OVLBI-ES MEMO NO. 41

Measurement Results: Corrugated Horns and FSS

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1 Abstract

During the last six months, extensive testing has been done on the elements of the GB-OVLBI Earth Station optics. These include the 7-9 GHz corrugated horn (X-band), the 14-16 GHz corrugated horn (Ku-band), and the frequency-selective-surface (FSS) that will be used to diplex the two bands. The results of these tests are summarized in this memo.

2 Corrugated Horn Design

Table 1 lists relevant parameters of the X- and Ku-band horns.

	Freq. (GHz)	α°	L(in)	r(in)	$\frac{r}{\lambda}$	$\frac{L}{\lambda}$	Δ	phase-ctr(in)	Beamwidth
X-band horn	7.2	8.0	30.7	4.3	18.7	2.62	0.18	-3.3	14.0
	7.85				20.4	2.86	0.20	-4.3	12.9
	8.5				22.1	3.09	0.22	-5.5	12.0
Ku-band horn	13.4	15.0	14.7	3.94	16.7	4.47	0.588	-11.0	12.8
	14.2				17.7	4.77	0.623	-11.4	12.6
	15.3				19.0	5.10	0.671	-11.9	12.5

Table 1: Parameters of X- and Ku-band Corrugated Feed Horns. α : horn semiflare angle, L: horn length, r: aperture radius, $\Delta = \frac{r}{\lambda}\tan\frac{\alpha}{2}$. Phase center and beamwidth were design goals, compare to measured values shown below

Sketches of the X-band horn and Ku-band horn appear in Figure 1 and in Figure 2.

3 Ku-Band Horn Test Results

3.1 Return Loss

The return loss of the Ku-band horn is shown in Figure 3, from 13 to 16 Ghz, with markers at several of the frequencies of interest for the OVLBI project. Note that the return loss is better than 25 dB across the band, and is better than 30 dB for the most part. This result is more than adequate since it is much better than some of the other front end components, such as the polarizer.

3.2 Antenna Patterns

Table 2 lists the important results that are taken from the Ku-band horn antenna range measurements.

Figure 4 and Figure 5 show the composite E- and H-plane antenna pattern measurements, respectively, for selected frequencies in the range from 13.4 to 16.0 GHz. The plots clearly show the desirable characteristic of near-uniform beamwidth across the band. The crosspolarization of the horn was measured in the 45-degree plane, with the result that nowhere in the band does the crosspolarization exceed 33 dB below the peak of the main beam. This is an excellent result, and implies that polarization conversion in the horn exists only to a negligible degree. Reflection from the offset ellipsoid is expected to contribute spurious crosspolarization to the Ku-band pattern, but this has not been measured yet.

