A NEW SHORT-BACKFIRE ANTENNA AS PRIME FOCUS FEED FOR THE GBT

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Introduction:

The details of implementation of the prime focus receiver requirements on the GBT are given in GBT Memo 69 [1]. The memo calls for five frequency bands each with bandwidth ratio of 1.35:1. The bands are 290-395 MHz, 385-520 MHz, 510-690 MHz, 680-920 MHz and 910-1230 MHz. The upper two bands will use single-mode corrugated horns with quad-ridged orthomode transducers. At the lower bands, wideband waveguide type of feeds are too large to fit in the available space in the prime focus boom and, hence, the only choice is dipole type of feeds. The half angle subtended by the main reflector of the GBT from prime focus is 39 degrees. This geometry requires a highly directional feed compared to ones on other NRAO telescopes. The short-backfire antenna [SBA] [2] possesses the required beam shape, however, not the bandwidth. In addition to being highly efficient, this antenna is simple, compact and easy to fabricate. This memo outlines the design effort on increasing bandwidth of a SBA and presents some measured results and calculated efficiency for the GBT with a SBA as prime focus feed.

Principles of Operation:

The backfire antenna conceived by Ehrenspeck [3] in the early 60's is characterized by multiple reflections of electromagnetic waves between two parallel plate reflectors of unequal size. This antenna has a slow-wave structure along the longitudinal axis where the energy is trapped. The spacing between the reflectors is the total axial length of the backfire antenna which is at least one wavelength (1λ). The SBA [2] is an offshoot of the backfire antenna and was first reported in 1965. A sketch of the SBA is shown in Figure 1. This antenna consists of two reflectors M and R spaced approximately $\frac{1}{2}\lambda$ apart. The large reflector is 2.0λ in diameter, the small reflector 0.4λ in diameter, and the width of the rim surrounding reflector M is 0.25λ. The antenna is excited between the two reflectors and the space between M and R acts as an open resonant cavity that radiates most of the energy from a virtual aperture in the plane surrounding the small reflector and extending even beyond the cross-sectional area of the large reflector. The SBA is essentially a leaky cavity structure and, hence, relatively insensitive to the configuration of the exciting source. The rim around the large reflector acts as a shield for the cavity and aids in reducing the level of sidelobes and backlobe.

Modifications to SBA and Results:

The SBA in its original configuration has a gain of about 15 dB. At 39 degrees, the half angle of the main reflector, the E-plane pattern has a -15.8 dB taper, while the H-plane has -13.5 dB taper at the design frequency. The sidelobes are below -20 dB and the backlobe is -25 dB. Ehrenspeck [2] reports of clean patterns over 30% bandwidth. There is no mention of the impedance characteristics. In 1972 Heckert [4] reported an impedance match bandwidth of about 5% for a SBA with return loss better than -14 dB. Ohmori *et. al.* [5] presented an improved version of the SBA in 1983. By changing the main reflector from a flat disk to a conical plane and by adding a second small reflector, they increased the bandwidth to 9% for return loss better than -14 dB. A sketch of this improved SBA is shown in Figure 2. Based on this design, a SBA was fabricated with dimensions given in Figure 2 for the 385-520 MHz band. The main reflector is 2.05λ at 450 MHz. A dipole fed by a dual-line balun was used to excite the SBA. The dipole is 13¼ inches long (0.5λ at 450 MHz) and ⅞ inch in diameter giving a length-to-diameter ratio of 15. In order to obtain increased bandwidth for impedance matching, open-sleeve dipole configuration was used. Since the SBA is insensitive to the configuration of the exciting source, the sleeves were omitted while optimizing the SBA for far-field patterns.

Far-field patterns of the SBA (version 1) were measured at five different frequencies. The E- and H-plane patterns are shown in Figure 3. The taper at the edge of the main reflector is also shown. The sidelobes in the E-plane are below -21 dB except at 520 MHz where the beam is too narrow and has sidelobes as high as -15 dB. In H-plane at 450 MHz, the sidelobes are -17 dB and at 520 MHz the main beam is very narrow and has sidelobes peaking at -7 dB. The above configuration has a 0.46λ small reflector and 0.41λ second small reflector. It was experimentally determined that reflectors of 0.41λ and 0.36λ in diameter result in improved patterns at the high end of the band. In further experiments, a conical reflector shaped similar to the large reflector but without the rim and cross-sectional width of 0.41λ gave even better performance compared to the flat reflectors. The field patterns for this configuration (version 2) are shown in Figure 4. These patterns are broader than those in Figure 3 by a small amount. However, the match between the patterns of the two planes is far better. The sidelobes in the H-plane at the high end of the band are below -15 dB. Finally, circular plates of 6" and 7" diameter were placed on either side of the dipoles forming the open-sleeve configuration, and patterns were measured. The patterns are the same as those patterns without the disks.

