Chapter 6
Feeds for Parabolic Dish Antennas
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Section 6.7 Other feeds

The feeds in this chapter are those that don't fit in any of the other categories. One thing they seem to have in common is a lack of design methodology: no explanation is given for why they should work, so there is no way of telling how the dimensions given were derived. In most cases, the dimensions were arrived at empirically, but performance data is sketchy or nonexistent, so we can't tell if some of these feeds really work. Where possible, I used **NEC2** computer modeling for the feeds, but some of the arcane topologies make modeling very difficult. For those feeds, I include published data where available. Finally, for the popular "Penny" feed, data was not available and good modeling seemed unlikely, so I built one and measured the pattern.

6.7.1 Clavin Feed

A feed described by Clavin[1] in 1974 is a cavity antenna fed by a resonant slot. Probes on either side of the slot excite the $\mathbf{TM}_{11}$ waveguide mode in addition to the dominant $\mathbf{TE}_{11}$ mode to broaden the E-plane pattern to match the H-plane — this is a dual-mode feed. The feed is physically small and can be built with hand tools; Figure 6.7-1 is a photograph of a 10 GHz version that I made from a 1-inch copper plumbing pipe cap. Dimensions are shown in Figure 6.7-2, and a photograph of a 5760 MHz version made by K1DPP is shown in Figure 6.7-3. The resonant slot makes this feed rather narrowband — if you are building one, make the slot slightly short and file it for good VSWR.

I've used the Clavin feeds successfully on small dishes at 10 GHz[2] and 5760 MHz[3]. Figure 6.7-4 is a plot of Clavin's original published data, with best efficiency at an ***f*/D** around 0.35 to 0.4. Peak efficiency is not as high as some other feeds. However, on small dishes the efficiency of the better feeds would be reduced by feed blockage. I measured[2] 53% efficiency on an 18-inch dish with ***f*/D** = 0.42.

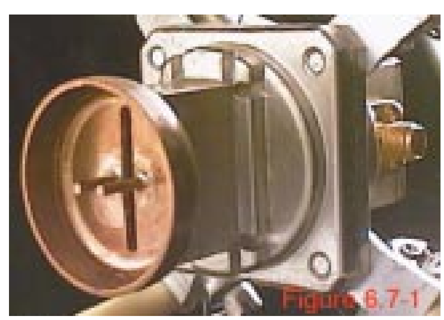
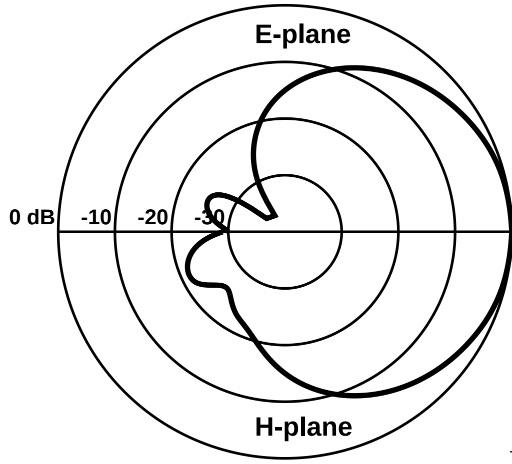


Figure 6.7-1

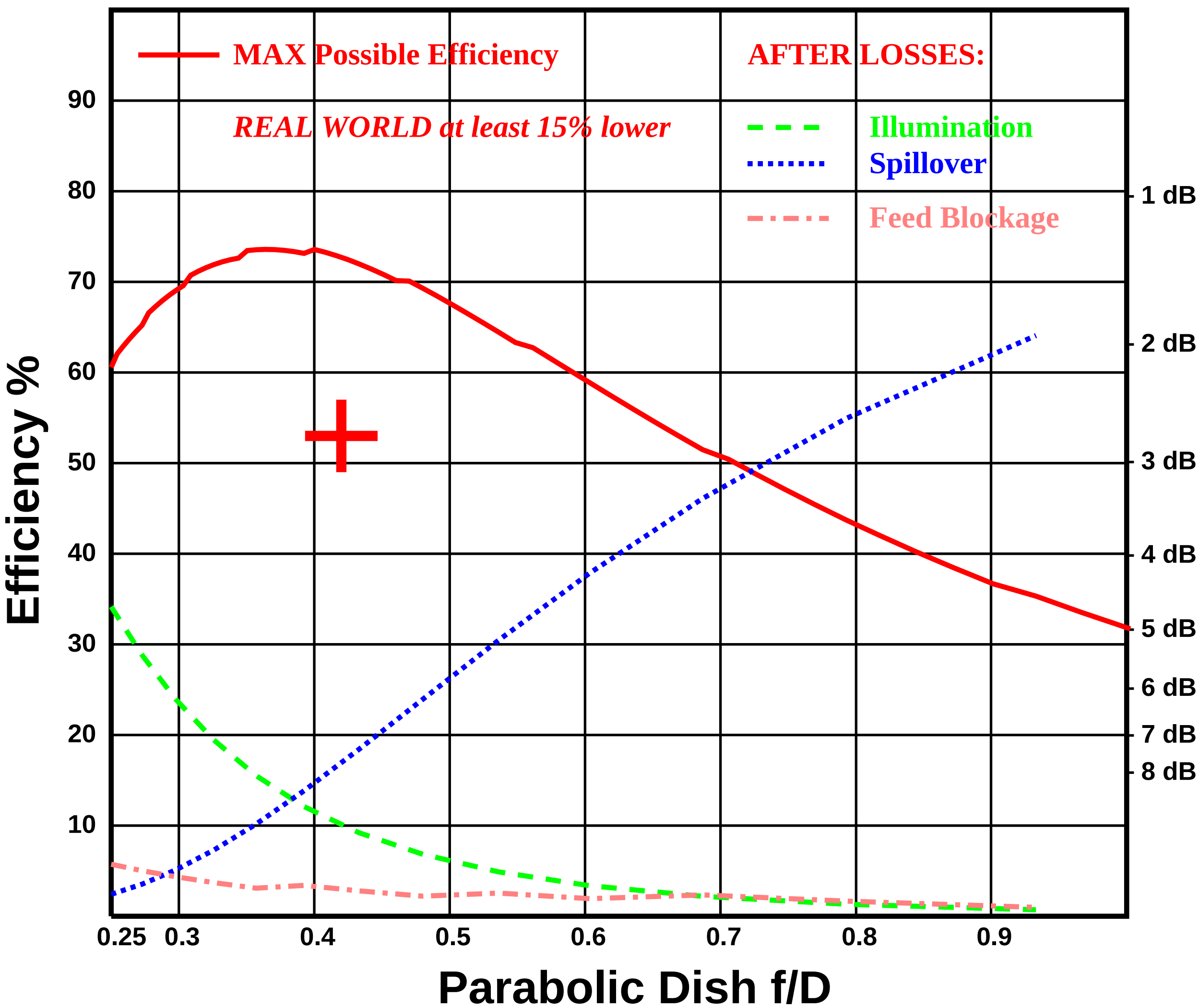
Clavin Feed (1974) from published data

Figure 6.7-4



N1BWT 1997

Dish diameter = 9 λ
Feed diameter = 0.88 λ



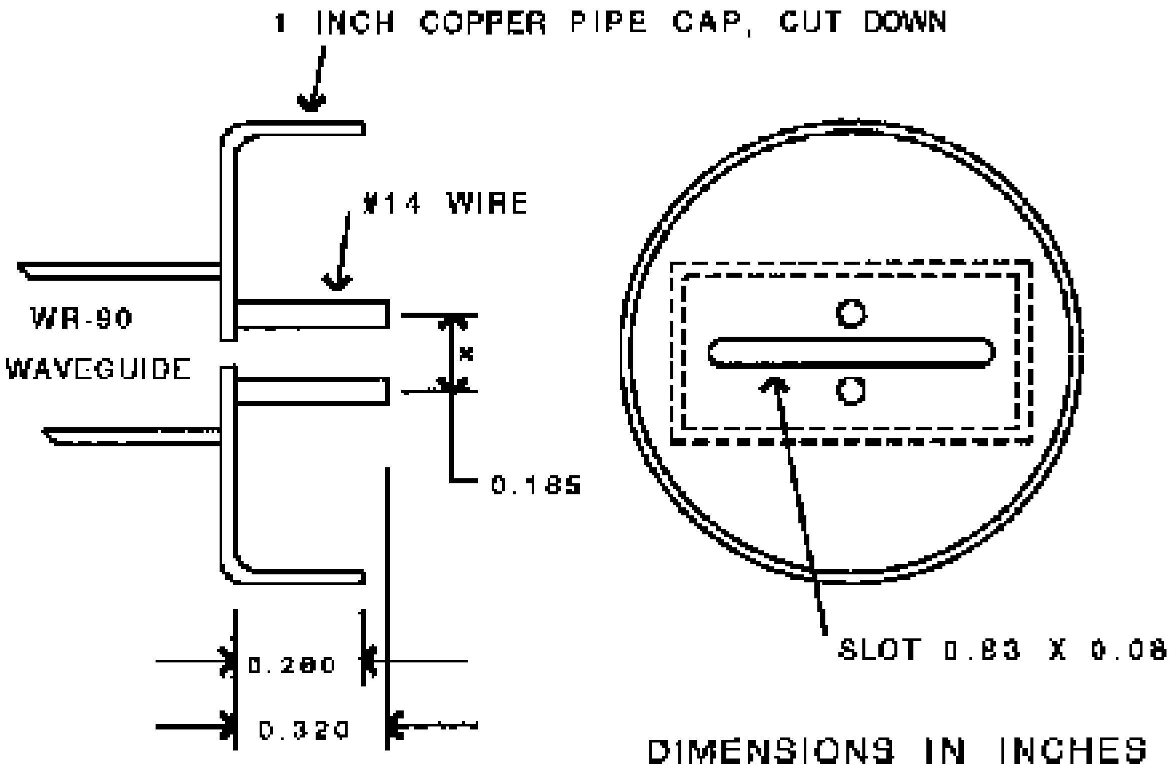


Figure 6.7-2

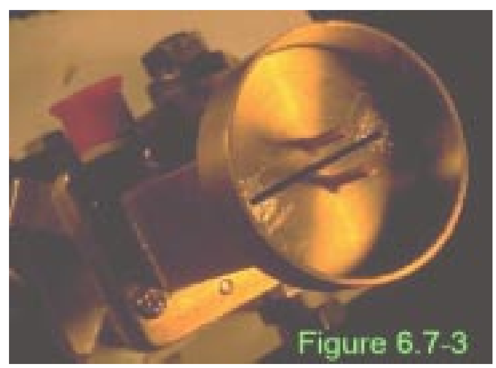


Figure 6.7-3

Only the amplitude data was published for this feed, and it would be difficult to model for NEC2 calculation. Thus, the calculated efficiency in Figure 6.7-4 does not account for possible phase error.