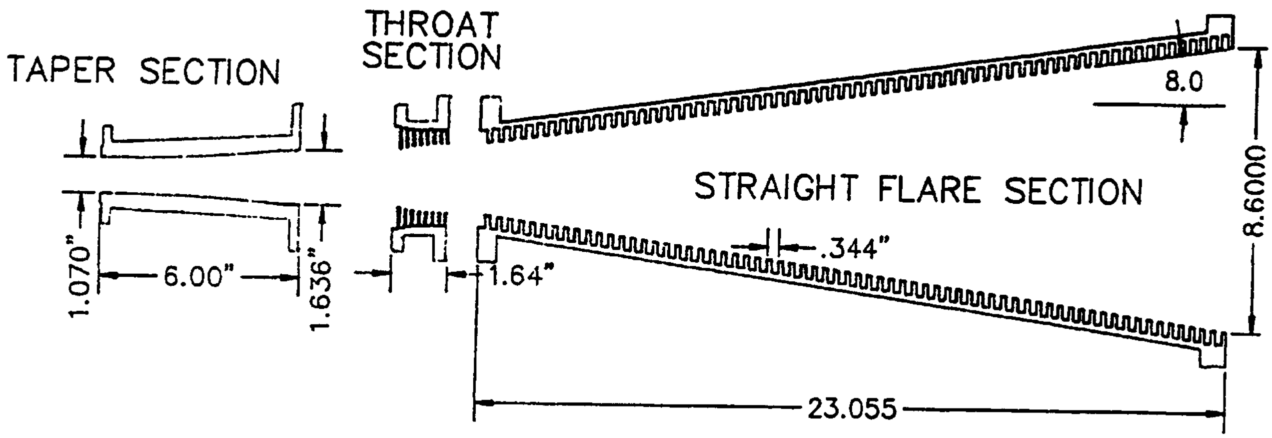

Figure 1: Sketch of X-band horn geometry

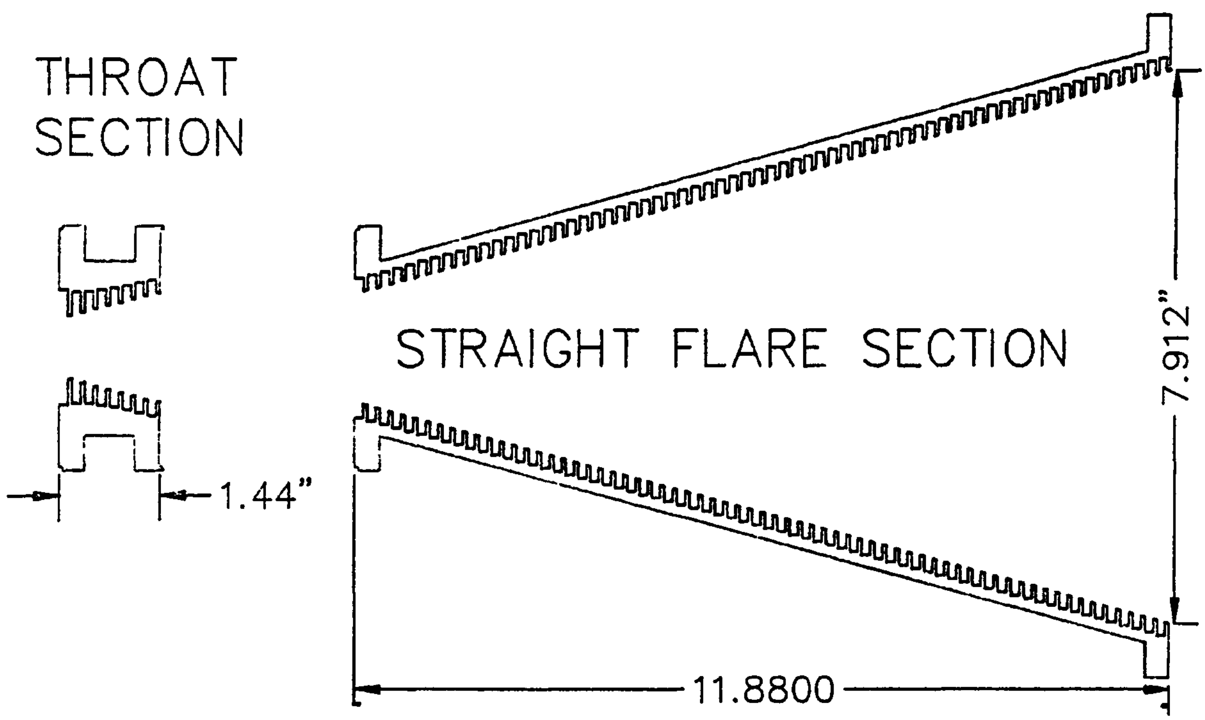

Figure 2: Sketch of Ku-band horn geometry

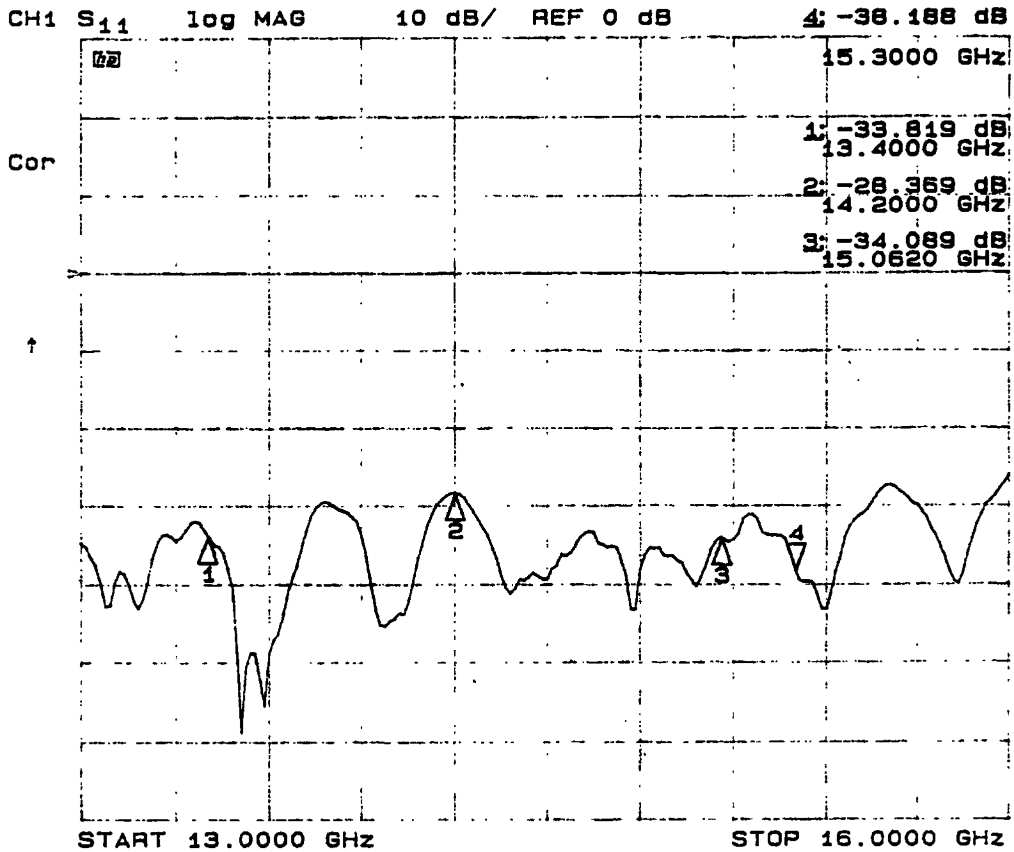

Figure 3: Return Loss of Ku-band horn

Freq. (GHz)	Beamwidth E-plane	Beamwidth H-plane	Beamwidth 45° plane	Xpol(max-dB) 45° plane	Return Loss (dB)	phase ctr.(in)
13.8	11.8	12.0	12.0	-34	30	-12.4
14.2	11.6	11.8	11.9	-36	28	-11.8
15.0	11.7	11.9	11.8	-34	34	-12.1
15.3	12.5	12.5	12.2	-35	38	-12.3

Table 2: Results of Ku-band Horn Measurements. Beamwidth is 12 dB half-beamwidth.

