Reduce Cross-Polarization In Reflector-Type Antennas

The experimental design of a small primary feed for use with reflector antennas is explained. The theory of the feed and of frequency reuse are presented in a mathematical and practical way.

With the ever expanding demand for more satellite communications channels comes the certainty that the orbiting transducers will employ the modern concept of frequency reuse along with reflector antennas. Available bandwidths in the commercial C-band and military X-band satellites are limited to 500 MHz, and the idea of frequency reuse enhances the communication channel bandwidth by transmitting or receiving (or both) two orthogonally linear or opposite circularly polarized signals[1]. It is essential for the cross-polarization generated in the far field to be maintained at a sufficiently low level to minimize the interaction between the signals. In other words, to produce the effect of 20-to 30-dB polarization discrimination, the primary feed must possess a symmetric radiation pattern.

Research in areas of dual-mode horns[2,3], corrugated waveguides[4,5], and several other types of horns[6] and feeds[7,8] have led in attempts to produce rotationally symmetric beams. The corrugated waveguide feed can maintain an extremely low cross-polarization; unfortunately, it is quite large and difficult to manufacture. Other approaches are either too large or structurally complex.

The feed described in the following paragraphs operates between 8 and 10.5 GHz and consists of a central circular waveguide structure surrounded by a ring-type waveguide (Figs. 1(a) and 1(b)). It has the advantage of being small, lightweight, easy to manufacture, and can sustain a peak cross-polarization level better than −30 dB. To consummate the size of the feed with respect to the pattern symmetry, it is necessary to understand that circular waveguide feeds are excited by the TE_{11} mode and have different patterns in the E-plane than in the H-plane. The central waveguide is fed by the dominant TE_{11} mode and the TE_{mn} and TM_{mn} modes are excited in the ring waveguide. The subscripts m and n identify the number of transverse-field variations in the circumferential and radial directions, respectively.

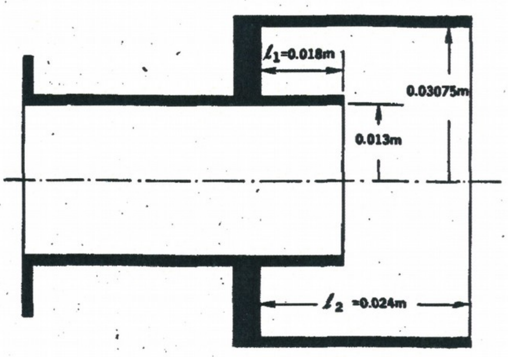
Waveguide diameter is important to the E-and H-plane

The diameter of the central waveguide is chosen on the basis of supporting only the TE_{11} mode. This selection is necessary to insure that the TE_{11}, TM_{11}, and TE_{12} modes are generated in the aperture of the feed. The cutoff wavelength for the TE_{mn} and TM_{mn} modes are calculated for the size of the waveguide by the following expressions[9]:

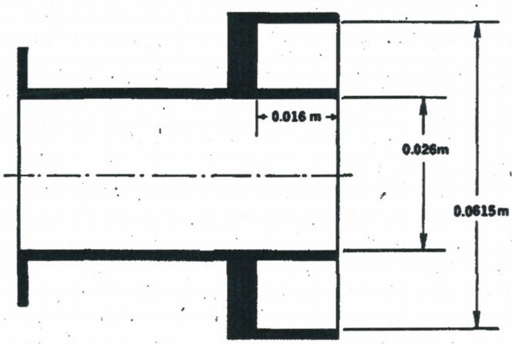
$$(\lambda_c)_{TE_{mn}} = \frac{2\pi r}{\rho'_{mn}}$$

$$(\lambda_c)_{TM_{mn}} = \frac{2\pi r}{\rho_{mn}}$$

where $(\lambda_c)_{TE_{mn}}$ and $(\lambda_c)_{TM_{mn}}$ are the cut-off wavelengths,



(a)



(b)

1. An experimental feed includes ring and circular waveguides (a). The same feed structure has been optimized to yield a low cross-polarization (b).

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r = the radius of the ring waveguide, and ρ'_{mn} and ρ_{mn} are the roots of the Bessel functions for the TE_{mn} and TM_{mn} modes, respectively. With this excitation system, all TE_{mn} and TM_{mn} modes, with m = 0, 2, 3, 4, 5, and 6, are suppressed which results in a high degree of symmetry. Therefore, only the three modes previously mentioned are in the aperture. To get the E-plane and H-plane symmetry, the relative phase of the TE_{11} mode to that of the TM_{11} and TE_{12} modes must be set in a manner that permits the electric fields of these superimposed modes to have the same phase in the magnetic plane of the aperture.

