CHAPTER 2

Fundamental Parameters of Antennas

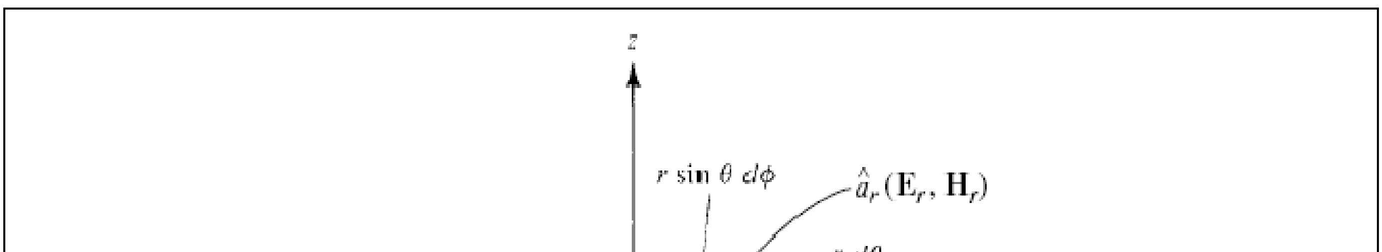
2.1 Introduction

To describe the performance of an antenna, definitions of various parameters are necessary. Some of the parameters are interrelated and not all of them need be specified for complete description of the antenna performance.

2.2 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. ***Radiation properties* *include power flux density, radiation intensity, field strength, directivity, phase or polarization***.

A convenient set of coordinates is shown in Figure 2.1. A trace of the received electric (magnetic) field at a constant radius is called the amplitude field pattern. On the other hand, a graph of the spatial variation of the power density along a constant radius is called ***an amplitude power pattern.***



Often the field and power patterns are normalized with respect to their maximum value, yielding normalized field and power patterns. Also, the power pattern is usually plotted on a logarithmic scale or more commonly in decibels (dB). This scale is usually desirable because a logarithmic scale can accentuate in more details those parts of the pattern that have very low values, which later we will refer to as minor lobes. For an antenna, the:

a) Field pattern (in linear scale) *typically represents a plot of the magnitude of the electric or magnetic field as a function of the angular space.*

b) Power pattern (in linear scale) *typically represents a plot of the square of the magnitude of the electric or magnetic field as a function of the angular space.*

c) Power pattern (in dB) *represents the magnitude of the electric or magnetic field, in decibels, as a function of the angular space.*

To demonstrate this, the two-dimensional normalized **field pattern** (*plotted in linear scale*), **power pattern** (*plotted in linear scale*), and **power pattern** (*plotted on a logarithmic dB scale*) of a 10-element linear antenna array of isotropic sources, with a spacing of d = 0.25λ between the elements, are shown in Figure 2.2. In this and subsequent patterns, the plus (+) and minus (−) signs in the lobes indicate the relative polarization of the amplitude between the various lobes, which changes (alternates) as the nulls are crossed. To find the points where the pattern achieves its half-power (−3 dB points), relative to the maximum value of the pattern, you set the value of the:

a. Field pattern at 0.707 value of its maximum, as shown in Figure 2.2a.

b. Power pattern (in a linear scale) at its 0.5 value of its maximum, as shown in Figure 2.2b.

c. Power pattern (in dB) at −3 dB value of its maximum, as shown in Figure 2.2c.

