Axially Symmetric Radiation Patterns from Flanged *E*-Plane Sectoral Horn Feeds

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A simple technique for obtaining identical *E*- and *H*-plane patterns from *E*-plane sectoral feed horn is presented. Half-power beam width and gain of the antenna are also improved considerably. Experimental results for a number of horns with flanges of various parameters are also presented. This system may find practical application in radar and space communication systems.

1 Introduction

An antenna structure having equal *E*- and *H*-plane patterns was proposed by Simmons and Kay[1]. Grooved walls in a horn would present the same boundary conditions for TM and TE waves and hence give symmetric radiation patterns. A large amount of work has been done on corrugated horns producing identical radiation patterns[2-6]. It is reported that an *E*-plane sectoral horn fitted with plane metallic flanges can have a beam with adjustable beam characteristics[7]. The effects of corrugated metal flanges on *H*-plane sectoral horn antenna have also been explored[8]. But the effect of corrugated flanges on *E*-plane sectoral horn has not been a topic of investigation so far. The work reported in this paper is a study of the effect of plane and corrugated flanges on both *E*- and *H*-plane radiation patterns of *E*-plane sectoral horns.

Fig. 1 shows the geometry of the flanged *E*-plane sectoral horn. Flange system can be slid back and forth along the entire length of the horn using a rack and pinion arrangement. A linear potentiometer is attached to this arrangement which gives an analog voltage reading corresponding to the position (Z) of the flange from the aperture of the horn. An X-band Gunn oscillator having $\lambda = 3.6$ cm is used as the source of microwaves. The TE_{10} mode electromagnetic waves were used to excite the antenna system.

Table 1 gives the various parameters of different *E*-plane sectoral horns used in this study. The investigations are carried out at *X*-band. The parameters of various flanges used are given in Table 2. The width, w, of the flange is of the order of 3λ. The height, h, of the corrugations is of the order of $\lambda/4 < h < \lambda/2$ to prevent surface waves[2]. The flanges are mounted in such a way that their edges are parallel to the *E*-vector.

2 Method of Measurements

The experiments were carried out in two steps, namely, (i) the variation of on-axis power density (P_0) and VSWR with the relative position of the flange, and (ii) plotting of the radiation patterns.

Experimental set-up used to study the variation of P_0 and VSWR is shown in Fig. 2. Flanged *E*-plane sectoral horn is treated as the transmitter of CW microwave signal. A standard pyramidal horn is used as the receiver, which is kept along the axis of the transmitter at a distance greater than $(d_1^2 + d_2^2)/\lambda$ to ensure plane electromagnetic waves, where d_1 and d_2 are the apertures of the transmitting and receiving horns, respectively. The received power is rectified and fed to one axis of the *X-Y* recorder and the dc signal from the linear potentiometer attached to the flange mount is given to the other axis. Now the flange system is moved at uniform slow speed along the length of the horn from its aperture and the variation of on-axis power density is automatically traced. This will give the variation of P_0 with Z. The VSWR corresponding to the maximum and minimum power positions of the flange are now measured separately using the slotted section and VSWR meter. The experiment is repeated for different horns with various flanges of varying parameters. Values of VSWR and P_0 corresponding to the simple horn alone is also noted in each case for comparison.

The set-up used for plotting the radiation pattern is shown in Fig. 3. Here a standard pyramidal horn is used as the transmitter and the flanged *E*-plane sectoral horn under test is used as the receiver. This part of the experiment is carried out inside an anechoic chamber

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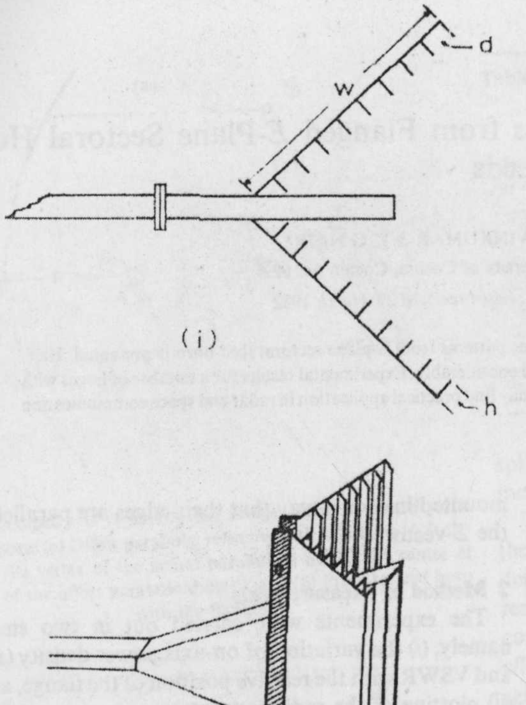

Fig. 1—Geometry of the flanged E-plane sectoral horn: (i) H-plane view and (ii) E-plane view (w = width of the flange, d = corrugation width, h = corrugation height.)

