NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WEST VIRGINIA

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Title: **SMALL-APERTURE SCALAR HORN AS A FEED FOR THE 7-FEED, 6-CM RECEIVER ON THE 300-FT TELESCOPE**

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SMALL-APERTURE SCALAR HORN AS FEED FOR THE 7-FEED, 6-CM RECEIVER ON THE 300-FT TELESCOPE

S. Srikanth

Introduction

The 7-beam, 14-channel (7 feeds x 2 polarizations) 6-cm receiver was proposed by J. J. Condon [1] for the purpose of making radio maps of the entire sky visible from Green Bank. This receiver, making use of NRAO cooled FET amplifiers, is being put together by G. Behrens and I. Jeffries and is scheduled to go on the 300-ft telescope in June 1986. The operating range of the receiver is 4.6 to 5.1 GHz. The proposed layout of the feeds is shown in Figure 1. The beam spacing is approximately 3 HPBW at the center frequency. Acceptable levels of beam distortion and loss of aperture efficiency warrant tight packing of the feeds and set the limitation on the maximum dimension of the feed at 4.25". The following two feeds were considered for this system.

Dual-Mode, Small-Aperture Feed

A dual-mode, small-aperture feed with an aperture diameter of 1.31 λ was designed [2], [3] and fabricated. In this feed, TE_{11} and TM_{11} modes are excited at the circular aperture where the relative phases and amplitudes of the two modes are adjusted to cancel the electric field at the aperture boundary. This tapered distribution over the aperture provides nearly circularly symmetric radiation patterns. Far-field pattern measurements made on the fabricated feed revealed that this feed did not have the required bandwidth. Due to the differential dispersion between the modes the amplitude and phase patterns on either side of the design frequency started to lobe, rendering this feed unsuitable.

Hybrid-Mode Scalar Horn

The second alternative was a hybrid-mode scalar horn (wide-flare-angle corrugated horn) where the two modes TE_{11} and TM_{11} are locked together in the HE_{11} mode configuration. The hybrid-mode condition is achieved by imposing an anisotropic boundary condition on the excitation structure leading to the aperture. These feeds exhibit radiation pattern symmetry resulting in high gain and low spillover. They radiate with very low cross-polarization. A bandwidth as high as 1.7:1 is attainable with the scalar horn. Scalar horns have been found to perform efficiently even when they are small in terms of wavelengths [4], [5], [6].

Experimental Results

A scalar horn with a flare half-angle of 45° shown in Figure 2 was designed and fabricated. The aperture diameter is approximately 1.31λ at the center frequency of 4.85 GHz. The input section of the horn is 1.768" diameter. The corrugations of this horn are perpendicular to the wall of the horn and have uniform slot depth of little more than a quarter wavelength at the lower frequency end. The widths of the slot and ridge are 0.12 λ and 0.03 λ, respectively. Because of the size of the aperture, only two corrugations could be accommodated. The location of the first corrugation has been chosen for a good match between the TE_{11}

mode in the circular waveguide and the TM_{11} mode in the corrugated circular section. The various dimensions are shown in Figure 3.

Co-polar and cross-polar field patterns in the two principal planes were measured. The results are shown in Figures 5 and 6. At the edge of the dish (300-ft) the field levels varied between -11 dB and -12.5 dB in the E-plane and between -14.5 and -16 dB in the H-plane. As can be seen from the plots, cross-polarization levels were never greater than -38 dB with respect to the boresight co-polarization levels in the two planes. The patterns in the two planes are almost identical down to about -9 dB. The phase centers in the two planes are found to be coincident.

A tuning washer has been introduced into the input section of the horn for improving the impedance match. The return loss measured is shown in Figure 4 and is found to be excellent.

The various efficiencies and noise temperatures contributed by the feed on the 300-ft telescope are shown in Table 1. The aperture efficiency varies between 69% and 75% while the spillover noise temperature varies between 6.5°K and 10°K. It can be concluded that scalar horns need not be electrically large for reasonably good performance.

REFERENCES

[1] J. J. Condon, "Multiple-Beam Receiver Proposal," Memorandum to R. J. Havlen, September 28, 1982.