Flat circular disks were used in place of cylindrical sleeves around the dipole arms of the balun-fed open-sleeve dipole exciting the resonant cavity of the SBA. The sleeves improve the VSWR response of the antenna. Disks of varying sizes between 5" and 8" were used to experimentally obtain acceptable impedance matching. Figure 5 gives the return loss for 7" disks equally spaced from the dipole. For a spacing of 30mm, the return loss is better than -15 dB up to 450 MHz. Figure 6 is the response for 7" and 5" disks spaced unequally above and below, respectively, about the dipole. In this case, the return loss is better than -12.4 dB over the entire 385-520 MHz band. It is evident that the SBA can be tuned to have very good VSWR characteristics over a limited bandwidth if the need arises. Figure 7 gives the final configuration of the SBA for the 385-520 MHz band. The measured feed patterns were used to calculate the aperture efficiency and spillover temperature of the GBT. The results are presented in Table 1.

Table 1

Freq. (MHz)	Taper (dB) at 39°		η_1	η_2	η_a	T_{spill} K	Xpol (dB)	HPBW (arcmin)
	E-Plane	H-Plane						
385	-8.4	-8.0	0.7003	0.9900	0.6933	13.3	-20.1	15.3
417	-11.5	-11.7	0.5974	0.9463	0.5653	10.5	-21.8	14.3
450	-12.5	-11.5	0.7562	0.9743	0.7368	10.2	-20.6	13.7
485	-13.0	-12.0	0.6664	0.9822	0.6545	9.7	-20.6	12.7
520	-14.8	-12.0	0.6502	0.9425	0.6128	9	-20.8	11.9

η_1 : Illumination * spillover efficiency
η_2 : Reflection coefficient of feed
η_a : Aperture efficiency
T_{spill}: Spillover temperature
Xpol : Cross-polarization below main beam
HPBW : Half-power beam width

Conclusion:

A new configuration for a SBA has been arrived at experimentally to give reasonably good far-field patterns and VSWR characteristics over 30% bandwidth. The SBA, when used as a prime focus feed on the GBT, results in good efficiency over the entire 385-520 MHz band. This feed will be scaled to the 290-395 MHz and 510-690 MHz bands. The performance of the SBA can be improved by adding a corrugated rim based on the work done by Kooi *et. al.* [6]. If this technique proves useful, the feature will be incorporated at a later stage.

Acknowledgements:

The authors wish to thank M. Barkley, R. Hanshew, P. Schaffner, R. Dickenson and M. Hedrick of the Green Bank machine shop for their work on the fabrication of the SBA and G. Anderson at the Jansky Lab for assisting during measurements. Special thanks goes to Shivy Srikanth who shuttled several times between the shop and the lab carrying parts of the SBA for modification.

References:

[1] G. Behrens, "Proposed Plan to Implementing Prime Focus Receiver Requirements for the GBT," GBT Memo No. 69, Oct. 14, 1991.

[2] H. W. Ehrenspeck, "The Short-Backfire Antenna," *Proc. of the IEEE* (correspondence), v. 53, pp. 1138-1140, Aug. 1965.

[3] H. W. Ehrenspeck, "The Backfire Antenna: A New Type of Directional Line Source," *Proc. IRE* (correspondence), v. 48, pp. 109-110, Jan. 1960.

[4] G. P. Heckert, "Investigation of L-Band Shipboard Antennas for Maritime Satellite Applications," Automated Marine Int. Rep. NASW-2165, Feb. 1972.

[5] S. Ohmori, S. Miura, K. Kameyama and H. Yoshimura, "An Improvement in Electrical Characteristics of a Short-Backfire Antenna," *IEEE Trans. Antennas Propagat.*, v. AP-31, pp. 644-646, July 1983.

[6] P. S. Kooi, M. S. Leong and T. S. Yeo, "Dipole-Excited Short-Backfire Antenna with Corrugated Rim," *Electronics Letters*, v. 15, no. 14, pp. 421-423, July 1979.

