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Design and Performance Analysis of 10 GHz Horn Antenna

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ABSTRACT

This paper observes the field pattern, radiation pattern, directivity of horn antenna. In E-plane sectoral horn, the E-plane pattern is found to be much narrower than the H-plane because of the flaring and larger dimensions of the horn in that direction. In H-plane sectoral horn, the H-plane pattern is much narrower than the E-plane because of the flaring and larger dimensions of the horn in that direction. The pattern of a pyramidal horn is very narrow in both planes. In this case ,the maximum does not occur on axis because the phase error taper at the aperture is such that the rays emanating from the different parts of the aperture toward the axis are not in phase and do not add constructively. For small aperture dimension (vertical length b1 & horizontal length a1) & larger horn length (ρ1), the pattern becomes narrower & beam width also increases for increasing aperture dimension and for decreasing horn length.

Keywords: *Radiation pattern; Beam width; Flare angle; Directivity.*

1. INTRODUCTION

An antenna is defined as "a usually metallic device for radiating or receiving radio waves. There are two basic types: the receiving antenna, which intercepts RF energy and delivers AC to electronic equipment, and the transmitting antenna, which is fed with AC from electronic equipment and generates an RF field. Antenna can convert electric current to electromagnetic waves and vice versa. A horn antenna is used for the transmission and reception of microwave signals. It derives its name from the characteristic flared appearance. The flared portion can be square, rectangular, or conical. The maximum radiation and response corresponds with the axis of the horn.

In order to function properly, a horn antenna must be a certain minimum size relative to the wavelength of the incoming or outgoing electromagnetic field. If the horn is too small or the wavelength is too large (the frequency is too low), the antenna will not work efficiently. Horn antennas are commonly used as the active element in a dish antenna. The horn is pointed toward the centre of the dish reflector. The use of a horn, rather than a dipole antenna or any other type of antenna, at the focal point of the dish minimizes loss of energy (leakage) around the edges of the dish reflector. Horn antennas are used all by themselves in short-range radar systems, particularly those used by law-enforcement personnel to measure the speeds of approaching or retreating vehicles. The Horn Antenna are extremely broad-band, has calculable aperture efficiency, and the back and side lobes are so minimal that scarcely any thermal energy is picked up from the ground. The conventional horn antennas have a limited band-width .The horn antenna produces an electric (E) field that is uniform in the direction of the E field and has constant amplitude across its radiating aperture in that direction. A problem that the uniform field that a standard horn antenna produces is high side lobe levels in the E plane of the electromagnetic field that emits from the antenna. Energy goes into and is needlessly expended in the side lobes. This side lobe energy is wasted and, in some applications, can interfere with main lobe performance. As such, they are generally undesirable. To make the side lobes as small as possible, therefore, reduces energy requirements and eliminates interference for the electromagnetic fields from the antenna. Some horn antennas use a parabolic reflector to direct or use the energy more efficiently. With a parabolic reflector, however, the side lobes problem still exists. Side lobes that miss the reflector produce unwanted response in directions outside the main lobe and waste energy. The side lobes also cause undesirable main lobe patterns when they hit the parabolic reflector. The only known way to minimize side lobe levels is to provide a co sinusoidal electromagnetic field distribution in both the electric or E field plane and the magnetic or H field plane. Horn antenna is linearly polarized and has medium gain, low VSWR, and a constant antenna factor.

E-Plane Sectoral Horn:

In E-plane sectoral horn the opening is flared in the direction of the E-field.

Radiation Pattern:

The E-plane pattern is much narrower than the H-plane because of the flaring and larger dimensions of the horn in that direction

For E-plane sectoral Horn,
E-plane ($\varphi=\pi/2$) [E□r=E□φ=0]
H-plane ($\varphi=0$) [E□r=Eθ=0]

When, ρ1=6λ, b1=2.75λ, a=0.5 λ, b=0.25λ, 2ψ=25.8°, beamwidth=32°.

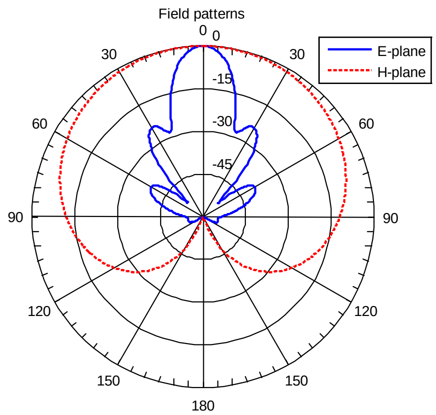

Fig 1: E-and H-plane patterns of an E-plane sectoral horn.