6.7.2 Backward or rear feeds

An enticing way to feed a conventional dish is with a waveguide through the center of the dish. The waveguide is both feedline and feed support. There are a few feeds that radiate backwards, along the incoming waveguide toward the reflector. We shall refer to these as backward or rear feeds. A backward feed providing good performance would be an ideal solution.


Figure 6.7-5b

A popular backward feed in Britain is the **G4ALN "Penny" feed**[4], shown in Figure 6.7-5a. It consists of an old (pre-decimalisation) English penny soldered to the end of a waveguide, with slots in the broad walls of the waveguide. I built one to test in 1995; the only English coin I had of the right diameter was ten new pence rather than an old penny (Scots must be aghast!), but silver should work at least as well as copper. The feed, shown close up in Figure 6.7-5b, is easy to build and has good VSWR, so it is easy to see why it is popular.

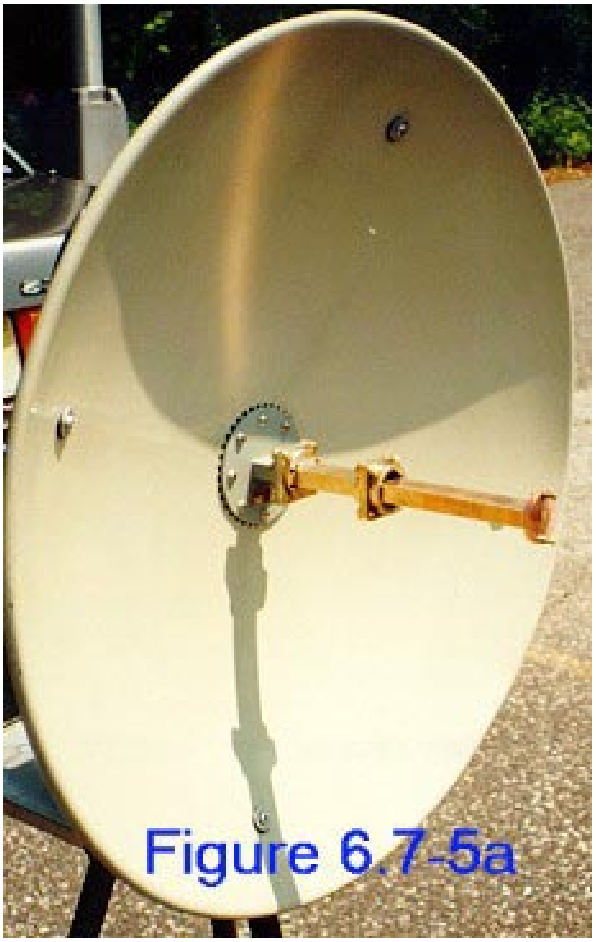


Figure 6.7-5a

On an antenna range, we measured[2] a disappointing efficiency of 41.5% feeding a 25-inch dish with ***f*/D** = 0.45. Since no radiation patterns have been published and modeling would be difficult, I measured the E- and H-plane patterns at 10.368 GHz. These are plotted in Figure 6.7-6, with mediocre efficiency peaking at an ***f*/D** around 0.25 and falling off significantly for the measurement dish ***f*/D** of 0.45. Since only amplitude data was measured, the calculated efficiency does not include phase error. However, for very deep dishes with ***f*/D** ~ 0.25, the Penny feed might be a reasonable choice since there aren't many feeds that provide better efficiency. A better choice would be a shallower dish!

Other variations[5] on the Penny feed have been described, with the round penny replaced with various shapes of metal with sundry bends, but these probably don't change the performance greatly.

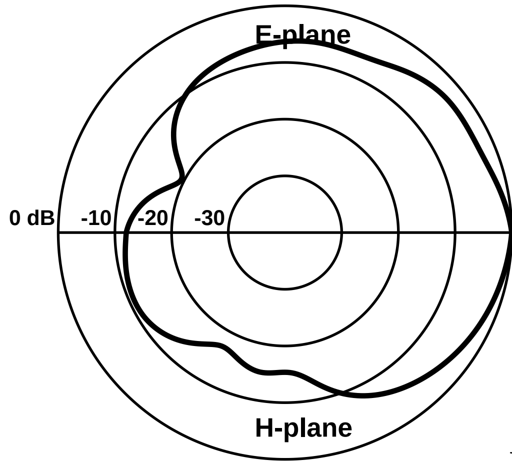
Clavin described another feed in 1954[6] which appears to be a dipole projecting through the broad sides of a waveguide, with a cavity reflector at the end of the waveguide so that the radiation is backwards along the incoming waveguide. The plot of the published radiation pattern in Figure 6.7-7 shows lower efficiency than the 1974 version in Figure 6.7-4.

The **1954 Clavin feed** is described as a significant improvement on those World War II vintage feed designs found in the old books (unfortunately, some newer books keep copying them). One type of vintage feed[7] has a flat metal projecting from the end of an open rectangular waveguide. The strip is the full width of the waveguide and is centered in the narrow dimension. A stubby dipole and reflector are centered in the flat metal strip, so it looks like a two-element Yagi with a flattened boom pointing back past the waveguide mouth toward the dish. In operation, the dipole is excited by radiation from the open waveguide, but it is hard to imagine that it would work well.

Other types of vintage feeds have some sort of cavity at the end of the waveguide with slots facing the reflector. One variation, which I has been referred to as a **"pillbox" feed**, is sold by **Procom**[8] for 10 GHz, with a claimed 27 dBd gain on a 480 mm dish, which works out to about 30% efficiency. This probably qualifies as truth-in-advertising, a rare commodity in antenna advertising.

