Online (ex-N1BWT) W1GHZ Microwave Antenna Book

Chapter 6
Feeds for Parabolic Dish Antennas

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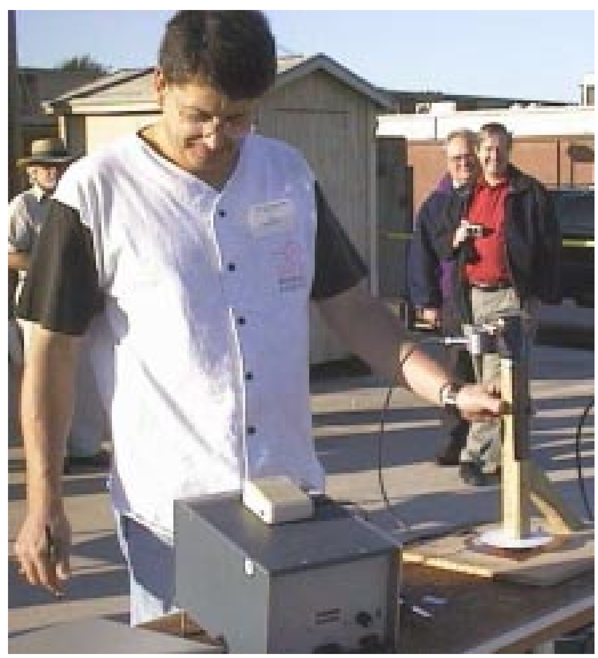
Section 6.9 Multi-band feeds

6.9.0 Co-Author

Joel Harrison, W5ZN, was invited to be co-author of this section since he has probably done more work with multi-band feed antennas than any other ham. Not only has he designed multi-band feeds and written about them[1,2], but more important, he has made extensive gain and pattern measurements[3] to validate the results using the techniques in Chapter 9. That's Joel in the photo, making antenna pattern measurements at Microwave Update '99 in Dallas.



6.9.1 Introduction

It would be a great convenience not to have a separate antenna for each amateur band. Yagi-Uda antennas are flat and stack reasonably well, but dishes require volume. Since a parabolic reflector works over a wide range of frequencies, a feed that also operates on multiple bands would reduce the number of antennas required for multi-band microwave operation.

Unfortunately, all multi-band antennas are a compromise, and what is compromised is performance. Even at HF, multi-band antennas have significantly lower performance compared to good single-band antennas. As we shall see, the performance of a dish with a multi-band feed is never quite as good as we can achieve with a good single-band feed, but some two-band feeds can come close enough to be acceptable.

The job of a feed antenna is to provide a radiation pattern that illuminates the parabolic reflector as uniformly as possible. This radiation pattern is controlled by the electrical dimensions of the feed, in wavelengths. Since any physical dimension must obviously be differing numbers of wavelengths at different frequencies, it would be impossible to have optimum dimensions at more than one frequency. We must choose a compromise, from one of several possible strategies:

- Choose dimensions that are equally far from optimum for two frequencies.
- Add additional physical structures for additional frequencies, hoping that interaction is small.
- Design a feed that operates in different waveguide modes at different frequencies.
- Optimize for a primary frequency and accept degraded performance at other frequencies.

We can find examples of all these compromise strategies.

Note that these are not broadband feeds, except for a few examples — a truly broadband feed is a much more difficult problem. It is hard enough to find a compromise that can achieve good operation over two bands, well separated but each relatively narrow. Broadband operation requires operation at all points in between as well, so the compromise much more difficult.

6.9.2 Multi-band dipole feeds

Multi-band dipole feeds use the second compromise strategy above, adding a dipole and reflector for each frequency. The classic multi-band feed is the WA3RMX triband feed[4], for 2304, 3456, and 5760 MHz, with a dipole and reflector for each band. The feed, shown in Figure 6.9-1, is printed on common epoxy-glass printed-circuit board, making it easily reproducible. A broadband tapered balun is also printed on the board, so simply attaching a length of semi-rigid coax cable makes it operational.

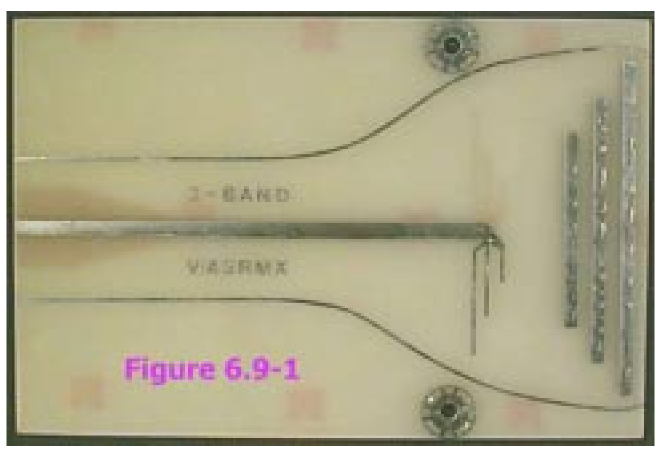


Figure 6.9-1

The triband feed uses a split dipole, with one half printed on each side of the PCB. Each side has a half-dipole for each band, joined to the feedline at a common point like a fork with tines of different lengths. This means that energy for a given band reaches all three dipoles; the resulting radiation from the other dipoles is not significant on the lower two bands, but is detrimental to the radiation pattern at 5760 MHz.

One serious shortcoming of the printed-circuit approach is that the epoxy-glass board is rather lossy at microwave frequencies — and dielectric losses increase with frequency. The result is excess loss in this feed, just like additional feedline attenuation. The original ***QST*** article estimates the loss at 0.75 dB at 2304 MHz, 1.25 dB at 3456 MHz, and 1.5 dB at 5760 MHz. Since the loss is concentrated in the feed, maximum power is limited. The article includes a photo of a feed destroyed by 200 watts at 2304 MHz, and others have reported serious damage by as little as 10 watts at 5760 MHz. Power that is cooking the feed is not being radiated, just wasted.

The additional complication of the printed-circuit board dielectric makes antenna calculations more difficult; I was able to calculate radiation patterns using a 3D simulation program, Zeland[5] **IE3D**. One thing that is apparent in the calculated patterns is a gain dip in the plane of the printed–circuit board, as energy that is propagating through the length of board is attenuated. This dip is apparent in the E-plane patterns in Figures 6.9-2, 3, & 4 (the dip is arbitrarily shown as 6 dB on all bands). I wasn't sure that the **PHASEPAT** program would accurately account for this dip when calculating efficiency, so I ran the efficiency calculations with and without the dip. The difference in efficiency was negligible, probably since the narrow dip angle is hidden by feed blockage. What is not negligible is the excess loss of the PCB, which is not accounted for by **PHASEPAT**, so we must reduce the calculated efficiency accordingly.

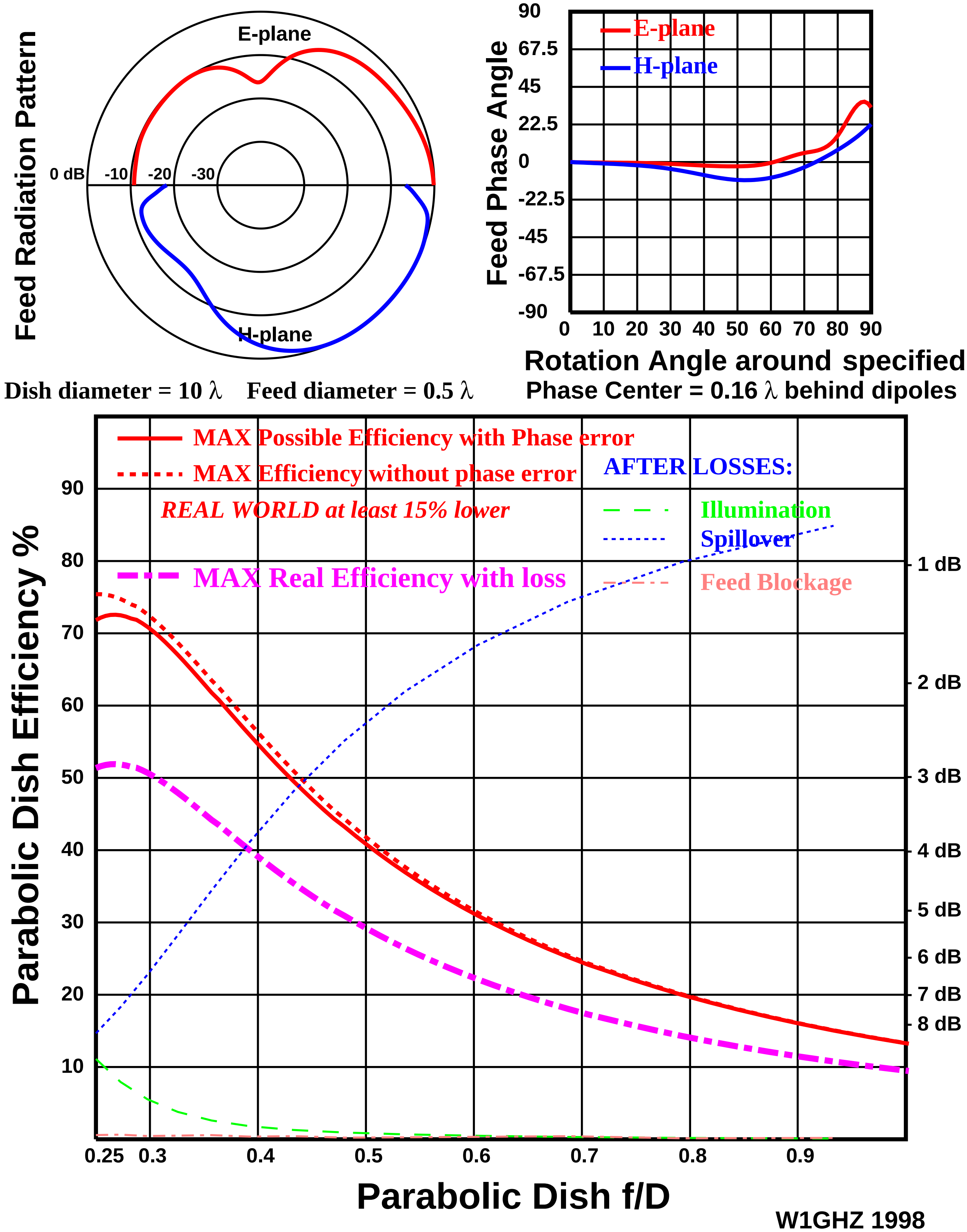
The calculated radiation patterns and efficiency at 2304 MHz are shown in Figure 6.9-2. At this frequency, the feed is comparable to the simple dipole-reflector feed in Figure 6.2-1, with slightly lower efficiency peaking at an ***f*/D** of about 0.28. For a normal feed, we would expect the real efficiency to be about 15% lower, but for the triband feed we must further reduce the estimate to account for PCB losses. Still, we might expect a very deep dish with this feed to approach the efficiency of a single-band feed, perhaps 50%. (Note that a shallower dish of the same size with a good feed can be significantly better).

At 3456 MHz, the calculated radiation patterns and efficiency are shown in Figure 6.9-3. The feed at this frequency is also comparable to Figure 6.2-1, so can expect that it will work well on this band. The excess PCB loss is slightly higher, so we might expect a deep dish with this feed to have perhaps 40% efficiency, down a bit from 2304 MHz. The reduced efficiency might be a good compromise for having multi-band operation, if it works as well on the other bands.

Finally, at 5760 MHz, we see a significant difference. The radiation patterns in Figure 6.9-4 have major sidelobes that reduce the calculated efficiency. In addition, the excess PCB loss is much higher, so we can expect a deep dish with this feed to have fairly low efficiency, no more than 30%.

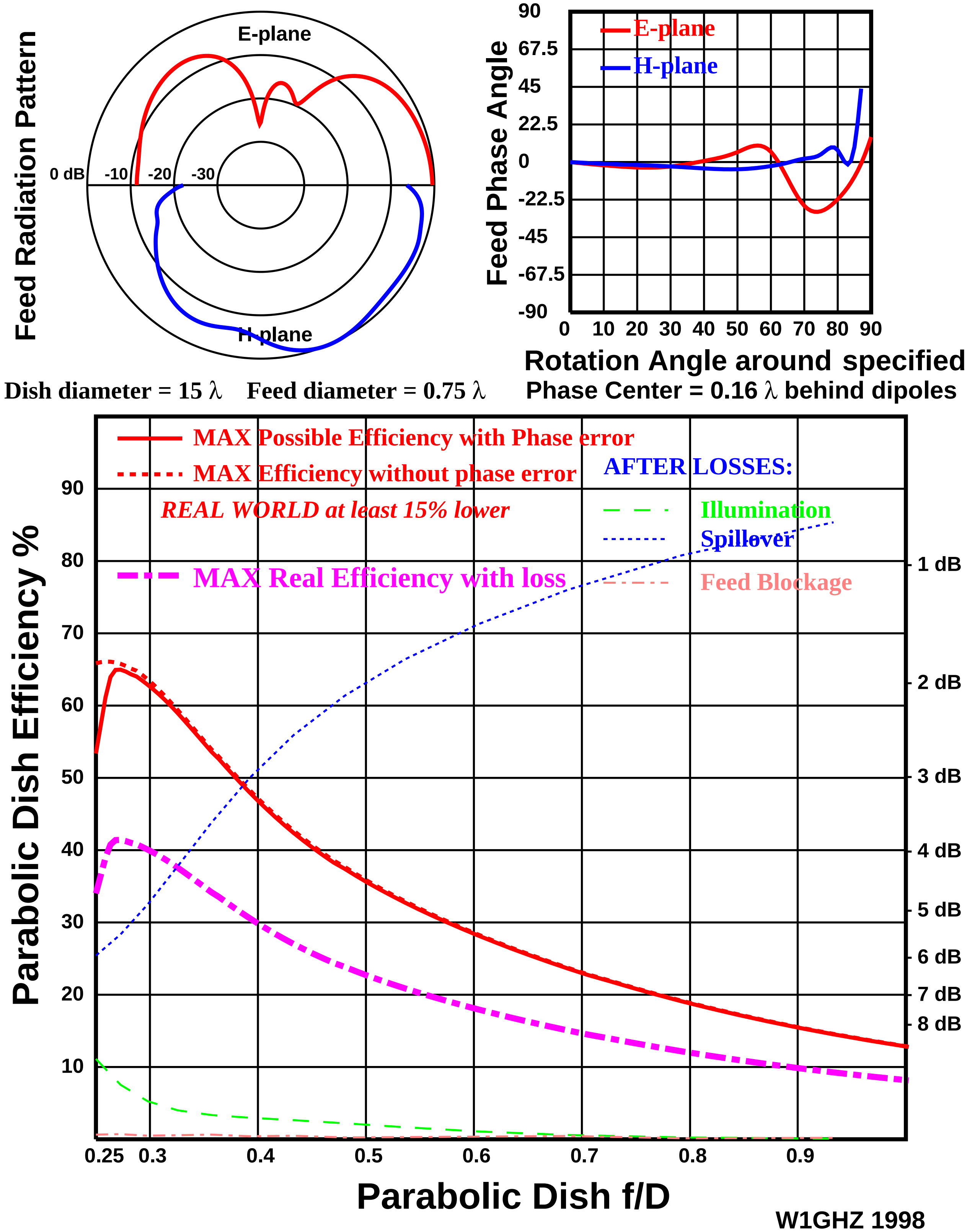
WA3RMX triband feed at 2304 MHz, by Zeland IE3D