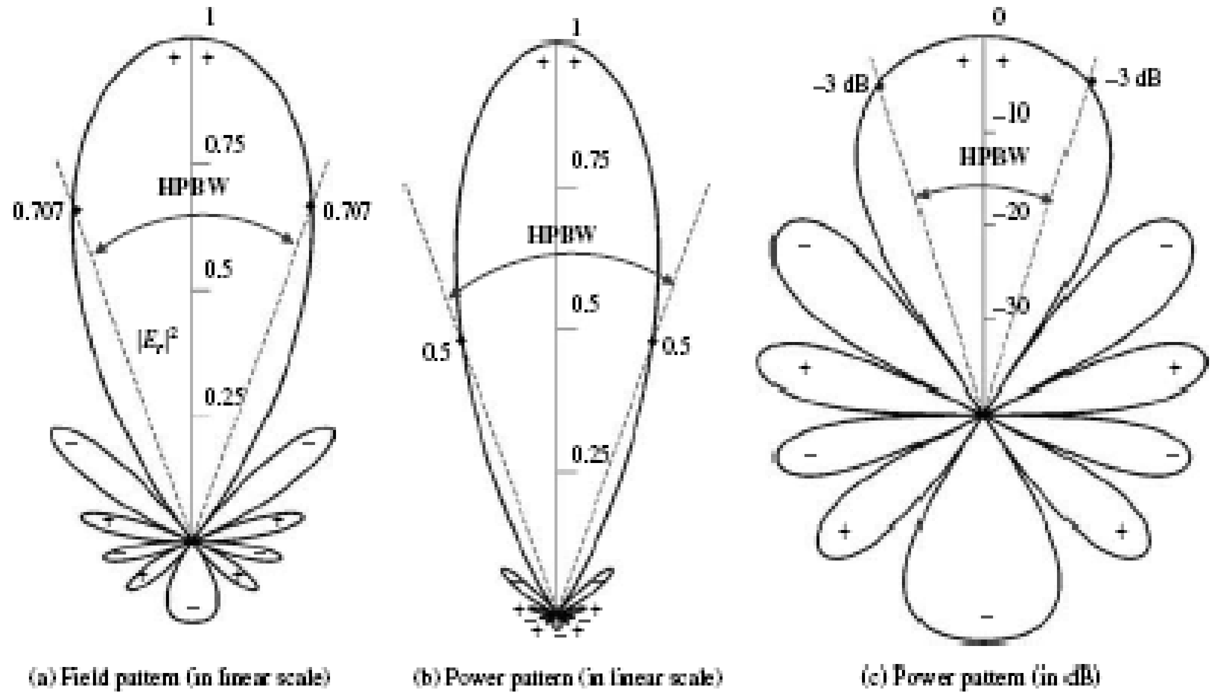


Figure 2.2 Two-dimensional normalized field pattern (linear scale), power pattern (linear scale), and power pattern(in dB) of a 10-element linear array with a spacing of d = 0.25 λ .

