2-11 A1

CORRUGATED FEED HORN FOR LOW-NOISE ANTENNA

T.B. VU, B.E., Ph.D.
School of Electrical Engineering,
The University of New South Wales
P.O. Box 1
KENSINGTON, N.S.W. 2033

The widespread use in recent years of large reflector antennas capable of low-noise reception has put much emphasis on the design of improved feed horns, so as to achieve higher overall efficiency and signal-to-noise ratio. Basically the problem involves the shaping of the feed radiation pattern, so that a satisfactory illumination of the reflector can be obtained. The classical approach made use of the so-called dominant-mode horn whose dimensions are so chosen that higher-order modes are suppressed. However, it is quite obvious that, with this kind of horn, one has very limited control over the shape of the feed pattern. To achieve a high signal-to-noise ratio, the spill-over loss must be kept small. Therefore, if only the dominant mode is used, the spill-over loss can be reduced but only at the expense of the overall efficiency.

Thus, it is only logical that multi-mode horns have received more attention in recent years. Theoretically, to increase the efficiency, all it is required is to increase the size of the horn, so that a higher number of modes can propagate. The practical problem however, involves the generation of the modes in such a way that correct amplitude and phase ratios can be obtained. In other words, the mode composition must be correctly maintained at the horn aperture if an efficiency close to the maximum theoretical value isto be achieved. With smooth waveguides, it is extremely difficult to realise the required amplitude and phase ratios when there are more than four propagating modes. On the other hand, the problem is much simpler when corrugated waveguides are used. The reason is, in this case, TE_{1n} and TM_{1n} propagate in pairs, so that the number of independent variables are effectively halved. These so-called hybrid modes also possess cylindrically symmetrical radiation patterns with zero cross-polarisation. Moreover, the radiation pattern of higher-order modes has the form of a hollow cone, the semi-angle of which increases as the order of the mode increases. This makes it possible to use hybrid-modes to compensate for spherical aberration in spherical reflectors.

Much has been written on the potential of corrugated waveguide as an aperture-type feed for paraboloidal and spherical reflector antennas [1,2,3]. The approach is based on the important work developed independently by Robieux [4] on the one hand, and Minnett and Thomas [5] on the other hand. The theoretical maximum efficiency obtainable with a given feed size is calculated by assuming that the field from the horn exactly matches, in the conjugate sense, the incident field at the horn aperture. Although, with a physical horn an exact match is out of the question, it can be shown that a near-perfect match can be obtained with hybrid-modes, so that an efficiency close to the theoretical maximum value can be achieved [5]. The main problem is to search for the correct mode composition for a given number of propagating modes. The advantage of field-matching technique is that an approximate solution can be found by using analytical methods [6]. Thus, the final solution can be easily obtained with the aid of the computer. Alternatively, the efficiency can be calculated from the feed pattern. As expected, results obtained by these two methods agree with one another. However, from the practical point of view, it is relatively easy to measure the feed radiation pattern accurately. In addition the effect of spill-over loss on the signal-to-noise ratio can be readily taken into account [2]. As an illustration, results obtained with a paraboloid having an $f/_D$ ratio equal to 0.435 is given below for various sets of hybrid modes.

No. of modes	Spill-over loss %	η_A %	η_o %
2	8	89	82
3	6	92.5	87
4	4	94	90
5	2.5	94.5	92

where η_o and η_A are overall and aperture efficiency respectively.

Extensive work has been carried out in our laboratory, the aim is to search for a satisfactory method of generating the modes, so that their composition can be readily controlled. Although very little results have been published in the literature [7], the work on horns capable of supporting two hybrid modes has been very satisfactory. Fig. 1 depicts an experimental set-up for the determination of the phase-centre of such a horn. Our next stage will be concerned with the design of three-hybrid-mode horns for both spherical and paraboloidal antennas.

In calculating the overall efficiency, we have neglected the loss in the waveguide. This however, is justified, since our experimental results as well as theoretical results obtained by Clarricoats et al.[8] have shown that this loss is in fact very small. It is also important to note that the maximum efficiency obtainable with a given number of hybrid-mode decreases as the $f/_D$ ratio decreases. Moreover, primary feed design to illuminate deep reflectors are more frequency-sensitive. A brief theoretical discussion on the bandwidth characteristics of corrugated horns can be found in the literature [9]. It is pointed out that to improve the frequency characteristics of the antenna, a secondary reflector should be used. Experimental results obtained to date have lent strong support to this theoretical observation.

Acknowledgment.

The work presented in this paper is currently supported by the Australian Research Grants Committee. It was also supported in part by the Max-Planck Institute for Radioastronomy, Germany.

References.

1. Minnett, H.C. and Thomas, B. MacA. IEEE Trans., 1966, AP-14 pp.654-656
2. Vu, T.B. Int. J. Electronics, 1970, 29, pp. 449-459.
3. Vu, T.B. IEEE Trans., 1969, AP-17, pp. 811-813.
4. Brown, G.H. "Space radio Communications" (Elsevier, 1962)pp.319-365.
5. Minnett, H.C. and Thomas, B. MacA. Proc. IEE 1968, 115, pp.1419-1430.
6. Vu, T.B. ibid., 1970, 117, pp.30-34.
7. Vu, T.B. and Vu, Q.H. Electronics Letters, 1970, 6, No.6, pp.159-160.
8. Clarricoats, P.J.B. and Saha, P.K. ibid., 1970, 6, No.12, pp.370-371.
9. Vu, T.B. Int. J. Electronics, 1971, 30, pp.

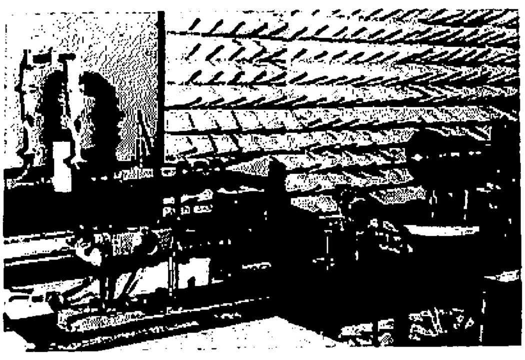

Fig.1. Experimental set-up for phase-centre measurement.