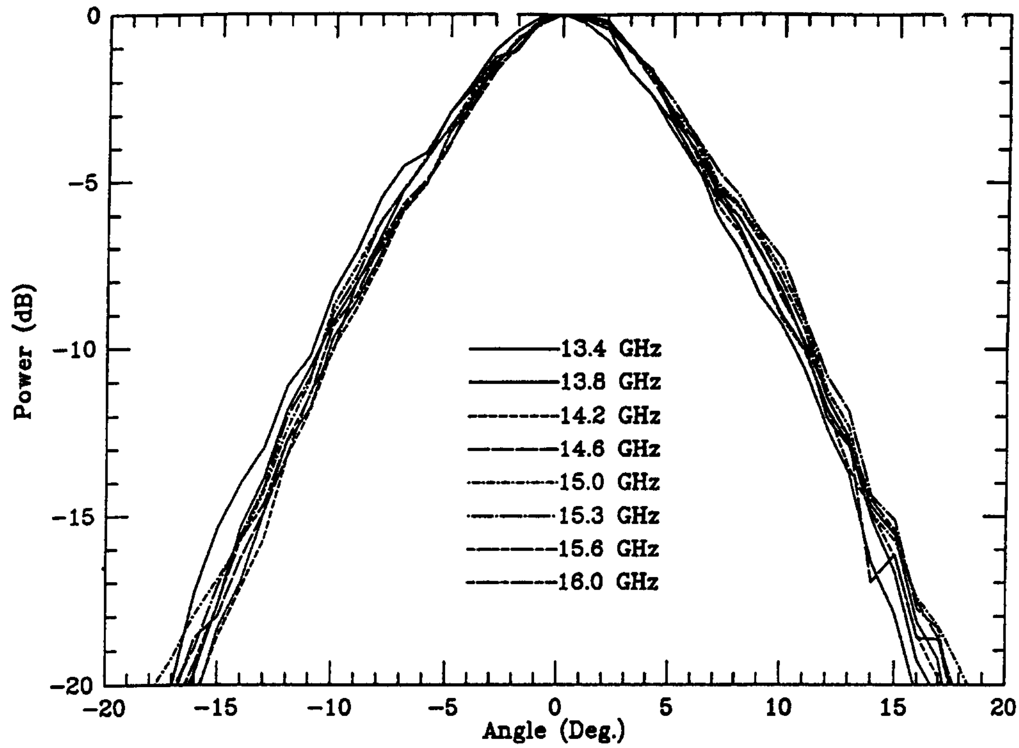

Figure 4: Ku-band horn E-plane radiation patterns

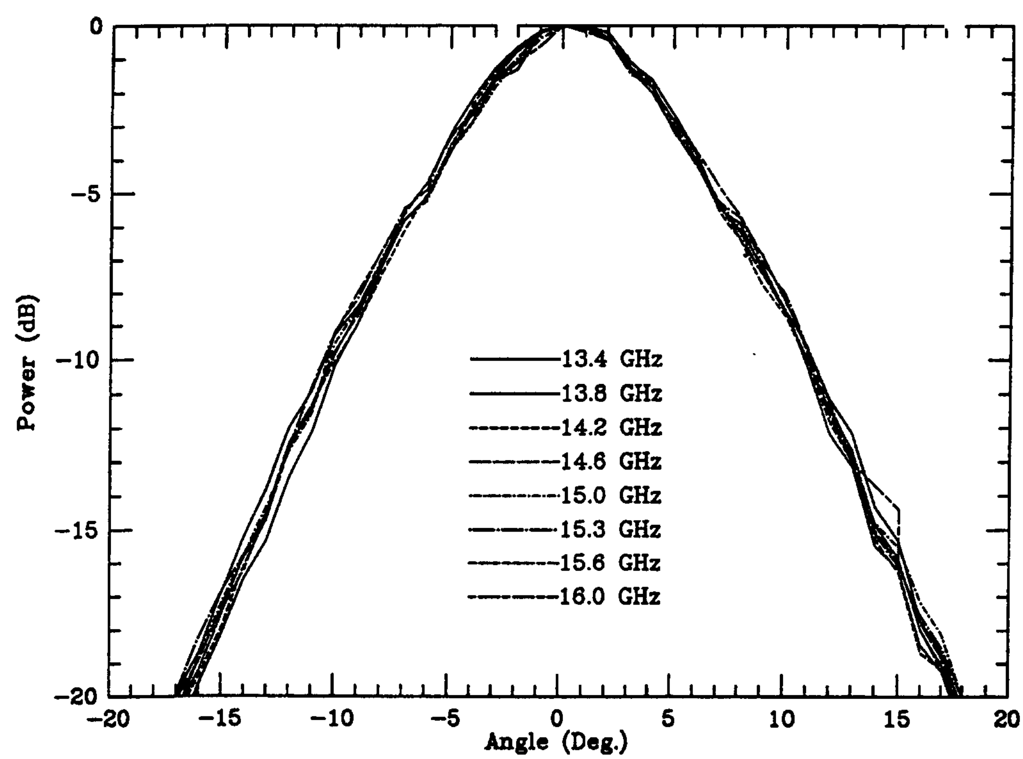

Figure 5: Ku-band horn H-plane radiation patterns

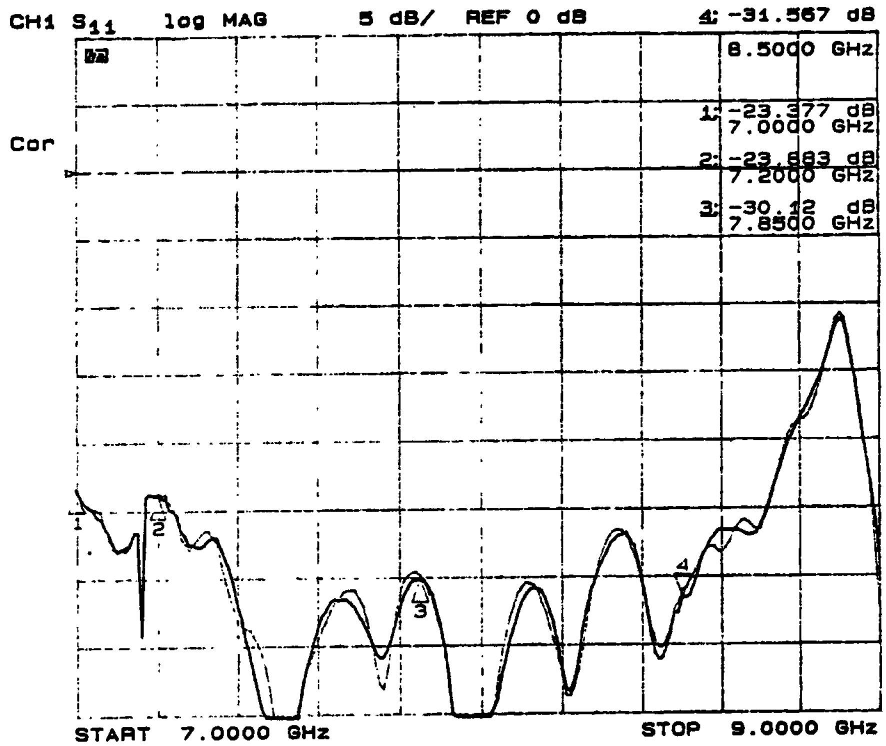

Figure 6: Return Loss of X-band horn

Freq.	Beamwidth			Xpol(max-dB)	Return	phase
(GHz)	E-plane	H-plane	45° plane	45° plane	Loss (dB)	ctr.(in)
7.20	13.7	13.7	13.8	-40	-23.8	-4.3
8.00	12.5	12.3	12.2	-42	-42	-5.0
8.50	11.7	11.7	11.6	-35	-31.5	-5.5

Table 3: Results of X-band Horn Measurements. Beamwidth is 12 dB half-beamwidth.

4 X-Band Horn Test Results

4.1 Return Loss

The return loss of the X-band horn is shown in Figure 6, from 6 to 10 Ghz, with markers at 7.0,7.2,7.8, and 8.5 GHz. The 20 dB bandwidth is about 6.95 GHz–8.80 GHz. The return loss at 7.2 GHz falls just short of the 25 dB figure-of-merit, but this is still a reflection level of only 3 parts in a thousand. The X-band polarizer, which attaches to the throat of the horn, has a return loss at 7.2 GHz of about 20 dB, so the reflection is again dominated by the polarizer.

4.2 Antenna Patterns

Table 3 lists the important results that are taken from the X-band horn antenna range measurements.