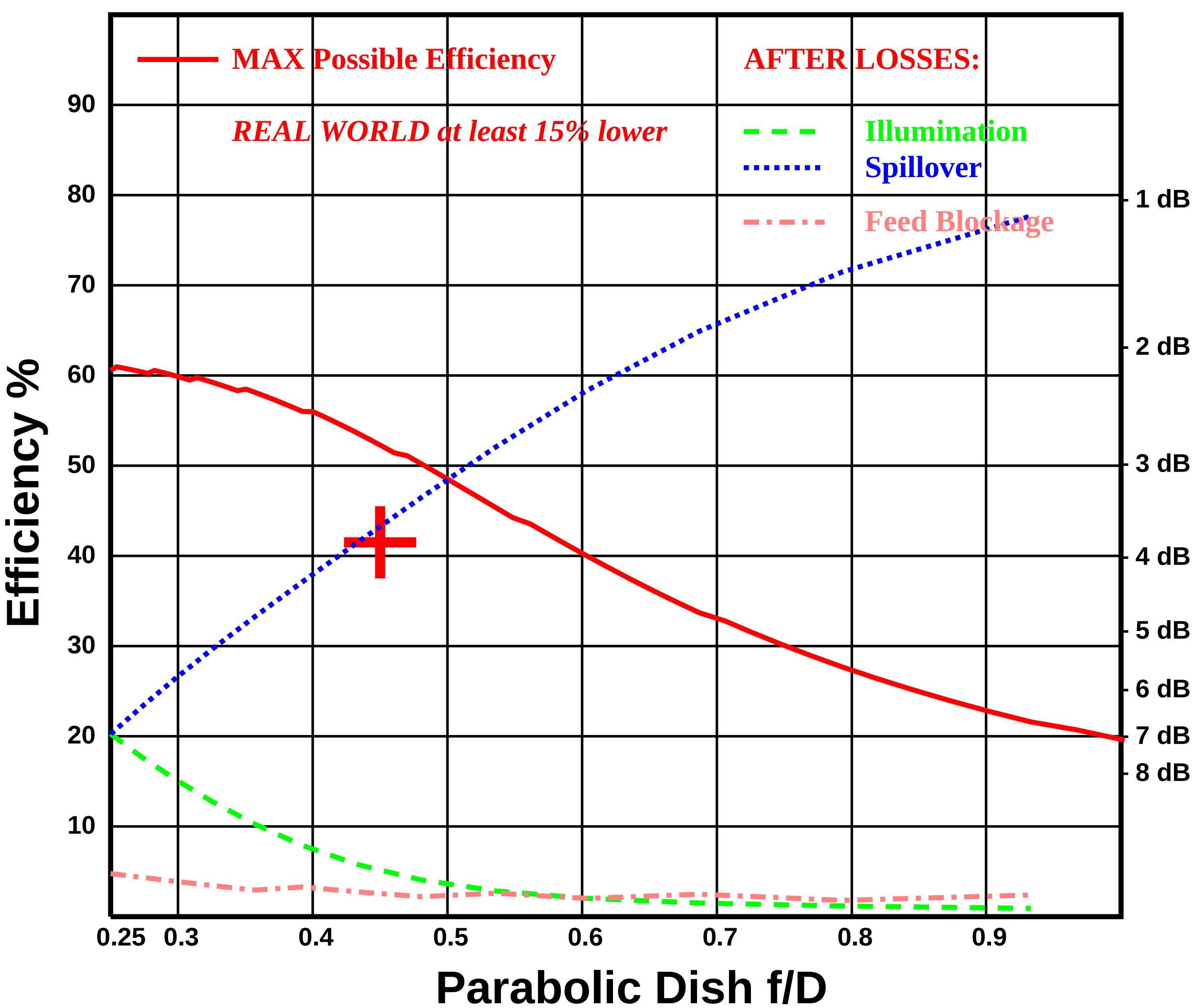
G4ALN Penny Feed measured at 10.368 GHz

Figure 6.7-6



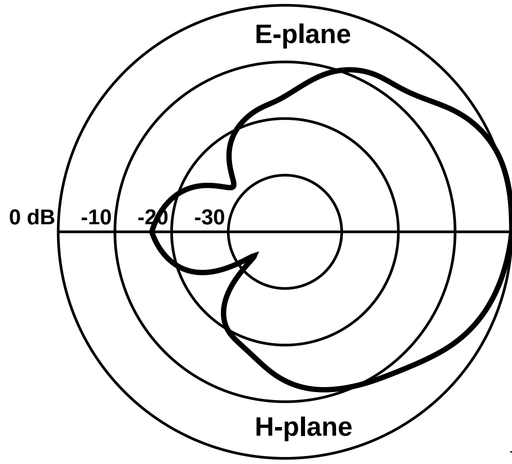
N1BWT 1997

Dish diameter = 10 λ
Feed diameter = 0.98 λ



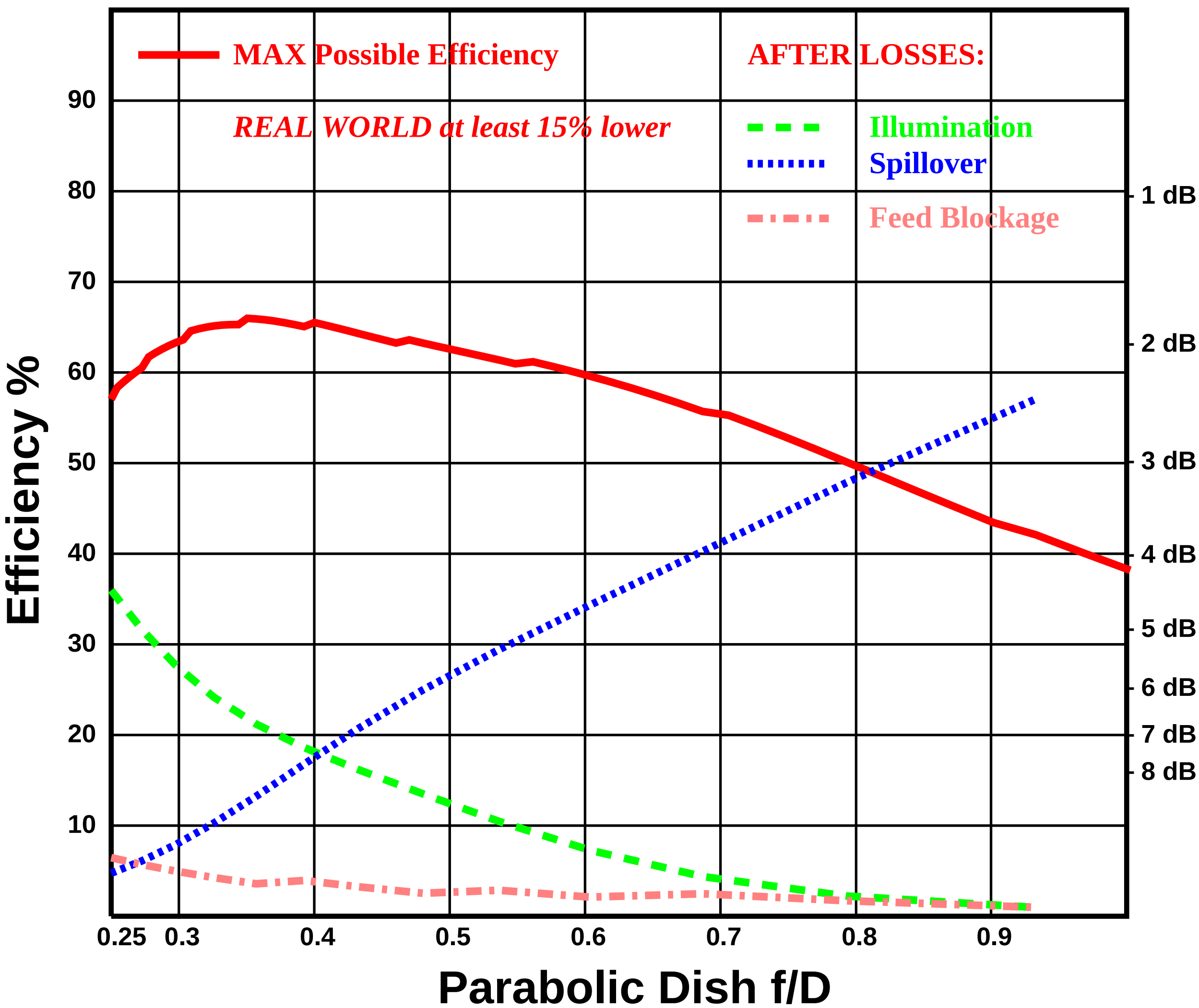
Waveguide Dipole with Cavity Reflector (Clavin 1954)

Figure 6.7-7



N1BWT 1997

Dish diameter = 9 λ
Feed diameter = 0.88 λ



The *RSGB Microwave Manual*, *Volume 3* describes an **indirect rear feed**[7] with a flat disc subreflector partway between the reflector and the focus, illuminated by a horn fed through the center of the dish. The illustrated geometry is such that the illumination angles for the dish and the disc subreflector coincide, so that the reflected feedhorn is a mirror image of the direct feed. When the indirect feed geometry is sketched out using geometric ray-tracing, a common optical technique illustrated in Figure 6.7-8, it looks like it should work.

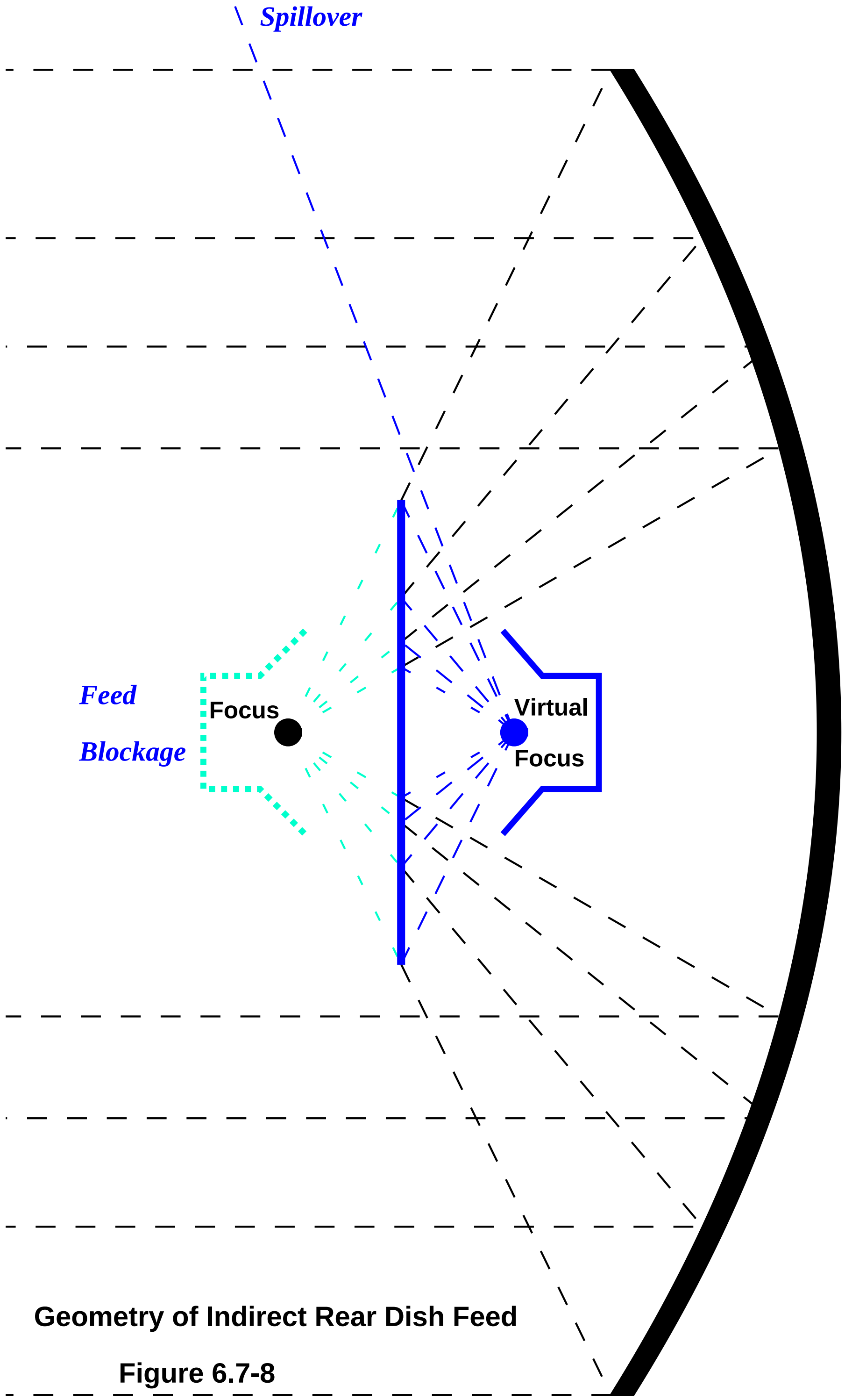
I made an **NEC2** model of the indirect feed using a 2.4λ diameter disc subreflector illuminated by a conical horn of 1.3λ diameter. First, I calculated the radiation pattern of the horn as a direct primary feed. Figure 6.7-9 shows this horn to provide very good efficiency for ***f*/D** around 0.5. The phase center is 0.06λ inside the center of the aperture — information necessary for positioning the indirect feed horn and subreflector. Then I used **NEC2** to calculate the radiation pattern for the indirect feed, as shown in Figure 6.7-10. The results are not good, with large spillover loss due to poor front-to-back ratio and large sidelobes.

