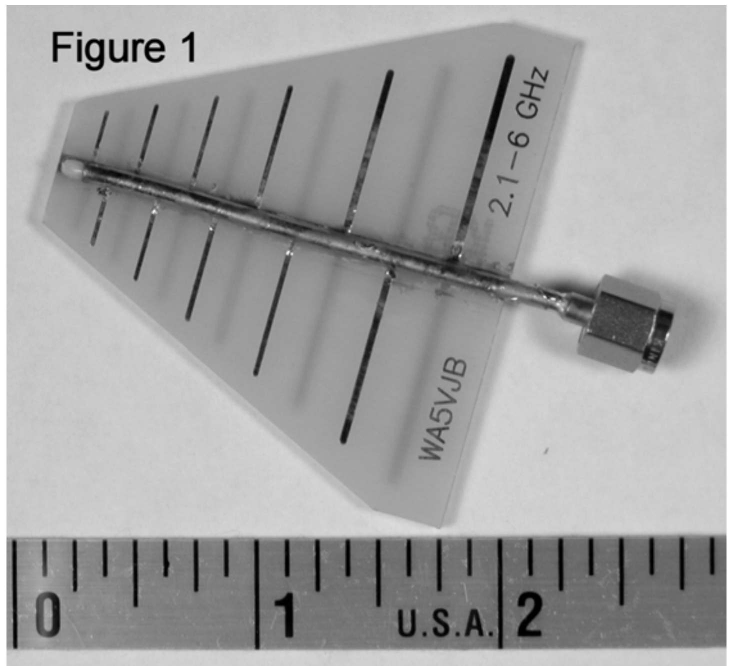
The WA5VJB LPA Antenna as a Multi-band Dish Feed

Paul Wade W1GHZ © 2004

A printed circuit antenna is more difficult to design and model than a wire or metal antenna – the wire is simpler since air behaves just like free space. The dielectric material distorts the fields in the antenna and adds loss, and the very thin metal is also lossy. Kent, WA5VJB, has done a lot of experimenting with printed antennas and has developed a good handle on designing them, so that he can offer several versions at very reasonable prices.



The log-periodic arrays (LPA) are attractive because they cover a wide range of frequencies. The WA5VJB 2 to 6 GHz LPA[1] covers three amateur bands with modest gain in a very compact size — Figure 1 is a photo of one. This is convenient for rover operation, but more gain would be useful for longer contacts. How would it work as a feed for a dish?

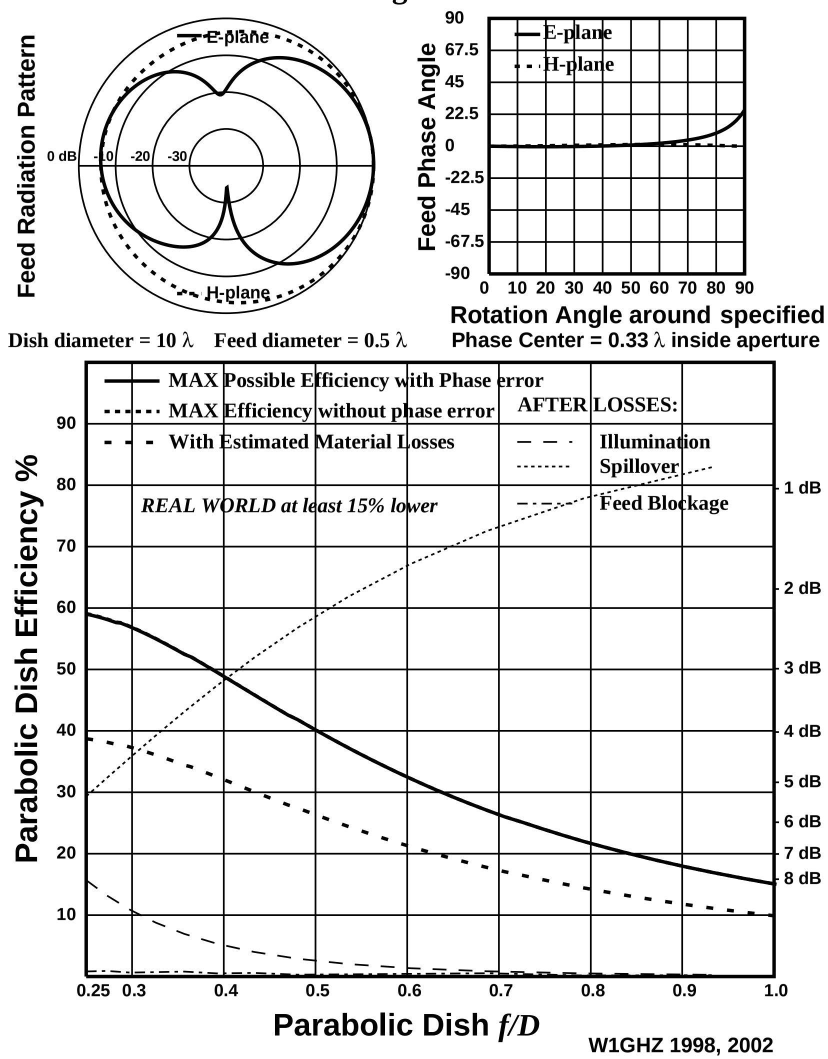
The appearance of a log-periodic antenna is somewhat like a Yagi-Uda beam with exagerated taper of the element lengths. The gain is similar to a very short beam with 2 or 3 elements. We might expect a radiation pattern similar to a 2-element beam, or dipole and reflector, often used as a feed for deep dishes. The pattern of the dipole-reflector is very broad in the H-plane, perpendicular to the dipole, and narrower in the E-plane, the plane of the elements.