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[3] R. H. Turrin, "Dual Mode Small-Aperture Antennas," IEEE Transactions on Antennas and Propagation, Vol. AP-15, pp. 307-308, March 1967.

[4] P. J. B. Clarricoats and A. D. Olver, "Design of Cylindrical and Conical Corrugated Horns," Chapter 5, Corrugated Horns for Microwave Antennas, 1984.

[5] P. J. B. Claricoats and P. K. Saha, "Propagation and Radiation Behaviour of Corrugated Feeds, Part 2: Corrugated - Conical - Horn Feed," Proc. Inst. Elect. Engrs., Vol. 118, pp. 1177-1186, September 1971.

[6] A. J. Estin, C. F. Stubenrauch, A. G. Repjar and A. C. Newell, "Optimized Wavelength-Sized Scalar Horns as Antenna Radiation Standards," IEEE Trans. on Inst. & Meas., Vol. IM-31, No. 1, pp. 53-56, March 1982.

TABLE 1

f GHz	Reflection η	H-PLANE				E-PLANE			
		Taper η	Spill-over η	Aperture η	Noise Temperature °K	Taper η	Spill-over η	Aperture η	Noise Temperature °K
4.6	0.9865	0.774	0.942	0.7192	9.2	0.793	0.937	0.7320	10.2
4.85	0.9999	0.752	0.951	0.7151	7.6	0.791	0.948	0.7498	8.4
5.1	0.9968	0.716	0.960	0.6852	6.5	0.773	0.951	0.7328	8.0

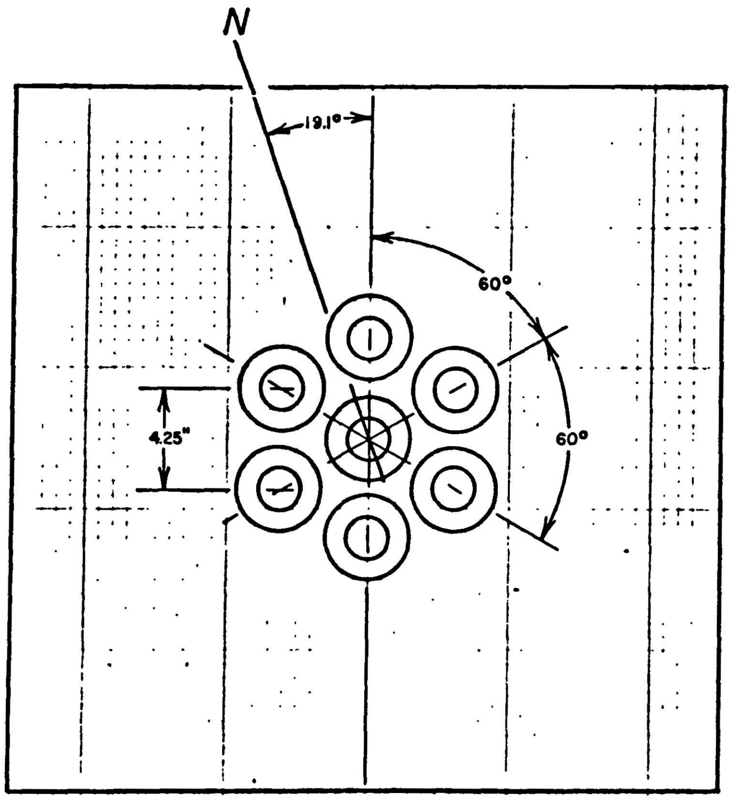


FIGURE 1. Layout of the 6-cm feeds.

