Chapter 8
Horn Antenna

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ABSTRACT

One of the simple and most widely used microwave antennas is the horn as a feed element for large radio telescopes, satellite tracking, and communication reflector, which are found installed throughout the world. In addition to its utility as a feed for reflectors and lenses, it is a common element of phased arrays and serves as a universal standard for calibration and gain measurement of other high gain antennas. Its widespread applicability stems from its simplicity in construction, ease of excitation, large gain, wide-band characteristics, and preferred overall performance. An electromagnetic horn can take many different forms, such as basic pyramidal, conical, corrugated, double-ridged, and dual polarized horns, as well as horns with lens and so on. The horn is nothing more than a hollow pipe of different cross-sections, which has been tapered to a larger opening aperture. This chapter explains the fundamentals of the pyramidal horn antenna in detail using aperture field method. Numerical and measured examples, are also shown.

HORN ANTENNA

Various types of primary feed antennas for microwave and millimeter wave reflector etc. are employed according to their application and purpose (Rudge, 1986; Chang, 1989). For example, the broadband conical spiral or the logarithmic periodic antenna, which is unthinkable a while ago, has been commercialized as a feeding antenna. However, for normal purposes, the horn antennas, probably the pyramidal horns, are most popular. There is a legitimate reason for this. At first the design is easy, the performance is almost equal to the theoretical calculation, and its manufacturability is excellent. Even if it is a horn antenna, they have many variations because it is such a basic antenna. Typical examples include the corrugated horn, the dielectric lens horn, the diagonal horn, and the like. Each of these also has a purpose and characteristics.

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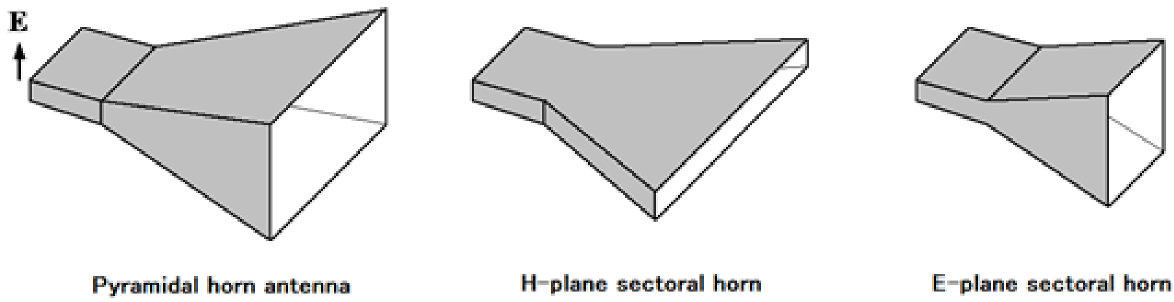
Figure 1. Basic types of pyramidal horn antenna



In this chapter, let us investigate a mathematical wave theory approach to show how to analyze antenna radiation characteristics as well as its applications. Preferentially the horn with a rectangular aperture, so-called pyramidal horn, should be paid attention as a typical boundary value problem in electromagnetics. Since this antenna is a three-dimensional object, it is also necessary to analyze the vector quantity in three-dimensions. However, this direct calculation is quite difficult, so that it is usually analyzed in two-dimensions. At this time, the three-dimensional pyramidal horn is reduced to a sectoral horn. The term "sectoral" here means a fan shape. Even though it is two-dimensions, the antenna is fed by a waveguide, so its height remains (see Figure 1). The electromagnetic field variation in this direction is assumed to be uniform, so that it can be a two-dimensional problem. The theoretical expressions of H- and E-planes obtained in this way have orthogonal relationship from Fourier transform theory, so the result of a pyramidal horn will be obtained by their superimposing. Horn antenna is a kind of the aperture antenna. In this case, if an electromagnetic field at a horn aperture is known, it is transformed by Fourier theory to obtain a spatial spectrum in a far-region, namely antenna pattern. The spatial spectrum of the far-field is the result of the response due to the aperture distribution as a secondary source. This method to predict the far-field from an aperture distribution is called the aperture field method (AFM) (Balanis, 1982; Rudge, 1986; Lo, 1988; Kobayashi, 2011).

At first, let us show how to calculate electromagnetic field distributions at horn aperture. Intuitively, it can be somehow calculated from the field in a feeding waveguide. In this chapter, therefore, starting with the wave-guide theory, the aperture distribution of the sectoral waveguide is searched. Then, an approximate distribution is calculated by cutting into a finite length. On the other hand, the radiation field should be formulated from the aperture distribution or its equivalent electromagnetic current distribution. Using the obtained sectoral aperture distribution, the far-field characteristics and directivity function of the sectoral horn are calculated. Finally, the radiation field of a pyramidal horn can be obtained by superimposing these two sectoral fields which have the orthogonal relation each other. In addition, since the obtained results of the pyramidal horn can be easily converted to those of a diagonal horn, let us examine this type of horn. At the same time, fabricated examples of a small horn with the double-ridge and the corrugation will be discussed. An aperture size of the double-ridged horn is less than a half of a wavelength. This special horn is applicable for active phased array antennas as an antenna element. The corrugated conical horn is fabricated by using a 3D-printer.

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