Horn Antenna – Intro

http://www.antenna-theory.com/antennas/main.php

Horn antennas are very popular at UHF (300 MHz-3 GHz) and higher frequencies (I've heard of horns operating as high as 140 GHz). They often have a directional radiation pattern with a high gain , which can range up to 25 dB in some cases, with 10-20 dB being typical. Horns have a wide impedance bandwidth, implying that the input impedance is slowly varying over a wide frequency range (which also implies low values for S11 or VSWR). The bandwidth for practical horn antennas can be on the order of 20:1 (for instance, operating from 1 GHz-20 GHz), with a 10:1 bandwidth not being uncommon.

The gain often increases (and the beamwidth decreases) as the frequency of operation is increased. Horns have very little loss, so the directivity of a horn is roughly equal to its gain.

Horn antennas are somewhat intuitive and not relatively simple to manufacture. In addition, acoustic horns also used in transmitting sound waves (for example, with a megaphone). Horn antennas are also often used to feed a dish antenna, or as a "standard gain" antenna in measurements.

Popular versions of the horn antenna include the E-plane horn, shown in Figure 1. This horn is flared in the E-plane, giving the name. The horizontal dimension is constant at **w**.

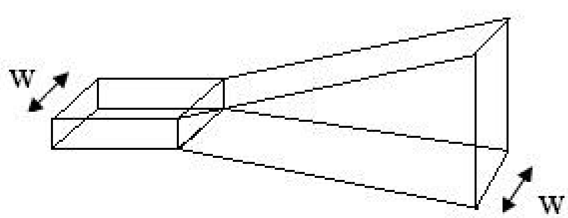

Figure 1. E-plane horn.

Another example of a horn is the H-plane horn, shown in Figure 2.

This horn is flared in the H-plane, with a constant height for the waveguide and horn of *h*.

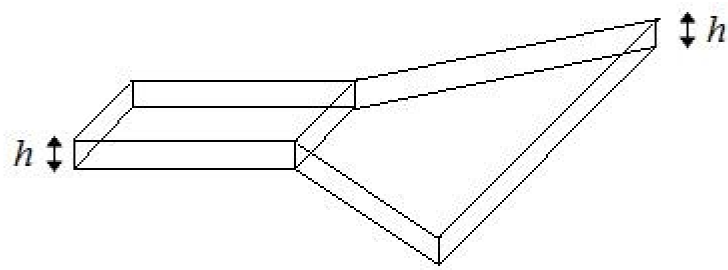

Figure 2. H-Plane horn.

The most popular horn is flared in both planes as shown in Figure 3. This is a pyramidal horn, and has width *B* and height *A* at the end of the horn.

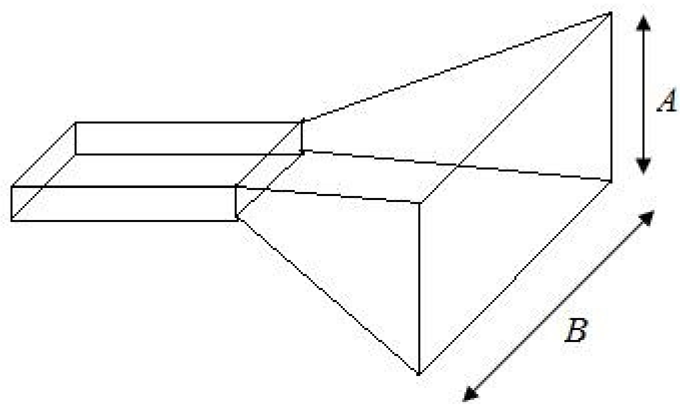

Figure 3. Pyramidal horn.

Horns are typically fed by a section of a waveguide, as shown in Figure 4. The waveguide itself is often fed with a short dipole, which is shown in red in Figure 4. A waveguide is simply a hollow, metal cavity. Waveguides are used to guide electromagnetic energy from one place to another. The waveguide in Figure 4 is a rectangular waveguide of width *b* and height *a*, with *b*>*a*. The E-field distribution for the dominant mode is shown in the lower part of Figure 1.

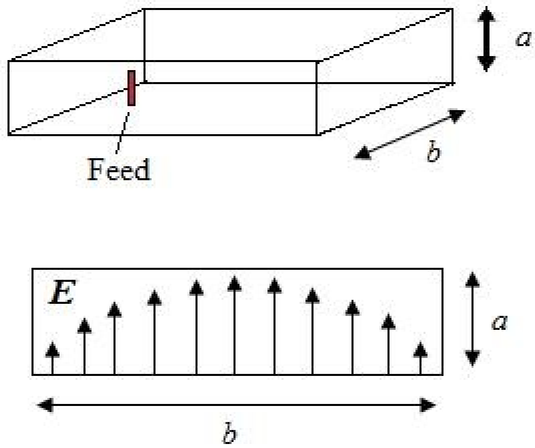

Figure 4. Waveguide used as a feed to horn antennas.