Experimentation produces the best results

There are no cross-polarized components in the radiation field of the two primary planes. The highest values of the cross-polarized fields appear in the planes 45 degrees from the axis of symmetry of the aperture distribution. The cross-polarized component produced by a small horn or circular waveguide is small. But, due to the lack of symmetry, the

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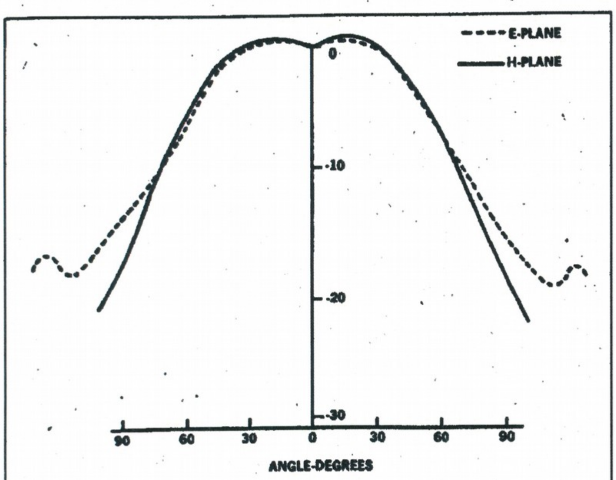
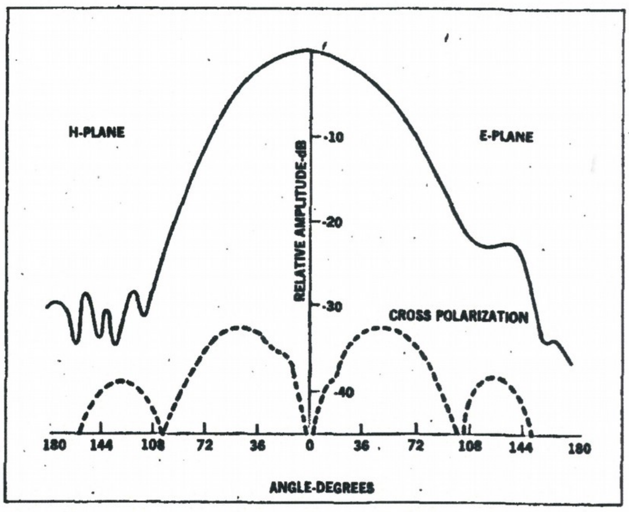
Table 1: E- and H-plane cross-polarization for an experimental feed having arbitrary dimensions.

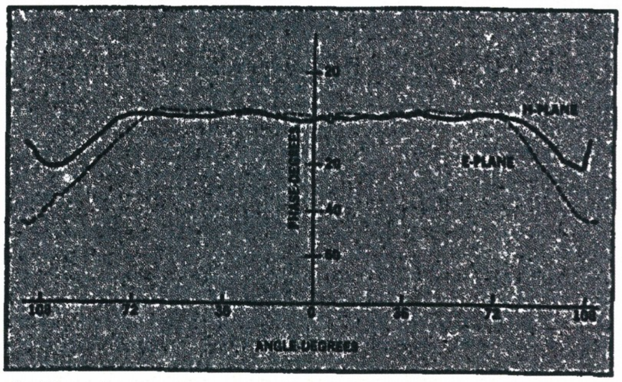
Frequency (GHz)	3-dB beamwidth (degrees) E-plane	H-plane	Peak cross-polarization level (dB)
8.0	84	42	−22
8.5	102	66	−20
9.0	96	90	−21
9.5	78	95	−15
10.0	98	96	−22
10.5	100	95	−22



2. E-plane and H-plane patterns for the experimental waveguide feed shown in Figure 1(a) reveal a cross-polarization level of −22dB.



***3. Cross-polarization patterns and E- and H-plane data** for the optimized waveguide feed in Figure 1(b) are plotted at 8.5 GHz. Note the peak cross-polarization level of −31 dB.*



***4. The phase patterns** for the optimized feed display an unusually flat phase front.*

level of the cross-polarization field for the offset fed reflectors may be relatively large.

The preceeding discussion can be used as a general guide, but for the most part, there is no exact theory available to optimize the length of the central and ring-type waveguides. From that, it is necessary to use experimental methods to determine the degree of cross-polarization.

Phase centers affect the feed's performance

The E- and H-plane patterns are approximately symmetrical when ℓ_1 = 0.018 m (0.709 in) and ℓ_2 = 0.024 m (0.945 in.) as shown in Fig. 1(a). The E-plane has a phase center at 0.002 m (0.079 in) behind the aperture while the H-plane phase center is located 0.006 m (0.24 in) behind the aperture feed. The cross-polarization performances are summarized in Table 1. Notice that the E- and H-plane symmetries are quite good at 10 GHz (98 to 96 degrees) and the peak cross-

Table 2: E- and H-plane cross-polarization for a feed with optimized dimensions

Frequency (GHz)	3-dB beamwidth (degrees) E-plane	H-plane	Peak cross-polarization level (dB)
8.0	75	75	−31
8.5	77	77	−31
9.0	84	85	−30
9.5	90	95	−26
10.0	102	90	−15
10.5	92	88	−23

polarization level is −22 dB with the radiation pattern shown in Fig. 2. The performance of the feed is poor because of the different phase centers in the two principle planes. With this in mind, further experimentation is needed.

Properly designed waveguides define phase fronts

Now, both the central and ring type waveguides are effectively designed so that the radiation patterns are symmetrical in the limited frequency range of 8 to 9 GHz. The new feed dimensions are shown in Fig. 1(b). Table 2 characterizes the radiation parameters of this feed in the original 8 to 10.5-GHz range. Between the restricted range of 8 to 9 GHz, the peak cross-polarization level is less than −30 dB (Fig. 3). Optimizing the waveguides brings the overall phase differences in the E- and H-planes closer together in the aperture of the device (Fig. 4). The phase is clearly constant over the range of ±72 degrees in both planes.

To summarize, this small primary feed gives a very low cross-polarization level with reasonable frequency response. The well defined phase-front renders the feed quite useful in frequency reuse applications exploiting reflector antennas with a f/D (focal length/aperture diameter) less than 0.035.••

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