Rapid Prototype Array (RPA) Feed

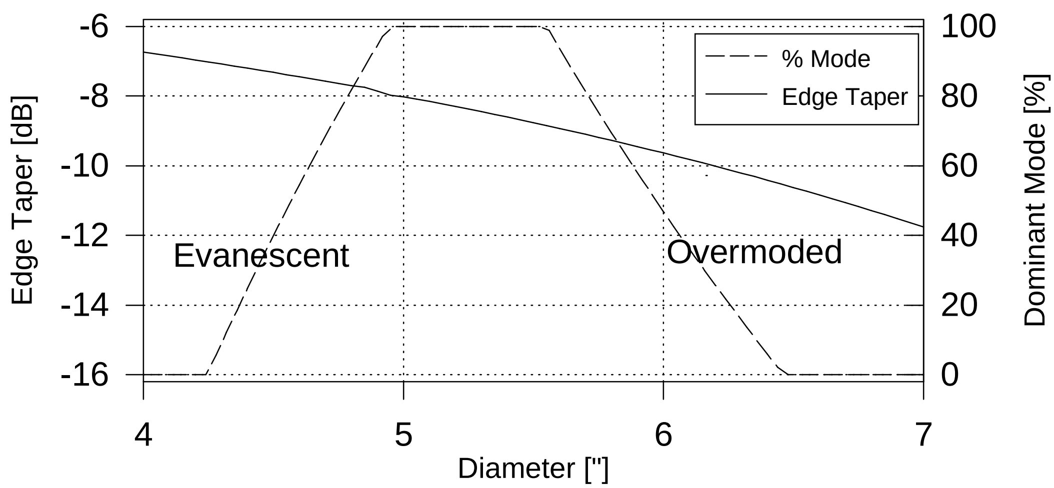
David R. DeBoer
October 29, 1999

I. Feed Assembly

The RPA feed design was influenced primarily by two sources: 1) the L-band prototype of the millimeter-wave ortho-mode transducer (BIMA Memo 74) and 2) the standard C-band TVRO feed/choke assembly. The balanced feed set-up provides wide-bandwidth performance with good cross-polarization and return loss. The choke improves the gain, cross-polarization and feed symmetry. The choke design also provides a good mount point to the antenna and many free parameters for feed focus and polarization. One downside of the feed is the inclusion of the 180° hybrid which drastically increases the system temperature.

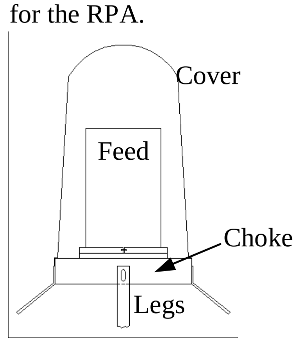
The diameter of the feed was constrained by (a) the desire to make it relatively large to improve the gain/spill-over versus (b) the desire to make it relatively small to avoid overmoding of the feed as a waveguide. Figure 1 shows the trade-offs as a function of diameter, modeling the pattern using a TE_{11} aperture field and an infinite ground plane. For the practical reasons that (a) there was an existing test fixture with a diameter of 6″ and (b) 6″ aluminum pipe was readily available, a diameter of 6″ was chosen for the feed. From the Fig.1, a 6″ feed is about 50% overmoded and yields about a -10 dB edge taper. Using the existing test fixture, an optimal back-short position of 2.2″ was determined (BIMA Memo 74).

Figure 1: RPA Feed Trade-Offs



The choke (or scalar ring) was designed based on experience with C-band TVRO feeds. Chokes are typically used to improve the match, gain, cross-polarization and pattern symmetry. A good reference for chokes is Olver *et al.* 1994, and results from that text will be summarized. In addition, the choke provides a convenient mount point for the feed, both in interfacing with the leg supports and in providing free parameters to optimize performance. Figure 2 shows a schematic of the feed assembly.

Figure 2: Feed/choke assembly for the RPA.



The choke depth is 2″ which corresponds to one-quarter wavelength at the center of the passband. It resembles a pie-plate with two concentric rings (one of which is the wall of the feed cylinder). The outer ring (the pie-plate edge) was set to have a diameter of 11″ so that the existing feed cover would fit to provide weather protection. The inner ring is the feed and the remaining ring was set to halfway between the other two. The choke mounts to the feed via a clamp which allows it to slide along the feed to change the focus of the feed assembly.