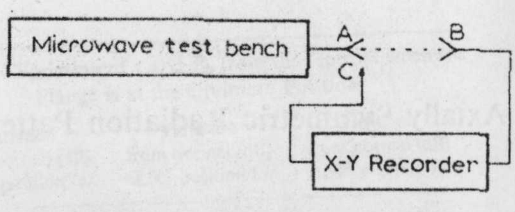

Fig. 2—Block diagram of experimental set-up used to study the variation of P_0 and VSWR (A: Flanged E-plane sectoral horn, B: Pyramidal horn and C: Terminal to the sliding potentiometer.)

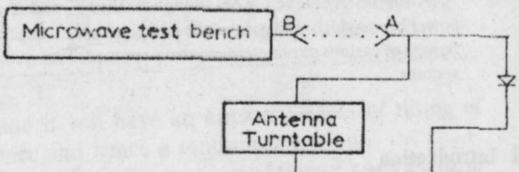

Fig. 3—Block diagram of experimental set-up used for plotting the radiation patterns (A: Flanged E-plane horn and B: pyramidal horn.)

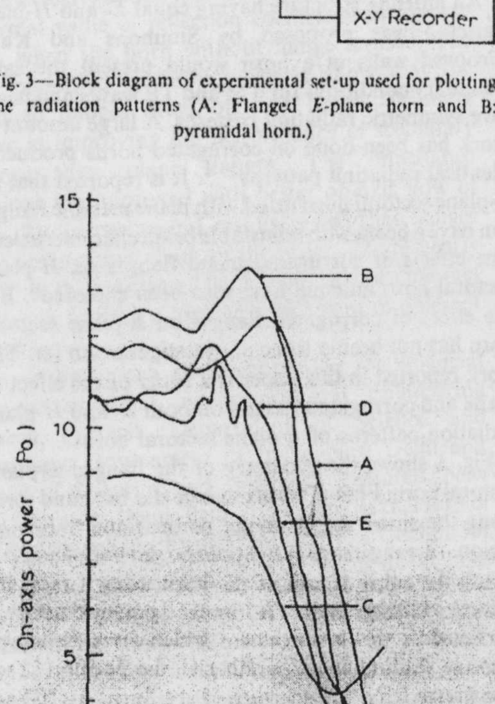

Fig. 4—Variation of P_0 with Z [Horn E_1, $2\beta = 60°$ for corrugation numbers A, 19; B, 14; C, 11; D, 8; E, 6 and F, natural (horn alone).]

Table 1—Parameters of Different E-plane Sectoral Horns Used

Horn No.	Flare angle deg	Aperture width (cm) in H-Plane	E-Plane
E_1	60	2.3	11
E_2	60	2.2	15.3
E_3	45	2.3	8.6

Table 2—Parameters of Different Corrugated Flanges Used

Flange No.	No. of corrugations (n)	Corrugation width (d) cm
1	0 (Plane)	—
2	6	1.66
3	8	1.25
4	11	0.90
5	14	0.714
6	19	0.526

having facilities for automatic pattern recording. The received microwave signal is rectified and fed to one axis of the recorder. The dc signal from the antenna positioner is given to the other axis.

3 Experimental Results and Discussion

3.1 Variation of P_0 with Z

For a particular horn operating at a fixed frequency with a particular flange and included angle (2β), P_0 varies with the position (Z) of the flange from the aperture. As Z is increased gradually, P_0 rises to a maximum value and then falls steadily as shown in Fig. 4. It is found from the experimental data that maximum on-axis power density is obtained when the flange system is near the aperture of the horn. The effects of increase in the number of flanges on the on-axis power from the natural horn, for different parameters are listed in Table 3. Here an increase of P_0 of 19.22 dB from the natural value is achived. It can also be noted from the VSWR studies that the position of the flange is not considerably affecting the matching conditions.

Table 3—Improvement of On-axis Power (P_0) from the Natural Horn in dB

Flange No.	Horn E_1 at flange angle (2β)			Horn E_2 at flange angle (2β)			Horn E_3 at flange angle (2β)		
	30°	45°	60°	45°	60°	90°	30°	45°	60°
1	11.64	15.93	11.68	16.15	16.18	6.57	12.38	12.69	11.71
2	10.53	12.81	10.81	18.29	17.21	10.88	12.28	15.69	11.50
3	11.10	10.55	10.81	18.40	15.01	7.23	13.70	13.68	10.76
4	7.00	15.32	6.49	11.47	15.36	9.54	11.69	14.97	8.82
5	10.76	15.80	12.97	19.62	15.56	8.53	11.93	14.47	10.76
6	11.69	15.25	13.73	19.22	13.46	9.91	13.52	13.84	11.87

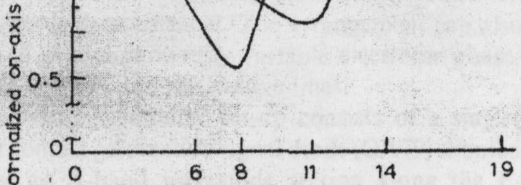

Fig. 5—Dependence of normalized P_0 for the number of corrugations (n) (Horn E_1: Curves A, B, C are for $2\beta = 30$, 45 and 60°, respectively.)

