microstrip antennas are low-profile, comformable to planar and nonplanar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mounted on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones. They are discussed in more detail in Chapter 14.



(a) Rectangular



(b) Circular

Figure 1.5 Rectangular and circular microstrip (patch) antennas.

4. Array Antennas

Many applications require radiation characteristics that may not be achievable by a single element. It may, however, be possible that an aggregate of radiating elements in an electrical and geometrical arrangement (*an array*) will result in the desired radiation characteristics. The arrangement of the array may be such that the radiation from the elements adds up to give a radiation maximum in a particular direction or directions, minimum in others, or otherwise as desired. Typical examples of arrays are shown in Figure 1.6. Usually the term *array* is reserved for an arrangement in which the individual radiators are separate as shown in Figures 1.6(a–c). However the same term is also used to describe an assembly of radiators mounted on a continuous structure, shown in Figure 1.6(d).

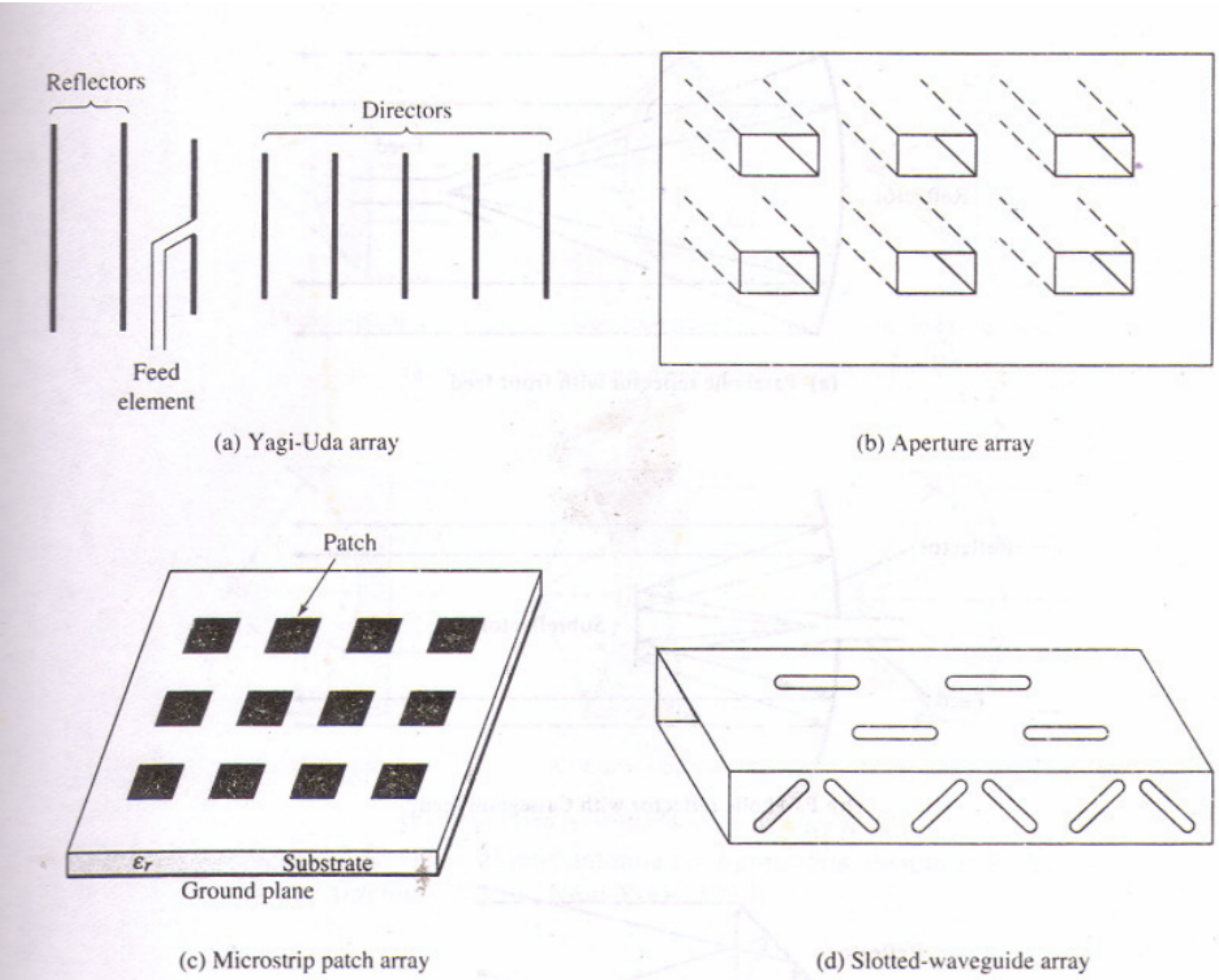
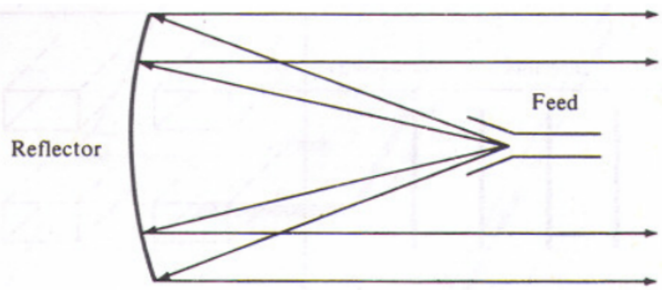


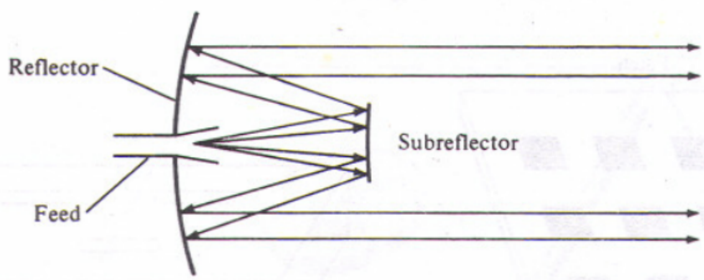
Figure 1.6 Typical wire, and aperture and microstrip array configurations.