Horn Antennas

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Antenna texts typically derive very complicated functions for the radiation pattern. To do this, first the E-field across the aperture of the horn is assumed, and the far-field radiation pattern is calculated using the radiation equations. While this is conceptually straight forward, the resulting field functions end up being extremely complex, and personally I don't feel add a whole lot of value. If you would like to see these derivations, pick up any antenna textbook that has a section on horn antennas. (Also, as a practicing antenna engineer, I can assure you that we never use radiation integrals to estimate patterns. We always go on previous experience, computer simulations and measurements.)

Instead of the traditional academic derivation approach, I'll state some results for the horn and show some typical radiation patterns, and attempt to provide a feel for the design parameters of horn antennas. Since the pyramidal horn is the most popular, we'll analyze that. The E-field distribution across the aperture of the horn is what is responsible for the radiation.

The radiation pattern of a horn will depend on *B* and *A* (the dimensions of the horn at the opening) and *R* (the length of the horn, which also affects the flare angles of the horn), along with *b* and *a* (the dimensions of the waveguide). These parameters are optimized in order to taylor the performance of the antenna, and are illustrated in the following Figures.

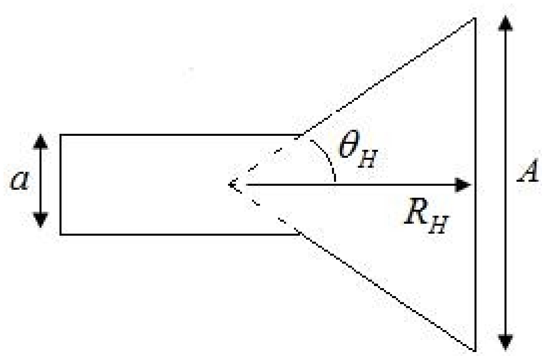

Figure 1. Cross section of waveguide, cut in the H-plane.

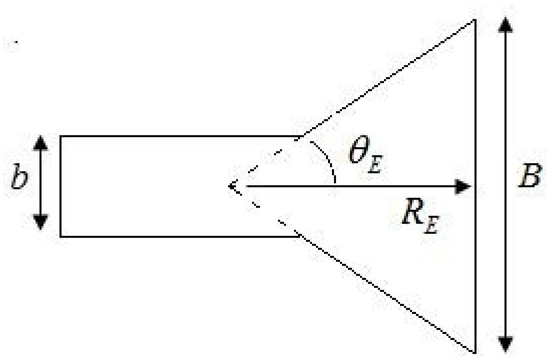

Figure 2. Cross section of waveguide, cut in the E-plane.

Observe that the flare angles (θ_E and θ_H) depend on the height, width and length of the horn.

Given the coordinate system of Figure 2 (which is centered at the opening of the horn), the radiation will be maximum in the +z-direction (out of the screen).

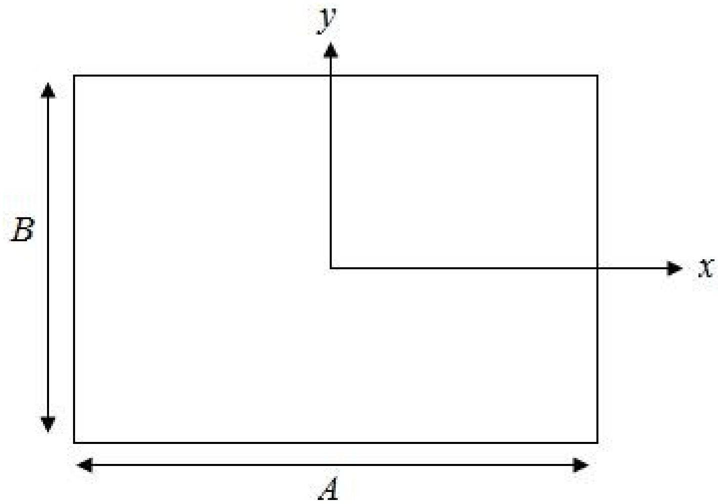

Figure 2. Coordinate system used, centered on the horn opening.

The E-field distribution across the opening of the horn can be approximated by:

$$\mathbf{E}_A = \hat{\mathbf{y}} E_0 \cos\left(\frac{\pi x}{A}\right) e^{-j\frac{k}{2}\left(\frac{x^2}{R_H} + \frac{y^2}{R_E}\right)}$$

The E-field in the far-field will be linearly polarized, and the magnitude will be given by:

$$|\mathbf{E}| = \frac{k}{4\pi r}(1+\cos\theta) \int_{-B/2}^{B/2} \int_{-A/2}^{A/2} E_A(x,y) e^{jk(x \sin\theta \cos\phi + y \sin\theta \sin\phi)} dx dy$$

The above equation states that the far-fields of the horn antenna are the Fourier Transform of the fields at the opening of the horn. Many textbooks evaluate this integral, and end up with supremely complicated functions, that I don't feel sheds a whole lot of light on the patterns.