6.7.3 Diffraction

A rule-of-thumb is that ray optics do not work well for reflector dimensions less than ~10λ, due to diffraction. Figure 6.7-11 adds some diffraction effects to the indirect feed geometry, shown in red. Diffraction occurs at every edge and results in energy scattering around the edge in all directions. The significant edge in this case is the perimeter of the subreflector, which is illuminated with a significant energy level.

When seen from the far-field, the horn appears to radiate from a single phase center; mirror reflections from the subreflector and parabolic reflector still appear to come from the phase center. However, the subreflector edge not a reflector; since it is very close to the horn, not in the far field, the horn radiation is a broad curved wavefront. Figure 6.7-11 shows how the subreflector edge is a varying distance from different parts of this curved wavefront, so that the edge illumination is not of constant phase. As a result, the diffracted radiation scattered from the edge will have peaks and valleys at different angles, adding sidelobes to the pattern. One additional factor is the spillover that misses both reflectors and contributes to the sidelobes.

How can we quantify the effects of diffraction? The mathematics appear rather difficult, more than I care to tackle at the moment. However, a couple of antenna books[9,10] do discuss diffraction loss in Cassegrain antennas with small subreflectors; the Cassegrain uses a hyperbolic subreflector. Diffraction losses for small flat disk subreflectors should be in the same ballpark. The two books have slightly different numbers, so I have plotted both in Figure 6.7-12. The blue curve shows a diffraction loss of almost 5 dB for the 2.4λ diameter subreflector of Figure 6.7-10; using the right hand scale on the efficiency plot, we can see that the indirect feed efficiency is roughly 5 dB lower than the direct feed in Figure 6.7-9.

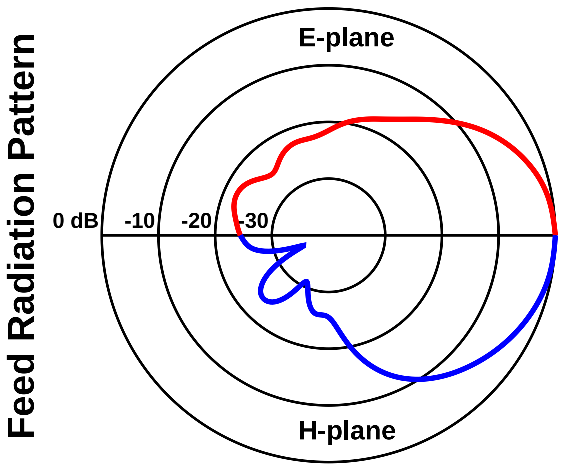


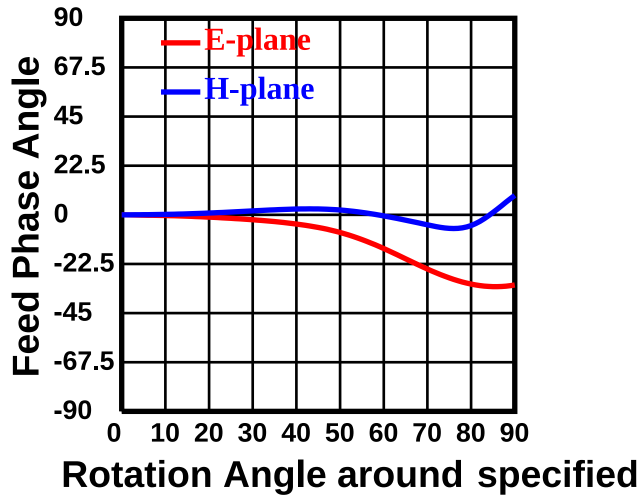
Geometry of Indirect Rear Dish Feed

Figure 6.7-8

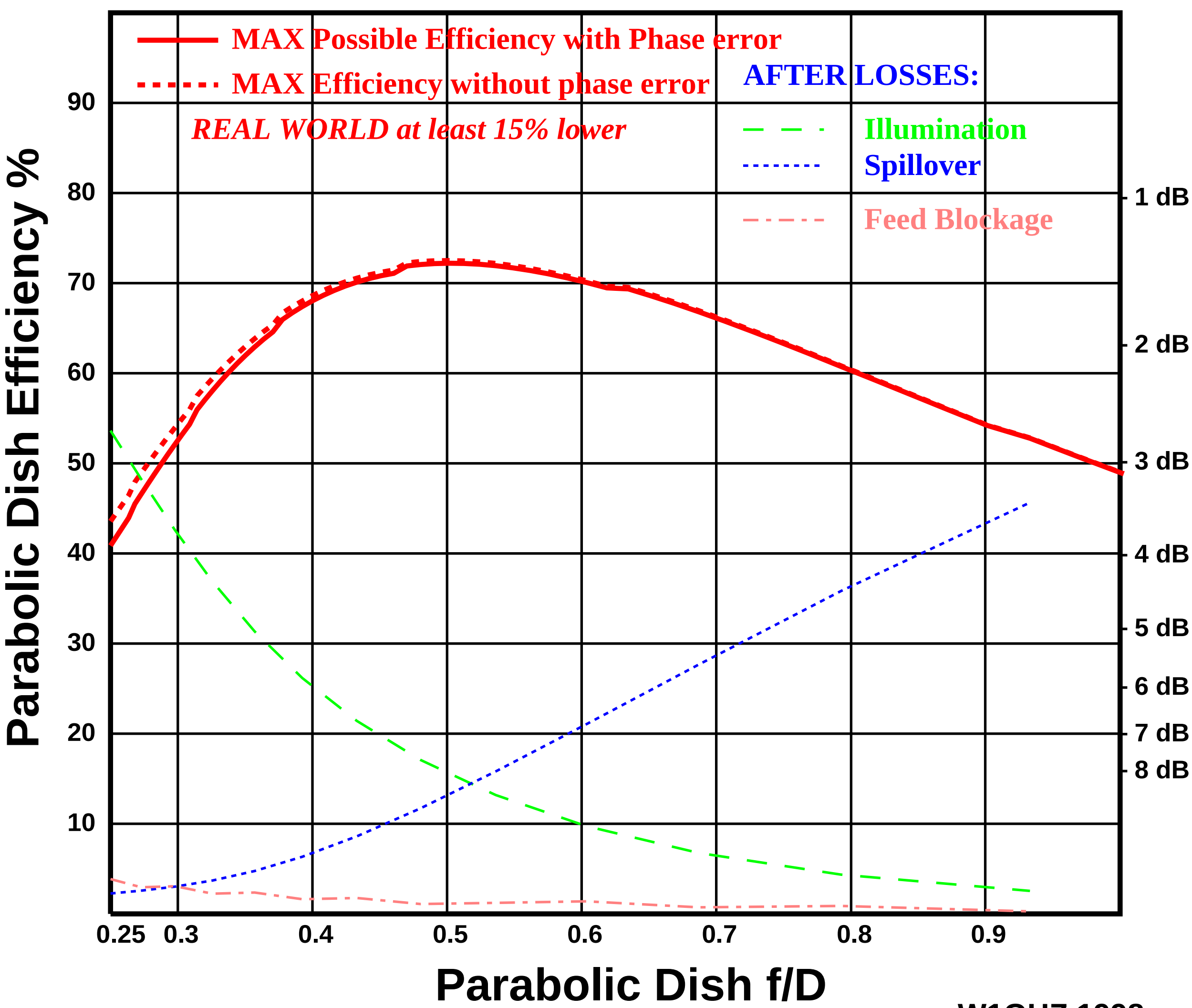
Conical horn feed, 1.3l diameter, 60 deg flare, by NEC2

Figure 6.7-9





Dish diameter = 20 λ   Feed diameter = 1.3 λ   Phase Center = 0.06 λ inside aperture



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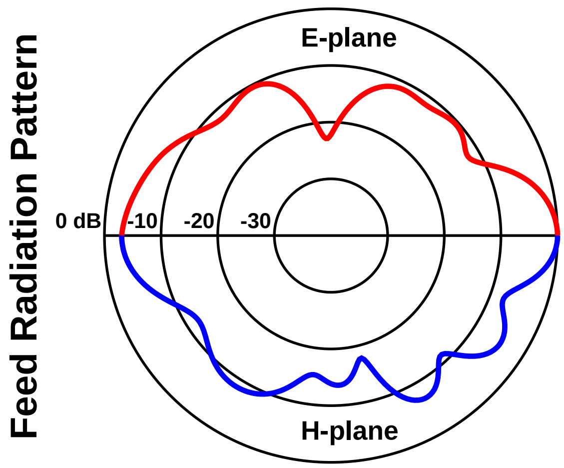
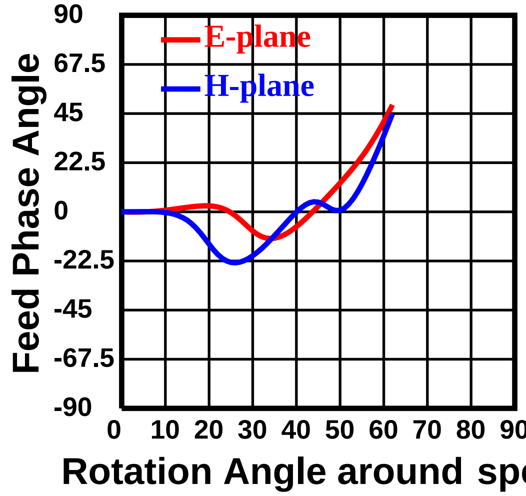
RSGB indirect rear feed, 2.4λ dia disk subreflector, by NEC2