5. Reflector Antennas

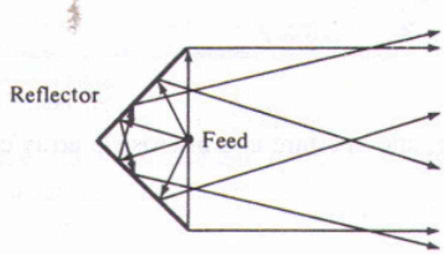
The success in the exploration of outer space has resulted in the advancement of antenna theory. Because of the need to communicate over great distances, sophisticated forms of antennas had to be used in order to transmit and receive signals that had to travel millions of miles. A very common antenna form for such an application is a parabolic reflector shown in Figures 1.7(a) and (b). Antennas of this type have been built with diameters as large as 305 m. Such large dimensions are needed to achieve the high gain required to transmit or receive signals after millions of miles of travel. Another form of a reflector, although not as common as the parabolic, is the corner reflector, shown in Figure 1.7(c). These antennas are examined in detail in Chapter 15.



(a) Parabolic reflector with front feed



(b) Parabolic reflector with Cassegrain feed

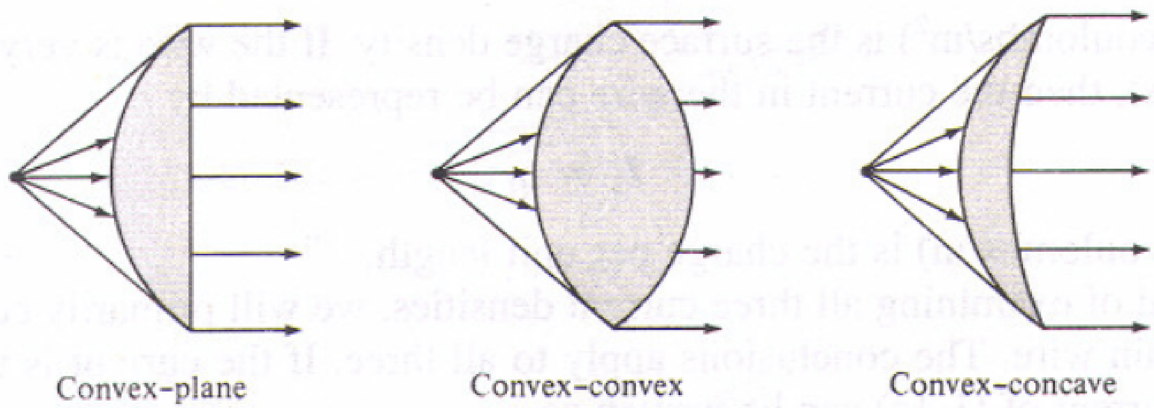


(c) Corner reflector

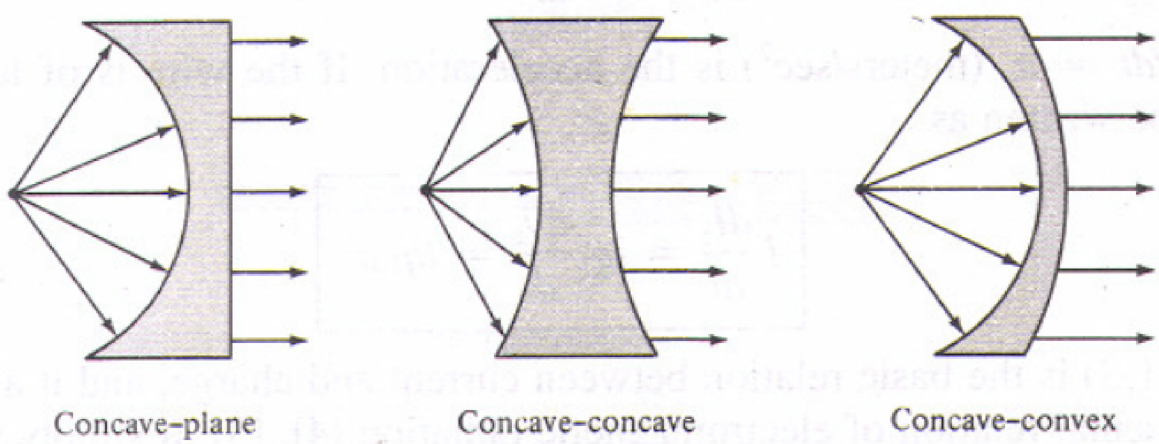
Figure 1.7 Typical reflector configurations.

6. Lens Antennas

Lenses are primarily used to collimate incident divergent energy to prevent it from spreading in undesired directions. By properly shaping the geometrical configuration and choosing the appropriate material of the lenses, they can transform various forms of divergent energy into plane waves. They can be used in most of the same applications as are the parabolic reflectors, especially at higher frequencies. Their dimensions and weight become exceedingly large at lower frequencies. Lens antennas are classified according to the material from which they are constructed, or according to their geometrical shape. Some forms are shown in Figure 1.8 [2].



(a) Lens antennas with index of refraction $n > 1$



(b) Lens antennas with index of refraction $n < 1$

Figure 1.8 Typical lens antenna configurations. (SOURCE: L. V. Blake, *Antennas,* Wiley, New York, 1966).

b)

Radiation Pattern

An antenna *radiation pattern* or *antenna pattern* is defined as ''a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far-field region and is represented as a function of the directional coordinates.

Directive gain *Directive gain* is defined as the ratio of the power density in a particular direction of one antenna to the power density that would be radiated by an omnidirectional antenna (isotropic antenna). The power density of both types of antenna is measured at a specified distance, and a comparative ratio is established.