To get a more detailed view, I simulated the radiation patterns for the amateur bands using Ansoft[2] HFSS software - Kent was kind enough to provide artwork files with accurate dimensions. The patterns and calculated dish efficiencies are shown in Figure 2 for 2304 MHz, Figure 3 for 3456 MHz, and Figure 4 for 5760 MHz. At all three frequencies, the pattern much broader in the H-plane, as we expected. The result of the broad pattern is that the LPA as a dish feed is best suited for deep dishes, with an *f*/D in the 0.25 to 0.35 range.

The combined losses of the printed-circuit board dielectric, using the standard loss tangent of 0.02, and the thin metal reduce the calculated efficiencies significantly, to about 50% at 3456 and 5760 MHz, and about 40% at 2304. The calculated loss decreases with increasing frequency, just the opposite of what we might expect. The reason for this is that the LPA coaxial feedpoint is closest to the highest frequency elements, so there is a very short path before energy is radiated, while at the lowest frequencies, the energy must traverse the whole length of the printed-circuit board before reaching a radiating element.

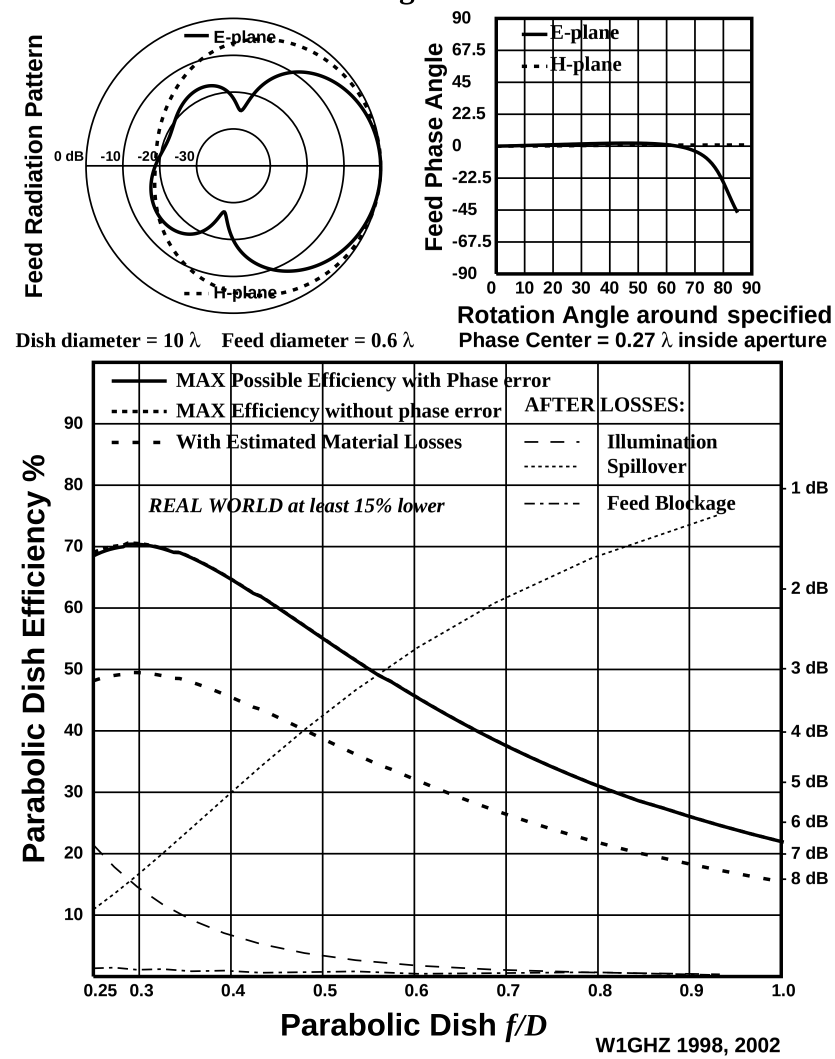
WA5VJB 2-6 GHz LPA at 2304 MHz, losses estimated

Figure 2



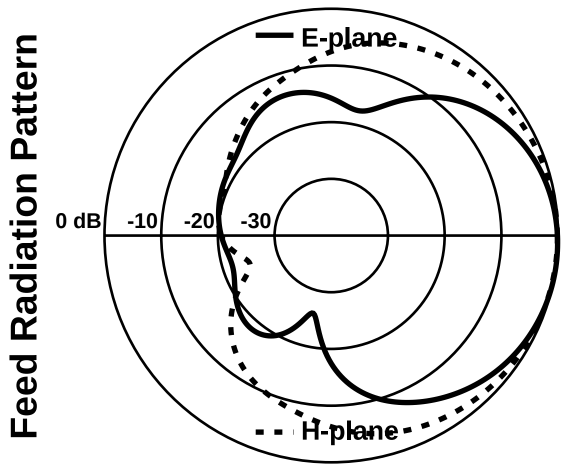
WA5VJB 2-6 GHz LPA at 3456 MHz, losses estimated