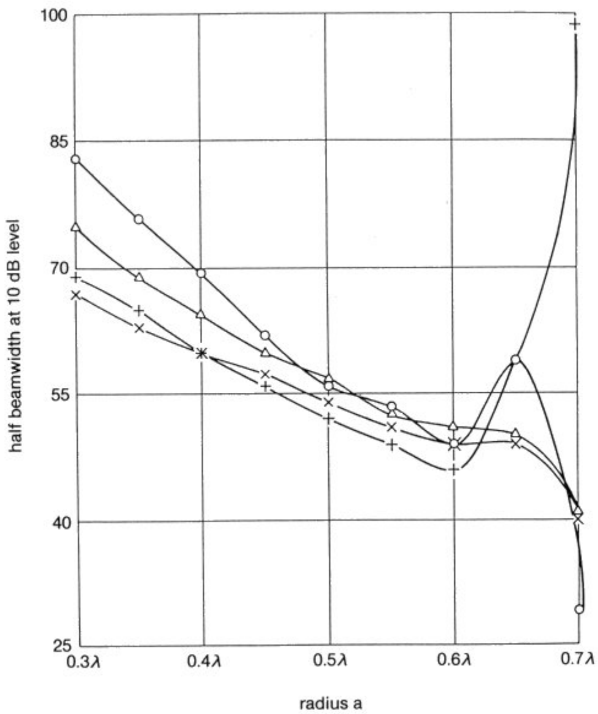
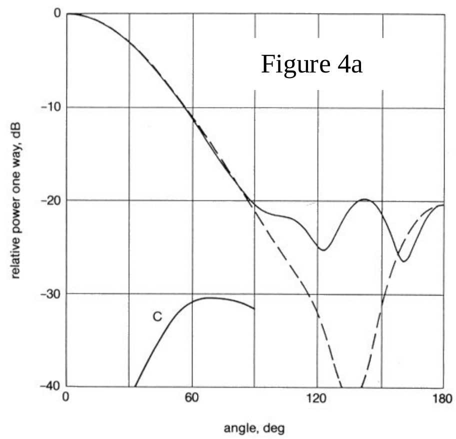


Figure 3 *10 dB beam angles for a circular waveguide*

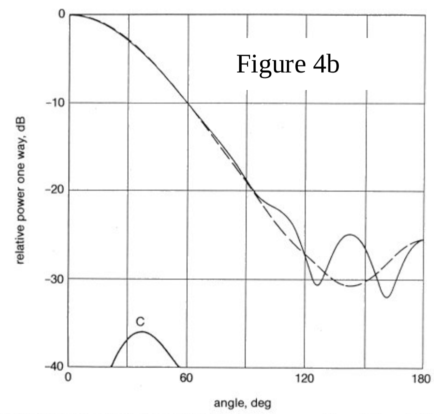
△ H-plane without a choke
○ E-plane without a choke
+ H-plane with a choke
× E-plane with a choke

Figure 3 shows the relative –10 dB point for the E and H planes with and without a choke (taken from Olver *et al*, Figure 7.3). Note that the choke in this case had only one concentric ring (in addition to the feed) whereas the RPA feed has two. For the RPA (radius = 0.38λ), without a choke we get the –10 dB point at 70°, as in Figure 1. With a choke, that point moves in to about 60°. In addition, the E and H planes are much more symmetric. Figure 4 (taken from Olver *et al*, Figures 7.4, 7.5) shows a beam pattern with and without a choke. Figure 5 (taken from Olver *et al*, Figure 7.6) shows the peak cross-polarization with and without a choke. For the RPA, the improvement corresponds to about 10 dB. Table I (from Olver *et al*, Table 7.1) details some of the other relevant parameters for different radii with and without the choke.

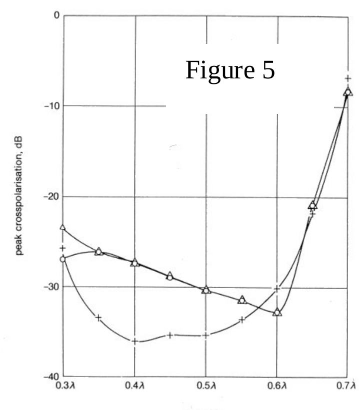
The location of the phase center is obviously another critical issue. The RPA feed is designed assuming that the central feed ring is flush with the concentric choke rings and that the phase center is about ½″ outside the aperture of the feed. If mount holes are drilled halfway up the choke (with the redesigned legs that were specified to Orbitron) that should place that point 51″ from the vertex of the dish. (Note the dishes are f/D=0.36 and D = 3.6m). The holes on the legs are slotted to allow some movement of the feed in order to maximize gain (*i.e.* focus). In addition, moving the feed within the choke also moves the phase center and is another means of focusing. Figure 6 (taken from Olver *et al*, Figure 7.22) shows the variation for different definitions of phase center while moving the feed relative to the choke. Note that Figure 6 assumes the feed in Figure 7 (taken from Olver *et al*, Figure 7.21). For comparison, the RPA has a feed diameter of 0.76λ, total extent of 1.4λ and one fewer choke ring.