Antenna gain or Directive Gain

$$D(dBi) = 10 \text{ Log}\left[\frac{\text{(power density in the direction of maximum radiation)}}{\text{(power density due to isotropic antenna or isotropic radiator)}}\right]$$

$$D(dBd) = 10 \text{ Log}\left[\frac{\text{(power density in the direction of maximum radiation)}}{\text{(power density due half - wave dipole))}}\right]$$

D (dBi) = D(dBd) + 2.15 dB

D (dBi) of Parabolic Reflector Antennas = 10 Log ($\pi^2 (D / \lambda)^2$)

D (dBd) of Parabolic Reflector Antennas = 10 Log ($6 (D / \lambda)^2$)

Bandwidth The term bandwidth refers to the range of frequencies the antenna will radiate effectively; i.e., the antenna will *perform satisfactorily* throughout this range of frequencies. When the antenna power drops to ½ (3 dB), the upper and lower extremities of these frequencies have been reached and the antenna no longer *performs satisfactorily*.

Half-Power Beam Width (HPBW):

The HPBW is the angular separation between the two points on opposite sides of the main lobe (the central and most intense part of the radiation pattern) where the power drops to half, or -3 decibels (-3 dB), of the maximum power.

In other words, HPBW is the angle between the points where the radiation intensity is 50% of the maximum.

Full-Power Beam Width (FPBW):

The FPBW, sometimes also referred to as the 3 dB beamwidth, is the angular width of the main lobe of the radiation pattern between the points where the power drops to the full power minus half power (-3 dB) on each side.
It represents the total angular coverage of the main lobe.

Polarization Polarization of an antenna refers to the direction in space of the *E* field (electric vector) portion of the electromagnetic wave being radiated (Figure 9-10) by the transmitting system.

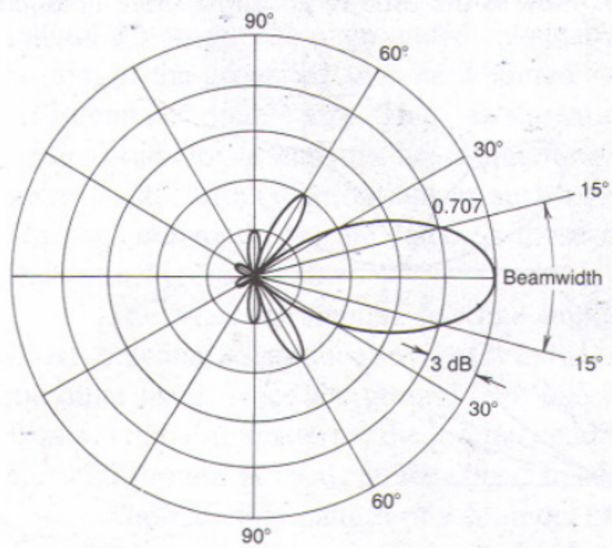


FIGURE 9-9 Beamwidth.

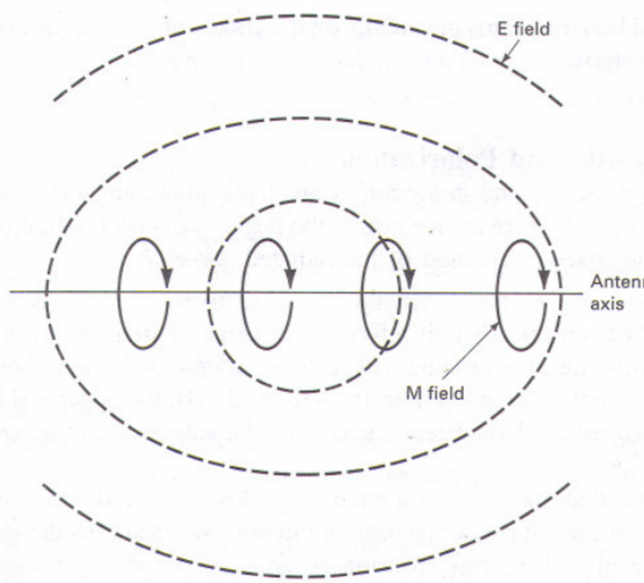


FIGURE 9-10 Polarization of the antenna showing *E* and *M* fields.

4. (a) Define 3 field regions of an antenna with the aid of a figure. If D is the largest dimension of an antenna, what are R_1 and R_2 which are boundaries of different regions. λ is the wavelength. (8 marks)

(b) Define omnidirectional antenna, isotropic antenna, directive antenna, E-plane pattern of antenna and H-plane pattern of an antenna. (7 marks)

(c) In radiation pattern of an antenna, define radiation lobe, major lobe, minor lobe, side lobe and back lobe (5 marks)

a)

The space surrounding an antenna is usually subdivided into three regions: (a) reactive near-field, (b) radiating near-field (Fresnel) and (c) far-field (Fraunhofer) regions as shown in Figure 2.5. These regions are so designated to identify the field structure in each. Although no abrupt changes in the field configurations are noted as the boundaries are crossed, there are distinct differences among them. The boundaries separating these regions are not unique, although various criteria have been established and are commonly used to identify the regions.

Reactive near-field region is defined as "that portion of the near-field region immediately surrounding the antenna wherein the reactive field predominates." For most antennas, the outer boundary of this region is commonly taken to exist at a distance $R < 0.62\sqrt{D^3/\lambda}$ from the antenna surface, where λ is the wavelength and D is the largest dimension of the antenna. "For a very short dipole, or equivalent radiator, the outer boundary is commonly taken to exist at a distance $\lambda/2\pi$ from the antenna surface."