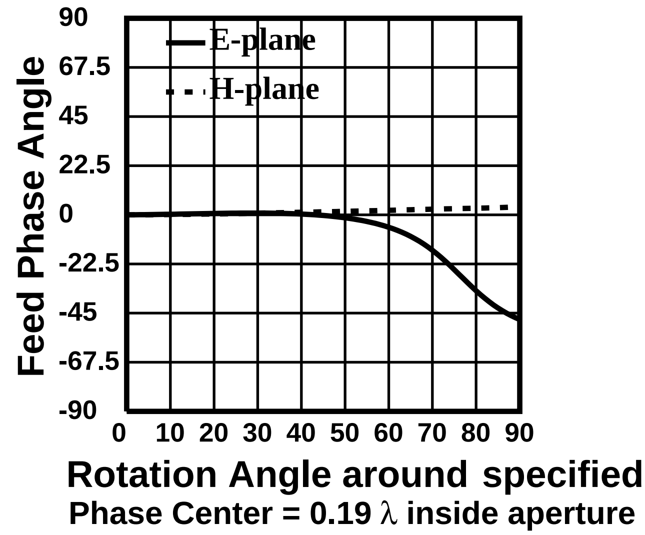
Figure 3



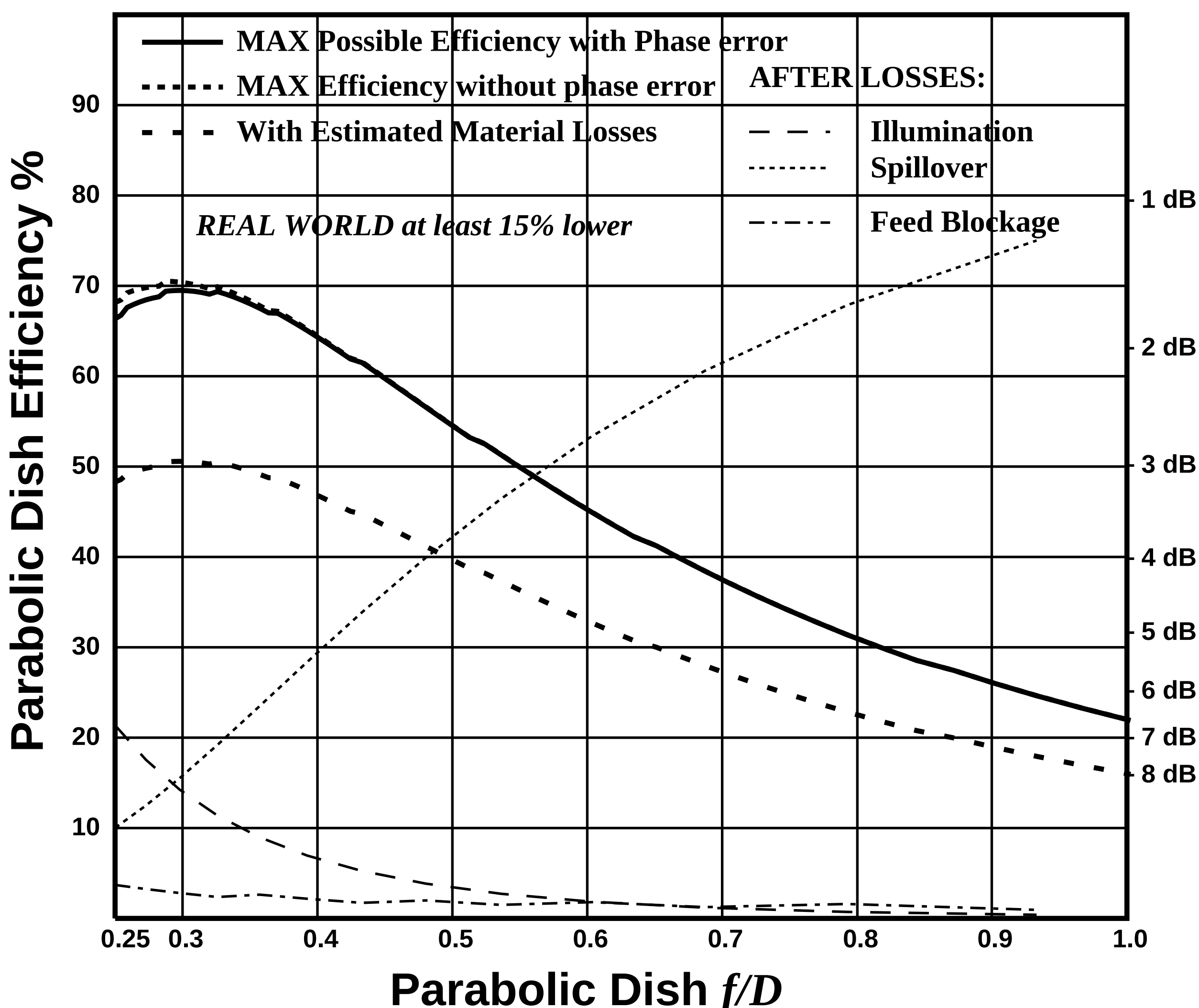
WA5VJB 2-6 GHz LPA at 5760 MHz, losses estimated