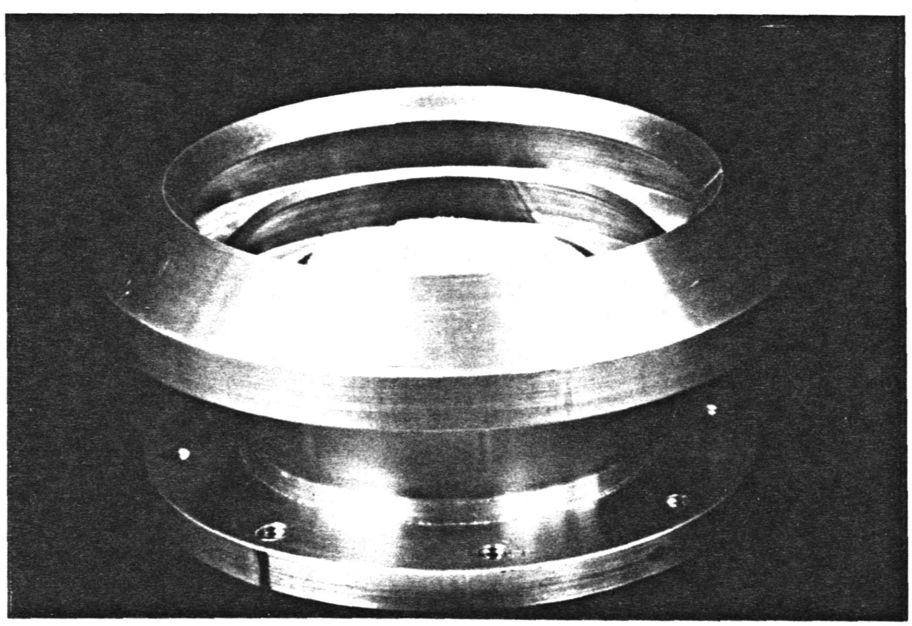


FIGURE 2. Small-aperture scalar horn with flare semiangle of 45°.

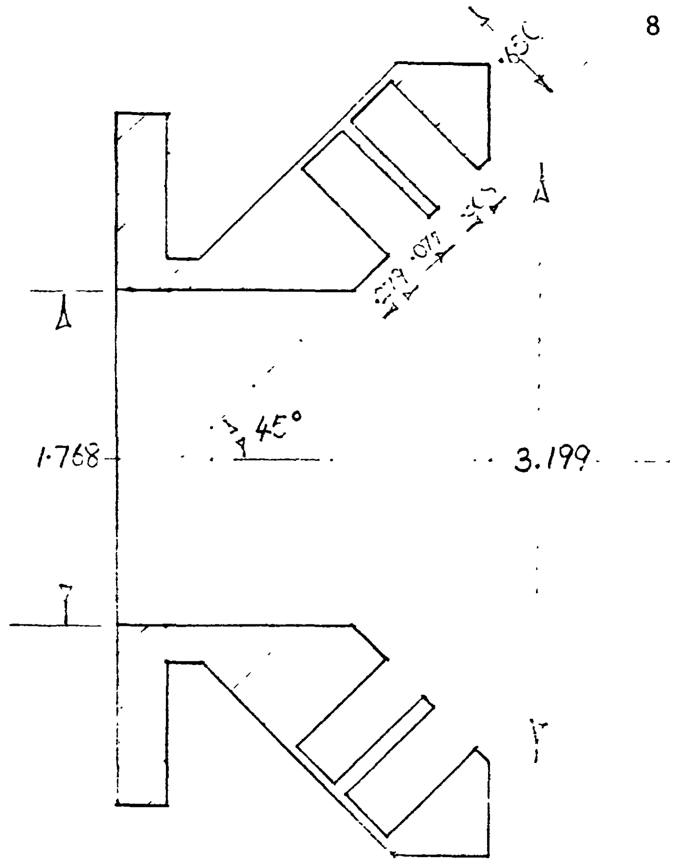


FIGURE 3. 6-cm Scalar Horn.
(All dimensions in inches.)