Radiating near-field (Fresnel) region is defined as "that region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon

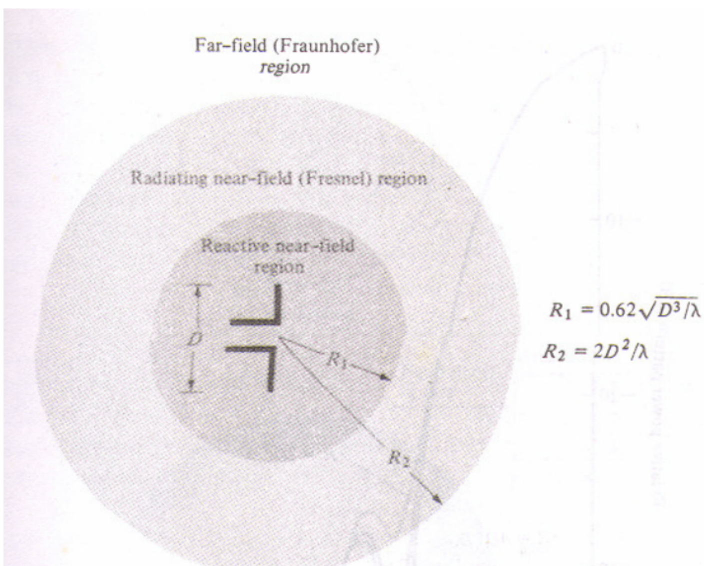


Figure 2.5 Field regions of an antenna.

the distance from the antenna. If the antenna has a maximum dimension that is not large compared to the wavelength, this region may not exist. For an antenna focused at infinity, the radiating near-field region is sometimes referred to as the Fresnel region on the basis of analogy to optical terminology. If the antenna has a maximum overall dimension which is very small compared to the wavelength, this field region may not exist." The inner boundary is taken to be the distance $R \geq 0.62\sqrt{D^3/\lambda}$ and the outer boundary the distance $R < 2D^2/\lambda$ where D is the largest* dimension of the antenna. This criterion is based on a maximum phase error of $\pi/8$. In this region the field pattern is, in general, a function of the radial distance and the radial field component may be appreciable.

Far-field (Fraunhofer) region is defined as "that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. If the antenna has a maximum* overall dimension D, the far-field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna, λ being the wavelength. The far-field patterns of certain antennas, such as multibeam reflector antennas, are sensitive to variations in phase over their apertures. For these antennas $2D^2/\lambda$ may be inadequate. In physical media, if the antenna has a maximum overall dimension, D, which is large compared to $\pi/|\gamma|$, the far-field region can be taken to begin approximately at a distance equal to $|\gamma|D^2/\pi$ from the antenna, γ being the propagation constant in the medium. For an antenna focused at infinity, the far-field region is sometimes referred to as the Fraunhofer region on the basis of analogy to optical terminology." In this region, the field components are essentially transverse and the angular distribution is independent of the radial distance where the measurements are made. The inner boundary is taken to be the radial distance $R = 2D^2/\lambda$ and the outer one at infinity.

b)

2.2.1 Isotropic, Directional, and Omnidirectional Patterns

An *isotropic* radiator is defined as "a hypothetical lossless antenna having equal radiation in all directions." Although it is ideal and not physically realizable, it is often taken as a reference for expressing the directive properties of actual antennas. A *directional* antenna is one "having the property of radiating or receiving electromagnetic waves more effectively in some directions than in others. This term is usually applied to an antenna whose maximum directivity is significantly greater than that of a half-wave dipole." An example of an antenna with a directional radiation pattern is shown in Figure 2.2. It is seen that this pattern is nondirectional in the azimuth plane [$f(\phi)$, $\theta = \pi/2$] and directional in the elevation plane [$g(\theta)$, ϕ = constant]. This type of a pattern is designated as *omnidirectional,* and it is defined as one "having an essentially nondirectional pattern in a given plane (in this case in azimuth) and a directional pattern in any orthogonal plane (in this case in elevation)." An *omnidirectional* pattern is then a special type of a *directional* pattern.

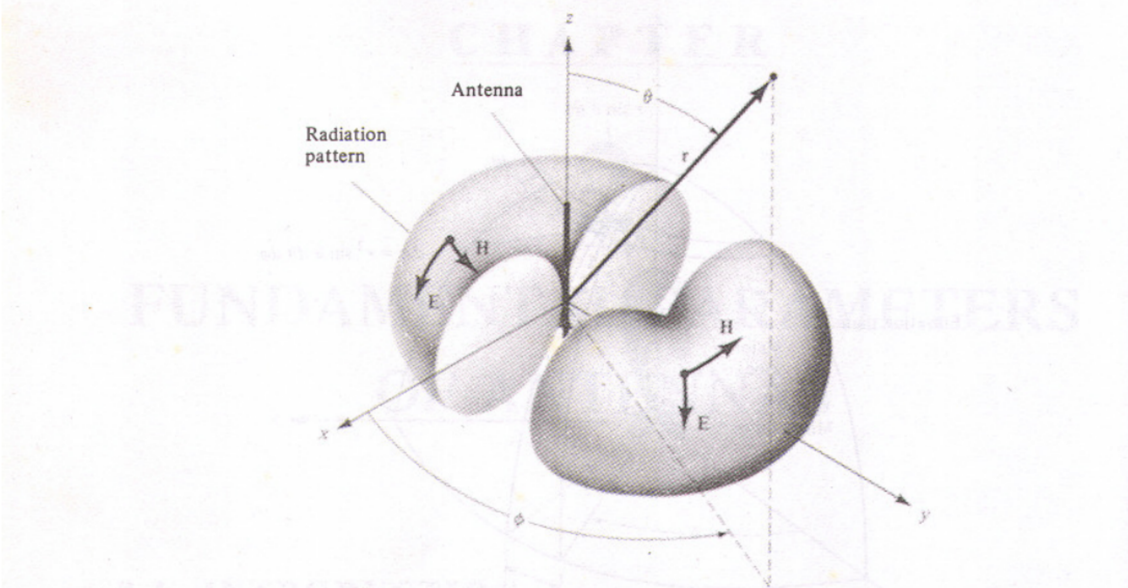


Figure 2.2 Omnidirectional antenna pattern.