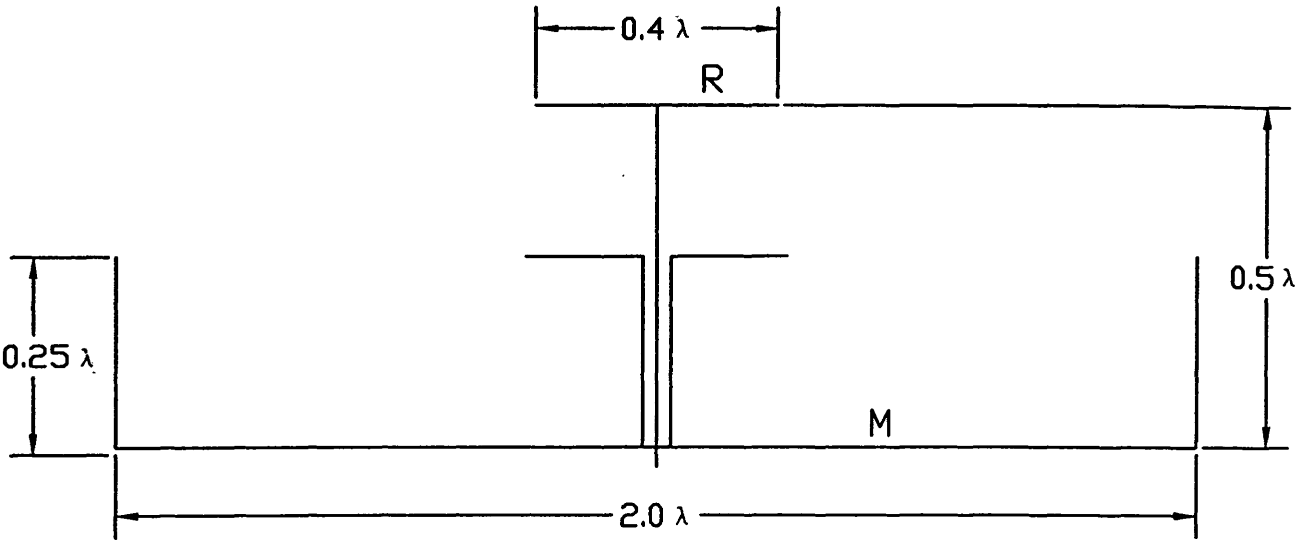
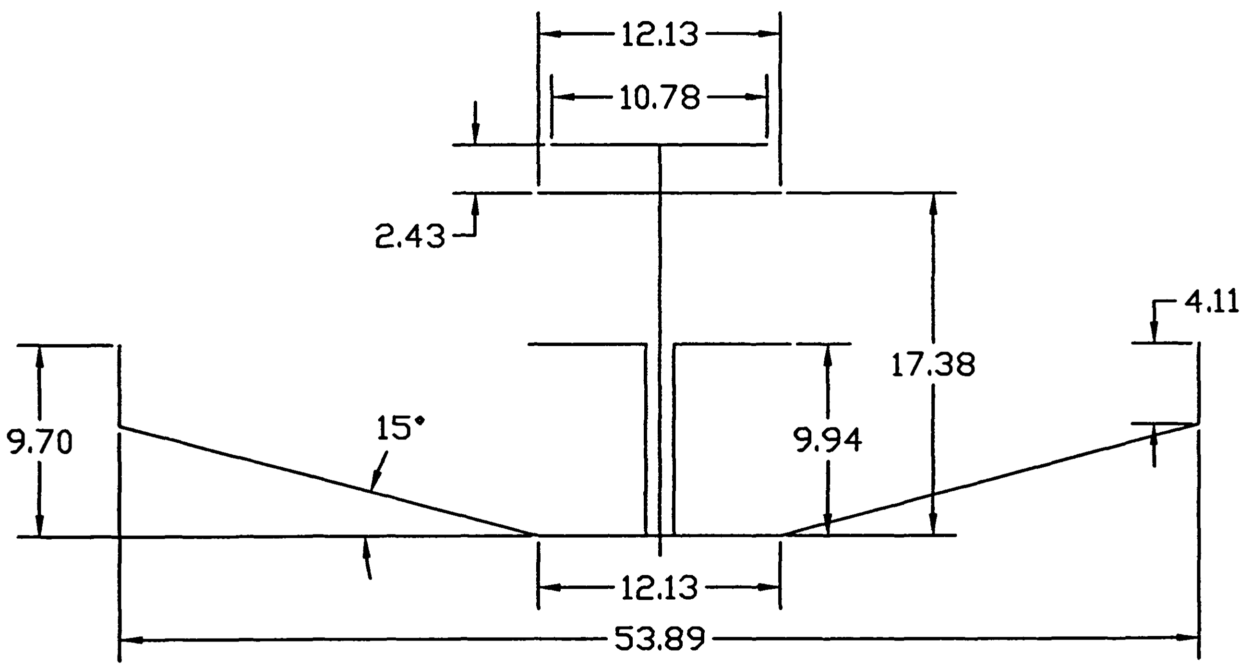
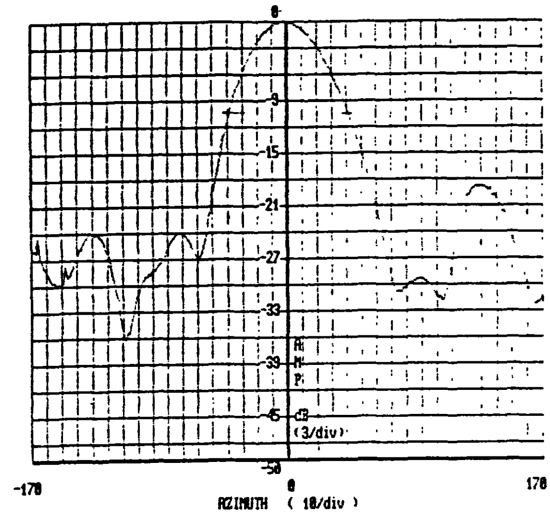


Figure 1. Original Short-Backfire Antenna

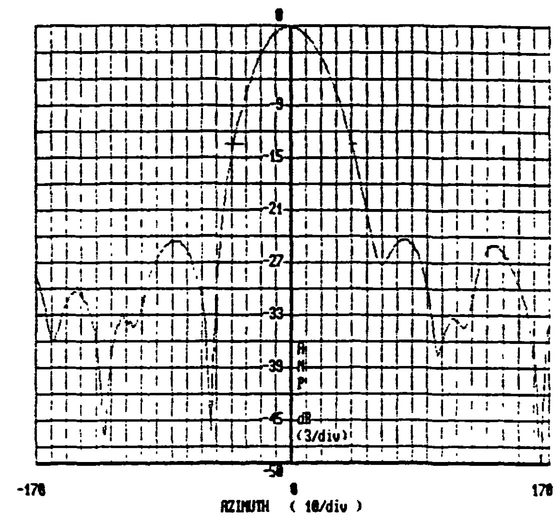


(All dimensions in inches)