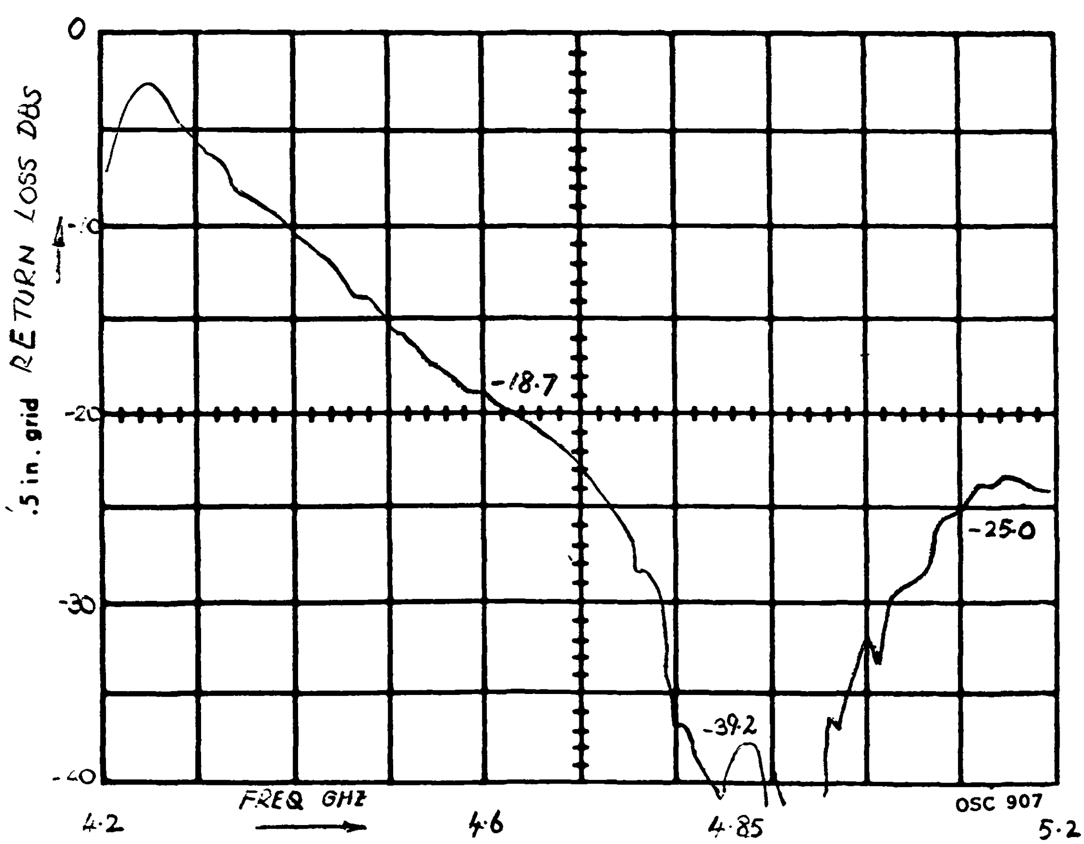
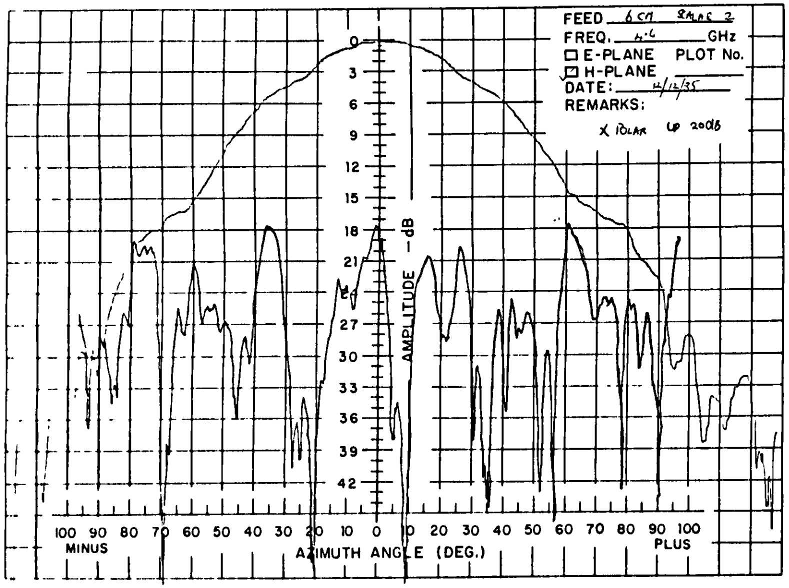
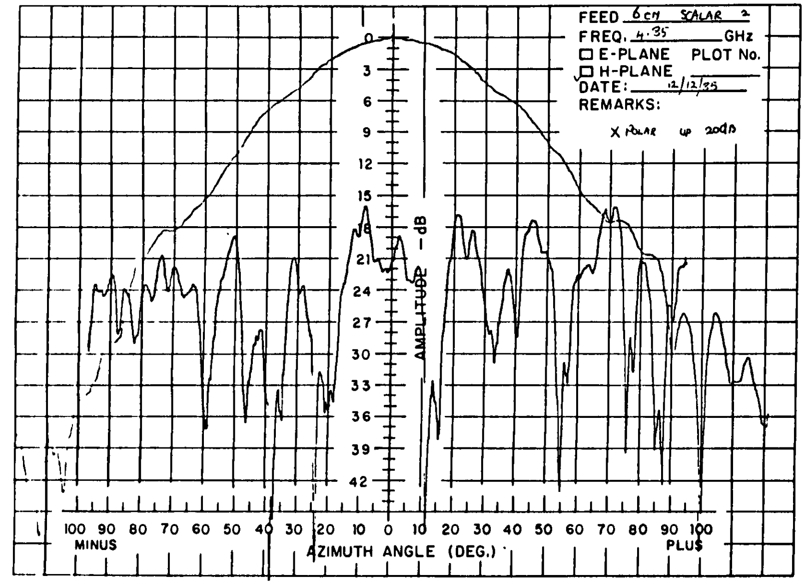