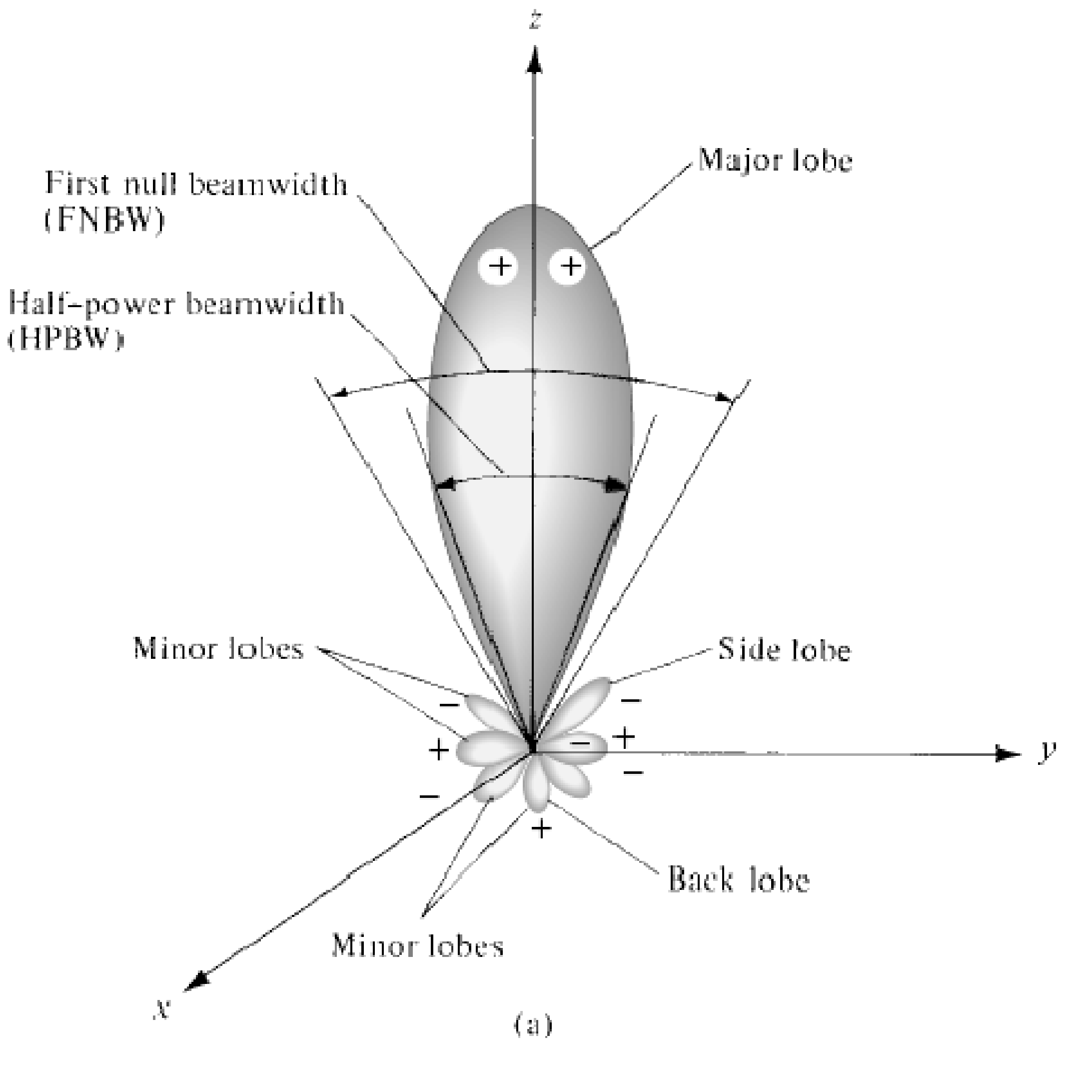
All three patterns yield the same angular separation between the two half-power points, 38.64°, on their respective patterns, referred to as HPBW and illustrated in Figure 2.2.

In practice, the three-dimensional pattern is measured and recorded in a series of two-dimensional patterns. However, for most practical applications, a few plots of the pattern as a function of θ for some particular values of φ, plus a few plots as a function of φ for some particular values of θ, give most of the useful and needed information.

2.2.1 Radiation Pattern Lobes

Various parts of a radiation pattern are referred to as lobes, which may be sub classified 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 2.3(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 2.3(b) illustrates a linear two-dimensional pattern [one plane of Figure 2.3(a)] where the same pattern characteristics are indicated.



(a)