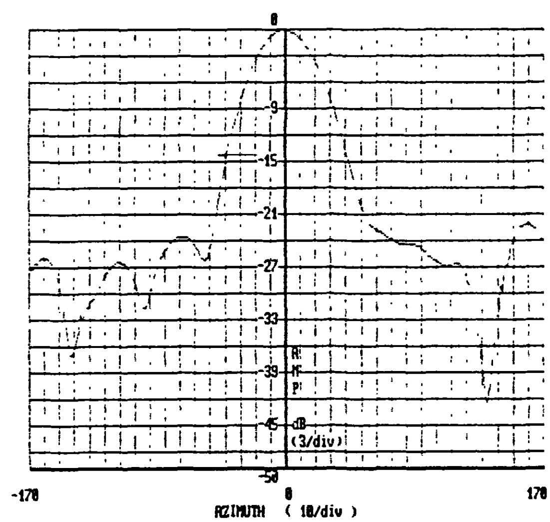
Figure 2. Improved Short-Backfire Antenna



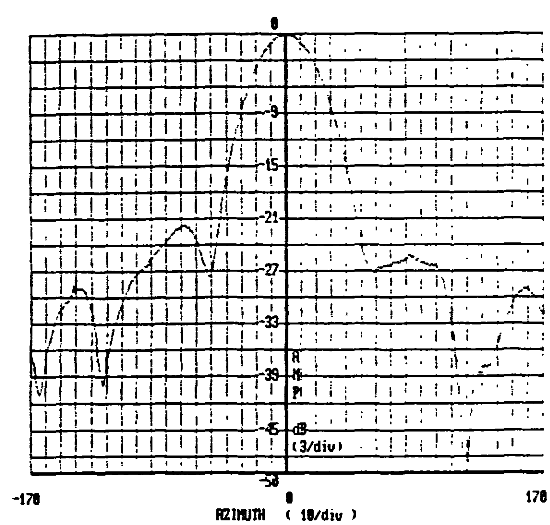
385 MHz (- 10.5 dB)



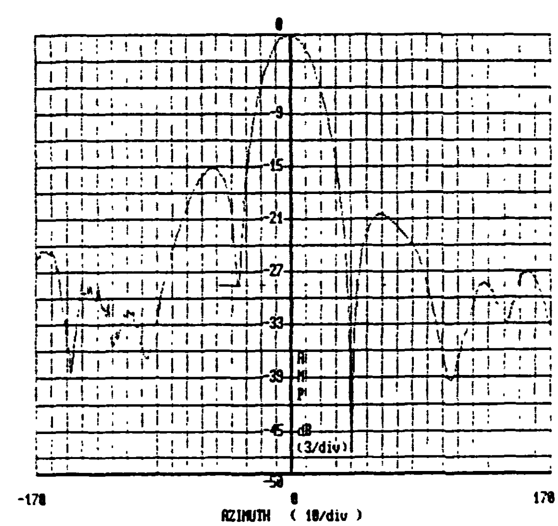
417 MHz (-13.5 dB)