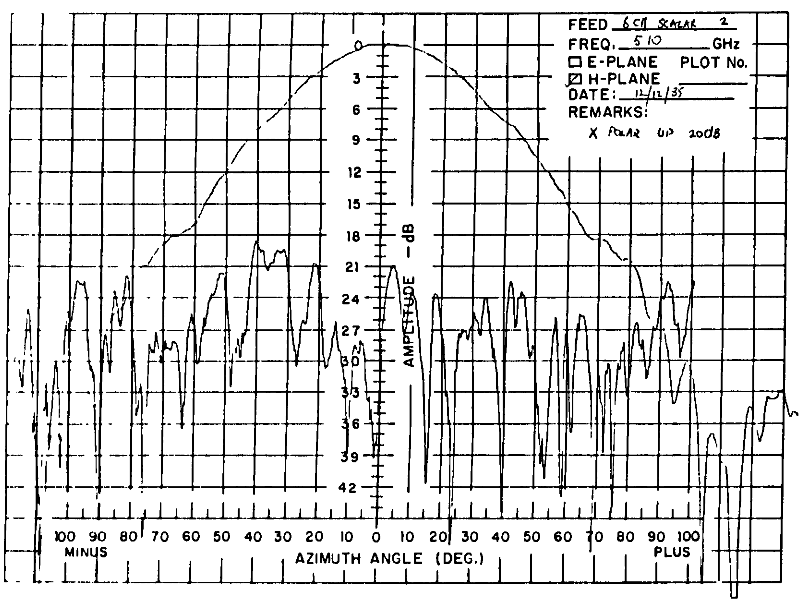
FIGURE 4. Return Loss.