Figure 6.9-2



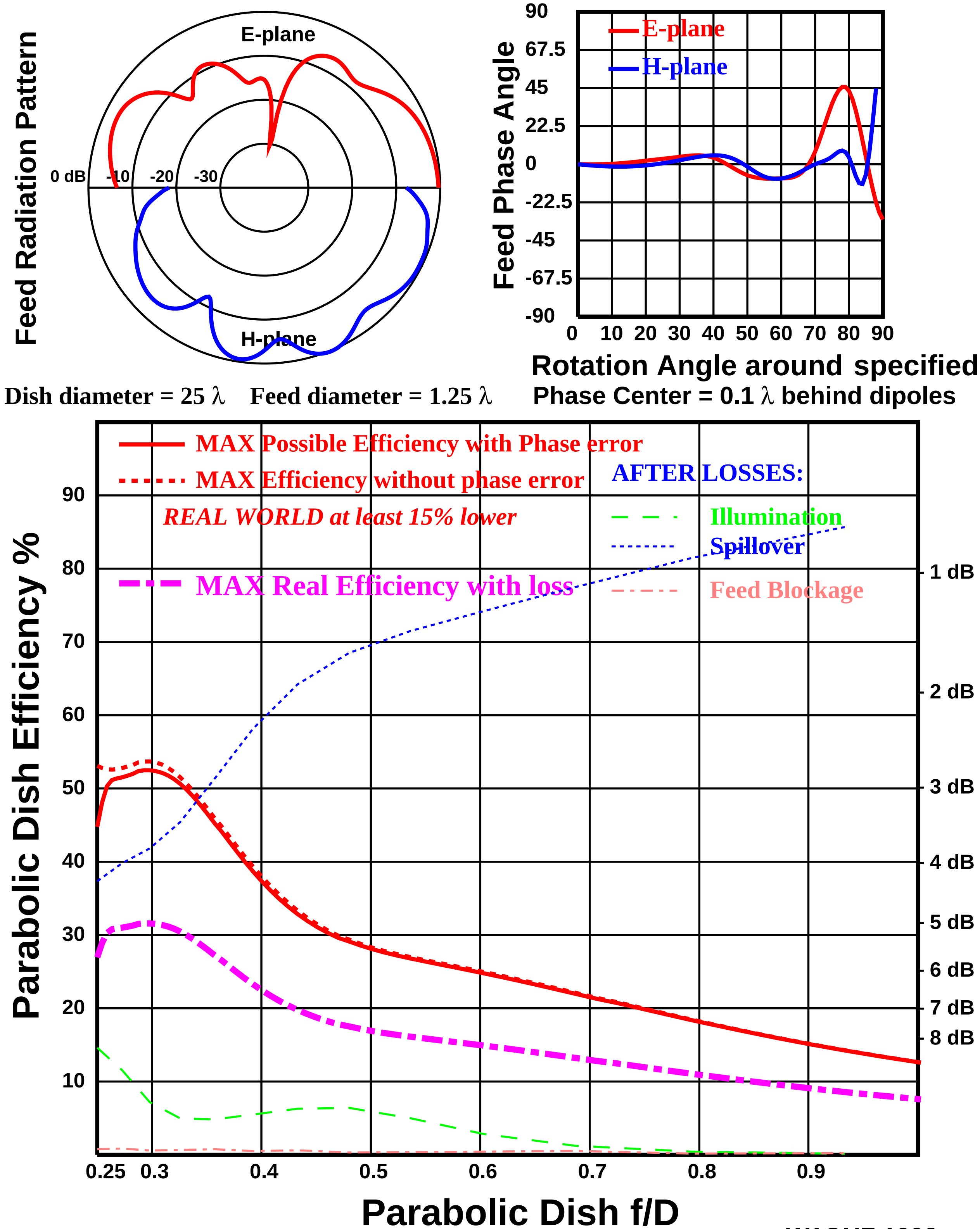
WA3RMX triband feed at 3456 MHz, by Zeland IE3D

Figure 6.9-3



WA3RMX triband feed at 5760 MHz, by Zeland IE3D

Figure 6.9-4



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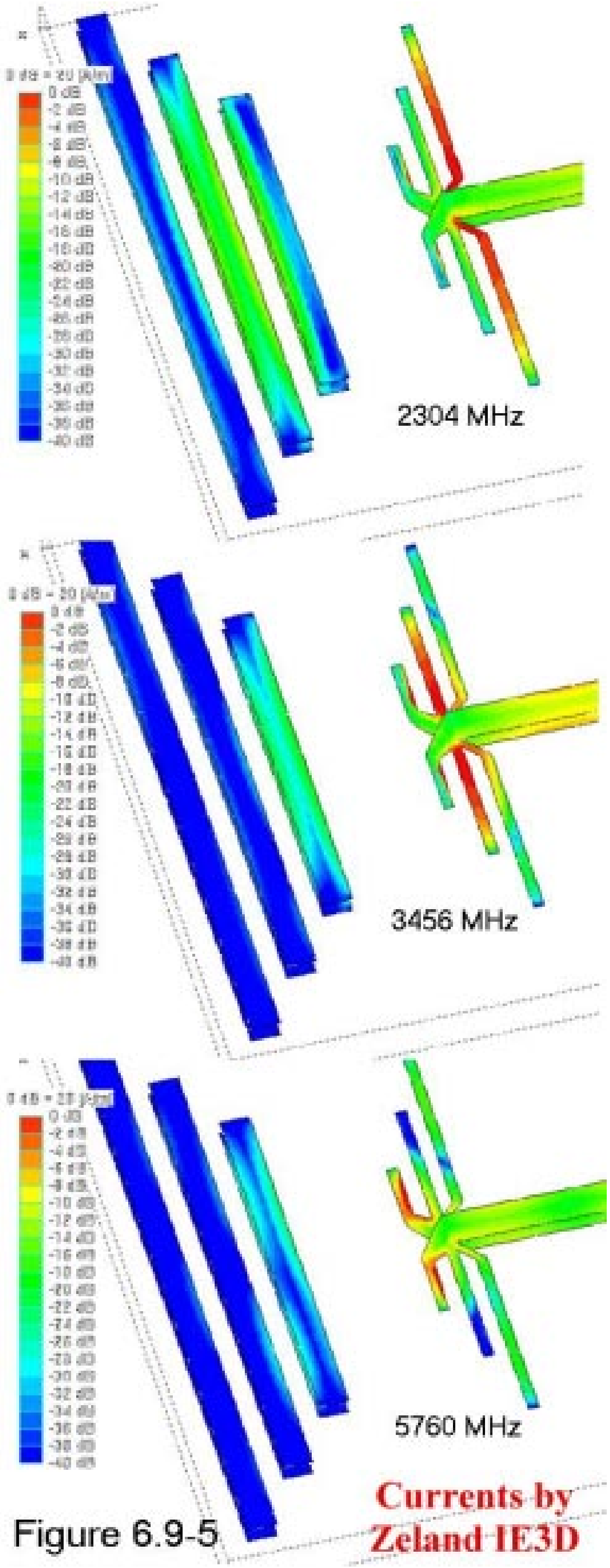


Figure 6.9-5

The Zeland **IE3D** simulator also calculates currents in the antenna. When we examine the currents in the triband feed at the different frequencies, shown in Figure 6.9-5, we can begin to understand why the performance is degraded at the highest frequency. At 2304 MHz, the current is concentrated in the longest dipole, so the radiation is predominantly from that dipole. Similarly, at 3456 MHz, the current is concentrated in the middle dipole, creating the predominant radiation. However, at 5760 MHz, there is some current in the longer dipoles, so they will all radiate. Also, at this highest frequency, the dipoles have enough physical separation, in wavelengths, to be radiating from different point in space, so that the combined radiation will not always be in phase. More important are the dimensions of the reflector elements — they are much longer than the dipoles. I suspect that the dipoles are shortened due to the PCB dielectric, but the reflectors are not. The currents in Figure 6.9-5 show that little energy reaches the longest reflector at any frequency, so the resonance of the shorter ones must be lowered by the dielectric, causing them to operate at lower frequencies. At 2304 MHz, most of the reflector current is in the middle reflector, so it is probably close to resonance, while at 3456 MHz, it is the shortest reflector that carries the current. This leaves no reflector short enough to be resonant at 5760 MHz — the shortest reflector has two current peaks, suggesting that it is closer to a full wavelength than a half-wave resonance. The combination of dipole currents and odd reflector currents results in the excess sidelobes we see in Figure 6.9-4.

The phase center of the triband feed is also well behaved on the lower two bands, about 0.16λ behind the center dipole on each band, toward the reflectors. At 5760 MHz, the phase center is much closer to the dipoles, only 0.1λ behind the center dipole, and the wavelength is much shorter. On a deep dish, the focal distance is critical; if we use the most critical phase center, at the highest frequency, it will cost another ½ dB at 2304 MHz.

In summary, the WA3RMX triband feed, combined with a very deep dish, offers mediocre performance on two bands, 2304 and 3456 MHz, and poor performance on the third band, 5760 MHz. This combination might still be a reasonable compromise for a rover station seeking to maximize capability in minimal volume. For shallower dishes, performance will be poor on all three bands; some other compromise is preferred.

WA5VJB extended the multi-band dipole feed to other frequencies, describing dual-band feeds[6] using traditional wire construction with no dielectric. The two dipoles are slightly above and below the horizontal plane, with the two reflectors behind them in the horizontal plane, each with the appropriate length and spacing from the dipoles for the desired frequency.

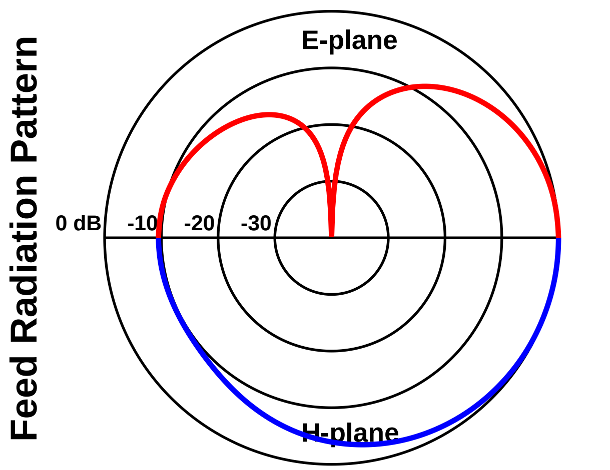
These feeds have no PCB, so they are easy to model using the **NEC2** program[7] — I chose to model the version for 903 and 1296 MHz. The calculated radiation patterns look pretty good. At both 903 MHz, in Figure 6.9-6, and 1296 MHz, in Figure 6.9-7, the patterns are comparable to the dipole-reflector feed of Figure 6.2-1, and the calculated efficiency is good for very deep dishes, of ***f*/D** = 0.25 to 0.3. The dielectric is air so there are no excess losses, and there is apparently very little interaction between the two feeds in the radiation patterns. Since they have a common feedpoint, there is probably more interaction in the input VSWR, but that can be compensated by a bit of fiddling.

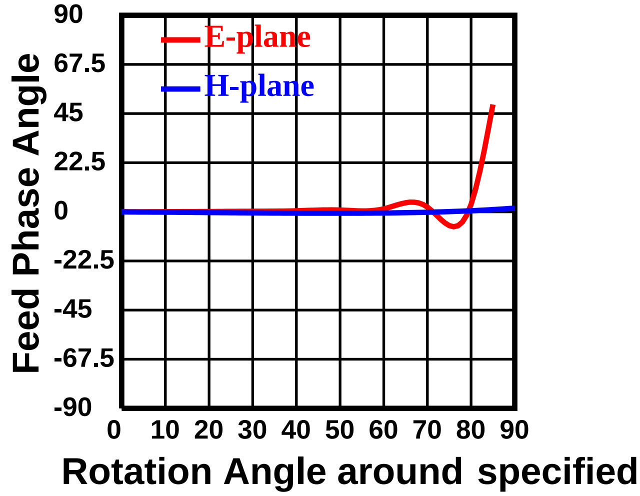
The phase centers for this feed on the two bands are very close. At 1296 MHz, the phase center is at the center of the two dipoles, while at 903 MHz the phase center is 0.06λ behind the dipoles, toward the reflector. This is a small difference, and the efficiency at 903 MHz is only 2% lower with the feed position optimized for 1296 MHz.

Similar feeds could probably be made for other pairs of bands with good results. More recently, WA5VJB has developed a dual-band feed for 903 and1296 MHz, on a printed-circuit board. He was selling them at Dayton last year, but apparently has not published the details. While I have not analyzed this feed, I would expect slightly lower performance due to dielectric loss. Again, this might be a good compromise *for very deep dishes only*, trading a little performance for reproducibility and convenience.