450 MHz (-14.2 dB)

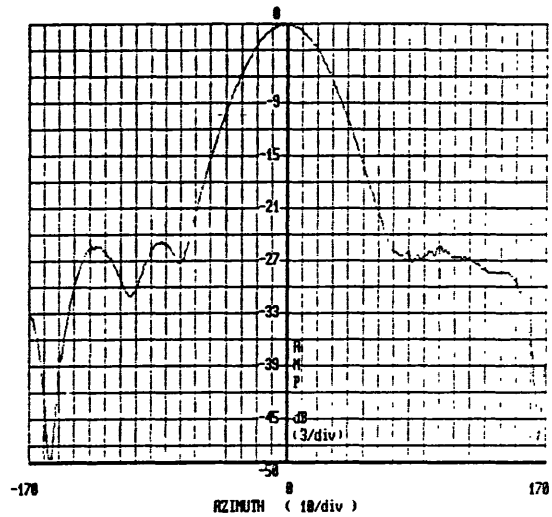


485 MHz (-15.0 dB)

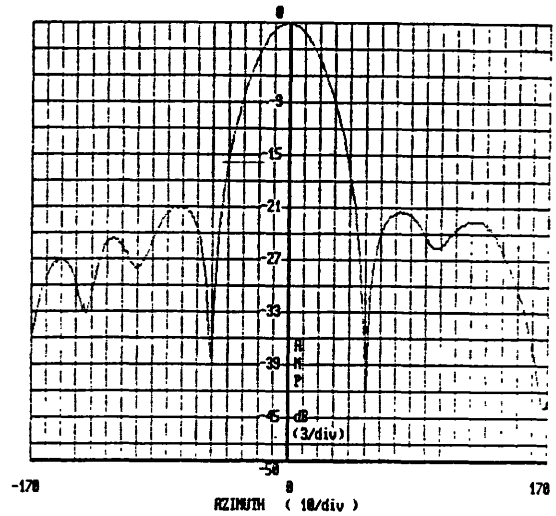


520 MHz (-28.5 dB)

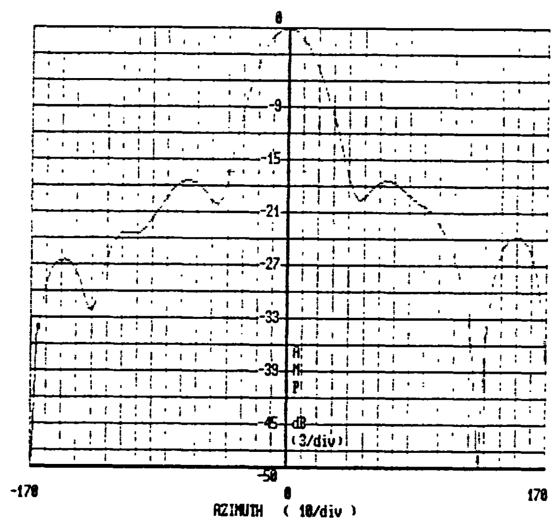
Fig. 3a. E-plane patterns (version 1).



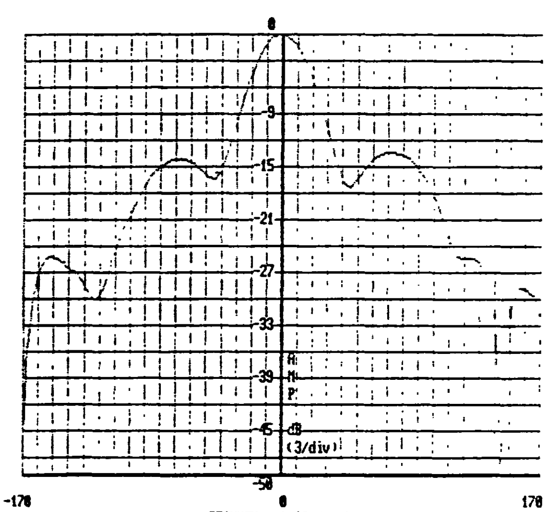
385 MHz (- 10.5 dB)



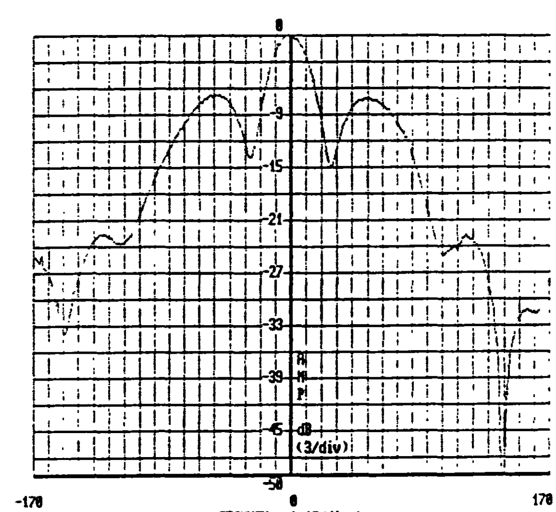
417 MHz (-16.0 dB)