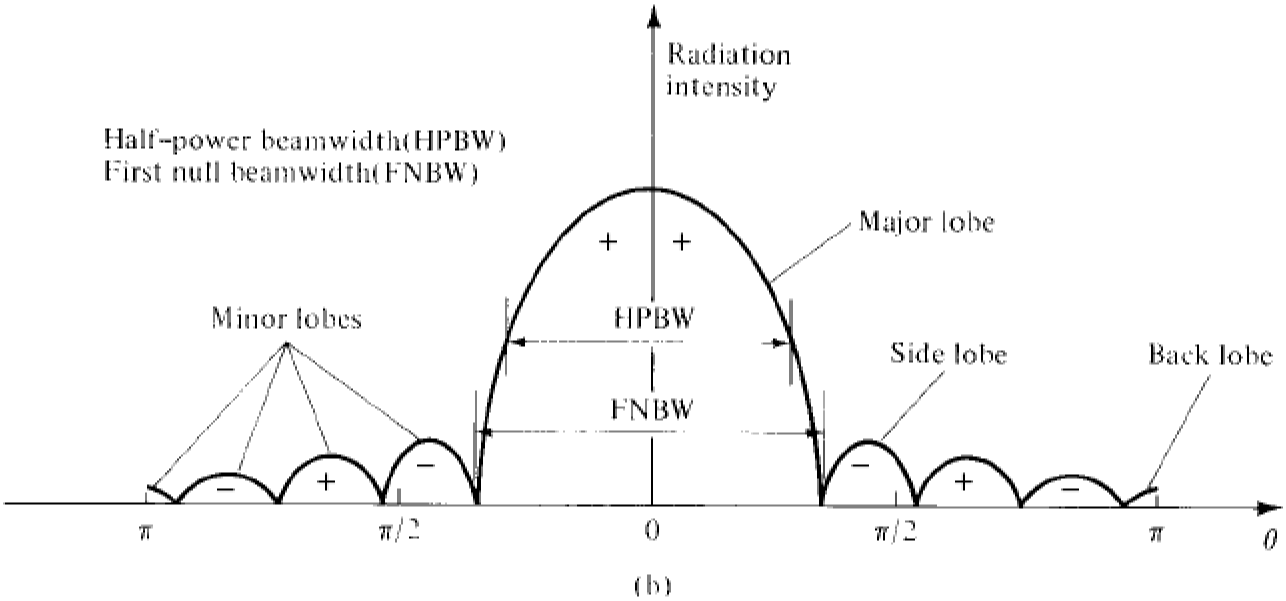


Figure 2.3 (a) Radiation lobes and beamwidths of an antenna pattern. (b) Linear plot of power pattern and its associated lobes and beamwidths.

2.2.2 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." Examples of antennas with directional radiation patterns are shown in Figures 2.4 and 2.5. It is seen that the pattern in Figure 2.5 is nondirectional in the azimuth plane [$f(\varphi)$, $\theta = \pi/2$] 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.

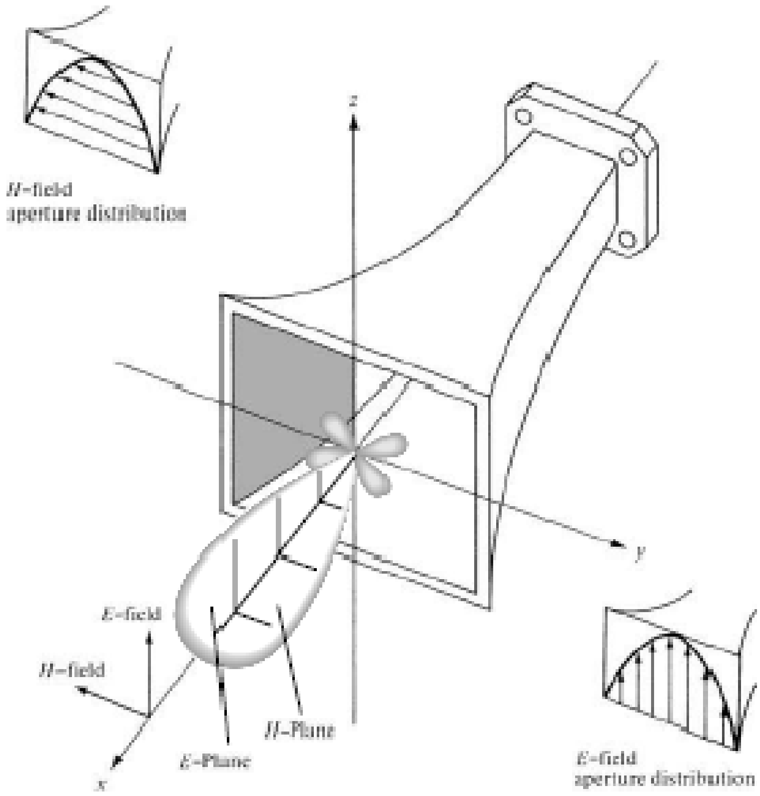


Figure 2.4 Principal *E*- an d*H*-plane patterns for a pyramidal horn antenna.