Copolar and crosspolar patterns of a waveguide without a choke
$a = 0.5\ \lambda$
——— E-plane
– – – – H-plane
—C— crosspolar



Copolar and crosspolar patterns of a waveguide with a choke
$a = 0.4\ \lambda$; ——— E-plane; – – – – H-plane; —C— crosspolar



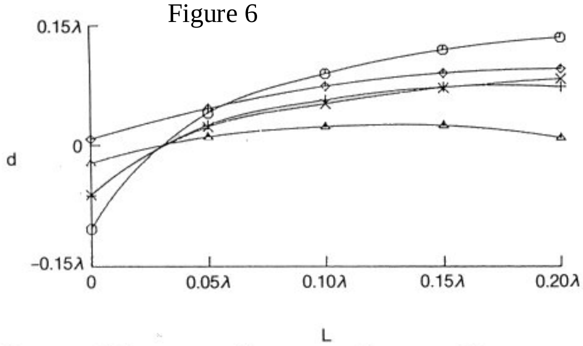
Peak crosspolarisation of a circular waveguide
○ $0 \leqslant \theta \leqslant 70°$ without a choke; △ $0 \leqslant \theta \leqslant 90°$ without a choke; + $0 \leqslant \theta \leqslant 90°$ with a choke

Table I

	Gain Factor (%)		Spillover (%)		f/D	
r/λ	without choke	with choke	without choke	with choke	without choke	with choke
0.30	68.72	72.78	81.95	85.10	0.33	0.40
0.35	70.07	74.12	82.42	86.42	0.37	0.42
0.40	71.78	75.04	84.47	86.97	0.40	0.45
0.45	73.54	75.84	84.80	88.47	0.45	0.47
0.50	75.15	76.65	86.07	88.17	0.49	0.51
0.55	76.58	77.35	88.48	89.15	0.51	0.54

The feed was simulated prior to building to verify performance. The simulated and measured patterns of the first feed built are shown in Figure 8.

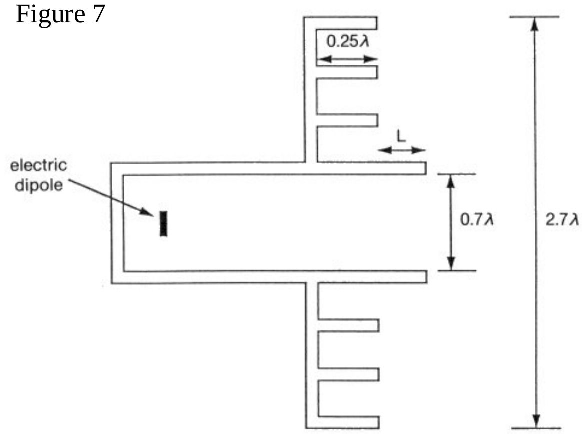
Figure 6



Distance of phase centres from waveguide open end for geometry of Figure 7

$a = 0.35\ \lambda$ + d_{av}
○ d_E × d_s
△ d_H ◇ d_c

Figure 7



It is suggested to mount one feed as suggested above, point the dish at an L-band geostationary satellite, and move both the choke relative to the dish and the feed relative to the choke, until maximum gain is achieved. Note that most of the L-band downlinks are right-hand circularly polarized, so orientation of the feed will not be an issue. Additionally, it would be a good idea to make sure the maximum gain point is similar for both linear polarizations.

References

Bock, Douglas "Measurements of a scale-model ortho-mode transducer", BIMA Memo 74, 1999.

Olver, A.D., P. J. B. Clarricoats, A. A. Kishk and L. Shafai, "Microwave Horns and Feeds", IEEE Press, 1994.

Figure 8: RPA feed response (1.3-1.7 GHz average)