450 MHz (-16.5 dB)

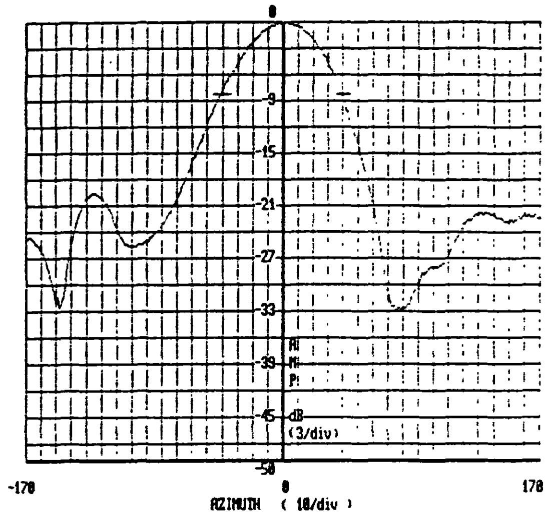


485 MHz (-15.5 dB)

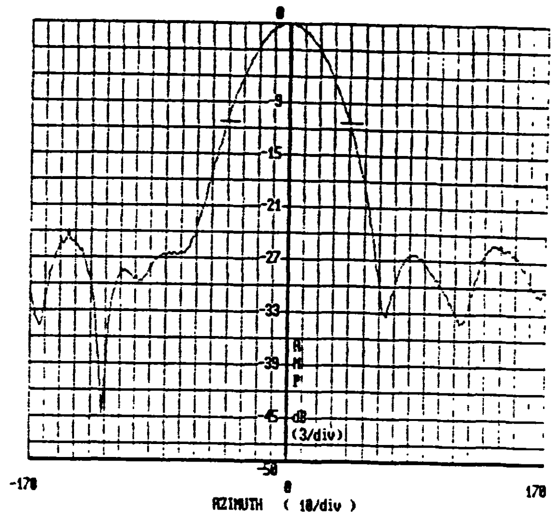


520 MHz

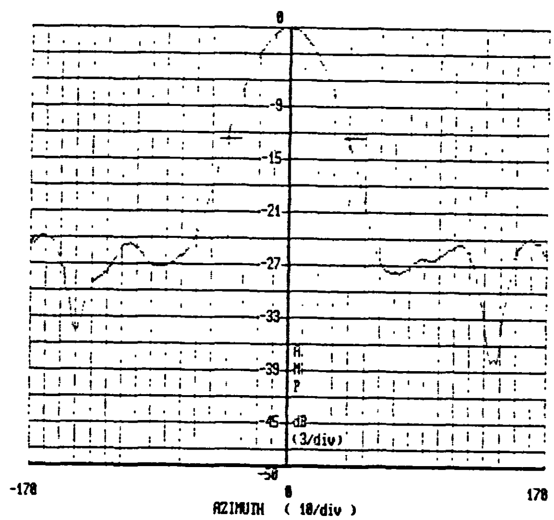
Fig. 3b. H-plane patterns (version 1).



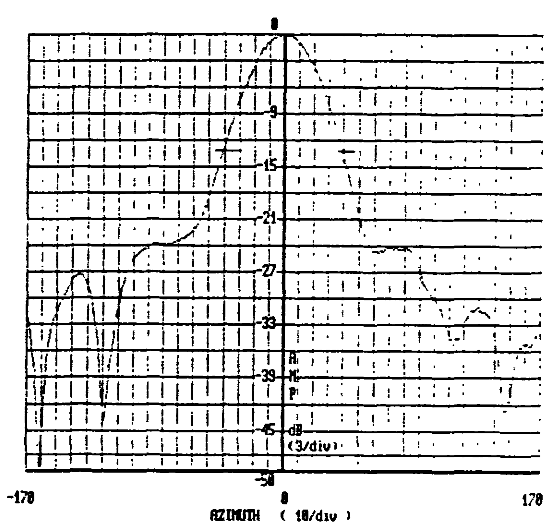
385 MHz (- 8.4 dB)



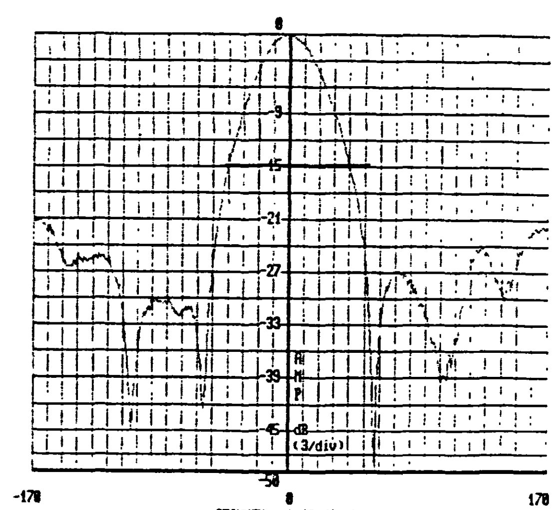
417 MHz (-11.5 dB)