Effect of Change of Value of b_1: When ρ_1 is fixed and b1 is variable.

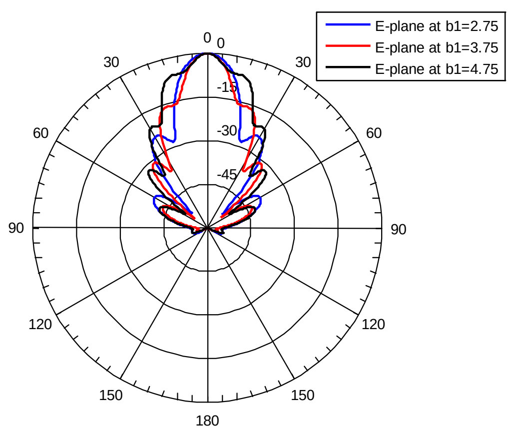

Fig 2: E-plane patterns of E-plane sectoral horn for constant ρ1 and different value of b1.

For small included b1, the pattern becomes narrower as the flare increases. As the length increases, the pattern begins to broaden and eventually becomes flatter (with a ripple).Beyond a certain length, the main maximum does not even occur on axis and the pattern continues to broaden and to become flatter (within an allowable ripple) until the maximum returns on axis. As the length increases, the beam-width also increases.

Effect of Change of Value of ρ1:

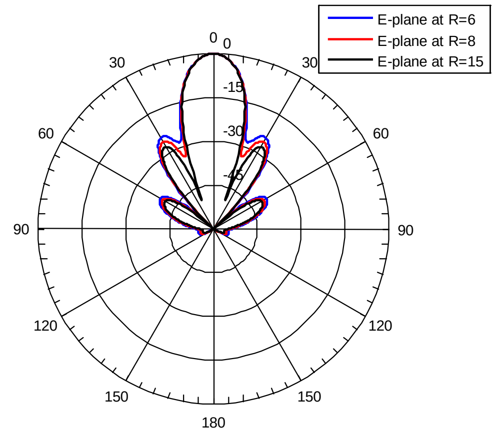

Fig 3: E-plane patterns of E-plane sectoral horn for constant b1 and different included value of ρ1.

For larger included ρ1, the pattern becomes narrower as the flare decreases. As the length decreases, the pattern begins to broaden and eventually with less flatter. Beyond a certain length, the main maximum does not even occur on axis, and the pattern continues to broaden and to become with less flatter until the m aximum returns on axis. The process continues indefinitely. As the length increases, the beamwidth also decreases.

H-Plane Sectoral Horn:

In H-plane sectoral horn the opening is flared in the direction of the H-field, while keeping the other constant.

Radiation Pattern

The fields radiated by the horn can be found by first formulating the equivalent current densities.

For H-plane sectoral Horn,
E-plane (φ=π/2) [Er=Eφ=0]
H-plane (φ=0) [E□r=Eθ=0]

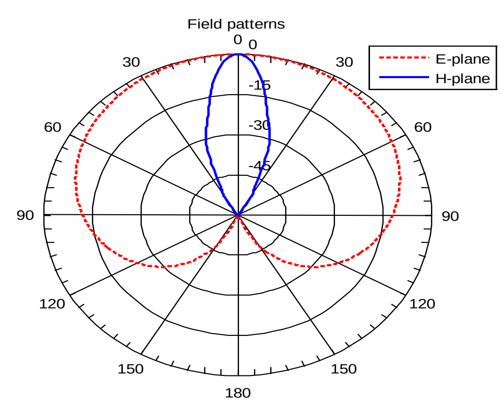

Fig 4: E-and H-plane patterns of H-plane sectoral horn.

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Effect of change of a1: For H-plane patterns for a horn antenna with ρ1=12λ and with flare angles of 15º < 2ψh < 30º are plotted in Figure 6.

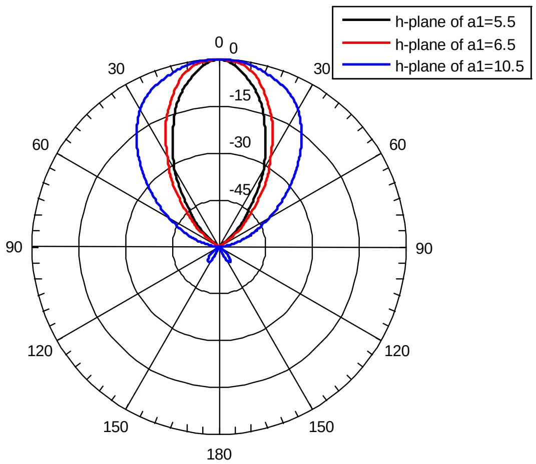

Fig 5: Effect of change of a1.