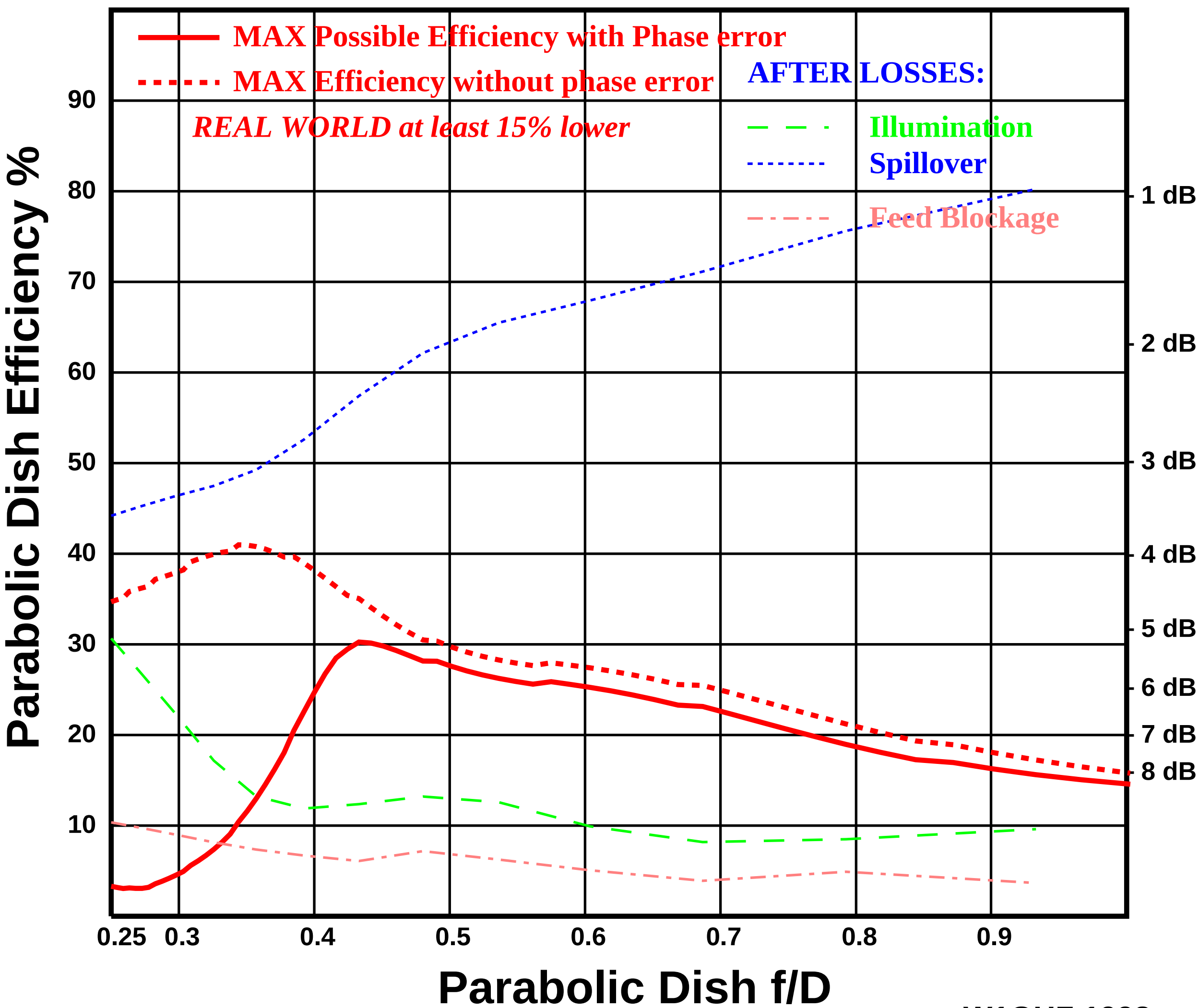
Figure 6.7-10





Dish diameter = 20 λ   Feed diameter = 2.4 λ

Phase Center = 0.5 λ inside aperture



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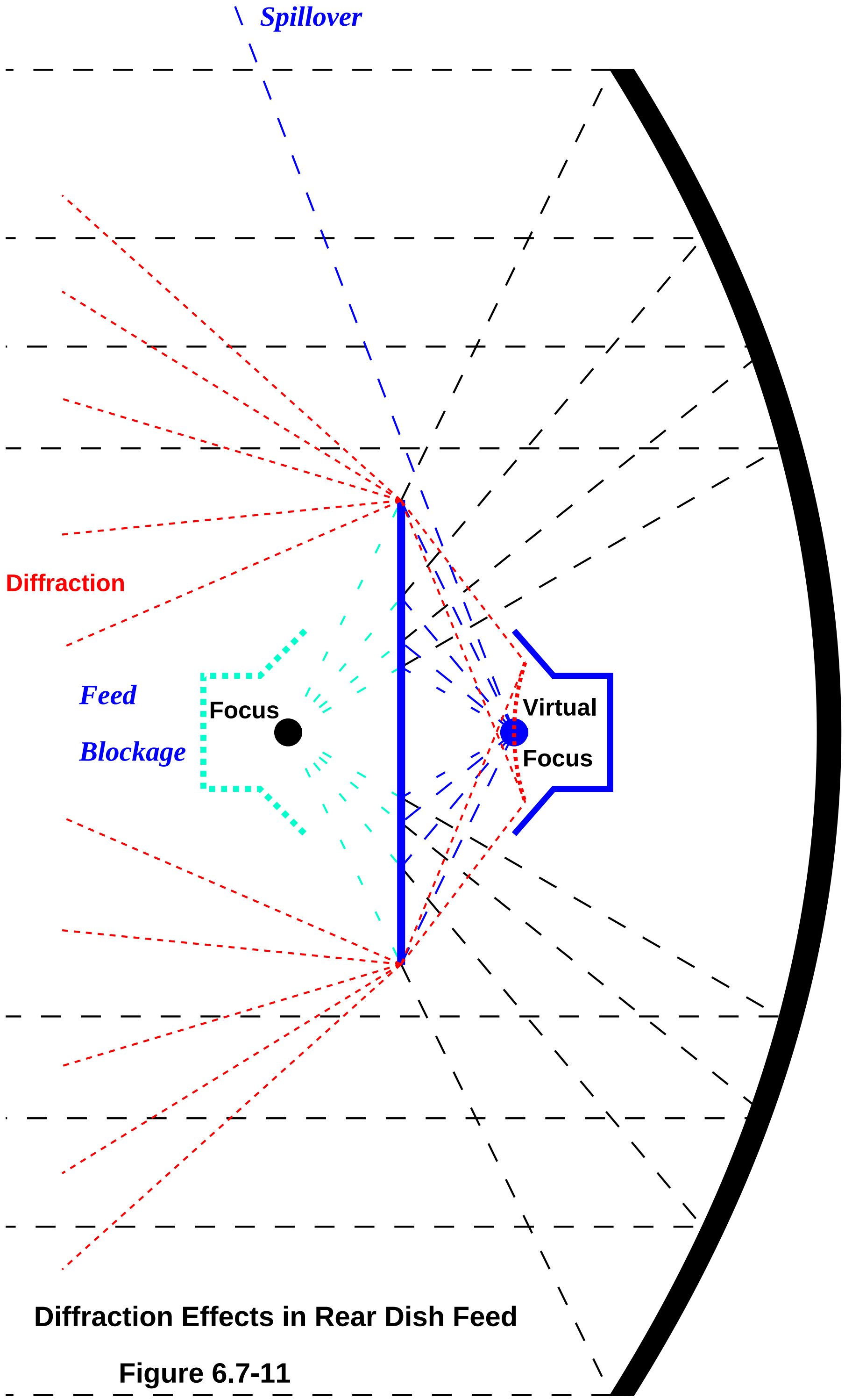
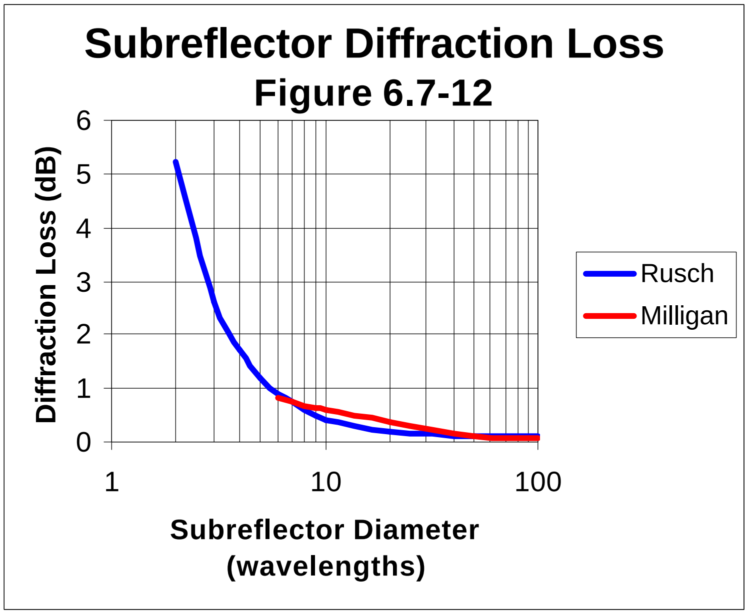


Diffraction Effects in Rear Dish Feed

Figure 6.7-11



Subreflector Diffraction Loss
Figure 6.7-12

It might occur to you to ask how the dipole-splasher feed in Figure 6.2-2 works well with a reflector diameter of only ½l. The answer is that a the splasher is a parasitic element like the reflector of the 2-element Yagi feed in Figure 6.2-1 — the elements are tightly coupled to the dipole and shape the field to affect the radiation pattern. The reflector and subreflector of a dish antenna function like mirrors and suffer from diffraction when they are small in terms of wavelengths.