WA5VJB dual-band dipole feed at 903 MHz, by NEC2

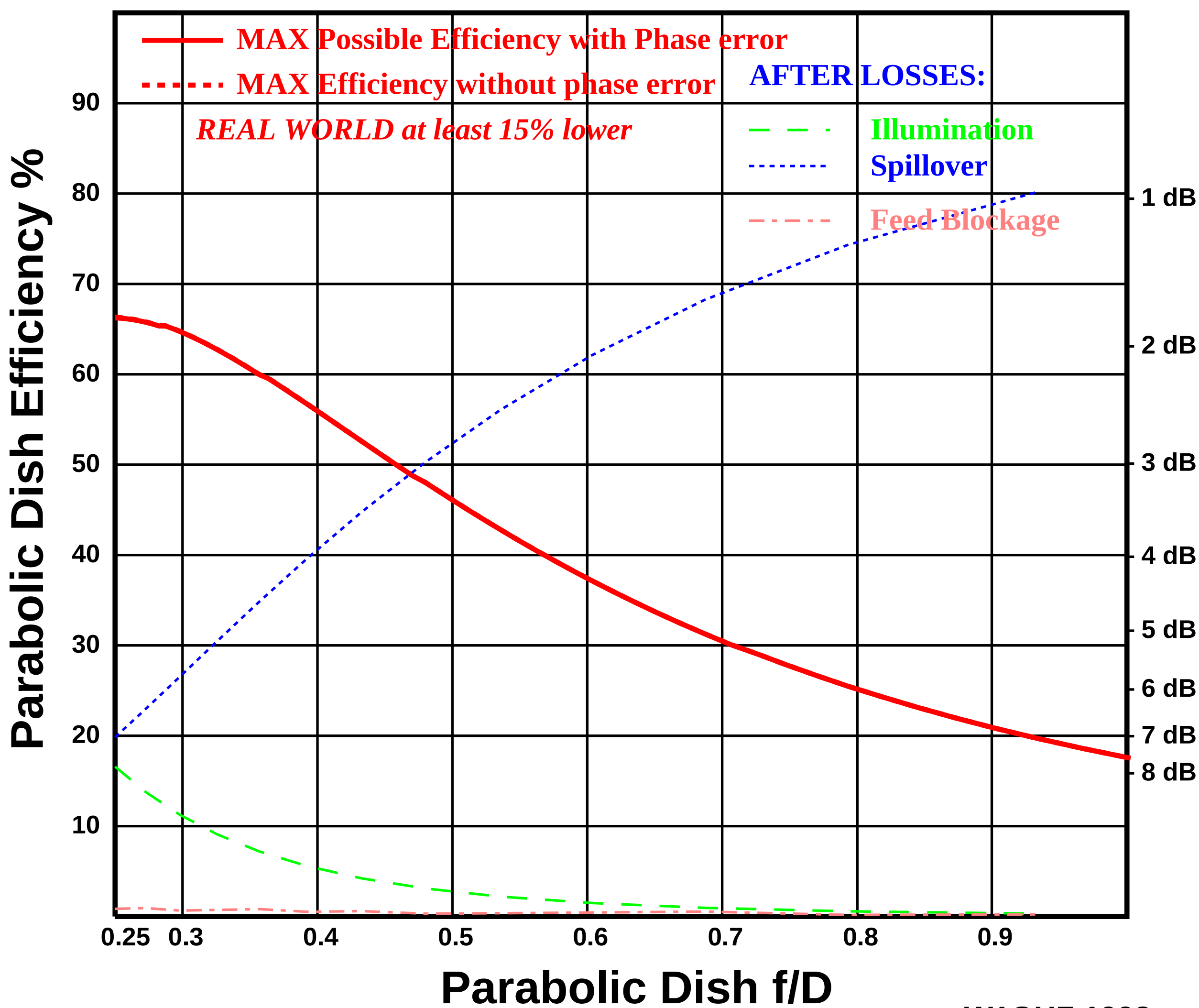
Figure 6.9-6





Dish diameter = 10 λ Feed diameter = 0.5 λ

Phase Center = 0.06 λ behind dipoles



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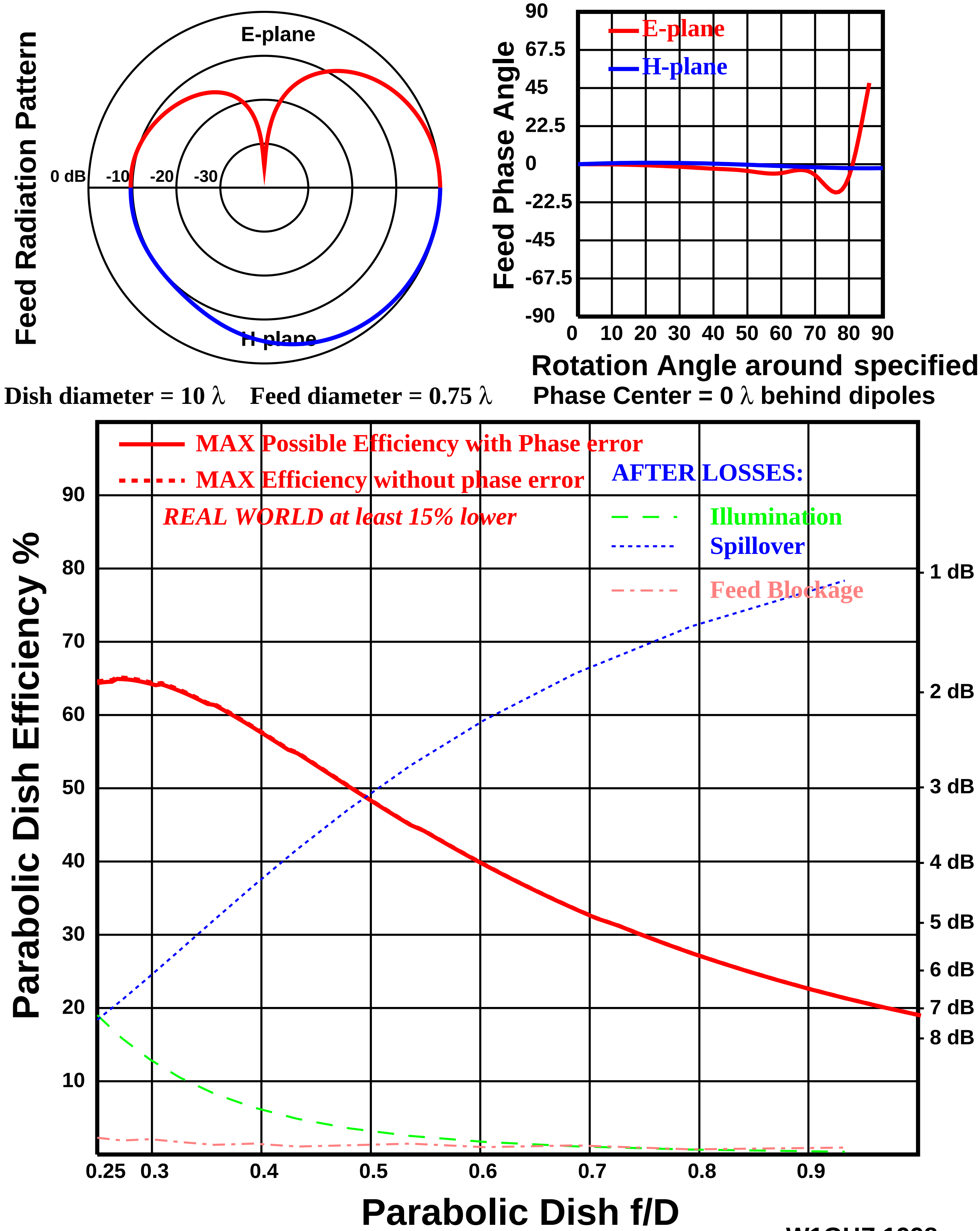
WA5VJB dual-band dipole feed at 1296 MHz, by NEC2

Figure 6.9-7



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6.9.3 Dual-band rectangular horns

A rectangular horn is inherently broadband — it transforms a waveguide to a larger aperture via a flared section. If the flare is gradual, additional waveguide modes are not excited, so the dominant waveguide mode will be radiated effectively. None of this is frequency specific, so a waveguide that covers more than one band can be used to feed a dual-band horn. The radiation pattern is controlled by the horn aperture dimensions and length, in wavelengths, so the patterns are different at different frequencies, but the dimensions may be adjusted independently to achieve patterns at both bands which are a usable compromise.

I took this approach in developing a dual-band feed[8] for a DSS offset dish at 5760 and 10368 MHz. Standard WR-112 rectangular waveguide just barely covers both bands, so it is the feed to the horn. I developed this horn before I had good pattern calculation capability, so I used G3RPE's graph[9,10] to estimate the beamwidth plus the **HDL_ANT** program to match the phase centers by adjusting the horn flare length. Since the DSS dish has an equivalent ***f*/D** of about 0.7, I picked aperture dimensions from the graph which would be under-illuminate the dish at the higher frequency and over-illuminate at the lower frequency. This tendency is natural, since the aperture in wavelengths increases with frequency, which makes the beamwidth narrower. The compromise is degradation by equal amounts at the two bands.

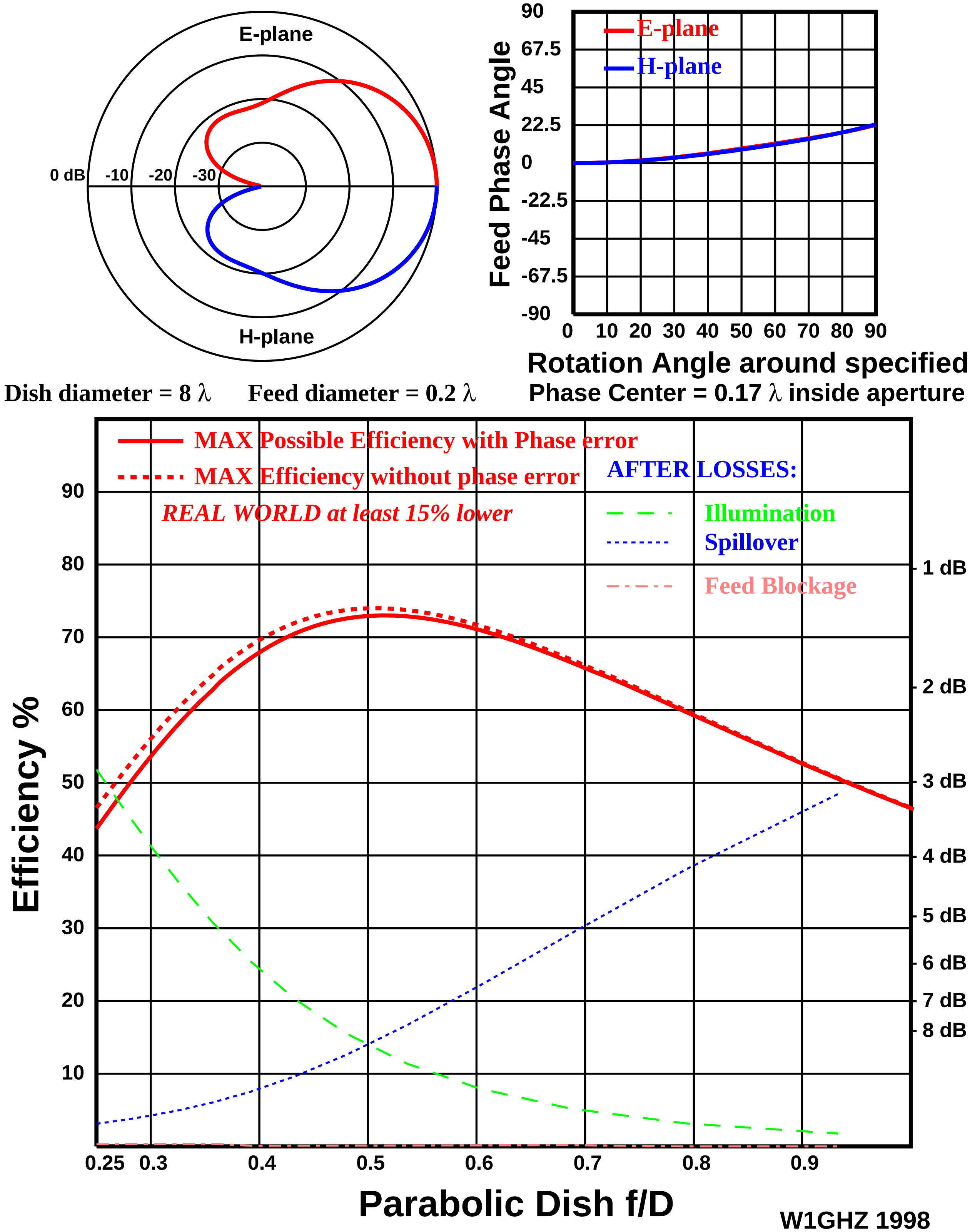
When I made sun noise measurements using this feed, the estimated dish gain on each band was about 1 dB lower than using an optimum feed for each band. Since an optimum feed on the DSS dish measures about 63% efficiency, the estimated efficiency for the dual-band horn is roughly 50%. Our compromise is 1 dB less gain on each band in exchange for dual-band capability.

Now, of course, it is easy to calculate radiation patterns for a rectangular horn. For the dual-band horn, these are shown in Figure 6.9-8 at 5760 MHz and in Figure 6.9-9 at 10368 MHz. The pattern at 5760 MHz is quite good, while the 10368 MHz pattern has a large sidelobe in the E-plane. As expected, the calculated efficiencies indicate under-illumination of the dish at the higher frequency and over-illumination at the lower frequency. Both frequencies are about the same amount below peak efficiency, so we have achieved the desired compromise. The dual-band feedhorn has aperture dimensions of 61 mm in the H-plane, 44.5 mm in the E-plane, and an axial length of 76 mm.

Figures 6.9-8 and 6.9-9 both plot the efficiency using the 10 GHz phase center, which is inside the horn by 0.3λ, or about 9 mm. The best phase center for 5760 MHz is not much different. Attempts to improve this horn were unsuccessful; no change in dimensions would improve the calculated efficiency on both bands. Most changes moved the phase centers apart at the two frequencies, which would hurt dual-band performance.

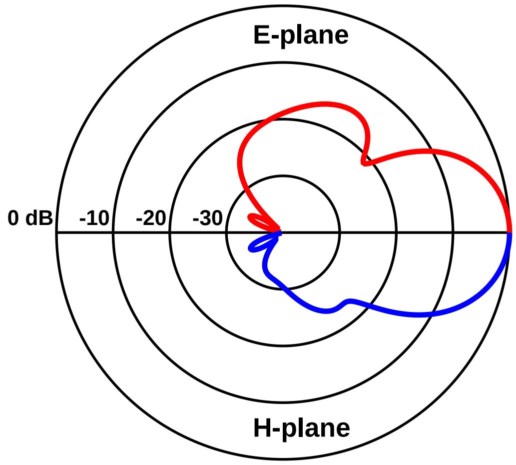
Dualband WR-112 offset rect. feedhorn at 5.76 GHz, by P.O.