For a linearly polarized antenna, performance is often described in terms of its principal *E*- and *H*-plane patterns. The *E-plane* is defined as ''the plane containing the electric-field vector and the direction of maximum radiation,'' and the *H-plane* as ''the plane containing the magnetic-field vector and the direction of maximum radiation.'' Although it is very difficult to illustrate the principal patterns without consid-

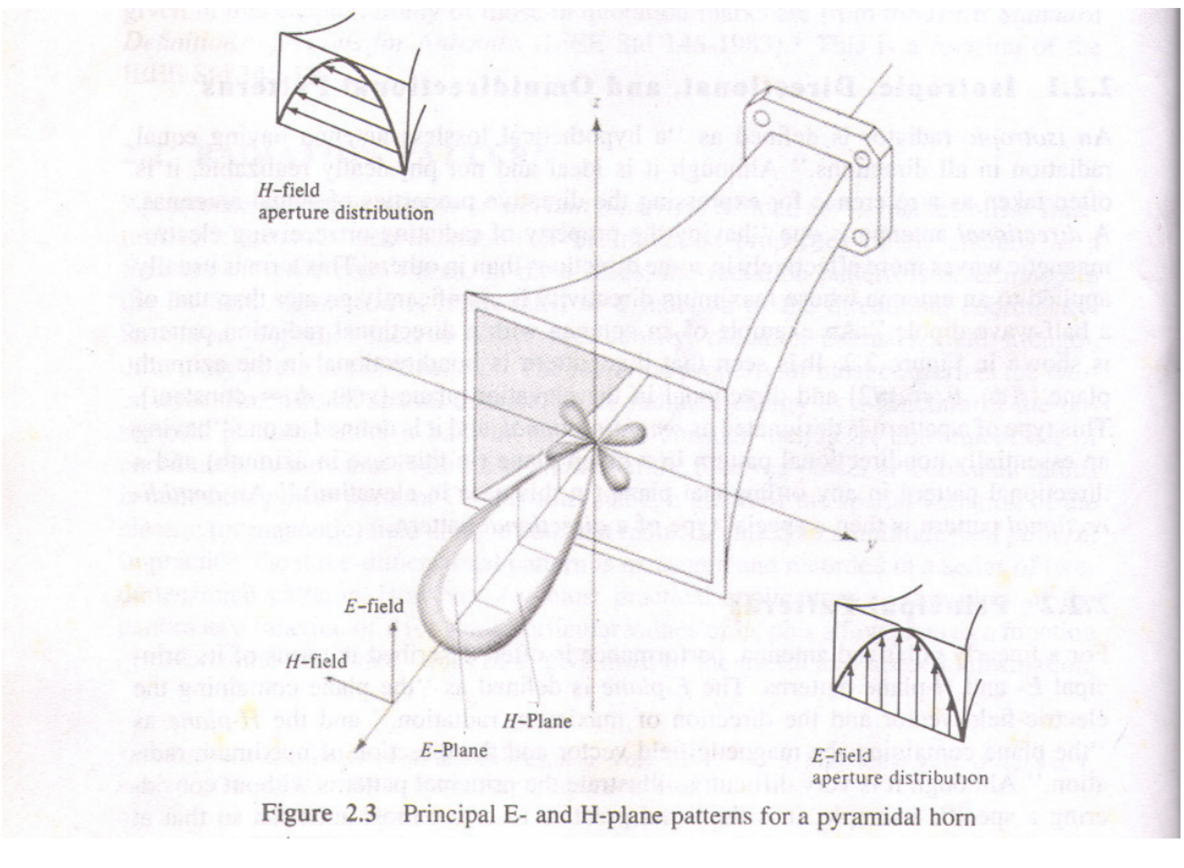


Figure 2.3 Principal E- and H-plane patterns for a pyramidal horn

c)

2.2.3 Radiation Pattern Lobes

Various parts of a radiation pattern are referred to as *lobes,* which may be subclassified into *major* or *main, minor, side,* and *back* lobes.

A *radiation lobe* is a "portion of the radiation pattern bounded by regions of relatively weak radiation intensity." Figure 2.4(a) demonstrates a symmetrical three-dimensional polar pattern with a number of radiation lobes. Some are of greater radiation intensity than others, but all are classified as lobes. Figure 2.4(b) illustrates a linear two-dimensional pattern [one plane of Figure 2.4(a)] where the same pattern characteristics are indicated.

A computer program entitled *2-D ANTENNA PATTERN PLOTTER: RECTANGULAR-POLAR* [1] is included at the end of the chapter to plot two-dimensional *rectangular* and *polar* graphs, to represent single-plane antenna patterns similar to those exhibited in Figure 2.4(a,b) and elsewhere throughout the book. This program is well commented to assist the user in its implementation and only the executable part is included. Each pattern can be plotted in a linear or logarithmic (dB) scale. The program is provided courtesy of Dr. Elsherbeni and Taylor [1], and it is to be used only in conjunction with this book and for not any other purpose.

A *major lobe* (also called main beam) is defined as "the radiation lobe containing the direction of maximum radiation." In Figure 2.4 the major lobe is pointing in the $\theta = 0$ direction. In some antennas, such as split-beam antennas, there may exist more than one major lobe. A *minor lobe* is any lobe except a major lobe. In Figures 2.4(a) and (b) all the lobes with the exception of the major can be classified as minor lobes. A *side lobe* is "a radiation lobe in any direction other than the intended lobe." (Usually a side lobe is adjacent to the main lobe and occupies the hemisphere in the direction of the main beam.) A *back lobe* is "a radiation lobe whose axis makes an angle of approximately 180° with respect to the beam of an antenna." Usually it refers to a minor lobe that occupies the hemisphere in a direction opposite to that of the major (main) lobe.