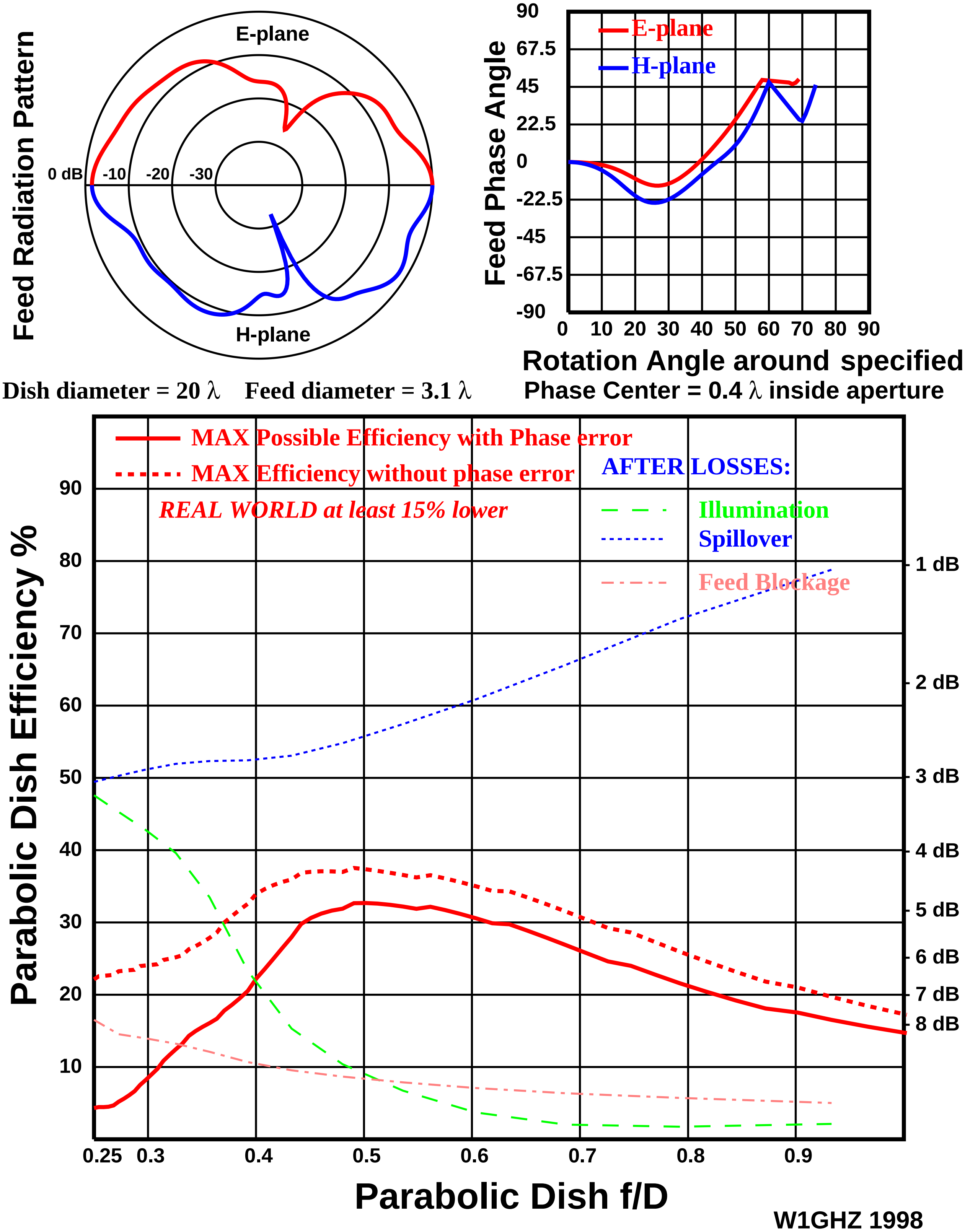
6.7.4 Backward or rear feeds continued

If diffraction loss is increases for small subreflectors, then larger subreflectors should work better. I tried increasing the subreflector disc diameter in steps, adjusting other dimensions appropriately, to 3.1λ, before **NEC2** ran out of memory. The larger discs provide a small improvement in efficiency, shown in Figure 6.7-13, but it is still far worse than the same horn used as a direct feed. Varying the other dimensions affected the ***f*/D** for best efficiency, but didn't improve the efficiency — the diffraction loss is still large.

Shortly thereafter, my new employer provided me with a faster PC with more memory: a 500 MHz Pentium 3 with 128 Megabytes of RAM. Since it often sits idle overnight, I gave it some work: larger subreflectors. A 3.8λ diameter subreflector shows slightly better efficiency in Figure 6.7-14, but even larger subreflectors do not. The 4.8λ diameter subreflector in Figure 6.7-15 and the 5.6λ diameter subreflector in Figure 6.7-16 have decreasing calculated efficiencies. Closer examination of the plots shows why: the feed blockage due to the larger subreflectors is lowering the efficiency. Recalculating the

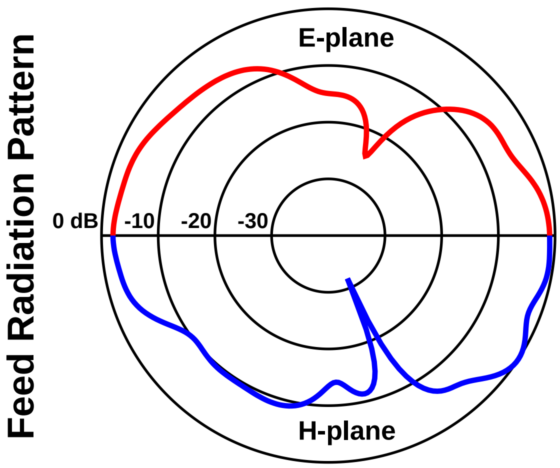
RSGB indirect rear feed, 3.1λ dia disk subreflector, by NEC2

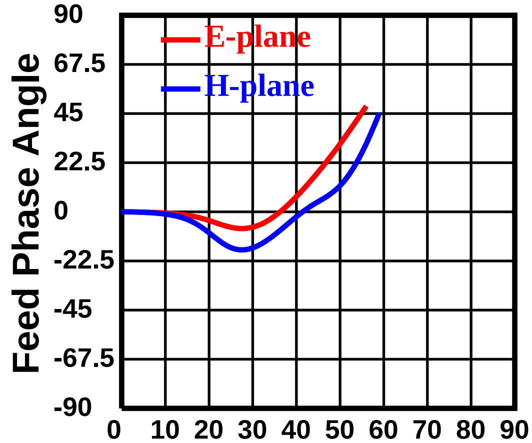
Figure 6.7-13



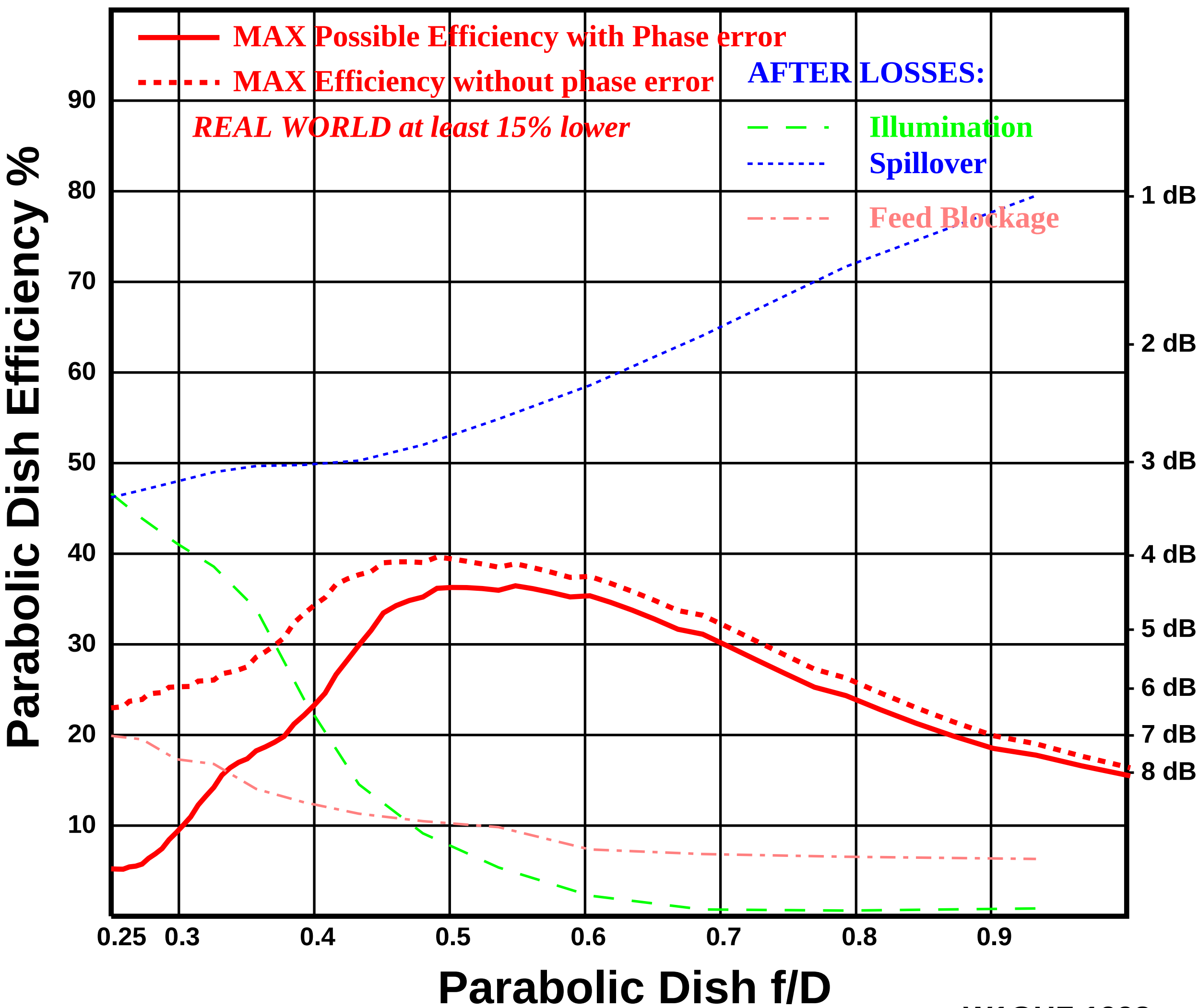
RSGB indirect rear feed, 3.8λ dia disk subreflector, by NEC2