Shown in Figure 7 and Figure 8 are the composite patterns of the X-band horn in the E- and H-plane, respectively, over the frequency range 7.0–9.0 Ghz. It can be seen that the X-band horn has more variability in its beamwidth than the Ku-band horn. This is a result of the fact that it is a narrow-band, small-flare angle design. A wide-angle horn design would have had uniform beamwidth, but at the expense of a much larger horn, and a much less compact optics design on the whole. The subtended half-angle of the X-band horn is 13 degrees, so the result is that the antenna will be slightly under-illuminated at 8.5 GHz, and probably well-balanced between spillover and illumination at 7.2 GHz. If we were to remove a few corrugations from the horn, not too difficult to do, the beam would get a little wider, and the "best illumination" condition

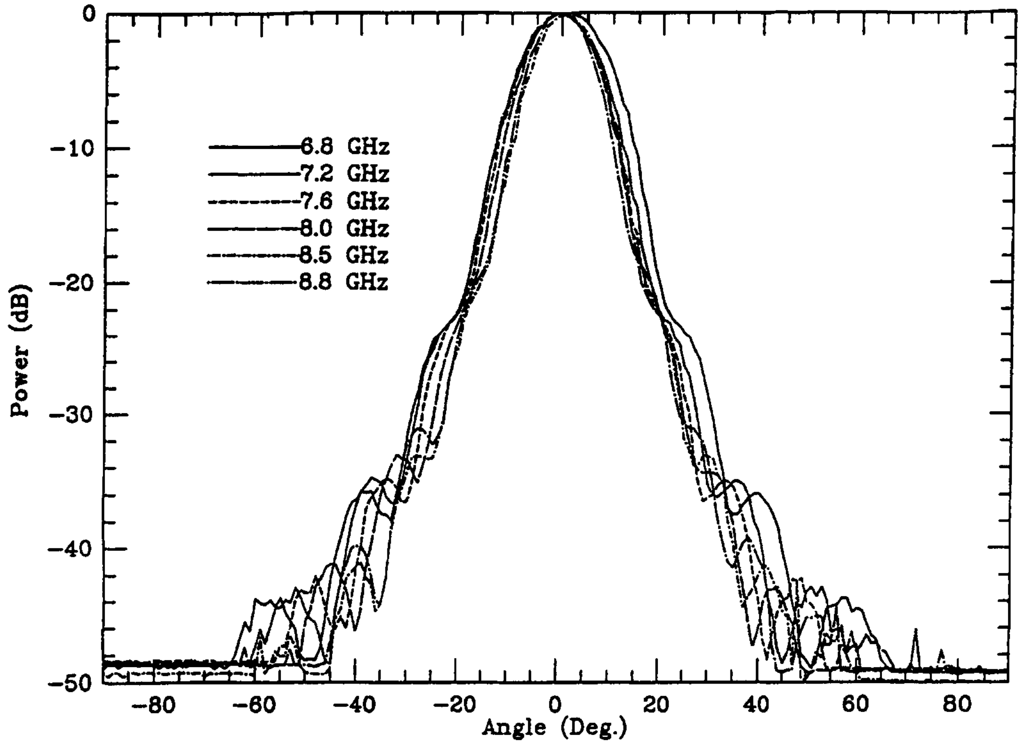

Figure 7: X-band horn E-plane radiation patterns

could be moved to 8.0 GHz from 7.2 GHz. Spillover would increase at 7.2 GHz, however. It is not clear at the present time if further action needs to be taken.