In the above figure the value of ρ1is fixed and the value of a1 is variable. For small value of a1 the pattern becomes narrower as the flare decreases. As the length increases, the pattern begins to broaden & eventually becomes flatter.

Effect of Change of ρ2: In this case the value of a1 is fixed and the value of ρ2 is variable. To examine the behaviour of the pattern as a function of ρ2, the H-plane patterns for a horn antenna with ρ2 = 6λ and with flare angles of 15º< 2ψh< 30º are plotted in Figure 7.

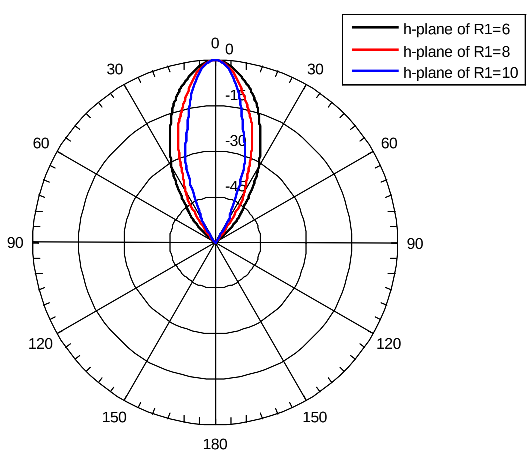

Fig 6: Effect of change of ρ2.

For larger value of ρ2 the pattern becomes narrower as the flare decreases. As the length increases, the pattern begins to narrower and beam width also decrease.

Pyramidal Horn:

The most widely used horn is the one which is flared in both directions and its radiation characteristics are essentially a combination of the E-and H-plane sectoral horns.

Radiation Pattern:

The principal E-plane pattern (φ = π/2) of a pyramidal horn, aside from a normalization factor, is identical to the E-plane pattern of an E-plane sectoral horn. Similarly the H-plane (φ = 0) is identical to that of an H-plane sectoral horn. Therefore the pattern of a pyramidal horn is very narrow in both principal planes and in fact, in all planes.

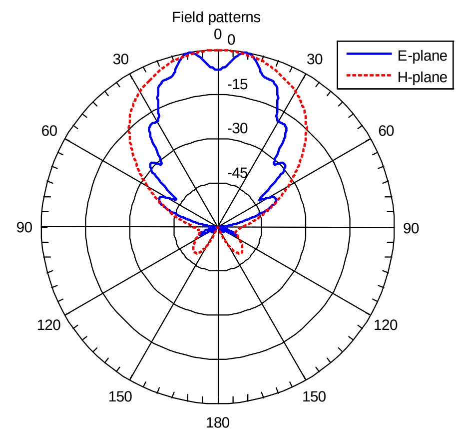

Fig 7: E-and H-plane amplitude patterns of a pyramidal horn with maximum not on axis.

Effect of change of b1:

With the change of value of b1, it affects only the E-plane pattern, not H-plane pattern.

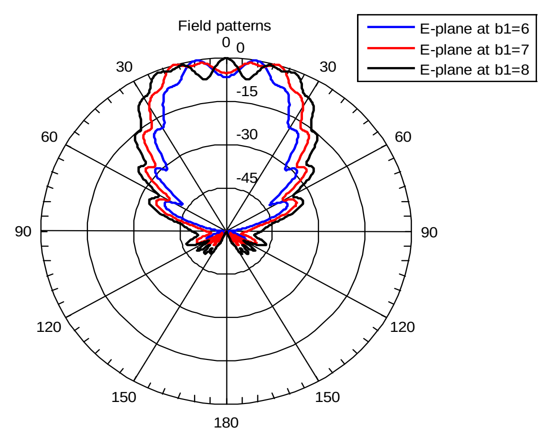

Fig 8: E-plane patterns of pyramidal horn for constant ρ1, ρ2, a1 and different value of b1.

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For small b1, the pattern becomes narrower as the flare increases. As the length increases by 1,the pattern begins to broaden and The maximum does not occur on axis because the phase error taper at the aperture is such that the rays emanating from the different parts of the aperture toward the axis are not in phase and do not add constructively. When the length increases by 1 again, pattern begins to broaden more than previous and the maximum occurs on axis because the rays emanating from the different parts of the aperture toward the axis are in phase and add constructively. As the length increases, the beam width also increases of the E-plane patterns of a pyramidal horn antenna.