450 MHz (-12.5 dB)

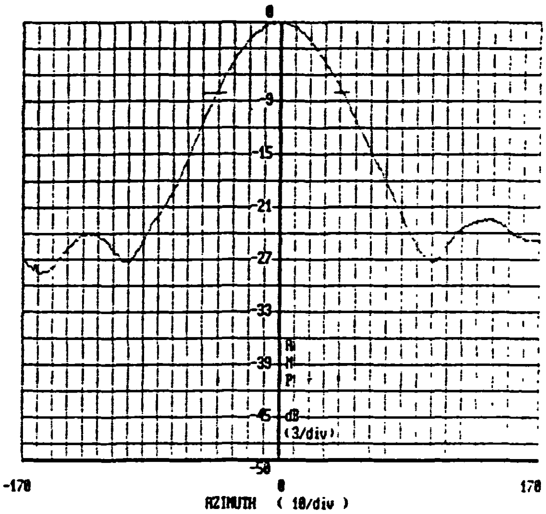


485 MHz (-13.0 dB)

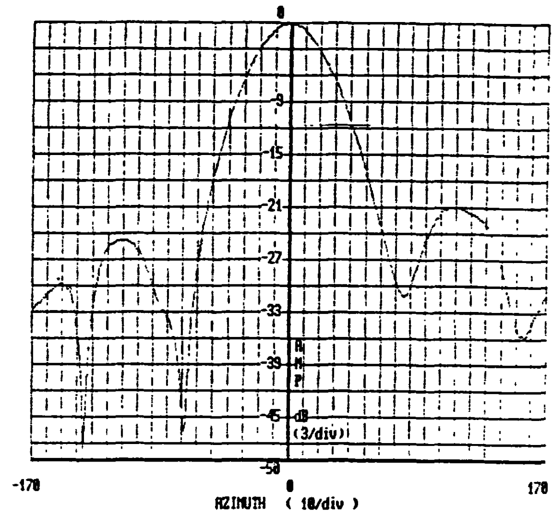


520 MHz (-14.8 dB)

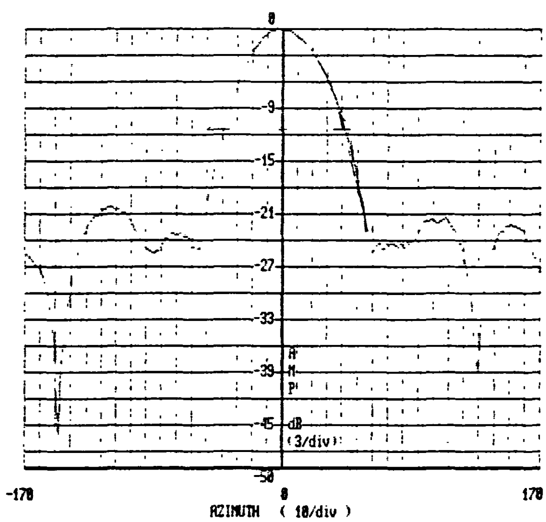
Fig. 4a. E-plane patterns (version 2).



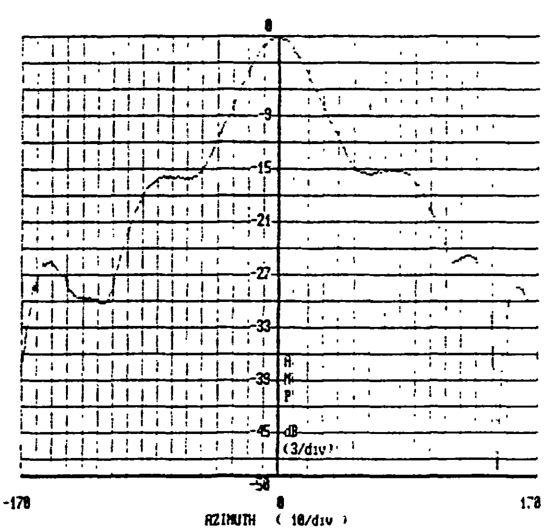
385 MHz (- 8.0 dB)



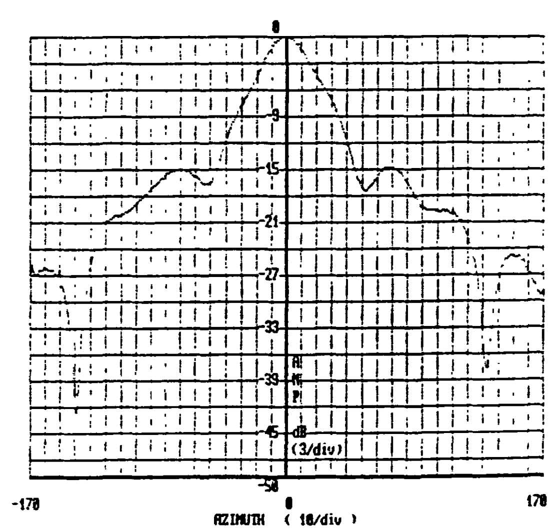
417 MHz (-11.7 dB)



450 MHz (-11.5 dB)



485 MHz (-12.0 dB)



520 MHz (-12.0 dB)

Fig. 4b. H-plane patterns (version 2).

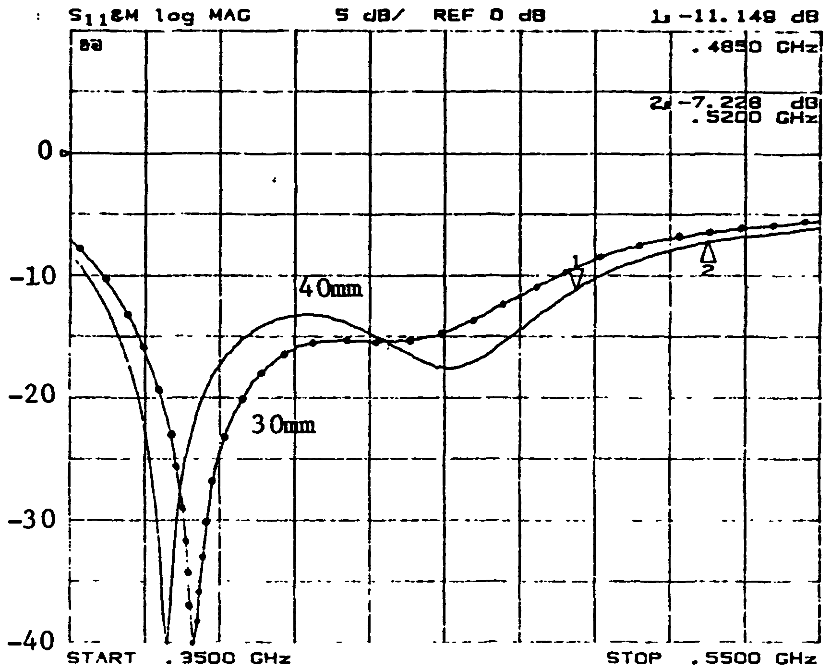


Fig. 5. Return loss: 7" disk equal spacing.