Figure 4





Dish diameter = 10 λ   Feed diameter = 0.9 λ



W1GHZ 1998, 2002

The phase center at each frequency is near the corresponding radiating elements: 9.7 mm behind the feedpoint at 5760 MHz, 22 mm behind at 3456 MHz, and 43 mm behind at 2304 MHz. We must choose a compromise location for the LPA feed; since the phase center error is in wavelengths, and should be within about a ¼ wavelength for very deep dishes, the highest frequency is most critical. Therefore, we would choose the best location for 5760 MHz and tolerate some degradation on the lower bands. With the LPA positioned for the best P.C. (phase center) at 5760 MHz, with performance shown in Figure 4, the performance at 3456 MHz in Figure 5 shows a slight degradation to about 44% peak efficiency. At 2304 MHz, the degradation in Figure 6 is greater, down to about 28% efficiency, some 4 dB worse than a good single-band feed.

For a given parabolic reflector size, there is an 8 dB difference in gain due to the relative wavelength — a 20 wavelength diameter dish at 5760 MHz is only 8 wavelengths at 2304 MHz. The additional degradation due to phase center error increases the difference. However, even if the phase center were optimized for 2304 MHz, the gain would only be increased by 1.5 dB, while the gain at 5760 would be drastically decreased.

How does the LPA compare with the classic WA3RMX triband[3] dipole feed? Calculated performance of the WA3RMX feed is shown in the *W1GHZ Microwave Antenna Book – Online*[4]. Both feeds provide relatively low dish efficiency because of material losses; however, the WA3RMX has loss increasing with frequency, so performance is worst at 5760 MHz, around 30% calculated efficiency, and better at 2304 MHz, around 50% efficiency. The WA3RMX feed has been observed to burn up at modest power levels on 5760 MHz, since the power is concentrated in a small dipole. No similar failures have been reported for the LPA. Since both feeds have radiation patterns suitable for illuminating very deep dishes, direct comparison on the same reflector should be possible.

A note about estimated losses: the efficiencies for the WA3RMX feed were calculated based on the author's estimates in QST. Calculated losses were roughly ½ dB higher, so the calculated losses used for the LPA efficiencies might be slightly pessimistic as well. For most amateur work, ½ dB is well within measurement error.

All multi-band feed are a compromise, but sometimes the only way to have an antenna on additional bands. Certainly it is preferable to be a few dB down than not on at all. For a rover, a multiband feed that is small, light, and cheap enough to carry a spare sounds like a winner.

References

1. Kent Britain, WA5VJB, "Designing PCB Log Periodic Antennas," Proceedings of Microwave Update 2000, ARRL, 2000, pp. 203-208.