Minor lobes usually represent radiation in undesired directions, and they should be minimized. Side lobes are normally the largest of the minor lobes. The level of minor lobes is usually expressed as a ratio of the power density in the lobe in question to that of the major lobe. This ratio is often termed the side lobe ratio or side lobe level. Side lobe levels of -20 dB or smaller are usually not desirable in most applications. Attainment of a side lobe level smaller than -30 dB usually requires very careful design and construction. In most radar systems, low side lobe ratios are very important to minimize false target indications through the side lobes.

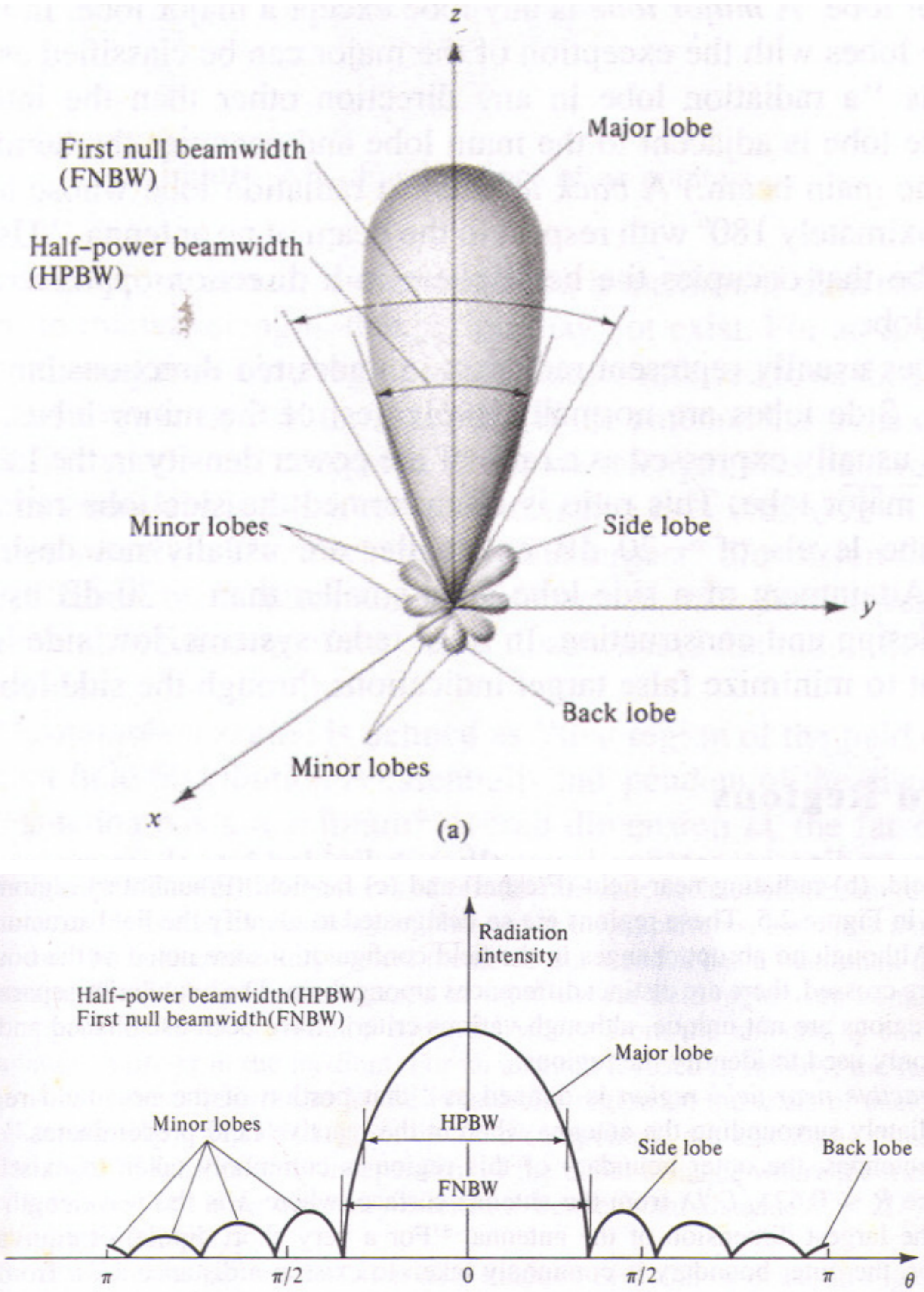


Figure 2.4 (a) Radiation lobes and beamwidths of an antenna pattern. (b) Linear plot of power pattern and its associated lobes and beamwidths.

(a) Explain Yagi-Uda array with the aid of a figure? What are advantages of this antenna in receiving VHF broadcast television? (7 mark)

The Yagi-Uda antenna A Yagi-Uda antenna is an array consisting of a driven element and one or more parasitic elements. They are arranged collinearly and close together, as shown in Figure 9-25, together with the optical equivalent and the radiation pattern.

Since it is relatively unidirectional, as the radiation pattern shows, and has a moderate gain in the vicinity of 7 dB, the Yagi antenna is used as an HF transmitting antenna. It is also employed at higher frequencies, particularly as a VHF television receiving antenna. The back lobe of Figure 9-25*b* may be reduced, and thus the *front-to-back ratio* of the antenna improved, by bringing the radiators closer. However, this has the adverse effect of lowering the input impedance of the array, so that the separation shown, 0.1λ, is an optimum value.