Figure 9 shows the crosspolar performance of the X-band horn. This is a composite plot of the horn patterns, both copolar and crosspolar, in the 45°-plane. With the exception of the high crosspol level of -16 dB at 9.0 GHz, the crosspol stays below 28 dB for all other frequencies. It should be negligible at the uplink/downlink frequencies of 7.2 and 8.5 Ghz, the crosspol level is below -35 dB, an absolutely negligible level.

5 Tests of X-band horn with FSS

Several tests were conducted with the FSS placed directly in front of the X-band horn and as close to our exact geometry as possible[1]. We were looking, in particular, at the total insertion loss, and also on what effect the FSS has on the horn pattern. We would expect some smearing of the pattern, perhaps, and also some elevated sidelobes. Insofar as our insertion loss measurements on the FSS do not differentiate between power lost to reflection and that lost to actual material loss, we cannot quantify the effect that the loss has on system temperature. If reflected power is directed back towards cold sky, then the detrimental effect will be minimized.

The measurements were taken with the FSS at 3.7 inches in front of the X-band horn. The final distance will more likely be 3.0 inches, but the actual position of the X-band horn on its axis is not very critical. Displacements are important only on the order of a wavelength (1.5 in.). It was found that placing the FSS too close to the horn (2.0 in.) results in an undesirable beam-broadening.

5.1 Swept measurement

A swept-frequency measurement was taken over the band of interest and the FSS insertion loss was measured. This was similar to the swept frequency measurement reported in OVLBI memo#26[2], but in this case the FSS

[1] B. Shillue, "Feed and Optics Design for the Green Bank OVLBI Earth Station," OVLBI-ES memo#27, April 27, 1992
[2] B. Shillue, "Measurement Results of Sandwich FSS," OVLBI-ES memo#26, April 24, 1992