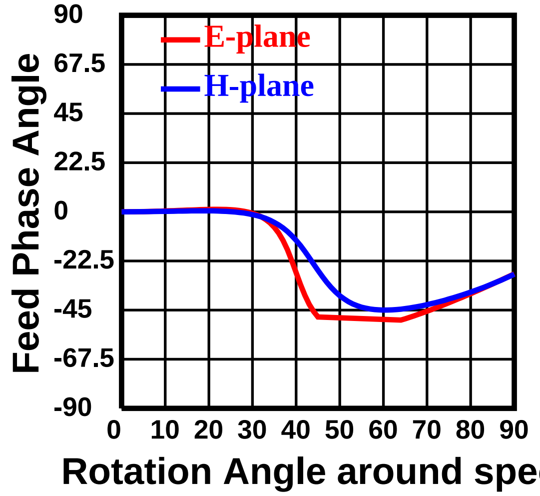
Figure 6.9-8



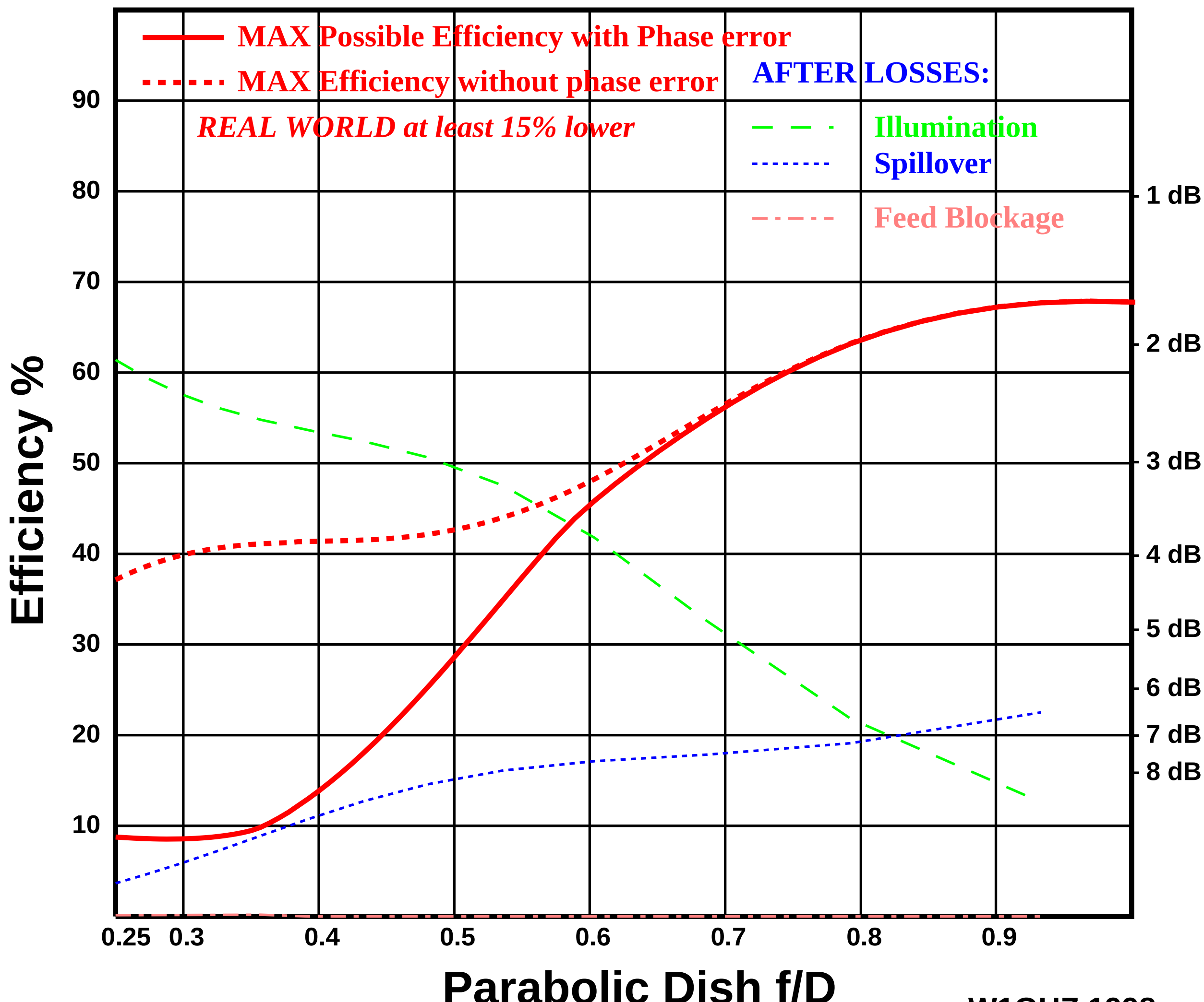
Dualband WR-112 offset rect. feedhorn at 10.368 GHz, by P.O.

Figure 6.9-9





Dish diameter = 15 λ   Feed diameter = 0.2 λ   Phase Center = 0.3 λ inside aperture



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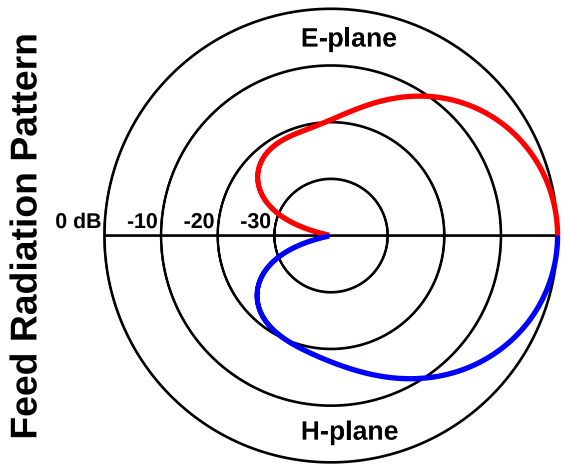
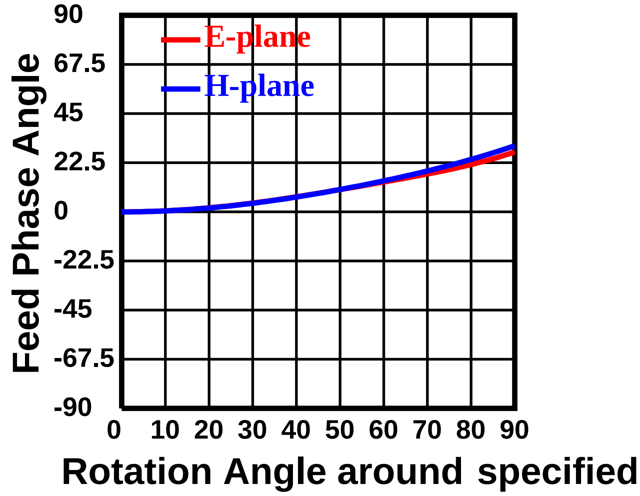
K1LPS suggested that the one-meter offset dishes that are becoming readily available would be good for 3456 and 5760 MHz. A dual-band feed could be useful if we could come up with one. Since the previous feed suggested that a simple compromise design would be adequate, so I used **HDL_ANT** to design a rectangular feedhorn for a 4.46 GHz — the geometric mean of the two target frequencies. The radiation patterns and calculated efficiency are plotted in Figure 6.9-10 at 3456 MHz and Figure 6.9-11 at 5760 MHz. For an offset dish with an equivalent ***f*/D** around 0.7, the efficiency is about the same on both bands, probably a dB down from an optimum single-band feed. The two phase centers are close enough that the lower band suffers by only 1 or 2% at the 5760 MHz phase center, inside the horn by 0.36λ, or about 19 mm. The horn is 69.5 mm long, with aperture dimensions of 96 mm in the H-plane and 72.5 mm in the E-plane — enter these dimensions in **HDL_ANT** to generate a template.

For most adjacent pairs of bands, there is a standard rectangular waveguide usable on both. However, rectangular horns make good feeds only for ***f*/D** larger than about 0.5, so they are best for offset dishes. Most common conventional dishes are deeper, so we must find other dual-band horns.

Dualband WR-187 offset rect. feedhorn at 3456 MHz, by P.O.

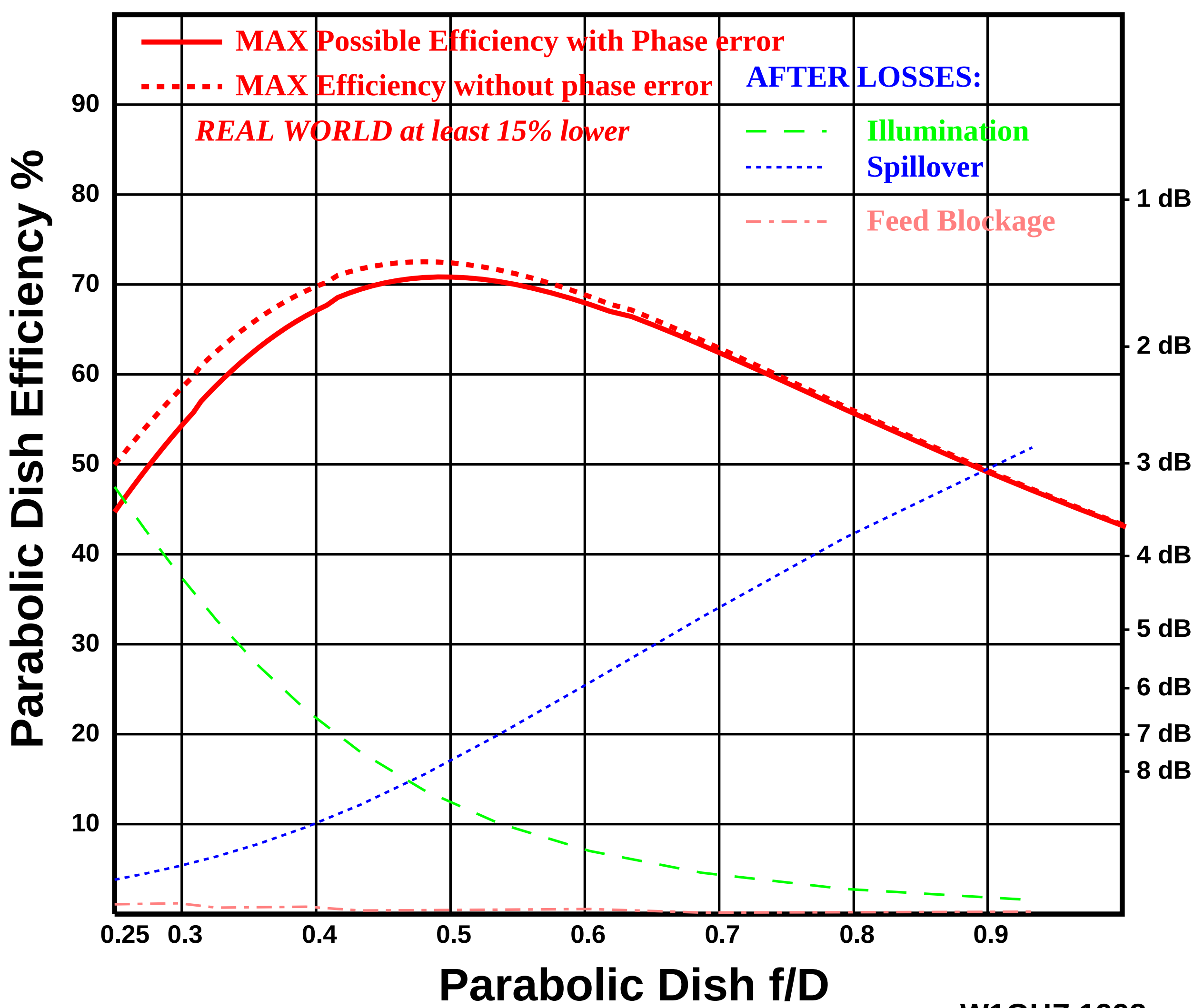
Figure 6.9-10





Dish diameter = 11.5 λ Feed diameter = 0.5 λ

Phase Center = 0.216 λ inside aperture



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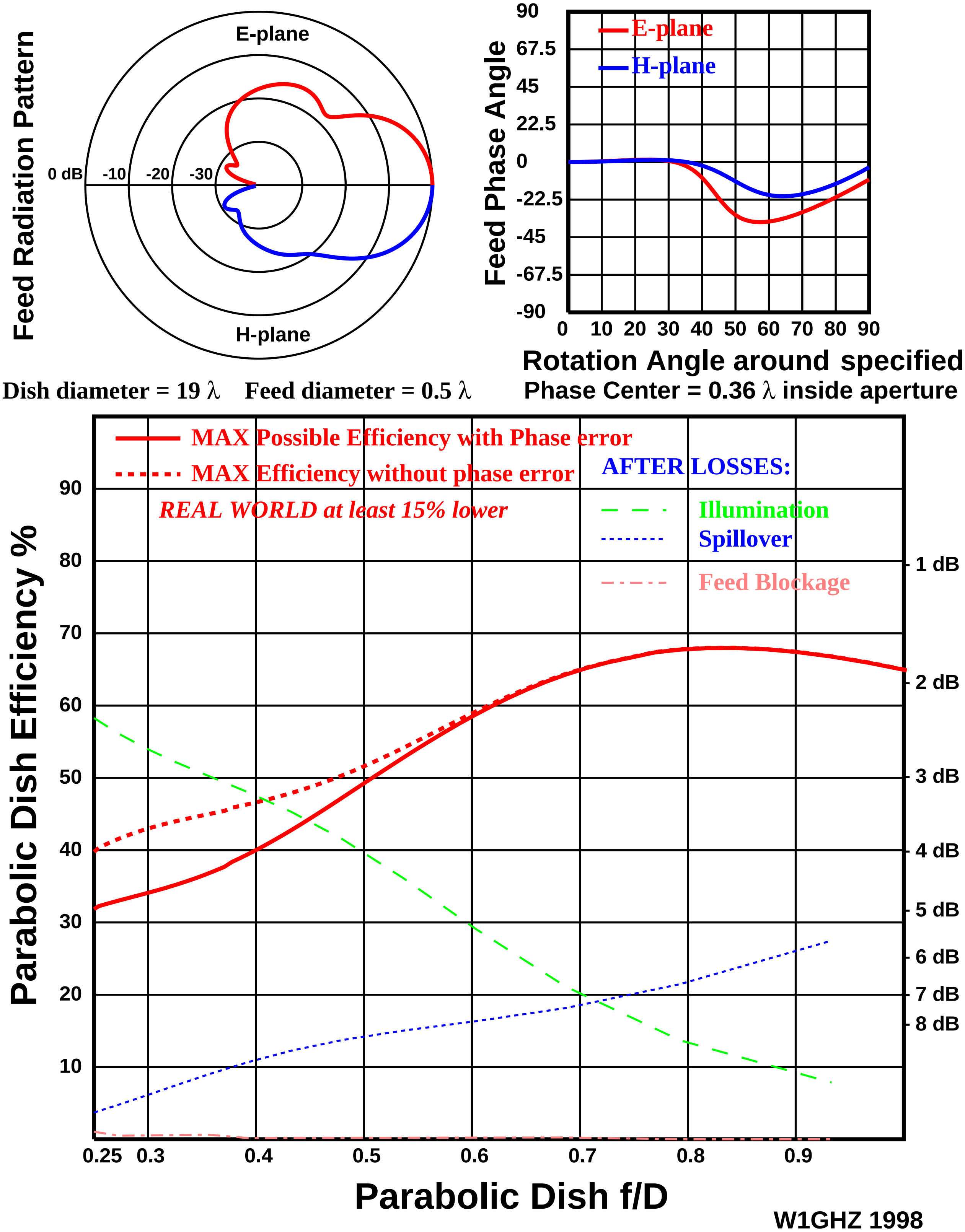
Dualband WR-187 offset rect. feedhorn at 5760 MHz, by P.O.