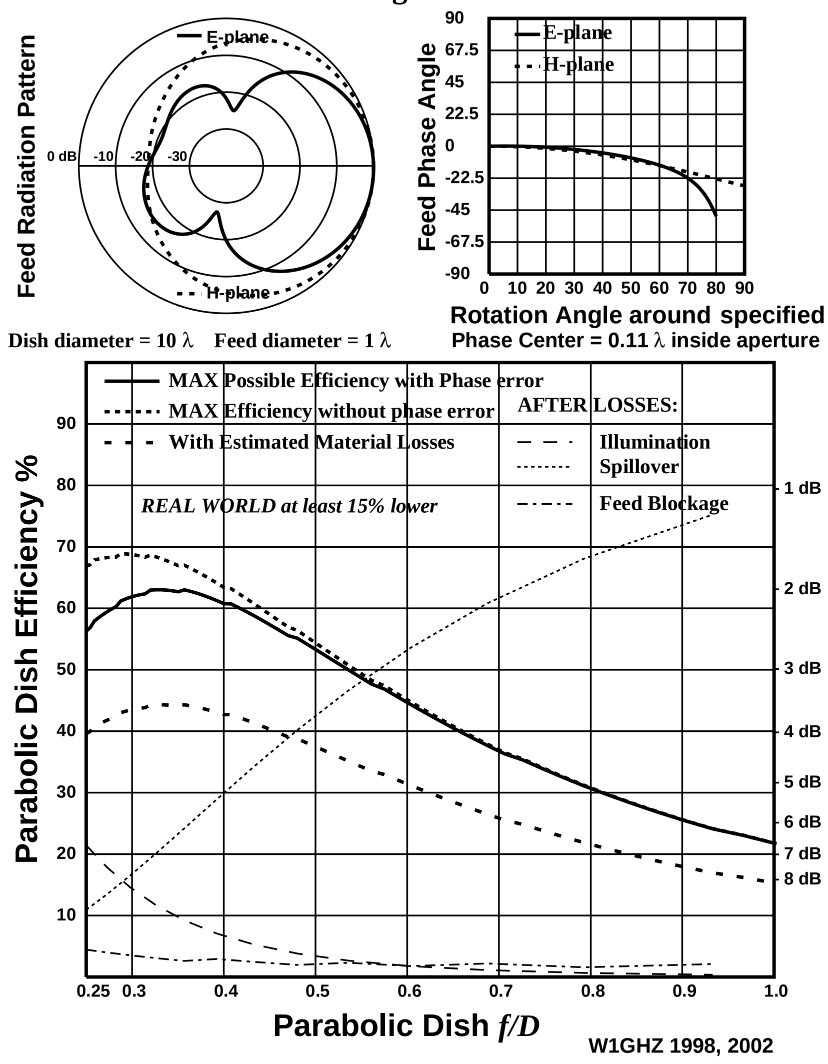
2. www.ansoft.com

3. T. Hill, "A Triband Microwave Dish Feed," QST, August 1990, pp.23-27.

4. www.w1ghz.org

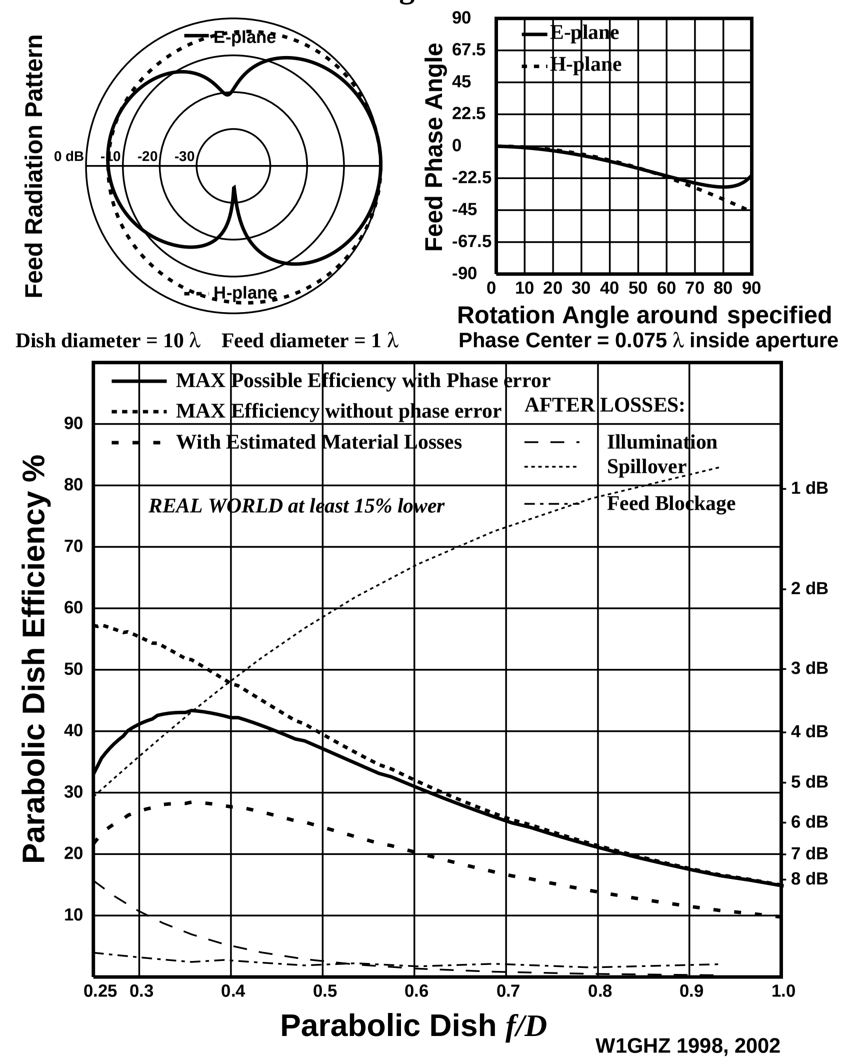
WA5VJB 2-6 GHz LPA at 3456 MHz, at 5760 P.C., losses est.

Figure



WA5VJB 2-6 GHz LPA at 2304 MHz, at 5760 P.C., losses est.

Figure 6



The WA5VJB LPA Antenna as a Multi-band Dish Feed
Part 2

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After I did the previous analysis of the LPA, Kent, WA5VJB informed me that his measured values for the dielectric were lower than I had used in the simulations. As stated in the first paragraph, the dielectric complicates design and analysis of printed antennas.

The problem is that the dielectric is not a single, well-defined, material. Printed-circuit board consists of layers of woven fiberglass cloth laminated in an epoxy resin. The two materials have different dielectric constants, and the proportions are adjusted by the manufacturer for maximum profit. The dielectric constant is usually listed as 4.1 to 4.5, with a loss tangent of 0.02. I have found that designing with a dielectric constant of 4.15 gives reasonable agreement with measured results at UHF and lower frequencies. However, at microwave frequencies, the apparent dielectric constant decreases slightly with increasing frequency, and may vary slightly in different directions.

WA5VJB suggested that boards from his supplier have an effective dielectric constant around 3.95, and a loss tangent lower than 0.02. To see what effect these values would have, I recalculated the radiation patterns for the 2-6 GHz LPA antenna with Er = 3.95 and $\tan\delta = 0.015$.