Figure 6.7-14





Dish diameter = 20 λ Feed diameter = 3.8 λ



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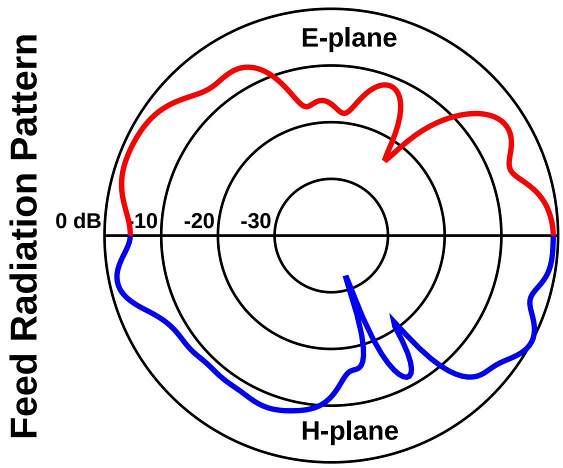
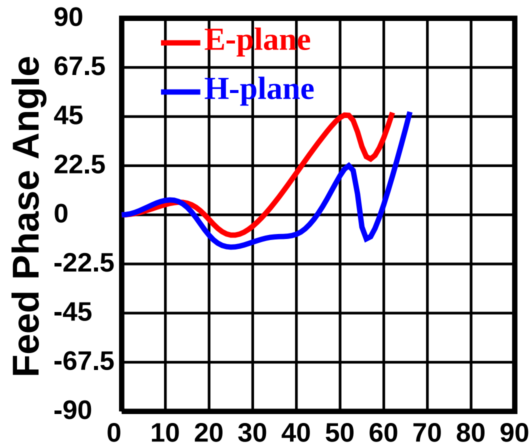
RSGB indirect rear feed, 4.8λ dia disk subreflector, by NEC2

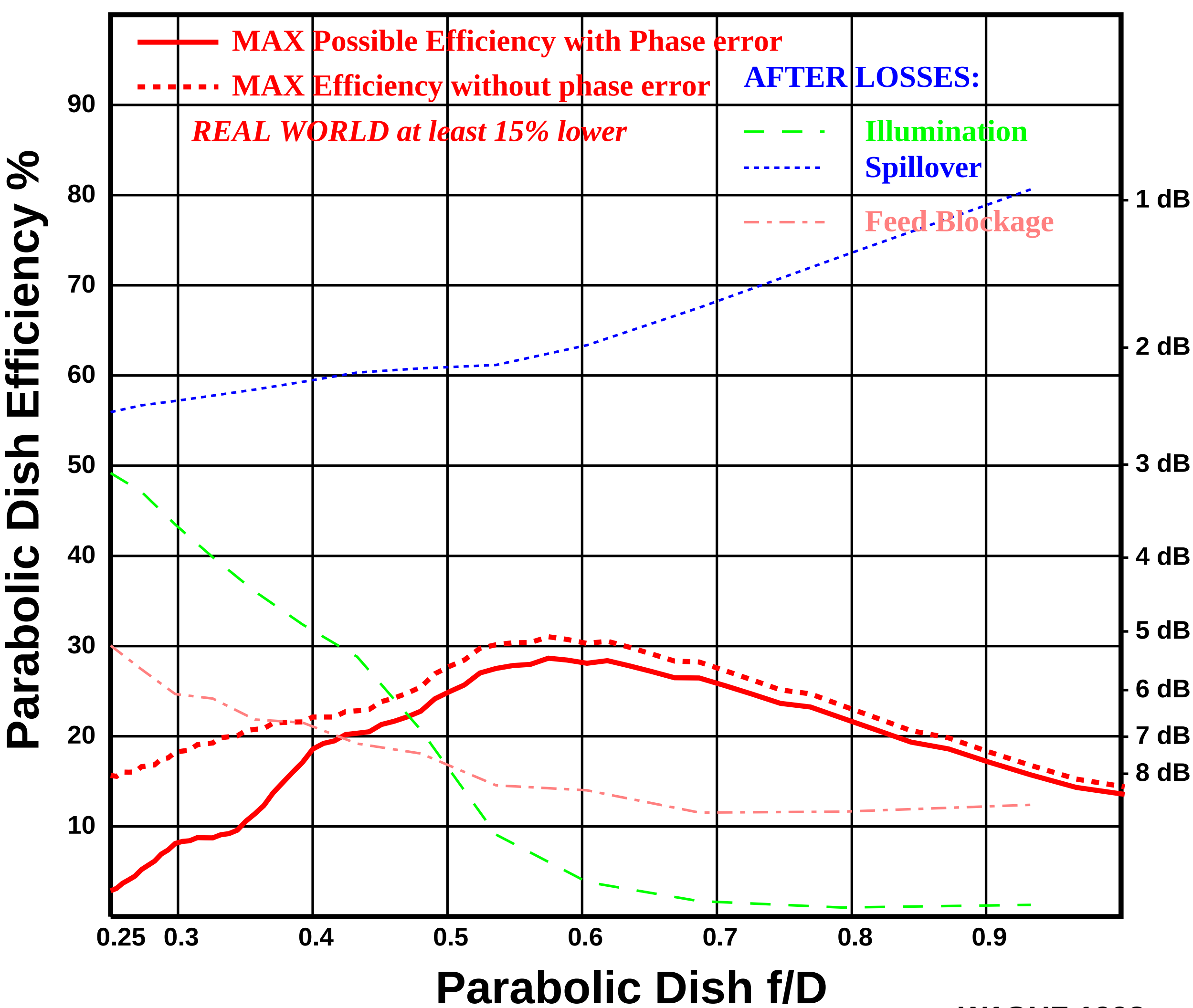
Figure 6.7-15





Rotation Angle around specified Phase Center = 0.13 λ inside aperture

Dish diameter = 20 λ   Feed diameter = 4.8 λ



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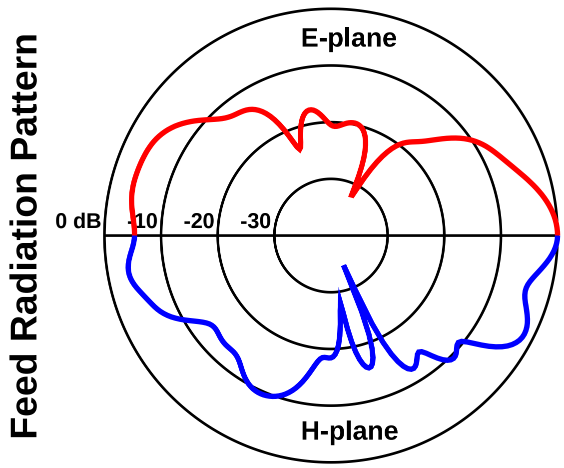
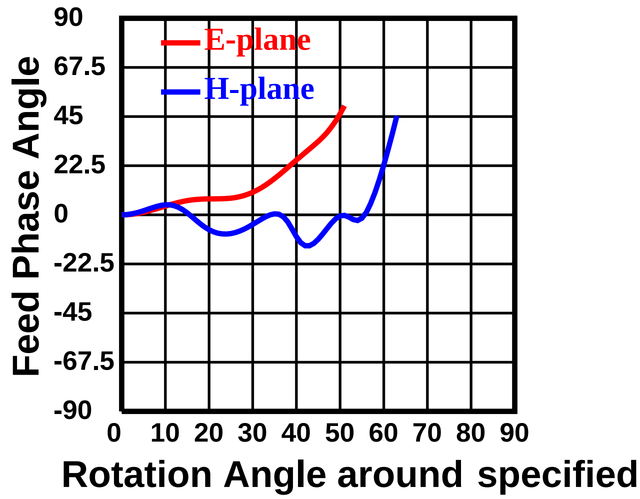
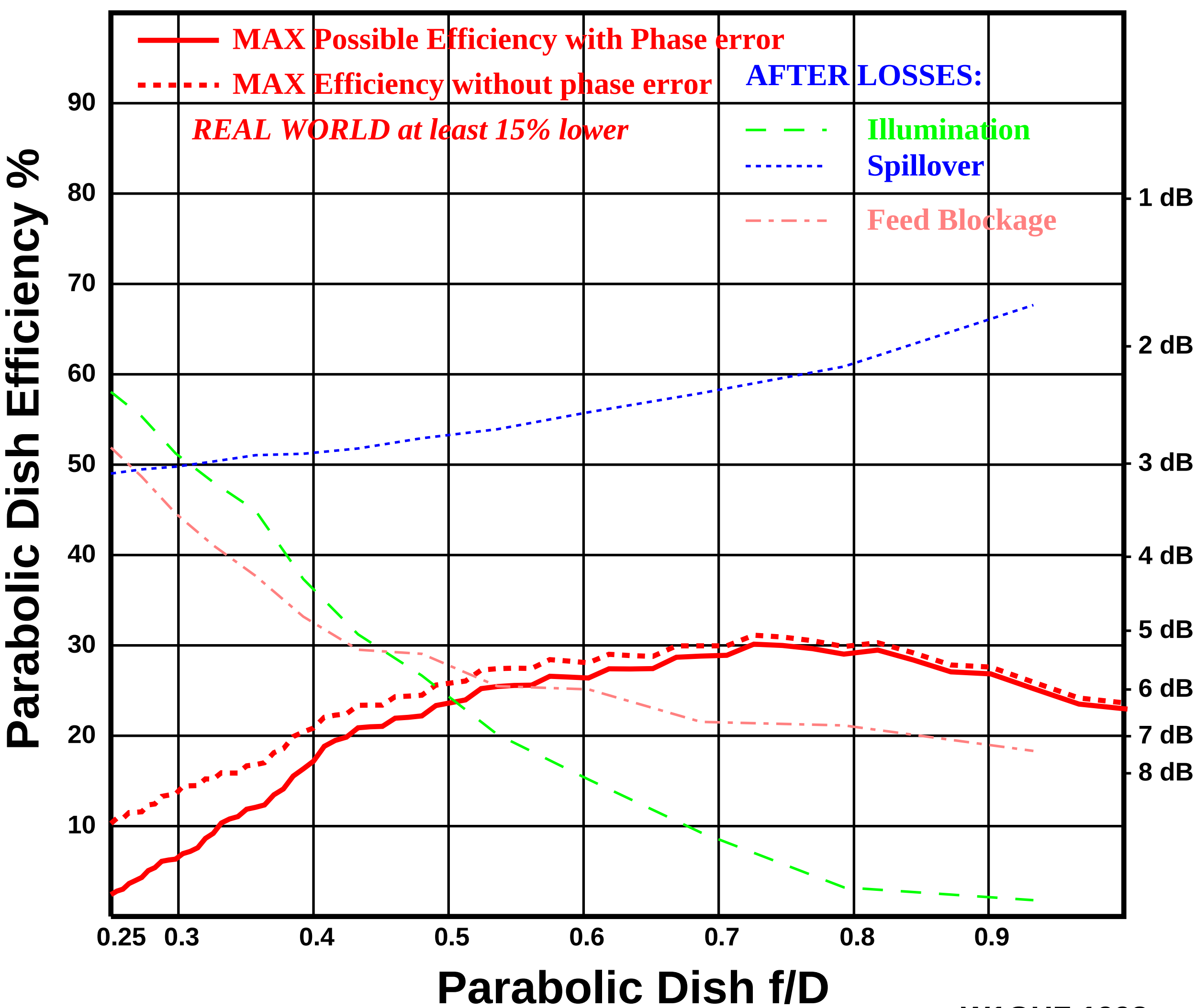
RSGB indirect rear feed, 5.6λ dia disk subreflector, by NEC2