Figure 6.9-11



6.9.4 Dual-band cylindrical horns

A cylindrical horn, like the coffee-can feed, is only usable over a limited range of frequencies before additional waveguide modes distort the pattern. W5LUA has developed two dual-band cylindrical feedhorns[11]; each resembles a coffee-can feed in series with a smaller can. The lower frequency horn is in front of the smaller, higher-frequency horn, with a separate feed probe in each. At the lower frequency, there should be little effect — this is a coffee-can feed with a small waveguide (beyond cutoff) behind it in the center of the closed end. At the higher frequency, however, the radiation from the small horn must pass through a larger diameter section to reach the larger aperture. We know from the dual-mode feeds in Chapter 6.5 that the increase in diameter will propagate additional waveguide modes; if the length of the larger-diameter horn is right, the additional modes can help rather than hurt performance.

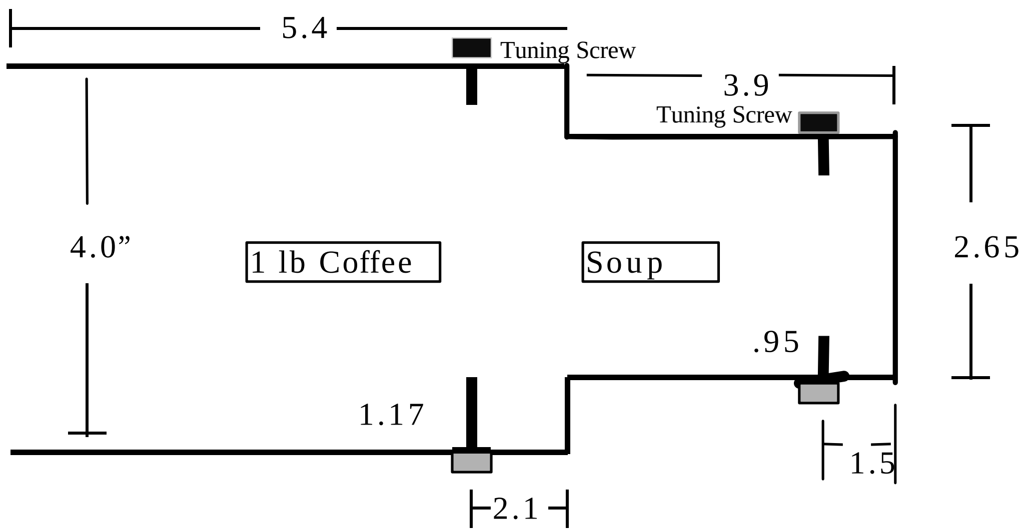
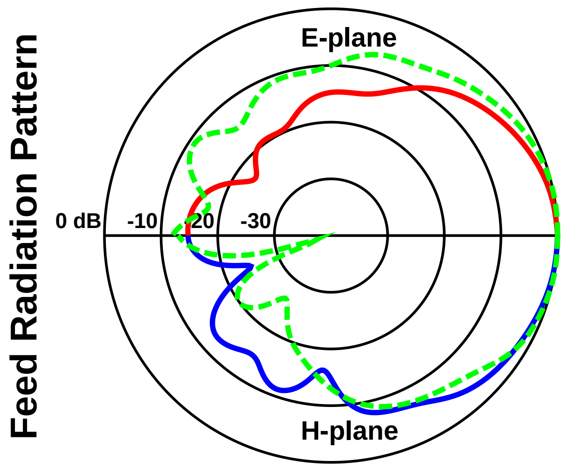


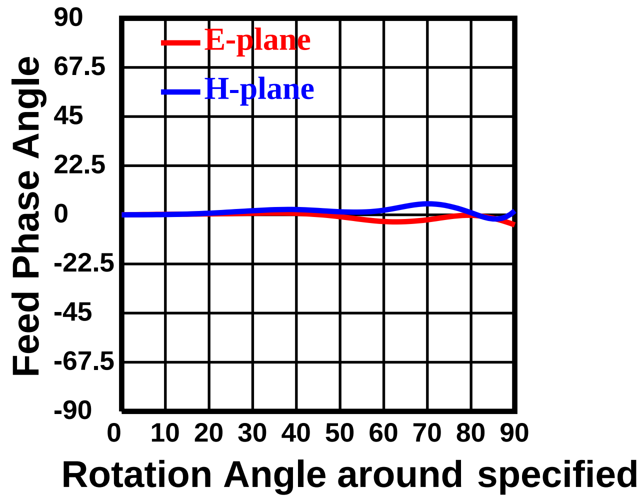
Figure 6.9-12 W5LUA Dual-band feed
For 2304 and 3456 MHz

The larger W5LUA dual-band feed, for 2304 and 3456 MHz, has a direct step in diameter between the two sections; dimensions are shown in Figure 6.9-12. At 2304 MHz, the radiation pattern calculated by **NEC2**, in Figure 6.9-13, is similar to the coffee-can feed of Figure 6.3-1, with good efficiency peaking at ***f/*D** around 0.4. At 3456 MHz, the pattern in Figure 6.9-14 shows the narrower beamwidth expected of a larger aperture, with best ***f/*D** around 0.5, and some additional sidelobes. Phase center on both bands is at the center of the aperture. Patterns measured by W5ZN at both frequencies are included as dashed green lines; the main lobes, which illuminate the reflector, correspond reasonably well with calculated patterns. There are some discrepancies in the side and back lobes, but the calculated efficiencies and range of best ***f/*D** are very similar. At a compromise ***f/*D** around 0.45, this feed should provide good efficiency on both bands, perhaps 50%; this is within about one dB of the best single-band feeds.

W5LUA dual-band cylindrical feed at 2304 MHz, by NEC2

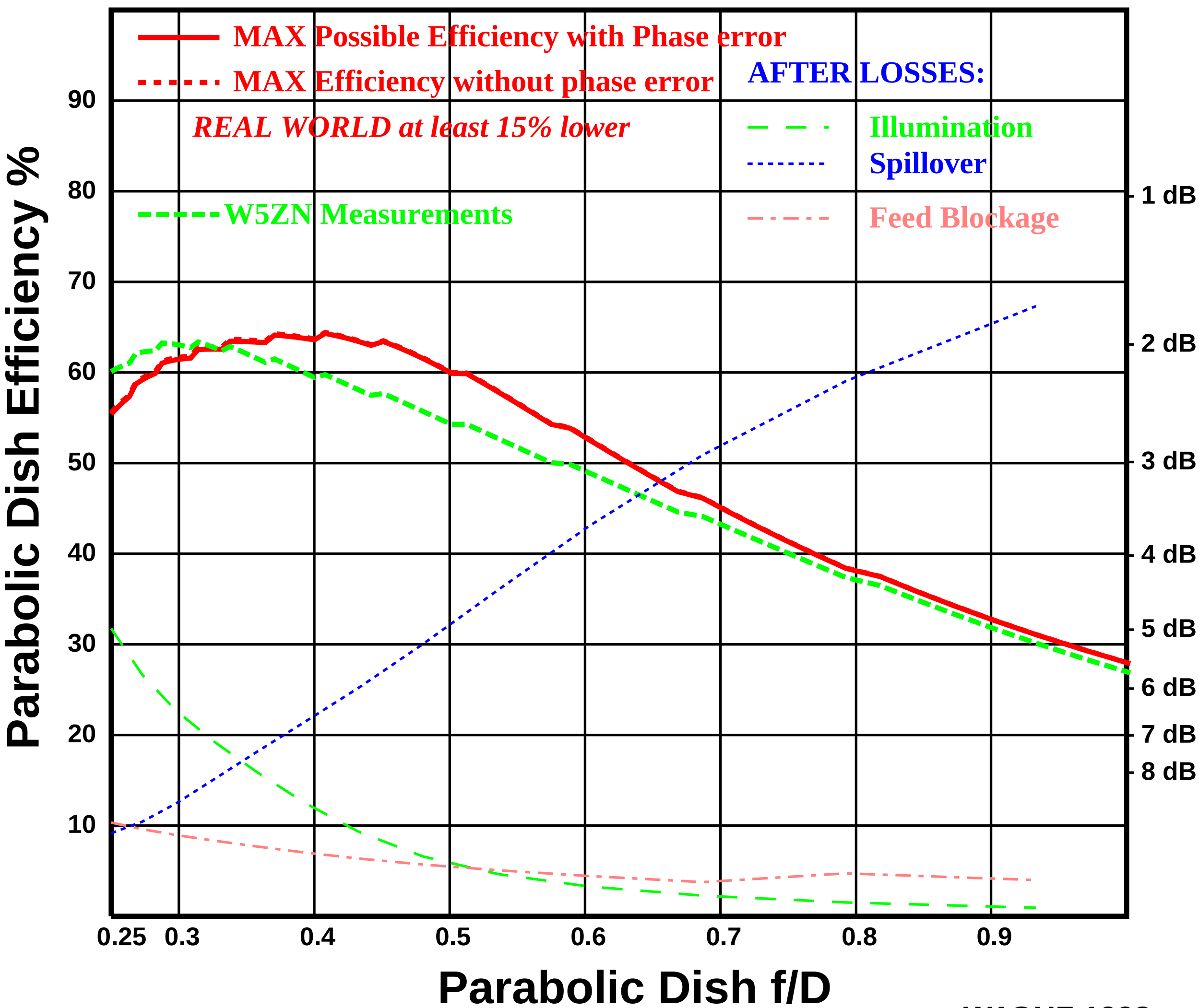
Figure 6.9-13





Dish diameter = 7 λ Feed diameter = 1 λ

Phase Center = 0 λ beyond aperture



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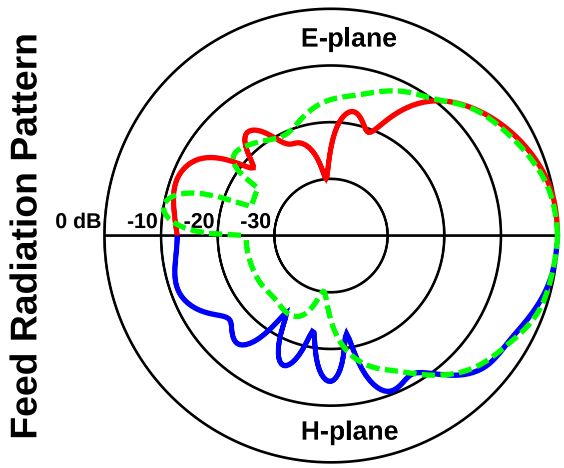
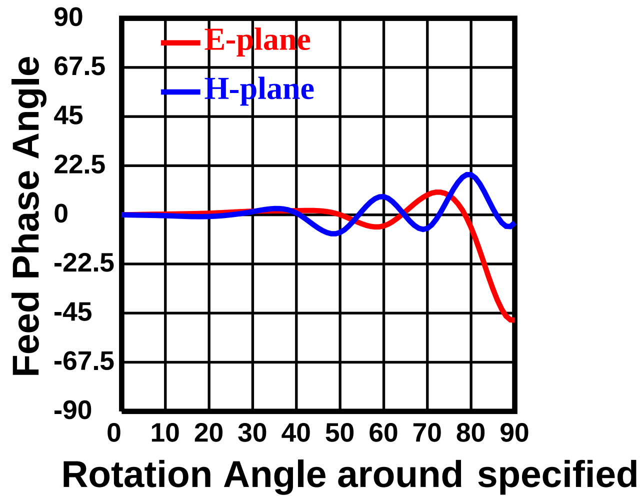
W5LUA dual-band cylindrical feed at 3456 MHz, by NEC2