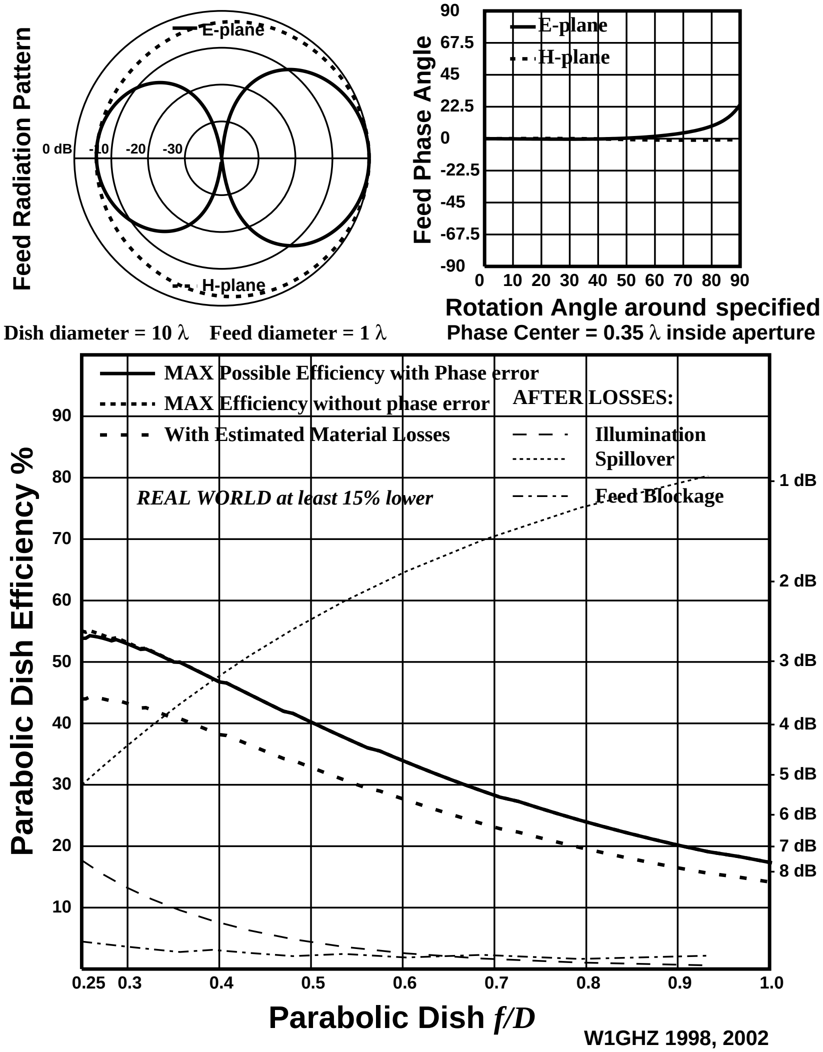
The results are shown in Figure 7 for 2304 MHz, Figure 8 for 3456 MHz, and Figure 9 for 5760 MHz. The patterns and calculated efficiencies are not significantly different than those with the higher dielectric constant — the antenna performance is similar, but the VSWR is probably more sensitive. With the smaller loss tangent, calculated losses are a bit lower, about 0.85 dB at 2304 MHz and 1.05 dB at 5760 MHz. Since the loss tangent is only a guess, the actual loss could be even lower, so the dish efficiency is probably somewhere between the curve with loss and the curve without.

For use as a triband feed, probably placement would be with the Phase Center (P.C.) for 5760 MHz placed at the focus of the dish. The Phase Center for the other bands would not be optimum, so there would be a bit of phase error. The calculated efficiency for this condition is shown in Figure 10 for 2304 MHz and Figure 11 for 3456 MHz.

In summary, the 2-6 GHz LPA as a dish feed offers reasonable performance on three bands. Best results will be found with a dish *f*/D in the 0.35 to 0.45 range. Performance is not as good as single band feeds, but the multiband capability may be an acceptable compromise.

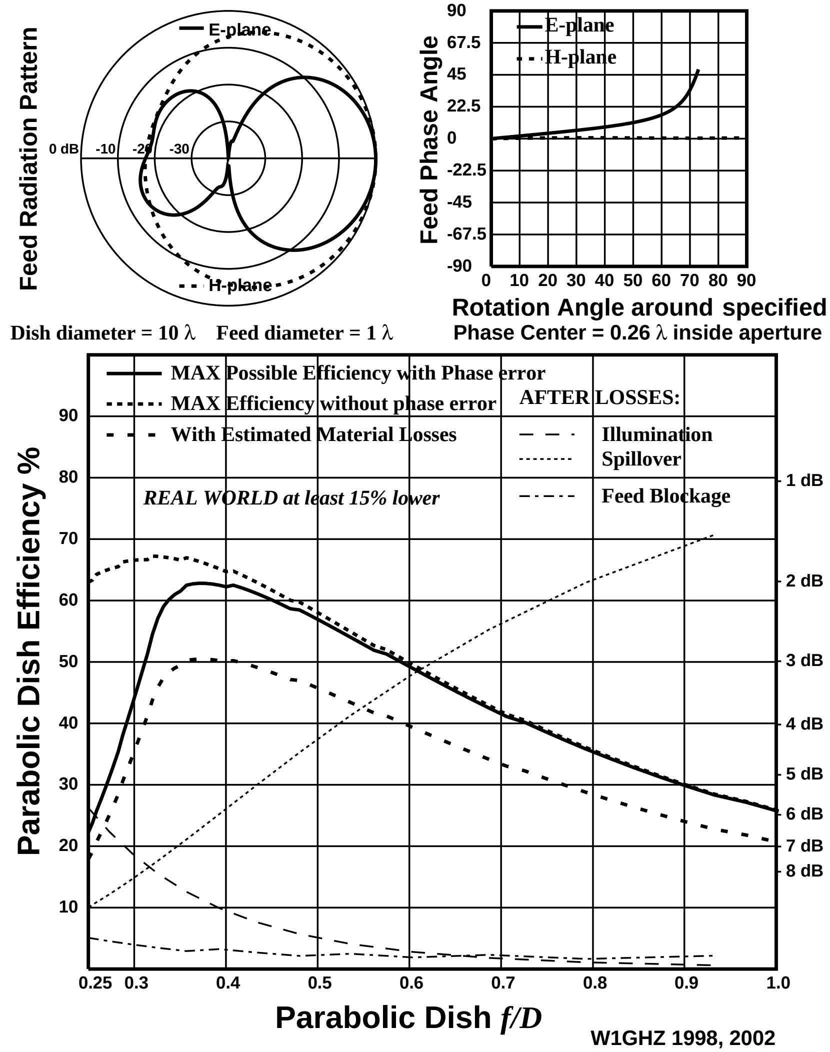
WA5VJB 2-6 GHz LPA as 2304 MHz feed, Er=3.95