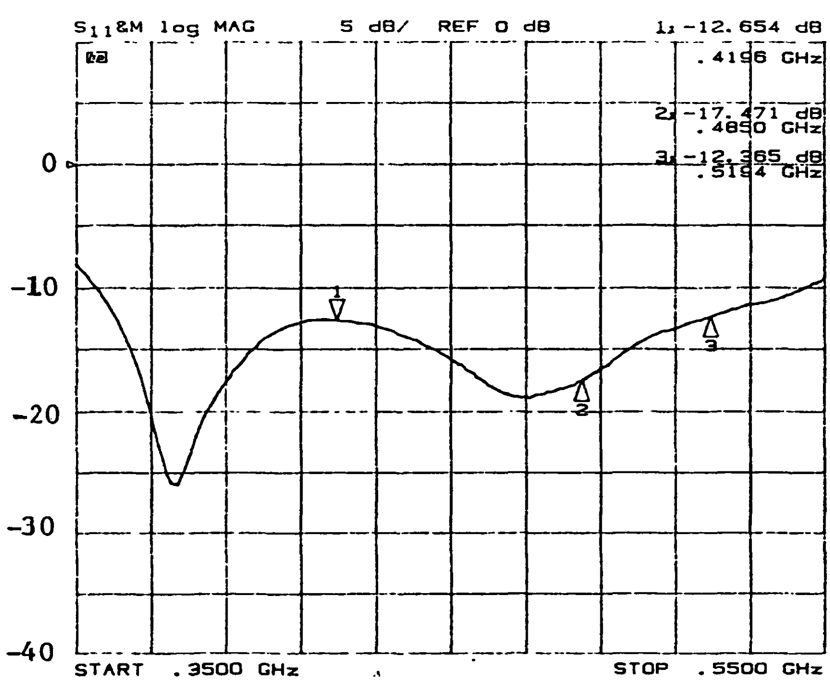
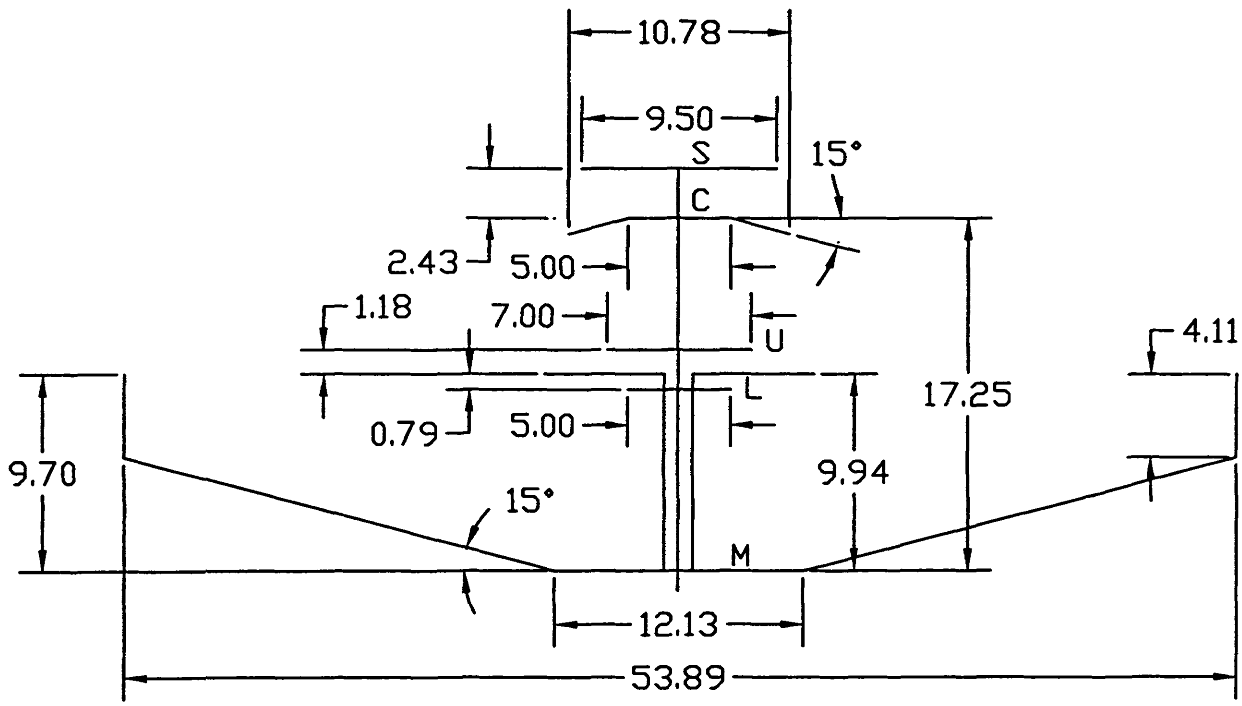


Fig. 6. Return loss: upper disk 7" at 30mm; lower disk 5" at 20mm.



(All dimensions in inches)

M - Large Reflector
C - Conical Small Reflector
S - Second Small Reflector
U - Upper Sleeve Plate
L - Lower Sleeve Plate

Figure 7. New Short-Backfire Antenna (385-520MHz)