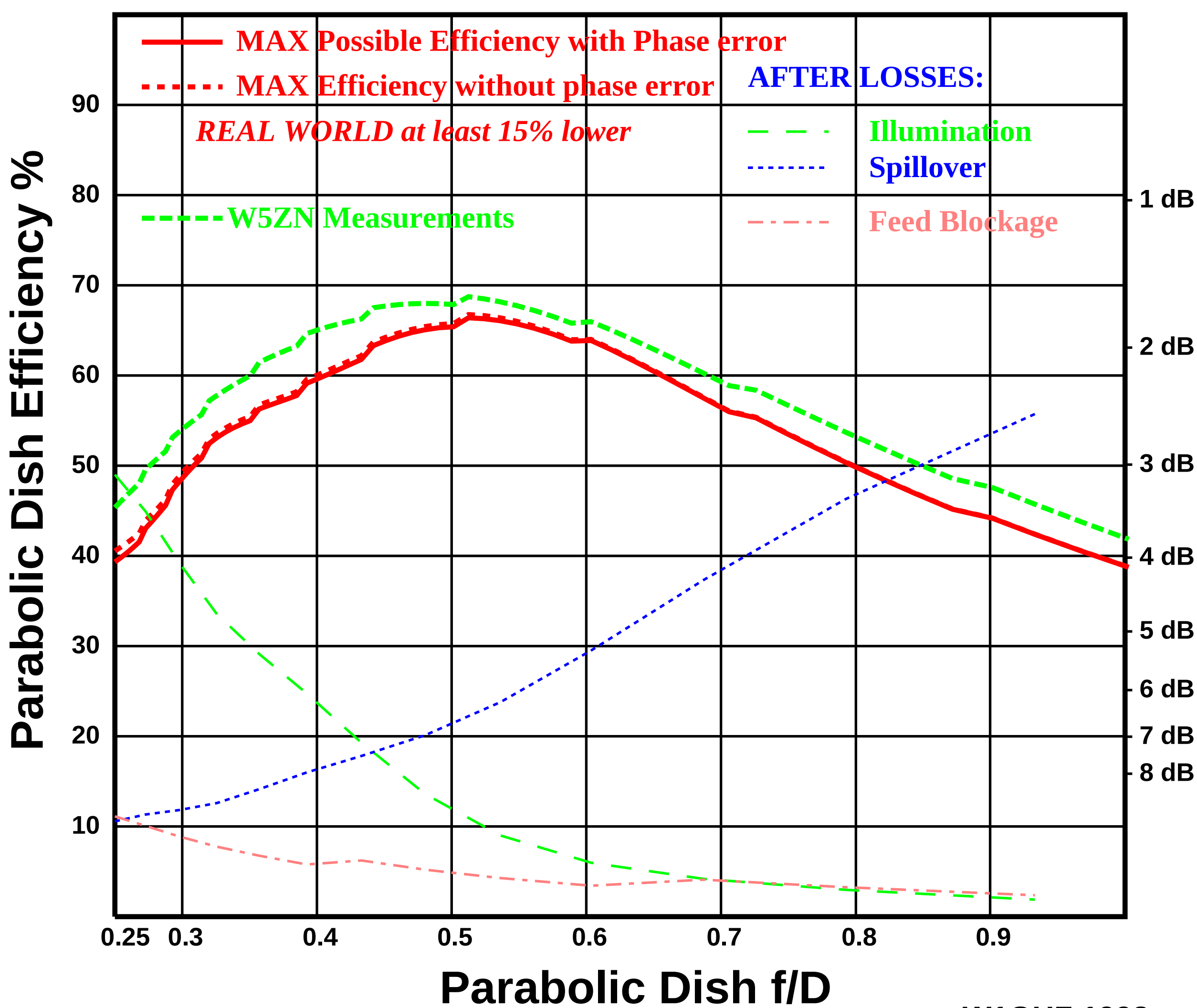
Figure 6.9-14





Dish diameter = 10.5 λ Feed diameter = 1.3 λ

Phase Center = 0 λ beyond aperture



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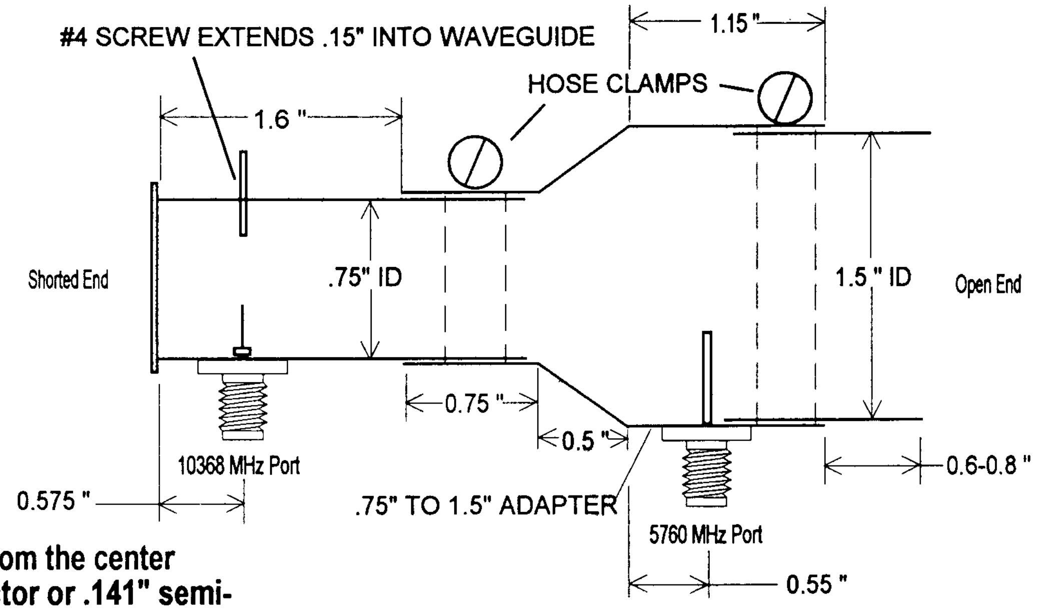
W5ZN also measured dish gain on both bands using this feed. Unfortunately, the dish was much too deep for this feed, with ***f*/D**=0.3, and very small, only 7λ diameter at 2304 MHz. From Figure 6.7-12, we can estimate that a dish this small suffer nearly a dB of diffraction loss, so the 37% efficiency at 2304 MHz calculated from the gain measurement is in the right ballpark. At 3456 MHz, the very deep dish suffers large illumination loss with this feed — from Figure 6.9-14, nearly a dB loss. Thus, the 36% efficiency at 3456 MHz calculated from the gain measurement is about what we would predict from the curve. With a larger, shallower dish, this feed is capable of better performance.

The smaller W5LUA dual-band feed, for 5760 and 10368 MHz, with dimensions shown in Figure 6.9-15, has a flared section between the two diameters like the W2IMU dual-mode feed in Chapter 6.5. In fact, the feed looks just like a 10 GHz dual-mode feed with a second feed probe for 5760 MHz added in the output section. The 1.5 inch diameter output section is 1.31λ at 10.368 GHz, exactly the dimension used by W2IMU; at 5760 MHz, it is 0.73λ in diameter, a good size for a coffee-can feed. The only discrepancy is that the 37° flare angle and the length of the output section are both slightly larger than the W2IMU dimensions; whether this is to optimize dual-band operation or simply to utilize available materials, I don't know.

The performance of this dual-band feed is about what we might expect from the description. At 5760 MHz, in Figure 6.9-16, the feed has a radiation pattern and calculated efficiency very similar to the coffee-can feed of Figure 6.3-1, with good efficiency peaking at ***f*/D** around 0.35. The measured pattern has a similar but slightly narrower main lobe, so that the best ***f*/D** is slightly higher. In Figure 6.9-17, the feed at 10368 MHz has a radiation pattern and calculated efficiency like a W2IMU dual-mode feed, with best efficiency at an at ***f*/D** around 0.55. The pattern is not quite as clean as a single-band dual-mode feed, probably due to the combination of slightly different dimensions and the distortions caused by the additional probe. There is also less correlation at the higher frequency between calculated and measured patterns, shown as green dashed lines in the plot. The measurement intervals are too large to capture the many lobes seen in the calculation, but the overall sidelobe level is higher, reducing the calculated efficiency.

As a dual-band feed, the best compromise ***f*/D** is about 0.45, where the calculated efficiencies are about the same. We might expect good efficiency on both bands, perhaps approaching 50%. W5ZN measured the gain on a 24-inch dish with ***f*/D**=0.45; the equivalent efficiency was 52% at 5760 MHz and 41% at 10GHz, about what we might predict from the measured patterns. The phase center for both bands is in the center of the aperture.

WB5LUA DUAL 5760 & 10368 MHz FEEDHORN

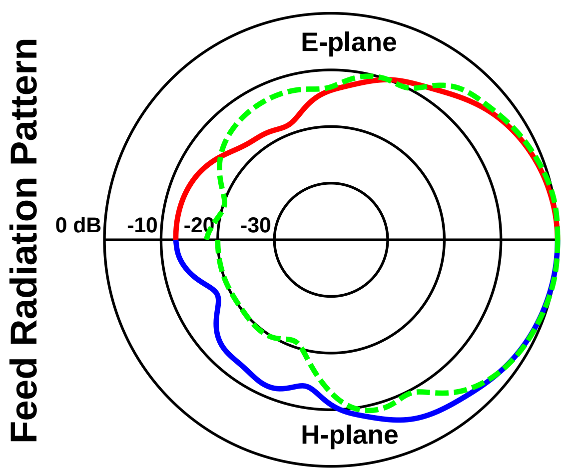


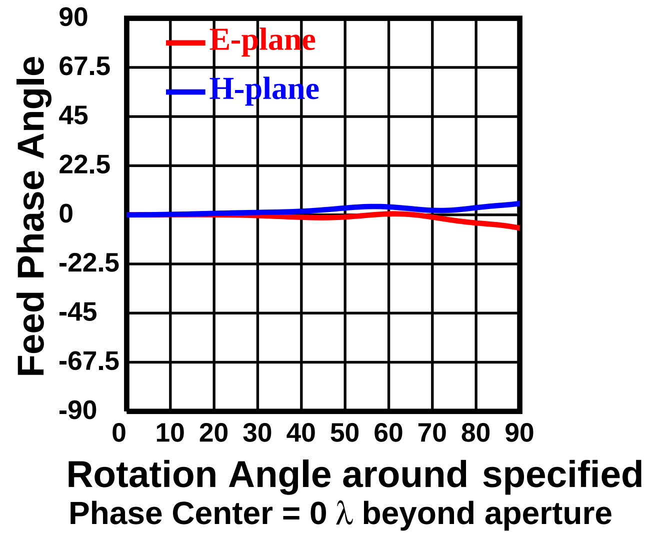
NOTES
1. 10368 MHz probe is made from the center conductor of an SMA connector or .141" semi-rigid cable. .070" of the teflon dielectric extends into waveguide. Length of pin above dielectric is 0.3". Tuning screw is diametrically opposite probe and is adjustable
2. 5760 MHz probe is .6 to .7" in length and can be made from tubing .07 to .1" in diameter
3. Tuning of both frequencies can be accomplished by tuning either probe length or waveguide length.
4. Isolation
10368 MHz signal @ 5760 MHz port = -19 dB
5760 MHz signal @ 10368 MHz port = -45 dB
5. Return loss > 23 dB at both ports

DRAWING NOT TO SCALE	DUAL 5760 & 10368 MHz FEEDHORN
06-18-97	Engineering Sketch by Al Ward WB5LUA

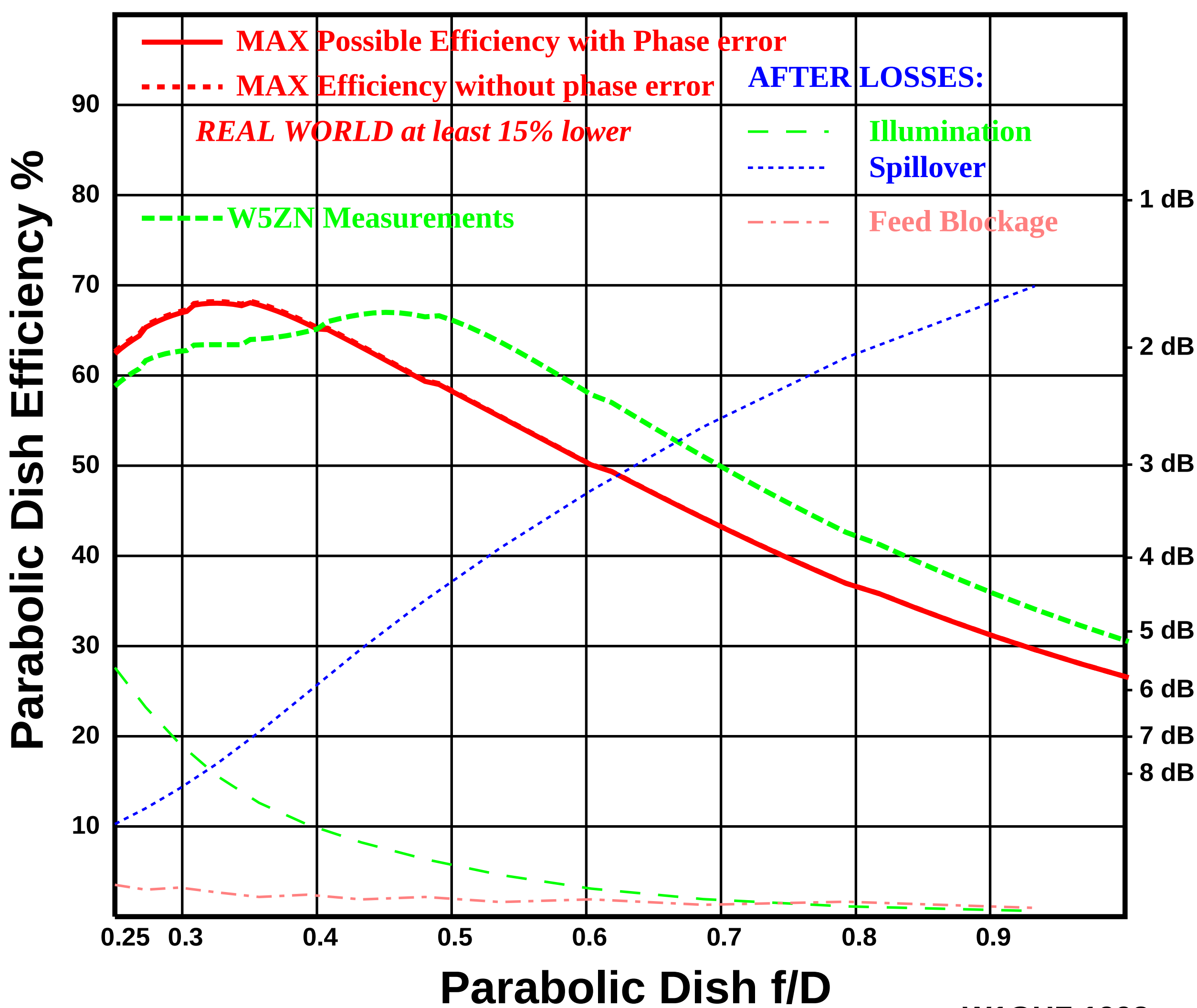
W5LUA dual-band small cyl. feed at 5760 MHz, by NEC2