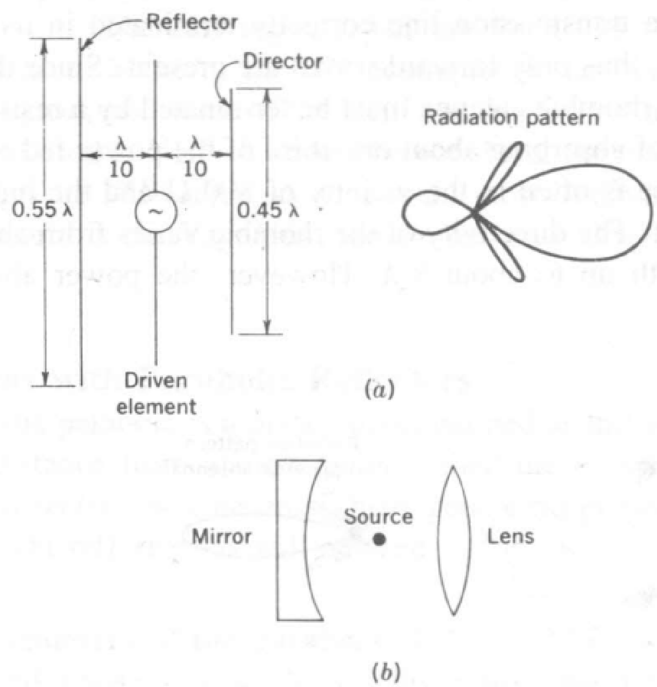


FIGURE 9-25 Yagi antenna. (*a*) Antenna and pattern; (*b*) optical equivalent.

(b) Calculate gain (dBi) and gain (dBd) at 6 GHz for parabolic reflector antenna of diameter 2 meters. Also, calculate half-power beamwidth. (6 marks)

$$\phi = \frac{70\lambda}{D}$$

$$\phi_0 = 2\phi$$

where λ = wavelength, m

ϕ = beamwidth between half-power points, degrees

ϕ_0 = beamwidth between nulls, degrees

D = mouth diameter, m

EXAMPLE 9-4 Calculate the beamwidth between nulls of a 2-m paraboloid reflector used at 6 GHz. *Note:* Such reflectors are often used at that frequency as antennas in outside broadcast television microwave links.

SOLUTION

$$\phi_0 = 2 \times \frac{70\lambda}{D} = 140 \times \frac{0.05}{2}$$
$$= 3.5°$$

(c) What are five variables for control of radiation pattern of array antenna of identical elements? (5 marks)

space. Ideally this can be accomplished, but practically it is only approached. In an array of identical elements, there are five controls that can be used to shape the overall pattern of the antenna. These are:

1. the geometrical configuration of the overall array (linear, circular, rectangular, spherical, etc.)
2. the relative displacement between the elements
3. the excitation amplitude of the individual elements
4. the excitation phase of the individual elements
5. the relative pattern of the individual elements

(d) Define array factor of an array antenna with identical elements. (2 marks)

$$(6\text{-}3)$$

It is apparent from (6-3) that the total field of the array is equal to the field of a single element positioned at the origin multiplied by a factor which is widely referred to as the *array factor*. Thus for the two-element array of constant amplitude, the array factor is given by

$$\mathrm{AF} = 2\cos\left[\tfrac{1}{2}(kd\cos\theta + \beta)\right] \tag{6-4}$$

which in normalized form can be written as

$$(\mathrm{AF})_n = \cos\left[\tfrac{1}{2}(kd\cos\theta + \beta)\right] \tag{6-4a}$$

The array factor is a function of the geometry of the array and the excitation phase. By varying the separation d and/or the phase β between the elements, the characteristics of the array factor and of the total field of the array can be controlled.

(a) Define directivity and maximum directivity of an antenna. Radiation intensity is U watts per unit solid angle. U_{max} and U_o are maximum radiation intensity and radiation intensity due to isotropic source. (6 marks)

International Electrotechnical Commission (IEC). Therefore ... *tenna* defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied." Stated more simply, the directivity of a nonisotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source. In mathematical form, using (2-15), it can be written as

$$\boxed{D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}} \tag{2-16}$$

If the direction is not specified, it implies the direction of maximum radiation intensity (maximum directivity) expressed as

$$\boxed{D_{max} = D_0 = \frac{U|_{max}}{U_0} = \frac{U_{max}}{U_0} = \frac{4\pi U_{max}}{P_{rad}}} \tag{2-16a}$$

D = directivity (dimensionless)

D_0 = maximum directivity (dimensionless)

U = radiation intensity (W/unit solid angle)

U_{max} = maximum radiation intensity (W/unit solid angle)

U_0 = radiation intensity of isotropic source (W/unit solid angle)

P_{rad} = total radiated power (W)

(b) Define overall efficiency of antenna in terms of reflection, conduction and dielectric efficiencies. Also, define reflection, conduction and dielectric efficiencies

(7 marks).

1. reflections because of the mismatch between the transmission line and the antenna
2. I^2R losses (conduction and dielectric)

In general, the overall efficiency can be written as

$$\boxed{e_o = e_r e_c e_d} \tag{2-51}$$

where

e_o = total efficiency (dimensionless)
e_r = reflection (mismatch) efficiency = $(1 - |\Gamma|^2)$ (dimensionless)
e_c = conduction efficiency (dimensionless)
e_d = dielectric efficiency (dimensionless)
Γ = voltage reflection coefficient at the input terminals of the antenna [$\Gamma = (Z_{in} - Z_0)/(Z_{in} + Z_0)$ where Z_{in} = antenna input impedance, Z_0 = characteristic impedance of the transmission line]

(b) For measurement of absolute gain of an antenna using two-antenna method, two identical antennas are separated by distance R. Describe procedure to measure gain using Friis transmission formula with aid of equations. (7 marks) urements. A very brief review of each will be included here. More details can be found in [6]–[8]. All of these methods are based on Friis transmission formula [as given by (2-118)] which assumes that the measuring system employs, each time, two antennas (as shown in Figure 2.25). The antennas are separated by a distance R, and it must satisfy the far-field criterion of each antenna. For polarization matched antennas, aligned for maximum directional radiation, (2-118) reduces to (2-119).