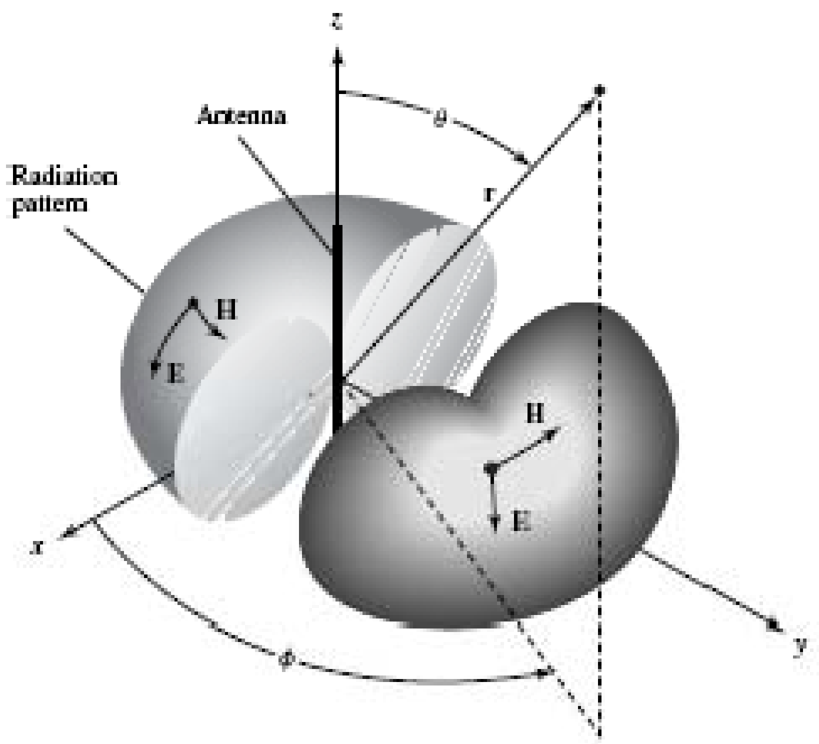


Figure 2.5 Omnidirectional antenna pattern.

2.2.3 Principal Patterns

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 considering a specific example, it is the usual practice to orient most antennas so that at least one of the principal plane patterns coincide with one of the geometrical principal planes. An illustration is shown in Figure 2.4. For this example, the **xz-plane (elevation plane; $\varphi = 0$) is the principal E-plane** and the **xy-plane (azimuthal plane; $\theta = \pi/2$) is the principal H-plane**. Other coordinate orientations can be selected. The omnidirectional pattern of Figure 2.6 has an infinite number of principal E-planes (elevation planes; $\varphi = \varphi_c$) and one principal H-plane (azimuthal plane; $\theta = 90^\circ$).

2.2.4 Field Regions

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 2.6. These regions are so designated to identify the field structure in each. ***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 $\left(R < 0.62\sqrt{D^3/\lambda}\right)$ from the antenna surface, where λ is the wavelength and D is the largest dimension of the antenna.

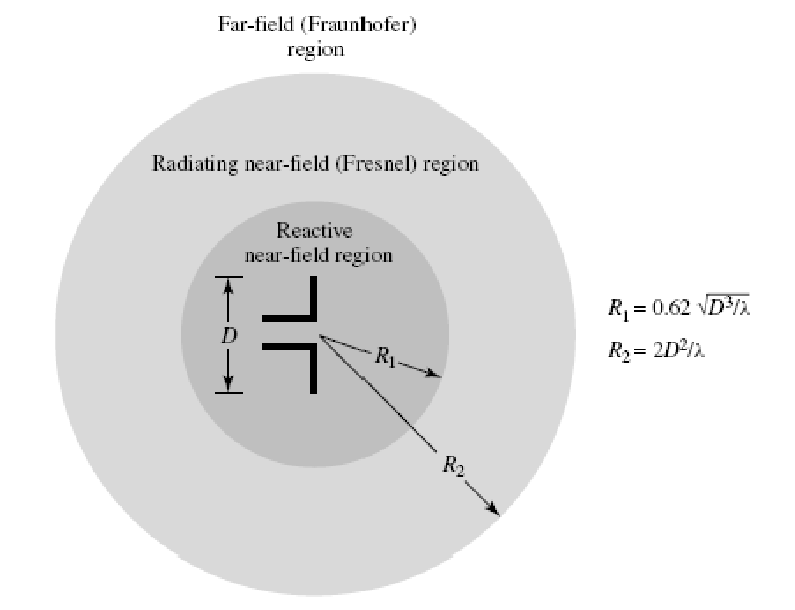


Figure 2.6 Field regions of an antenna.