Figure 6.9-16





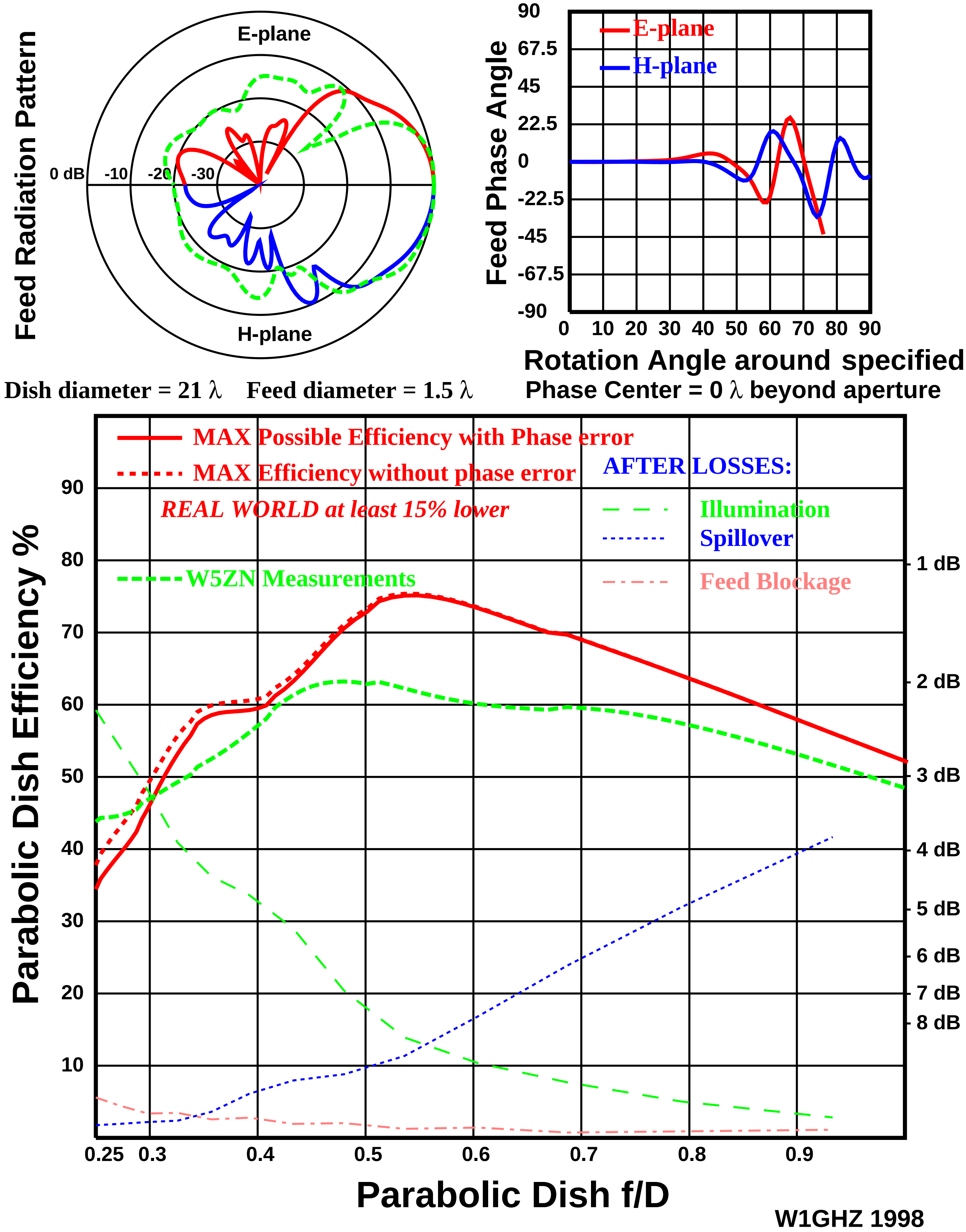
Dish diameter = 11.7 λ Feed diameter = 1 λ



W1GHZ 1998

W5LUA dual-band small cyl. feed at 10368 MHz, by NEC2

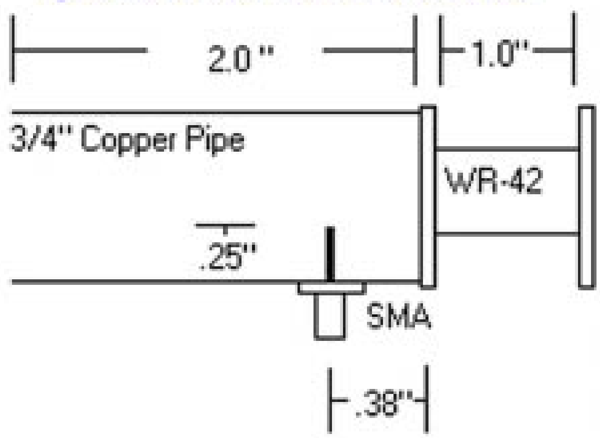
Figure 6.9-17



6.9.5 Dual-band mixed horns

W5ZN has described[2] and measured an interesting dual-band feed for 10 and 24 GHz. It appears to be a coffee-can feed for 10 GHz, made from ¾" copper water pipe, with a section of WR-42 waveguide for 24 GHz attached to the back; dimensions are shown in Figure 6.9-18. The waveguide is the feedline for 24 GHz, while a coaxial probe is the input at 10 GHz; at 10 GHz, the waveguide is far beyond cutoff, so it should have no effect.

Figure 6.9-18 W5ZN feed for 10 & 24 GHz



Since I don't have confidence in using **NEC2** for rectangular waveguides, I used another Zeland[7] 3D-simulation program to model this feed, Zeland **Fidelity**. At 10 GHz, as we can see in Figure 6.9-19, radiation pattern and calculated efficiency very similar to the coffee-can feed of Figure 6.3-1, with good efficiency peaking at ***f*/D** around 0.35 to 0.4. The W5ZN measurements, shown as green dashed lines in the plots, show similar patterns and calculated efficiency. The surprise is at 24 GHz, where the performance is even better. In Figure 6.9-20, the calculated efficiency is very good, with best ***f*/D** around 0.4 to 0.5. I expected the large 10 GHz feed probe to distort the 24 GHz pattern, so I calculated the 24 GHz patterns with the probe both open and shorted; the results were identical, suggesting that the 10 GHz probe adds no ill effect. The measured patterns show some differences, but a similar calculated efficiency curve.

The phase center at 10 GHz is in the center of the aperture, while at 24 GHz, the phase center is 0.2λ inside the aperture. W5ZN reports[3] a similar phase center in the field but not on the antenna range. I recently found a paper[12] that shows that a range length of $\mathbf{100 \bullet D^2/\lambda}$, or *fifty times the Rayleigh distance*, is needed to accurately locate the dish focus; on a short range, the difference could as much as a half-wavelength. For Joel's 24-inch dish at 24 GHz, a range length of nearly two miles would be needed to accurately adjust the focus. ***Lesson: don't try to adjust a feed position in your backyard!***

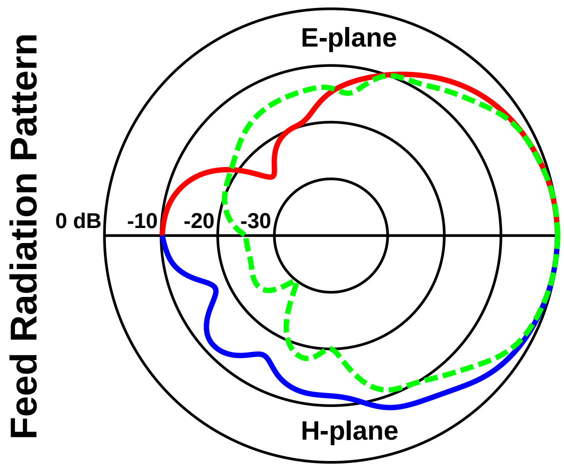
At a compromise ***f*/D** of about 0.4, we might expect good efficiency from this feed on both bands, perhaps 50%. W5ZN made gain measurements using this feed on a 24-inch dish with ***f*/D**=0.45. At 10.368 GHz, the equivalent efficiency was 46%, while at 24 GHz, the equivalent efficiency was down to 42% (which is still 40.0 dB of gain!). Other factors, like reflector surface accuracy, become very important at 24 GHz.

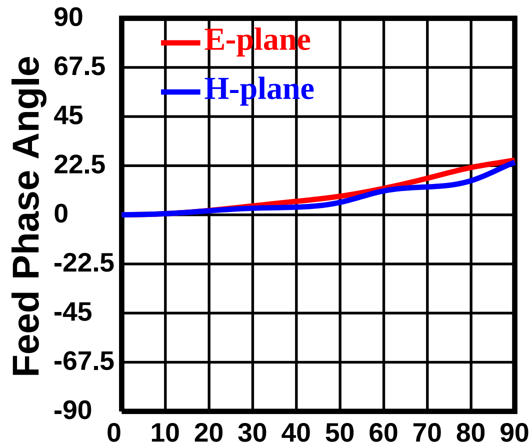
What is exciting for this dual-band feed is the potential for aiming a dish of reasonable size on 24 GHz, where the beamwidth is extremely sharp. If we can peak the dish accurately on 10 GHz, where the beamwidth is 2.4 times broader and we probably have higher power available, then we have a much better chance for a 24 GHz contact.