A. Two-Antenna Method

Equation (2-119) can be written in a logarithmic decibel form as

$$(G_{0t})_{\mathrm{dB}} + (G_{0r})_{\mathrm{dB}} = 20\log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10\log_{10}\left(\frac{P_r}{P_t}\right) \quad (16\text{-}14)$$

where

$(G_{0t})_{\mathrm{dB}}$ = gain of the transmitting antenna (dB)
$(G_{0r})_{\mathrm{dB}}$ = gain of the receiving antenna (dB)
P_r = received power (W)
P_t = transmitted power (W)
R = antenna separation (m)
λ = operating wavelength (m)

If the transmitting and receiving antennas are identical ($G_{0t} = G_{0r}$), (16-14) reduces to

$$(G_{0t})_{\mathrm{dB}} = (G_{0r})_{\mathrm{dB}} = \frac{1}{2}\left[20\log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10\log_{10}\left(\frac{P_r}{P_t}\right)\right] \quad (16\text{-}15)$$

By measuring R, λ, and the ratio of P_r/P_t, the gain of the antenna can be found. At a given frequency, this can be accomplished using the system of Figure 16.22(a). The system is simple and the procedure straightforward. For continuous multifrequency measurements, such as for broadband antennas, the swept frequency instrumentation of Figure 16.22(b) can be utilized.

(c) In the two-antenna method, calculate the gain of a horn antenna at 10 GHz. If the separation between two identical antennas is 60 cm and the ratio of power received to power transmitted (P_r / P_t) is -15 dB. (6 marks)

C Put values in above formula.

1. (a) Antenna field regions are divided into reactive near-field, radiation near-field and far-field. Electric and magnetic fields are functions which vary as electrostatic field component (varies as $1/r^3$), inductive field component (varies as $1/r^2$) and radiation field component (varies as $1/r$). What are ranges of kr in these regions? Where k is a wave number and r is the distance from center of the antenna. From observation of field components in the antenna regions of infinitesimal dipole, state components dominating three antenna regions. (6 marks)

4.2.3 Radian Distance and Radian Sphere

The **E**- and **H**-fields for the infinitesimal dipole, as represented by (4-8a)–(4-8b) and (4-10a)–(4-10c), are valid everywhere (except on the source itself). An inspection of these equations reveals the following:

(a) At a distance $r = \lambda/2\pi$ (or $kr = 1$), which is referred to as the *radian distance*, the magnitude of the first and second terms within the brackets of (4-8b) and (4-10a) is the same. Also at the radian distance the magnitude of all three terms within the brackets of (4-10b) is identical; the only term that contributes to the total field is the second, because the first and third terms cancel each other. This is illustrated in Figure 4.2.

(b) At distances less than the radian distance $r < \lambda/2\pi$ ($kr < 1$), the magnitude of the second term within the brackets of (4-8b) and (4-10a) is greater than the first term and begins to dominate as $r \ll \lambda/2\pi$. For (4-10b) and $r < \lambda/2\pi$, the magnitude of the third term within the brackets is greater than the magnitude of the first and second terms while the magnitude of the second term is greater than that of the first one; each of these terms begins to dominate as $r \ll \lambda/2\pi$. This is illustrated in Figure 4.2. The region $r < \lambda/2\pi$ ($kr < 1$) is referred to as the *near-field* region.

(c) At distances greater than the radian distance $r > \lambda/2\pi$ ($kr > 1$), the first term within the brackets of (4-8b) and (4-10a) is greater than the magnitude of the second term and begins to dominate as $r \gg \lambda/2\pi (kr \gg 1)$. For (4-10b) and $r > \lambda/2\pi$, the first term within the brackets is greater than the magnitude of the second and third terms while the magnitude of the second term is greater than that of the third; each of these terms begins to dominate as $r \gg \lambda/2\pi$. This is illustrated in Figure 4.2. The region $r > \lambda/2\pi$ ($kr > 1$) is referred to as the *intermediate-field* region while that for $r \gg \lambda/2\pi$ ($kr \gg 1$) is referred to as the *far-field* region.

(d) What are assumed current distributions and radiation patterns of infinitesimal, half-wave dipole and eight-wave dipole? (3 marks)

9-2.1 Current and Voltage Distribution

When an RF signal voltage is applied at some point on an antenna, voltage and current will result at that point. Traveling waves are then initiated, and standing waves may be established, which means that voltage and current along the antenna are out of phase.

The radiation pattern depends chiefly on the antenna length measured in wavelengths, its power losses, and the terminations at its end (if any). In addition, the thickness of the antenna wire is of importance. For this discussion such antennas may be assumed to be lossless and made of wire whose diameter is infinitely small.

Figure 9-4 shows the voltage and current distribution along a half-wave dipole. We can recognize the similarity to the distribution of voltage and current on a section of ¼-λ transmission line open at the far end. These voltage and current characteristics are duplicated every $\lambda/2$ length, along the antenna (Figure 9-5).

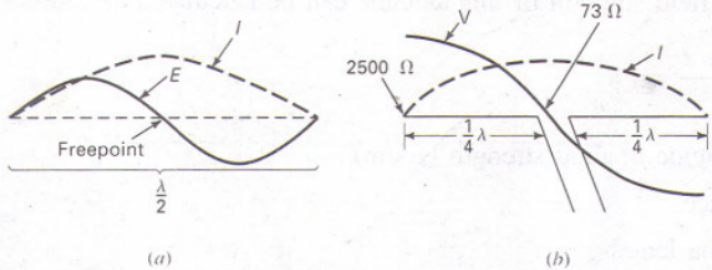


FIGURE 9-4 Voltage and current distribution on a half-wave dipole.