(a) 4.6 GHz



(b) 4.85 GHz

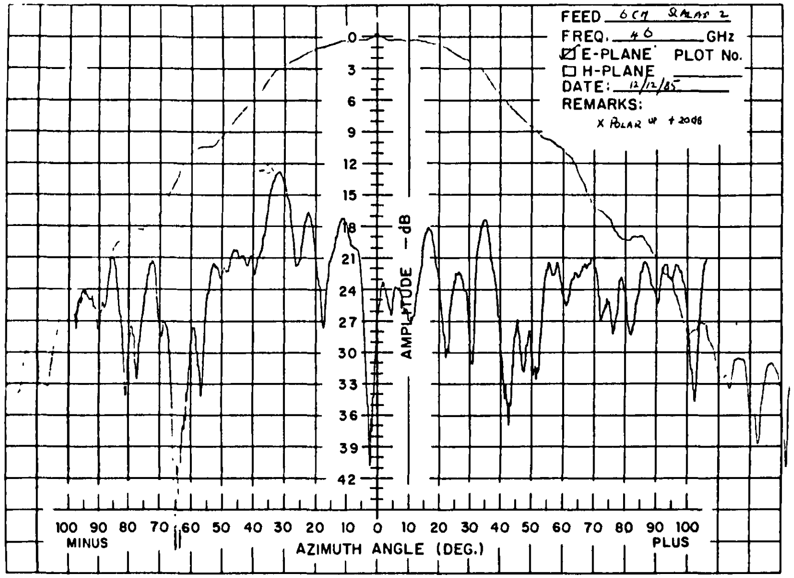


(c) 5.1 GHz

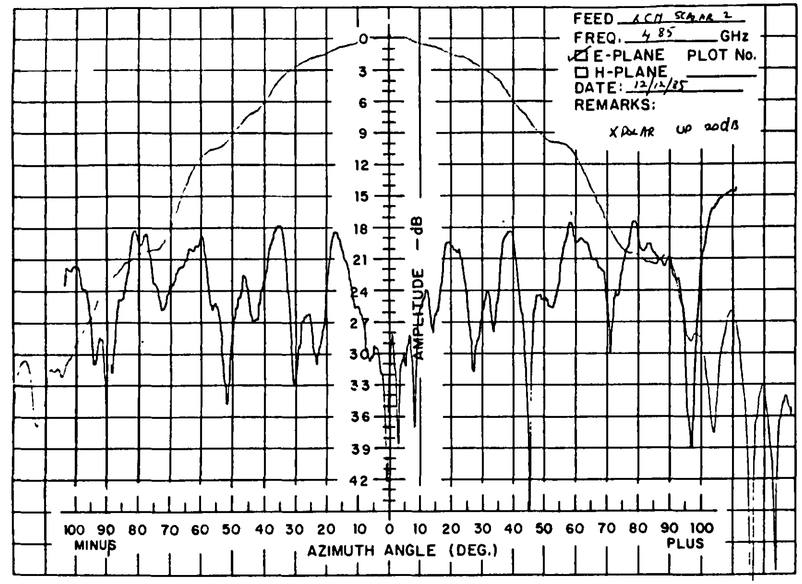
FIGURE 5

Co-polar and cross-polar patterns:
H-Plane

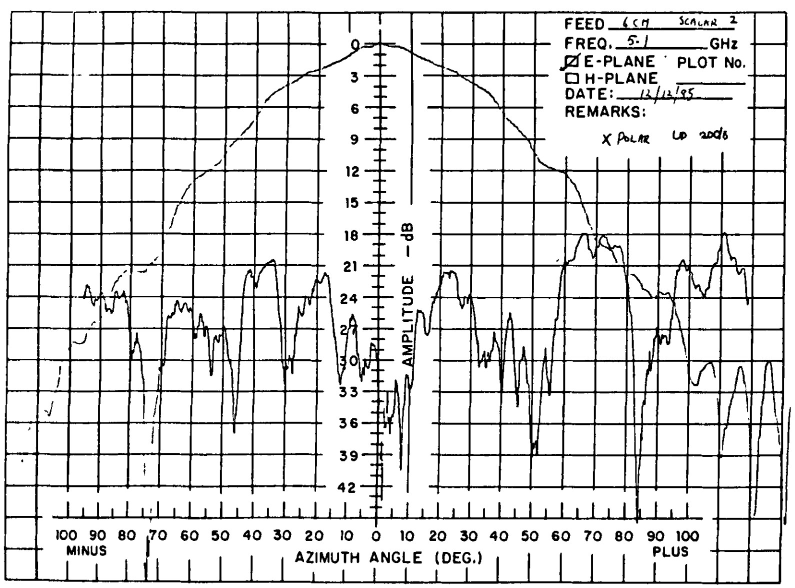
Note: X-polar pattern up + 20 dB.



(a) 4.6 GHz



(b) 4.85 GHz



(c) 5.1 GHz

FIGURE 6

Co-polar and cross-polar patterns:
E-Plane

Note: X-polar pattern up + 20 dB.