Horn Antenna - Radiation Patterns

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To give an idea of the fields from a horn, a specific example will be given. The waveguide dimensions are given by *a*=3.69 inches, *b*=1.64 inches, $R_E = R_H = 47.7$ inches, *A*=30 inches, and *B*=23.8 inches. This horn is somewhat large, and will work well above roughly 2 GHz. Horns made for higher frequencies are smaller. This horn antenna, with a waveguide feed is shown in Figure 1.

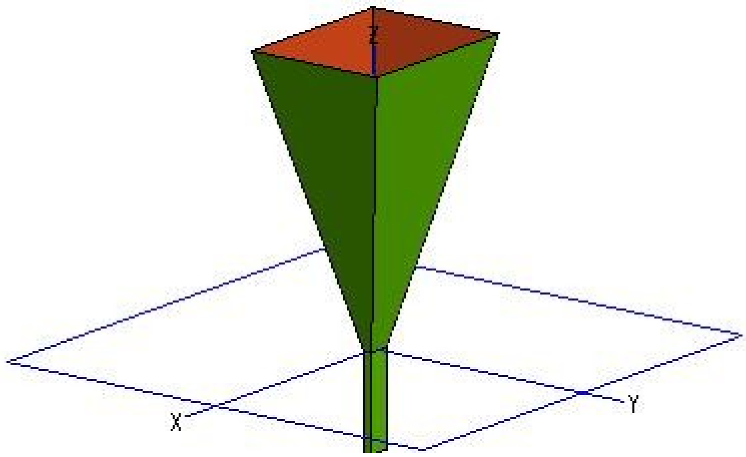

Figure 1. Horn antenna described above.

This antenna is simulated using a commercial solver, FEKO (which runs method of moments). The radiation pattern at 2 GHz is shown in Figure 2.

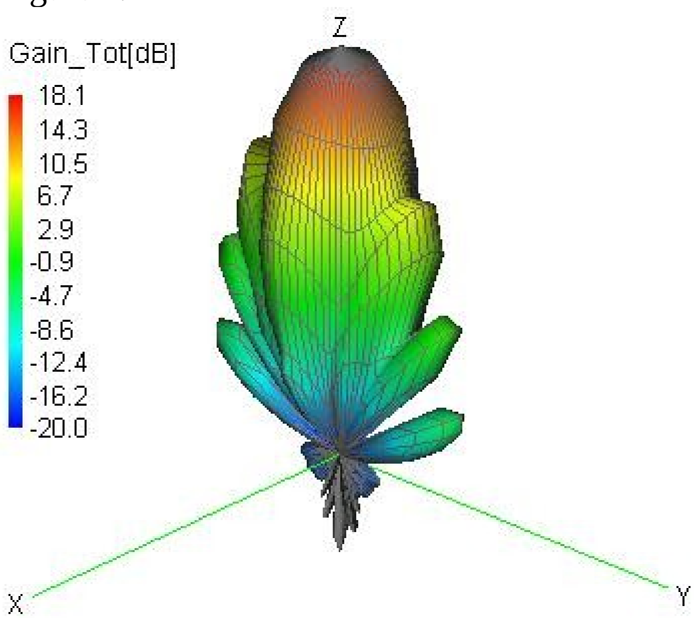

Figure 2. Horn radiation pattern at 2 GHz.

The gain of the horn is 18.1 dB in the +z-direction. The half-power beamwidth is 15 degrees in the xz-plane (H-plane) and 11 degrees in the yz-plane (E-plane).

The gain at 1.5 GHz is -2.54 dB, approximately 20 dB lower than at 2 GHz. The waveguide feed acts as a high-pass filter; it blocks energy below its 'cutoff' frequency and passes energy above this level. At 2.5 GHz, the gain increases slightly to 18.8 dB.

The horn geometry affects the gain of the antenna. For a desired gain, there are tables and graphs that can be consulted in antenna handbooks that describe the optimal geometry in terms of the length and aperture size of the horn. However, this optimal geometry is only valid at a single frequency. Since horns are to operate over a wide frequency band, they are often designed to have optimal gain at the lowest frequency in the band. At higher frequencies, the geometry is no longer optimal, so the E-field across the aperture is not optimal. However, the horn's aperture becomes electrically larger at higher frequencies (the aperture is more wavelengths long as the frequency increases or the wavelength decreases). Consequently, the loss of an optimal aperture field is offset by an electrically larger horn, and the gain actually increases as the frequency increases.