3.2 Dependence of P_0 on Number of Corrugations (n)

For a particular horn and flange angle (2β), the on-axis power density varies with the number of corrugations. If the operating frequency and horn is fixed, maximum on-axis power is achieved for a particular corrugation number, n, as shown in Fig. 5.

3.3 Variation of P_0 with 2β

The on-axis power density also varies with the flange angle. *A typical variation of P_0 and 2β is shown in* Fig. 6. The optimum flange angle is a constant only for a particular flange used on a particular horn.

3.4 Effect of Radiation Pattern in H-plane

The radiation patterns of natural horn in both E- and H-plane are traced initially for comparative

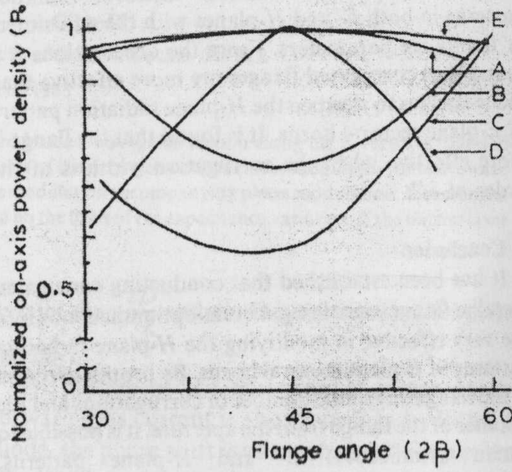

Fig. 6—Variation of normalized P_0 with flange angle (2β) (Curves A, B, C, D and E are for corrugation numbers 0, 6, 8, 11 and 14, respectively.)

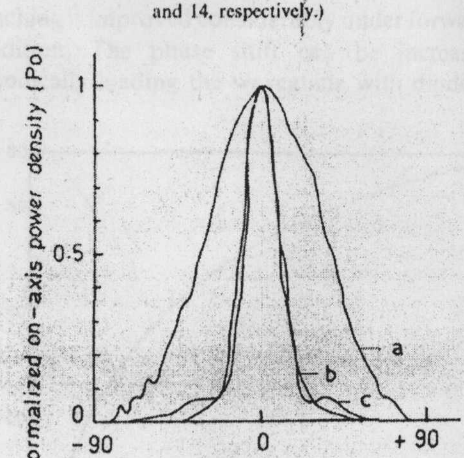

Fig. 7—Typical radiation patterns [(a) Natural H-plane pattern, (b) shaped H-plane pattern and (c) natural E-plane pattern.]

analysis. The flange is now kept at the 'O' and 'M' positions[9] and radiation patterns in both planes are again plotted. Fig. 7 shows these typical radiation patterns. Fig. 7 shows that at 'O' position (on X-axis) the beam is highly sharpened and beam width is reduced. Considerable improvement in the gain is also noted. The gain is calculated from the radiation patterns.

It can be shown that by choosing the proper values of 2β, Z and n the axially symmetric radiation patterns from a E-plane sectoral horn can be achieved. In Fig. 7, the normal gain is 17.25 dB and HPBW in H- and E-planes is 74.37 and 21.79°, respectively. But when the flange is kept at the 'O' position the gain is found to be 24.97 dB and HPBW in H-plane is found to be 22.26°. Thus we could make almost identical radiation patterns in both E- and H-planes with the adjustment of the flange parameters. From the observations it is found that corrugated flanges are more effective than plane flanges to sharpen the H-plane radiation pattern of E-plane sectoral horns. It is found that the flange is more effective when the corrugation width is of the order of $\lambda/2$.

4 Conclusion

It has been established that conducting corrugated metallic flanges satisfying certain optimum conditions are very effective in modifying the H-plane radiation patterns of E-plane sectoral horns. By proper selection of the flange angle, the number of corrugations and the distance of the flange from the aperture, it is possible to obtain symmetrical E- and H-plane patterns. Compared to the fixed system of sectoral horns with corrugated sides, the present system offers great convenience in adjusting antenna characteristics by trimming the flange parameters. These axially symmetric patterns may find application for illuminating axially symmetric antennas like paraboloids and polarization measurements in radio astronomy.

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