Figure 7, with estimated loss



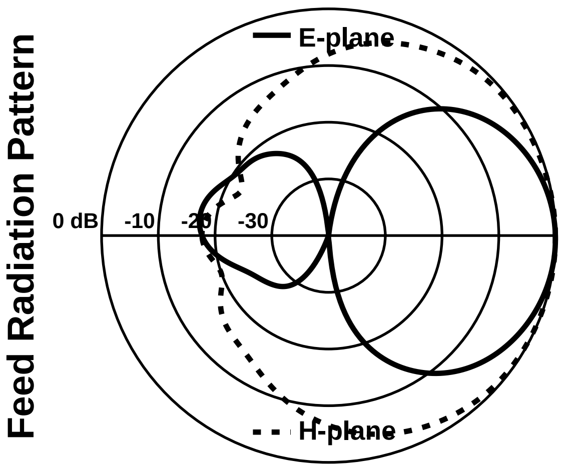
WA5VJB 2-6 GHz LPA as 3456 MHz feed, Er=3.95

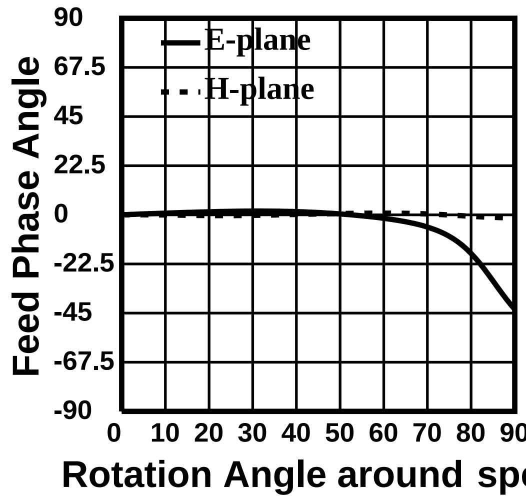
Figure 8, with estimated loss



WA5VJB 2-6 GHz LPA as 5760 MHz feed, Er=3.95

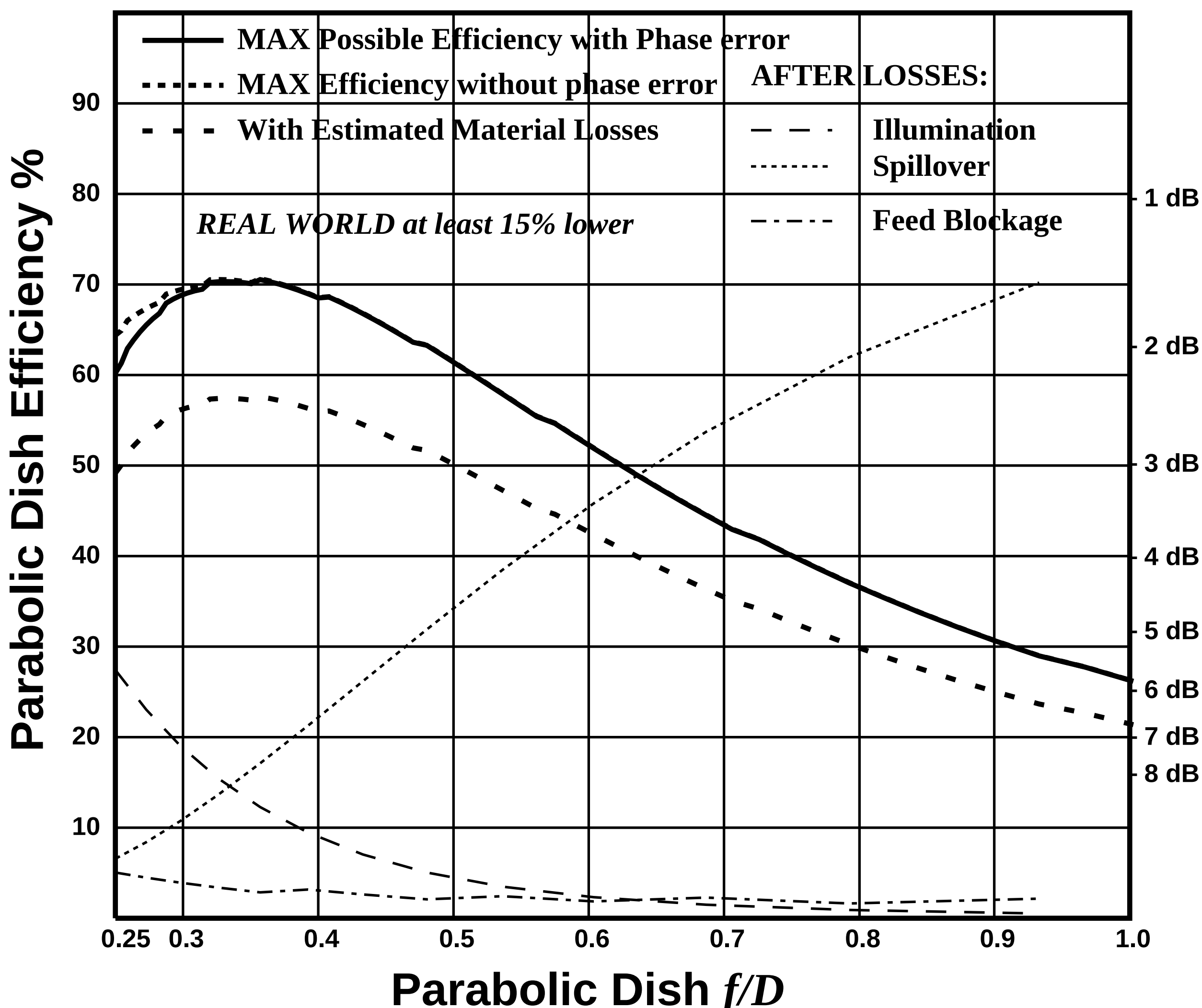
Figure 9, with estimated losses