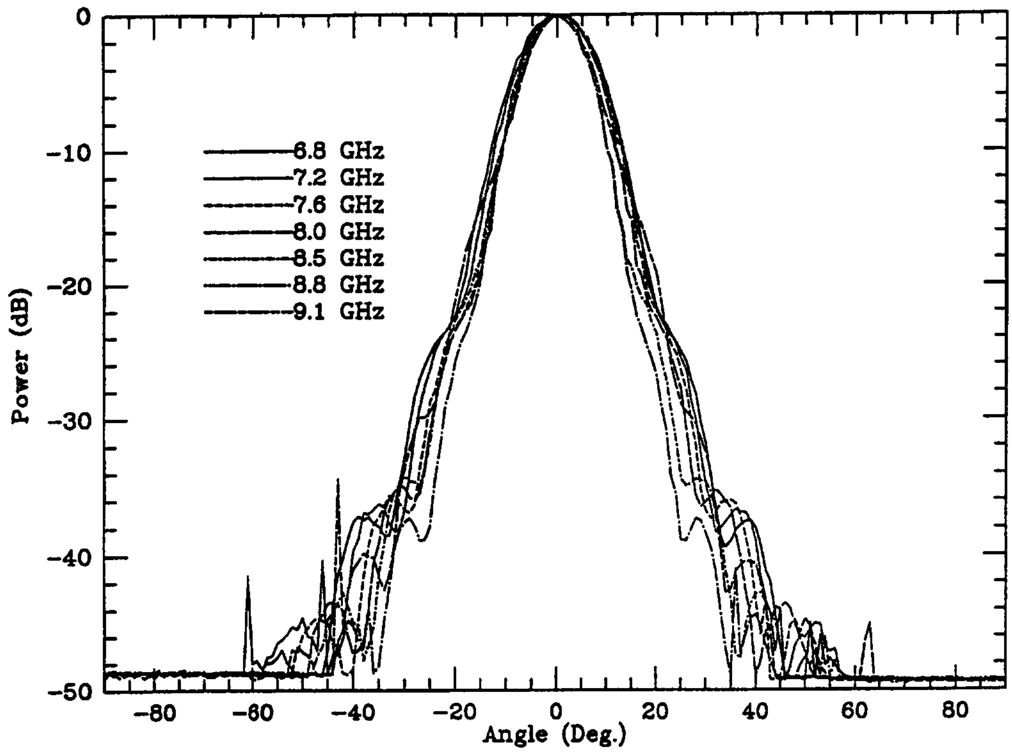

Figure 8: X-band horn H-plane radiation patterns

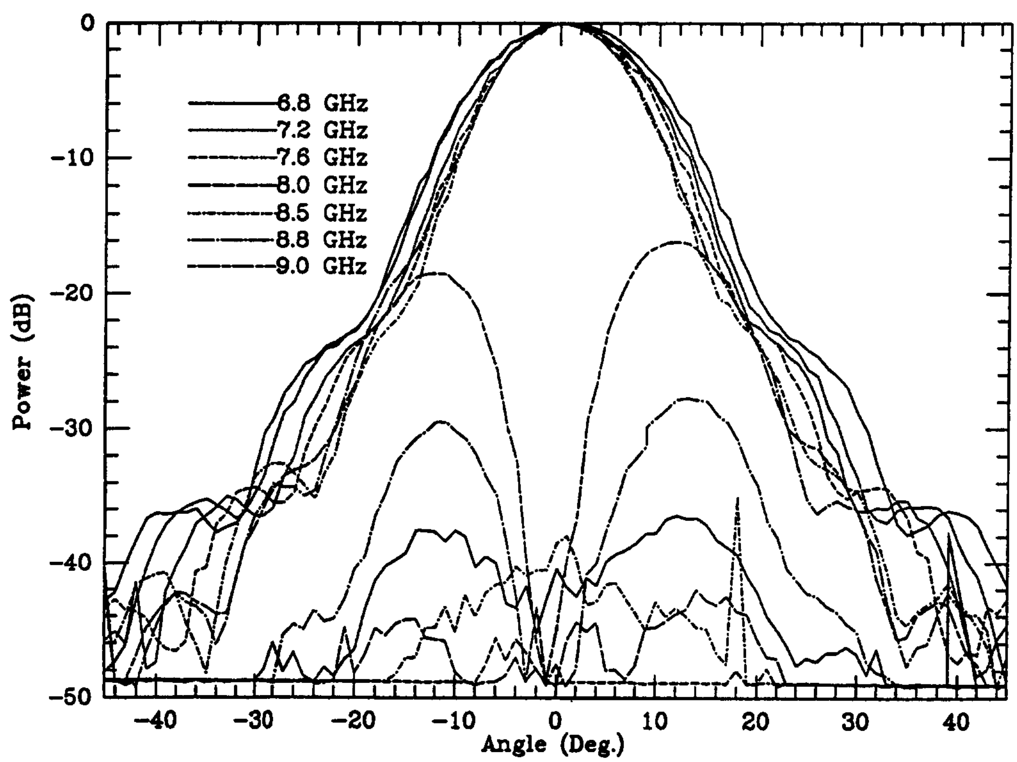

Figure 9: X-band horn 45-plane radiation patterns: copolar and crosspolar

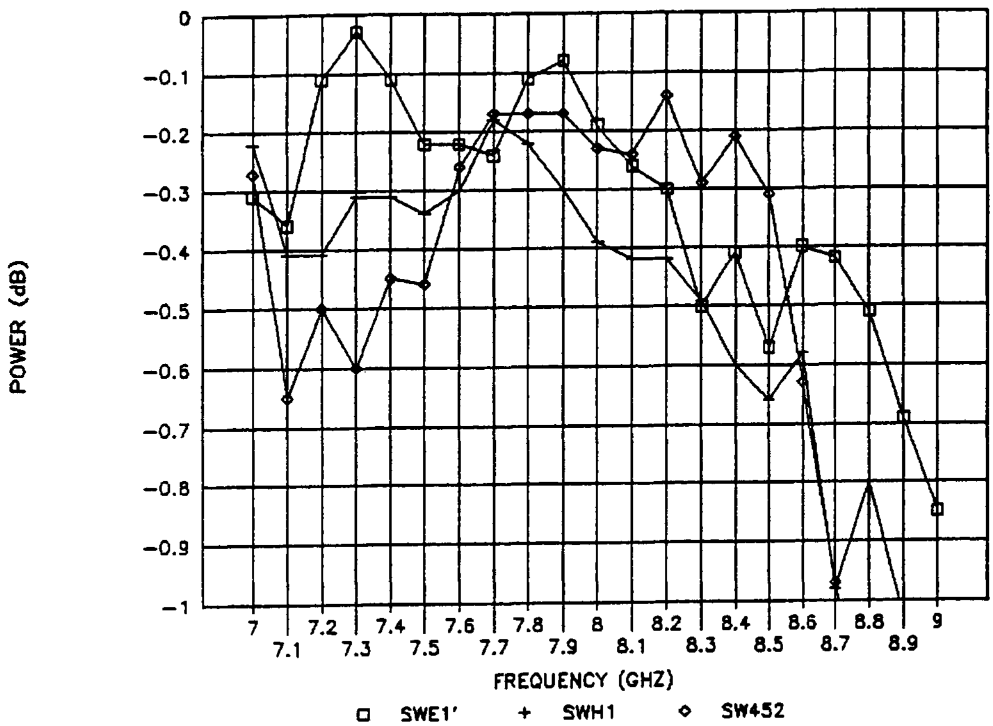

Figure 10: X-band swept frequency insertion loss of the FSS

was tilted at 25 degrees, its "design angle." The result is shown in Figure 10. Note the frequencies 7.2 GHz and 8.5 GHz especially, the insertion loss at 7.2 GHz is .35, .40, and .65 dB for the E-,H-, and 45-planes, respectively. At 8.5 GHz, the insertion loss is .57, .65, and .30 dB for the E-, H-, and 45-planes, respectively. The composite insertion loss should be very close to 0.5 dB for both frequencies. This was cited earlier as a worst case, and unfortunately we have been unable to demonstrate better performance. The only possibilities for improvement are a new FSS design, which would be only an incremental change offering small improvement, or the unexpected discovery that the frame used in the antenna range measurements contributed to the loss.

5.2 X-band horn-FSS antenna patterns

A number of X-band horn antenna patterns were taken with the FSS directly in position. The results are shown in Figure 11, Figure 12, and Figure 13 for 7.2 GHz, 8.0 GHz, and 8.5 GHz, respectively.