W5ZN dual-band feed for 10 & 24 GHz at 10.368 GHz,

by Zeland Fidelity™

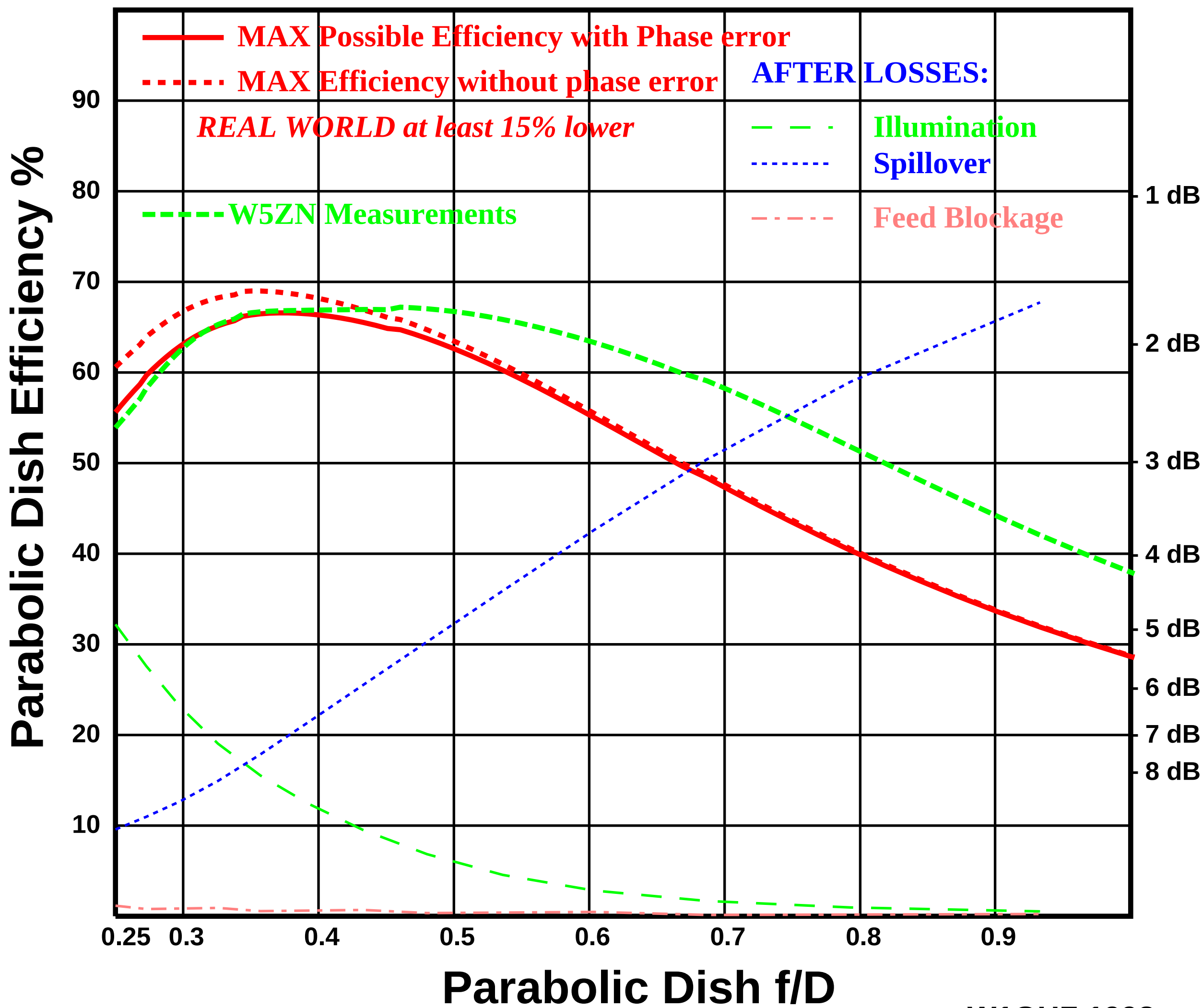
Figure 6.9-19





Dish diameter = 21 λ   Feed diameter = 1 λ

Phase Center = 0.086 λ inside aperture

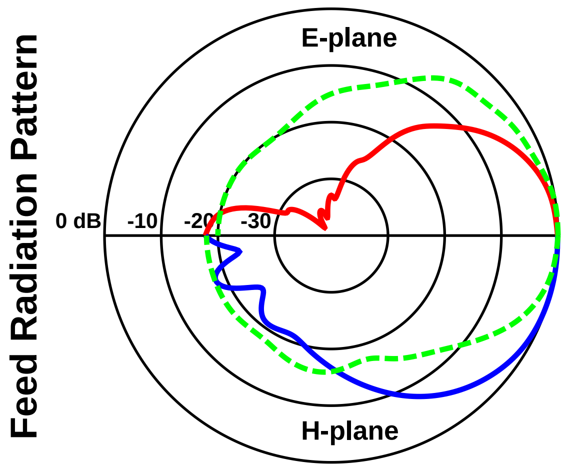


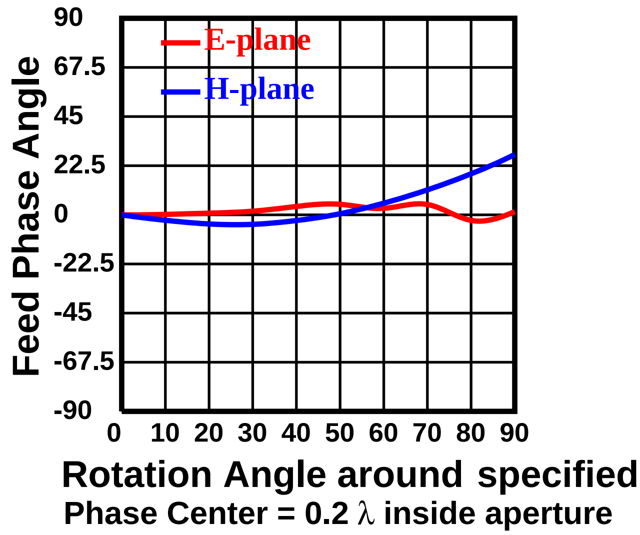
W1GHZ 1998

W5ZN dual-band feed for 10 & 24 GHz at 24.192 GHz,

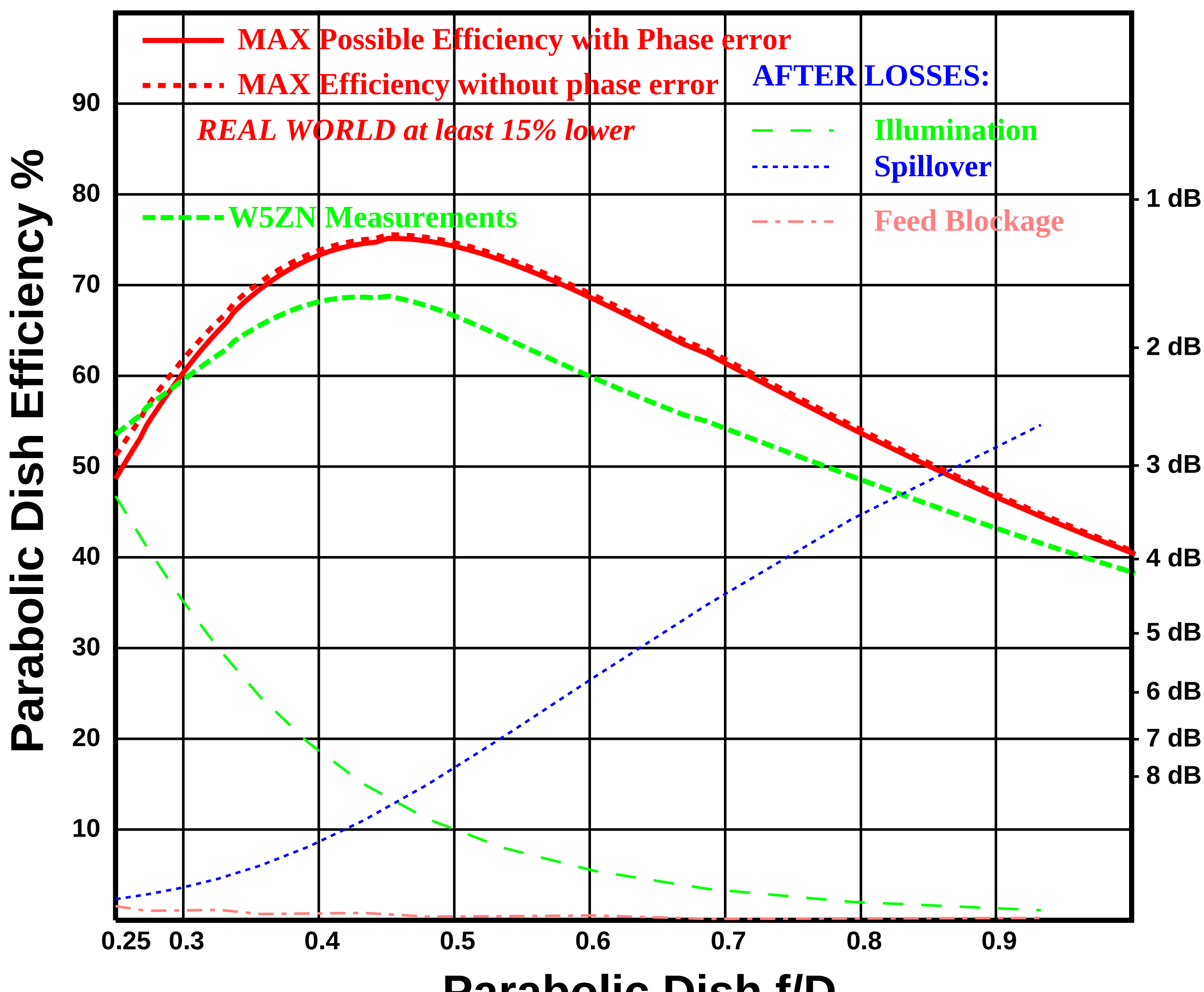
by Zeland Fidelity™

Figure 6.9-20





Dish diameter = 49 λ Feed diameter = 2.3 λ



W1GHZ 1998


Figure 6.9-21 AA6IW Dual-band feed for 10 and 24 GHz

At Microwave Update '99 in Dallas, W5ZN was making feed pattern measurements[13]. AA6IW brought a 10 and 24 GHz dual-band feedhorn for measurement. I didn't get the dimensions, but I did take a photo — Figure 6.9-21. The feedhorn looks like a 10 GHz Chaparral-style feed (Section 6.3.4) with a WR-42 waveguide input for 24 GHz in the back, like the W5ZN horn. To model this feed, I added two choke rings to the W5ZN horn model, 8.8 mm deep by 44 mm and 66 mm in diameter, with the ring openings flush with the horn aperture. At 10 GHz, the choke rings provide the improvement we might expect: the radiation patterns and calculated efficiency in Figure 6.9-22a are very similar to the Chaparral feed in Figure 6.3-16. The measured pattern on the AA6IW feed is very similar. At 24 GHz, however, the choke rings reduce the performance slightly; Figure 6.3-22b shows calculated efficiency reduced by a larger rear lobe and by phase error. Again, the measured pattern at 24 GHz does not agree exactly, but does show the same trends for calculated efficiency and ***f*/D**.

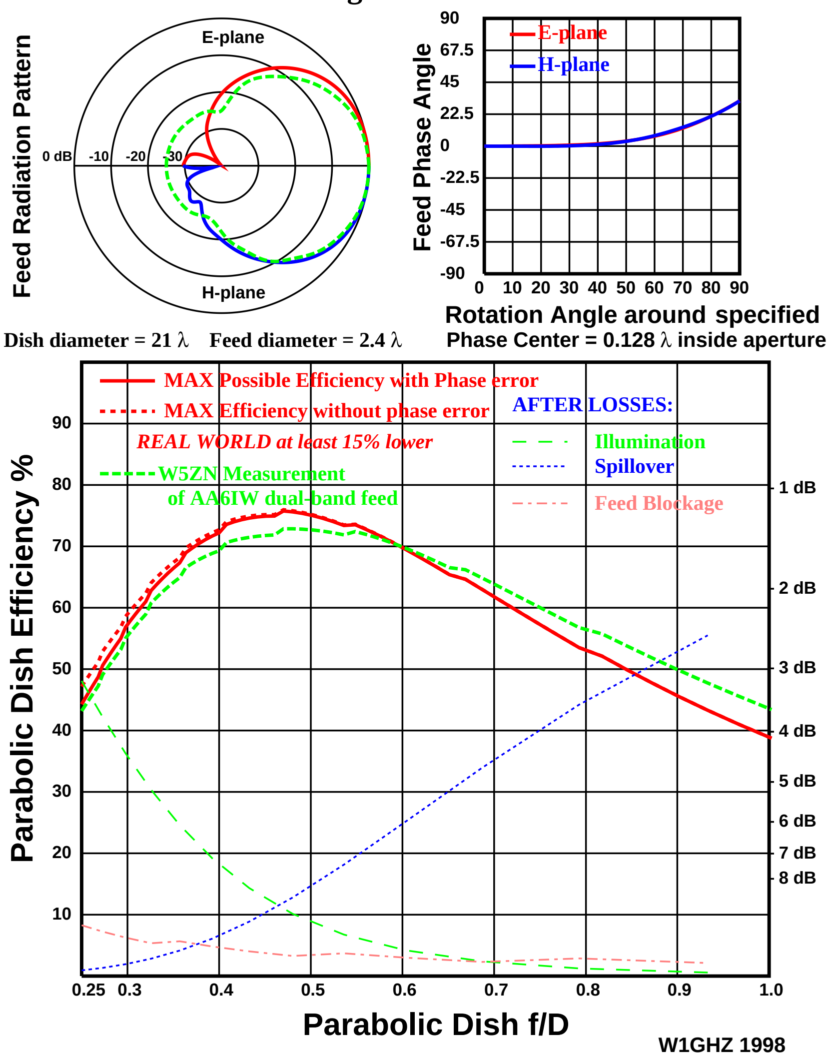
For both bands, the best ***f*/D** is in the 0.4 to 0.5 range, but the phase centers are farther apart: in the center of the aperture at 10 GHz, and 0.3λ inside the aperture at 24 GHz. Because of the wide frequency separation, using the 24 GHz phase center for both bands caused very little degradation at 10 GHz.

Since the addition of the choke rings improved the 10GHz efficiency at the expense of 24 GHz performance, perhaps moving the rings back away from the horn aperture might find a better balance. Backing off the rings by ¼λ at 24 GHz, or about 3mm, produced the desired result: Figure 6.3-23 shows better 24 GHz efficiency without significantly decreasing the 10 GHz performance. Also, the phase center is very close to the center of the aperture at both frequencies. This feed can really provide excellent performance at both bands for an ***f*/D** range around 0.4 to 0.5.

Both versions of this feedhorn are pretty good for dual-band operation at 10 and 24 GHz, with the plain version favoring 24 GHz and the ones with choke rings favoring 10 GHz. Perhaps further optimization of the dimensions could better balance the compromise. The best choice for very small dishes would be the plain feed to minimize feed blockage.

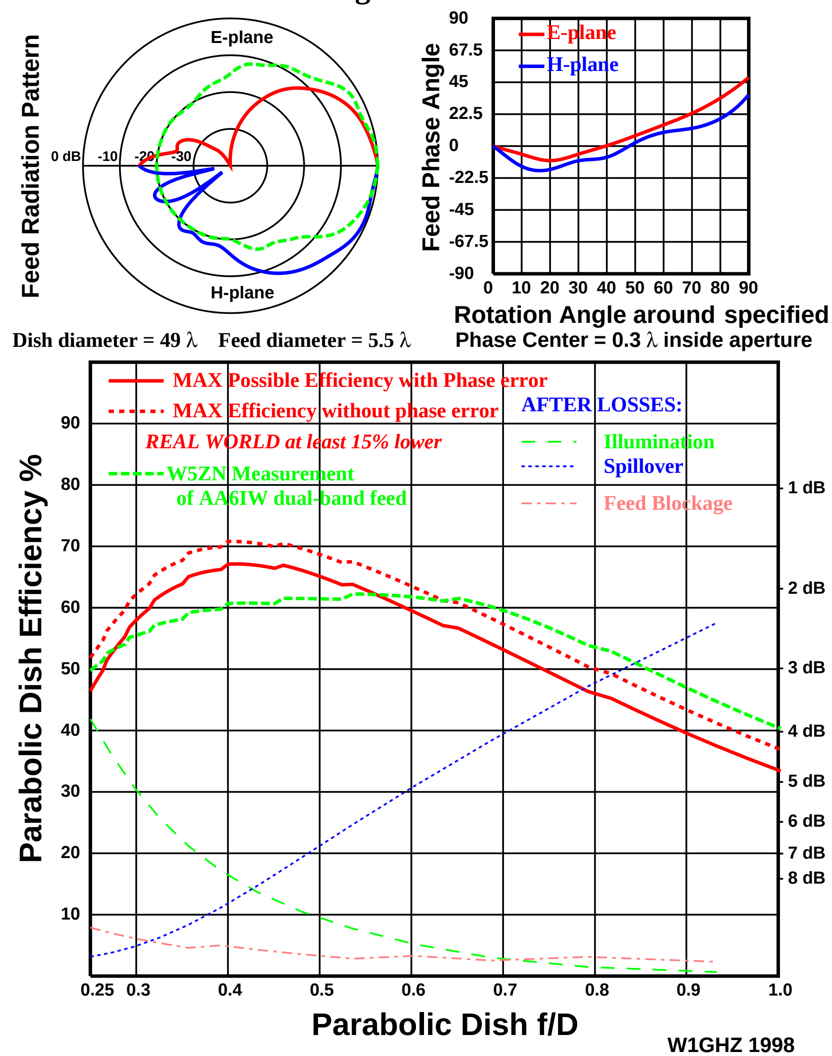
W5ZN dual-band feed with choke rings at 10.368 GHz,
by Zeland Fidelity™

Figure 6.3-22a



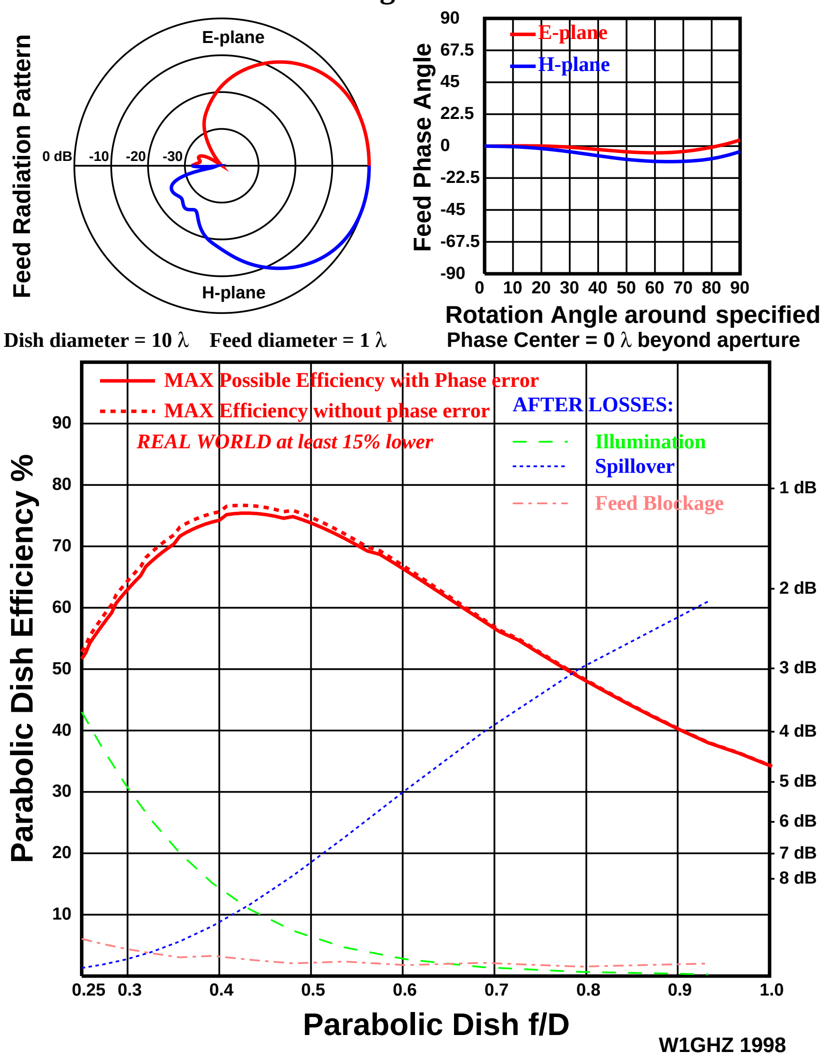
W5ZN dual-band feed with choke rings at 24.192 GHz,
by Zeland Fidelity™

Figure 6.3-22b



Dualband 10 & 24 GHz feed at 10 GHz with choke back 3 mm, by Zeland Fidelity™

Figure 6.3-23a



Dualband 10 & 24 GHz feed at 24 GHz with choke back 3 mm, by Zeland Fidelity™

Figure 6.3-23b