Dish diameter = 10 λ   Feed diameter = 1 λ

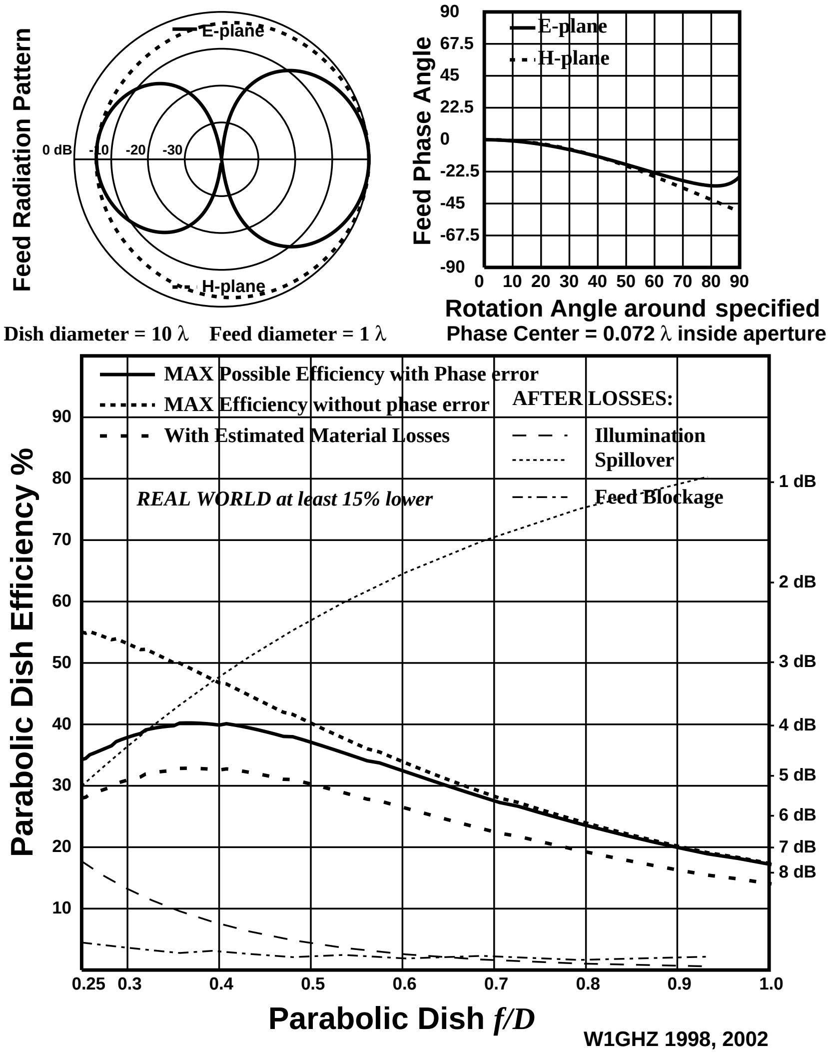
Phase Center = 0.18 λ inside aperture



W1GHZ 1998, 2002

WA5VJB 2-6 GHz LPA at 2304 MHz, at 5760 P.C.

Figure 10, Er=3.95 with estimated loss



WA5VJB 2-6 GHz LPA at 3456 MHz, at 5760 P.C.

Figure 11, Er=3.95 with estimated loss