The effect of the FSS on the horn radiation pattern is clearly shown in these plots. At 7.2 GHz and 8.5 GHz, the sidelobes are seen to rise to about 20 dB at 40 degrees in either direction. At 8.0 GHz, where the FSS is very close to resonance, there is very little effect on the horn radiation pattern, the sidelobes are kept to less than -30 dB. In all three plots, there is some noticeable action between +40 and +60 degrees. There are seen to be peaks followed by sharp nulls, which would indicate a region of rapidly varying phase. This is at an angle at which the frame edge falls between the transmit horn and the receive horn, so it is probably scattering from the FSS edge or the frame edge. In any case, the effect is real, not an artifact of the measurement, since we will have a finite size FSS and frame. Some benefit might accrue by making the FSS larger in one dimension. Although it is difficult to tell without taking more complete radiation pattern data, one can imagine a model of the FSS effect as redistributing power from the main beam into sidelobes. If it were to do this uniformly, then a constant sidelobe level of -30 dB would be equivalent to -1.0 dB loss; -35 dB would be -.34 dB loss; and -40 dB would be -.11 dB loss. The only instruction to be taken from this for the present is that it is quite possible that the majority of FSS insertion loss is due to scattering and not material loss. In fact, there is a -17 dB sidelobe at about 120 degrees that corresponds to energy reflected (not scattered) from the FSS. This sidelobe, at the very least, should be terminated somehow on cold sky. This will be attempted when the secondary optics mounting structure is designed.

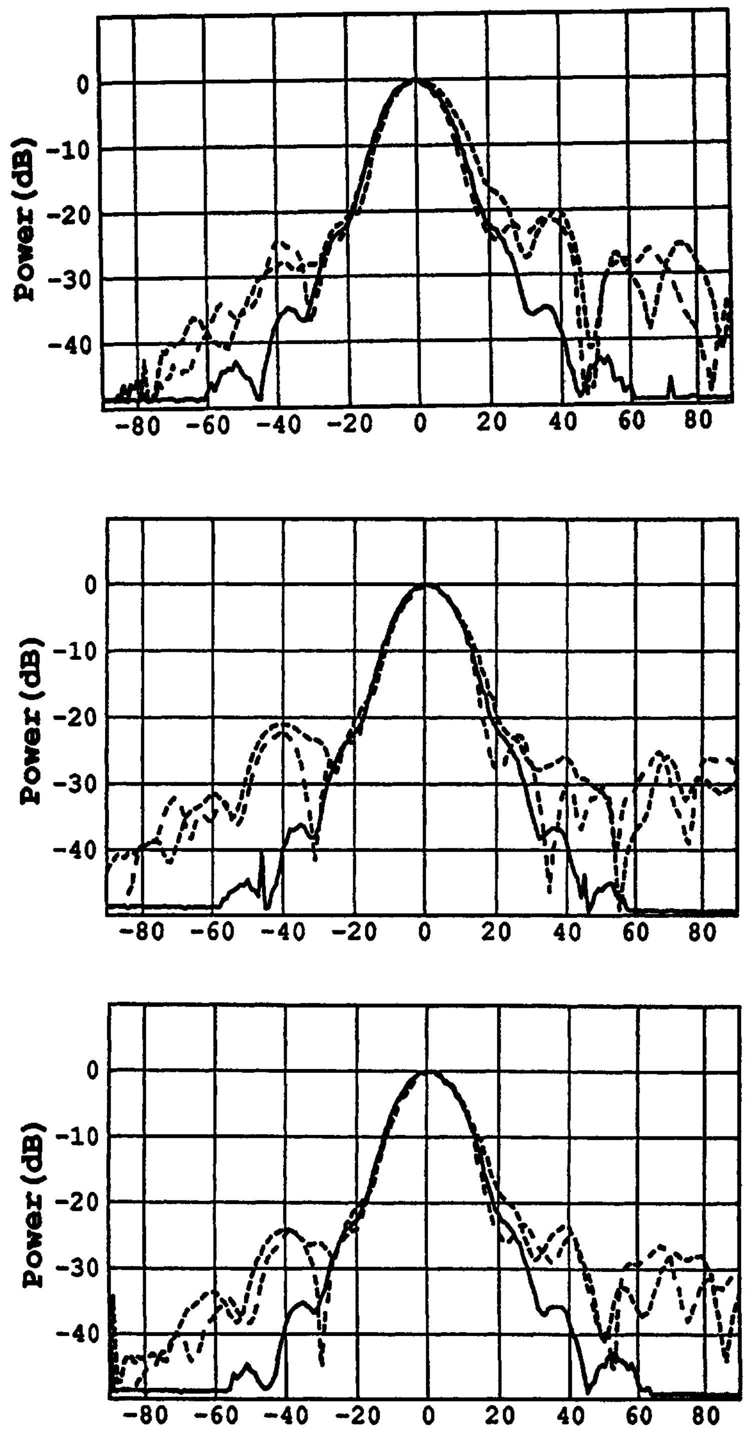

Figure 11: X-band horn with FSS: E-, H-, and 45-plane radiation patterns at 7.2 GHz