Effect of Change of a1:

With the change of value of a1, it affects only the H-plane pattern, not E-plane pattern.

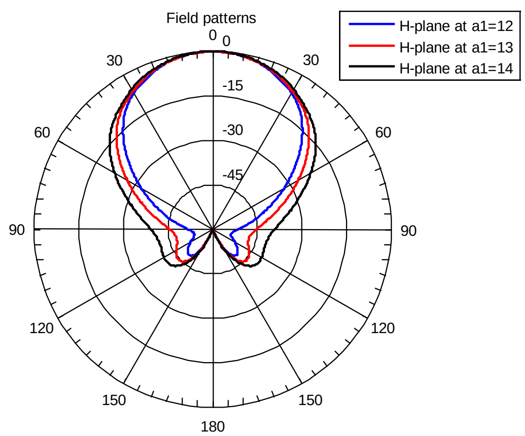

Fig 9: E-plane patterns of pyramidal horn for constant ρ1, ρ2, a1 and different value of a1.

For small included b1, the pattern becomes narrower as the flare increases. As the length increases, the pattern begins to broaden. As the length increases, the beam width also increases of the H-plane patterns of a pyramidal horn antenna.

Effect of change of ρ1 and ρ2:

In this case the value of a1 and b1 is fixed and the value of ρ1 and ρ2 is variable .To examine the behaviour of the pattern as a function of ρ1 and ρ2 in the E-plane pattern is shown in figure 11.

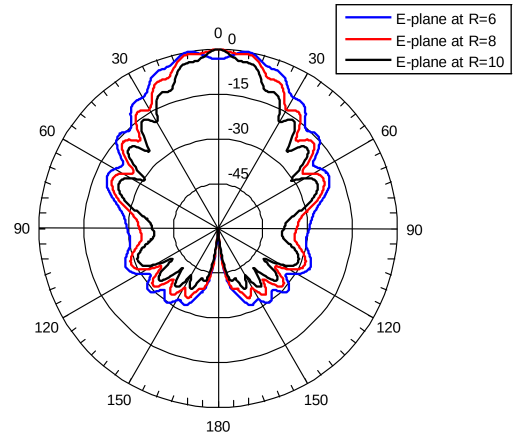

Fig 10: E-plane patterns of pyramidal horn for constant, a1, b1 and different value of ρ1, ρ2.

For larger included ρ1, the pattern becomes narrower as the flare d ecreases. As the length decreases, the pattern begins to broaden and eventually with less flatter. As the length increases, the beam-width also decreases. To examine the behaviour of the pattern as a function of ρ1 and ρ2 in the H-plane pattern is shown in figure 12.

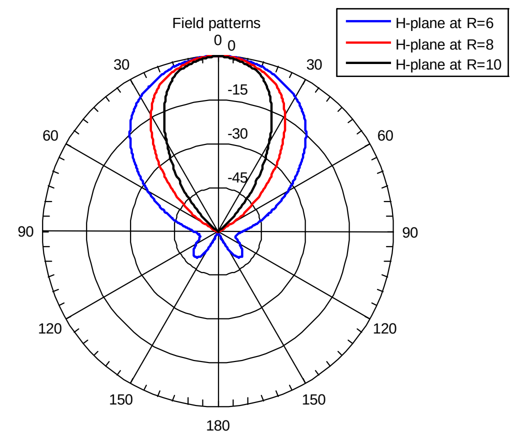

Fig 11: H-plane patterns of pyramidal horn for constant, a1, b1 and different value of ρ1, ρ2.

For larger value of ρ1 the pattern becomes narrower as the flare decreases. As the length decreases, the pattern begins to broaden. As the length increases, the beam-width also decreases.

2. CONCLUSIONS

Here field pattern, radiation pattern and directivity of different kinds of horn antenna are analysed. The effect of change of aperture dimensions and horn length in field pattern are same for E-plane, H-plane and pyramidal horn antenna. In these report, horn antennas are studied theoretically for 10 GHz. For E-plane sectoral horn, as the aperture length increases, the beam-width also increases. As the horn length increases, the beam-width decreases. Similarly for H-plane sectoral horn and for pyramidal horn, the beam-width increases for increasing aperture length and decreases with decreasing horn length.Here designed a 10GHz horn antenna of brush metal but failed to carry out experiment because of the unavailability of connector used to feed power to the antenna. Therefore, no comparison between our theoretical works with the practical one has shown here. This work is kept for future study.

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