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 the distance from the antenna".***

The inner boundary is taken to be the distance $\left(R \geq 0.62\sqrt{D^3/\lambda}\right)$ and the outer boundary the distance $(R < 2\,D^2/\lambda)$ where D is the largest dimension of the antenna (D must be large compared to the wavelength ($D > \lambda$)).

If the antenna has a maximum dimension that is not large compared to the wavelength, this region may not exist.

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 (D must be large compared to the wavelength ($D > \lambda$)), the far-field region is commonly taken to exist at distances greater than $(2\,D^2/\lambda)$ from the antenna, λ being the wavelength.

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 $(2\,D^2/\lambda)$ and the outer one at infinity.

The amplitude pattern of an antenna, as the observation distance is varied from the reactive near field to the far field, changes in shape because of variations of the fields, both magnitude and phase. A typical progression of the shape of an antenna, with the largest dimension D, is shown in Figure 2.7. It is apparent that in the reactive near field region the pattern is more spread out and nearly uniform, with slight variations. As the observation is moved to the radiating near-field region (Fresnel), the pattern begins to smooth and form lobes. In the far-field region (Fraunhofer), the pattern is well formed, usually consisting of few minor lobes and one, or more, major lobes.

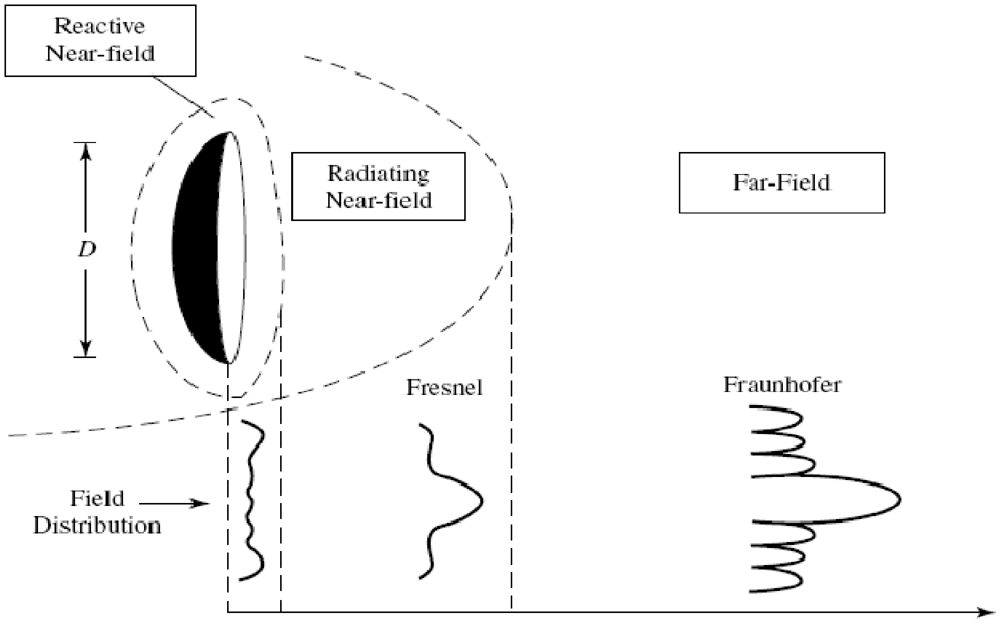


Figure 2.7 Typical changes of antenna amplitude pattern shape from reactive near field toward the far field.