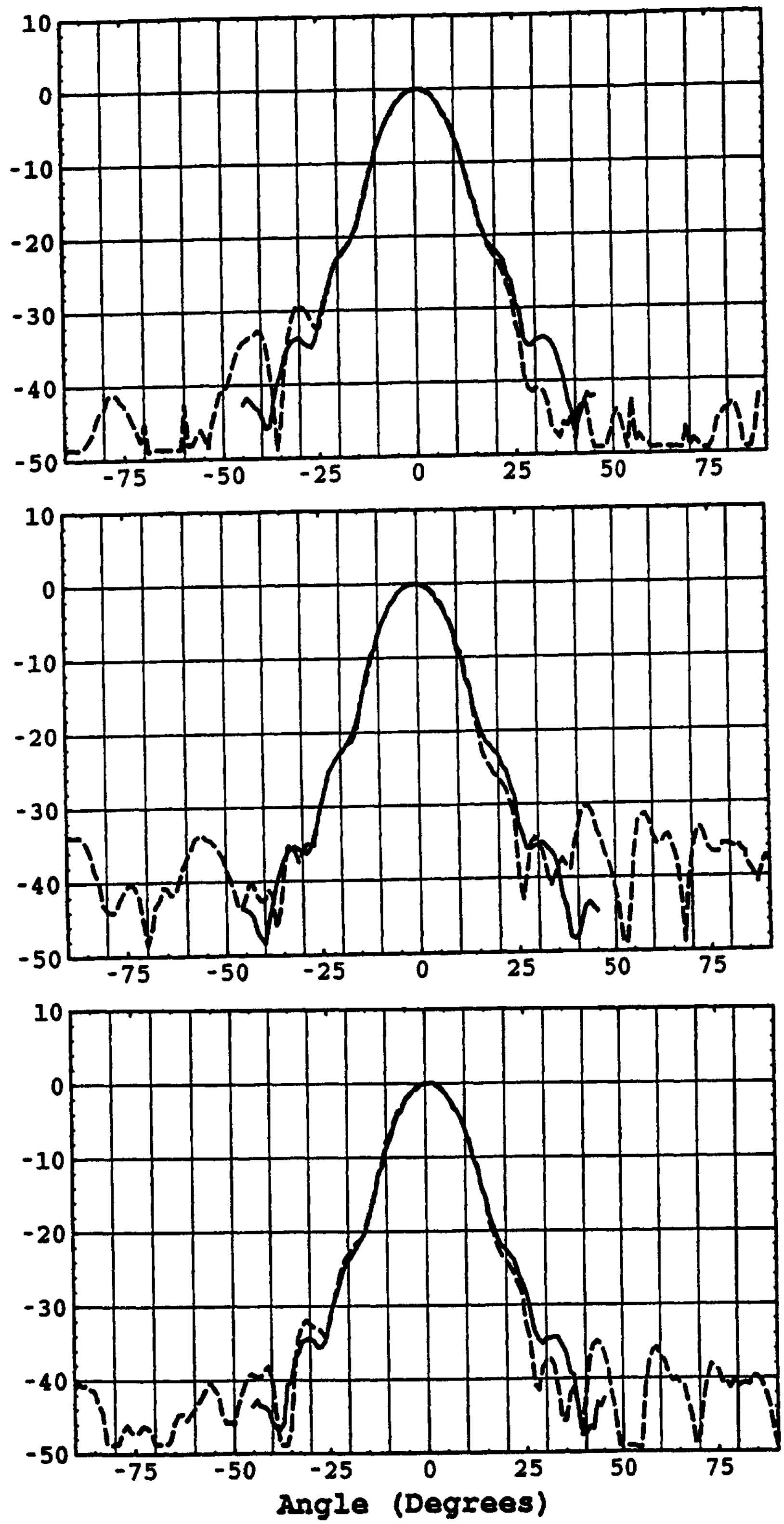

Figure 12: X-band horn with FSS: E-, H-, and 45-plane radiation patterns at 8.0 GHz

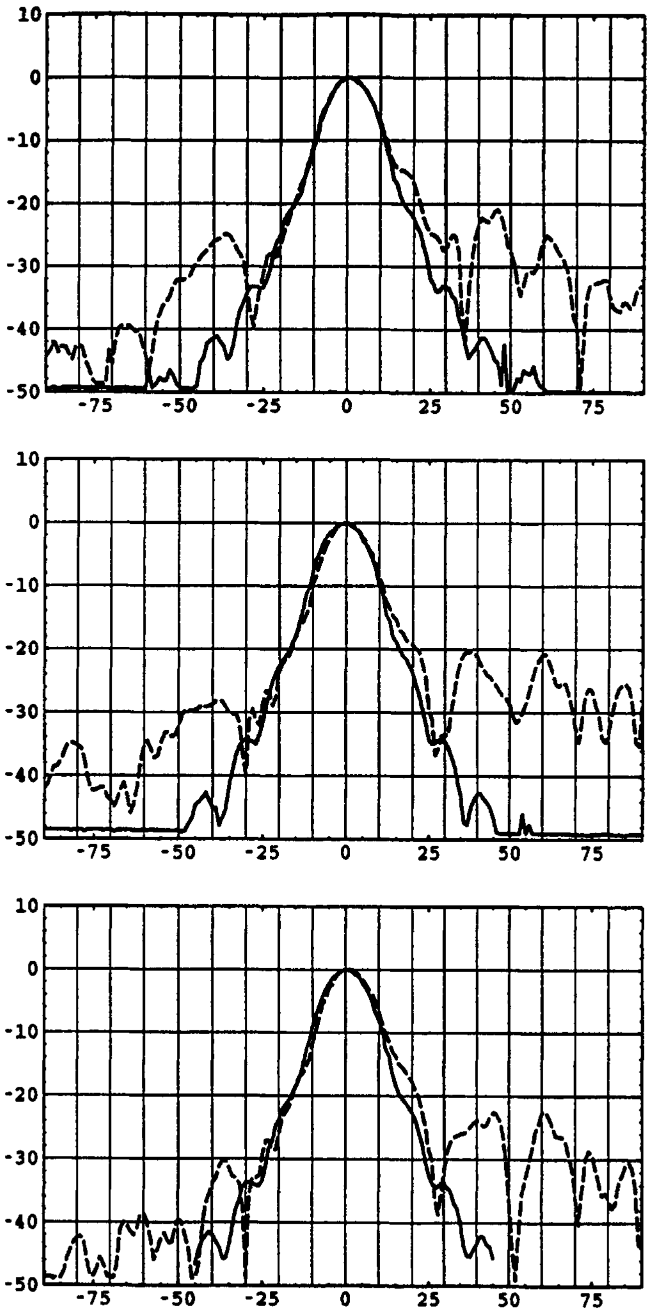

Figure 13: X-band horn with FSS: E-, H-, and 45-plane radiation patterns at 8.5 GHz