Figure 6.7-16





Dish diameter = 20 λ   Feed diameter = 5.6 λ   Phase Center = 0.1 λ inside aperture



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5.6λ diameter subreflector with a very large main reflector raises the calculated efficiency to around 40%, still far lower than provided by a direct feed.

At this point, **NEC2** was again running out of memory, so larger subreflectors were not considered. Also, the 5.6λ diameter pattern took over an hour to calculate. Clearly, we are pushing the limits of computer simulation with today's hardware, and should remember that simulation is only an approximation. The real point is that it doesn't make sense to use an inefficient feed on a large dish.

Another alternative is to hammer the subreflector disc into a hyperbolic shape and make a true Cassegrain antenna[11]. This works well for large antennas, as we shall see in Section 6.10, but small reflectors will still suffer from significant diffraction loss. One analysis[12] suggested that a Cassegrain antenna must have a minimum diameter of 50λ, with a subreflector diameter of 20λ, before the efficiency is higher than an equivalent dish with a primary feed.

There are other rear feeds using small subreflectors. **DK2RV**[13] described a **circular waveguide rear feed**, with a small disk subreflector illuminated by an open circular waveguide. The radiation pattern calculated by **NEC2**, in Figure 6.7-17, is rather ugly. The H-plane pattern shows a regular sidelobe pattern as diffracted energy from the edge of the disk adds and cancels, and a poor front-to-back ratio. The disk diameter is 30 mm, barely one wavelength. DK2RV improved this feed by enlarging the disk to 60 mm and adding a 7 mm high rim toward the reflector. In Figure 6.7-18, the radiation pattern calculated by **NEC2** is improved somewhat, but the front-to-back ratio is still low due to diffraction around the edges.

The DK2RV feeds require complicated **NEC2** models and rather long run times, so I did not try to optimize them. There is probably a more optimum combination of feed position and disk spacing, since the measured efficiencies reported by DK2RV are better than the calculated values. However, at 35% efficiency for the plain disk version and 40% for the improved version, these are still low-performance feeds.

6.7.5 Summary

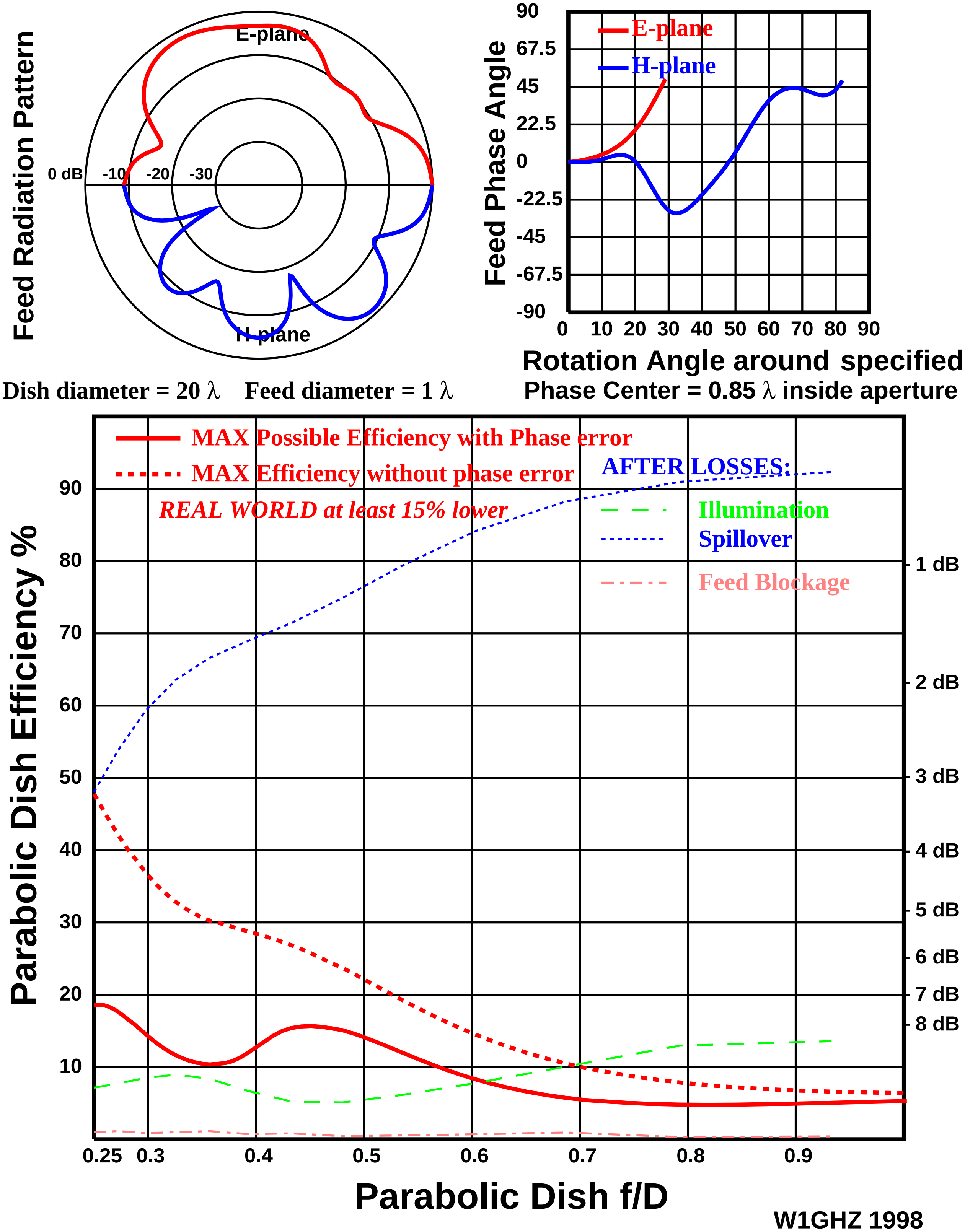

Figure 6.7-19

What the backward feeds seem to have in common is low performance — we are paying a price for convenience. The feed will appear to be working, since the dish will provide a sharp pattern and good gain — it's just that the gain is 3 or more dB below what is achievable with a good feed. Without measurements, it's easy to be fooled. In this league, the Penny feed is a stellar performer, but there are many superior primary feeds.

If a rear-fed antenna is important, a plain horn antenna can easily and reproducibly

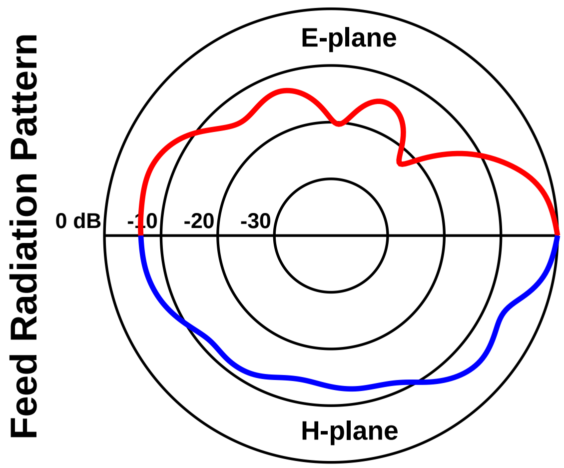
DK2RV circular waveguide rear feed with 30 mm disk, by NEC2

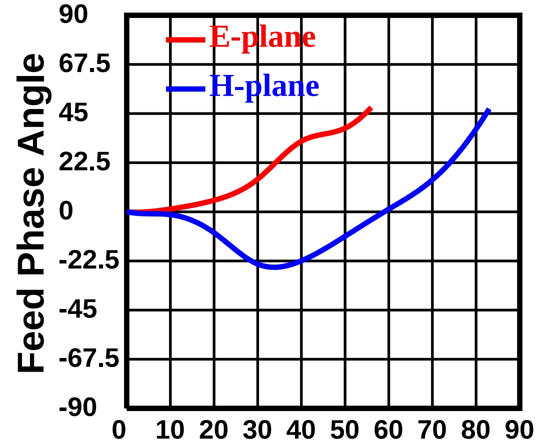
Figure 6.7-17



DK2RV circular waveguide rear feed, 60mm with rim, by NEC2

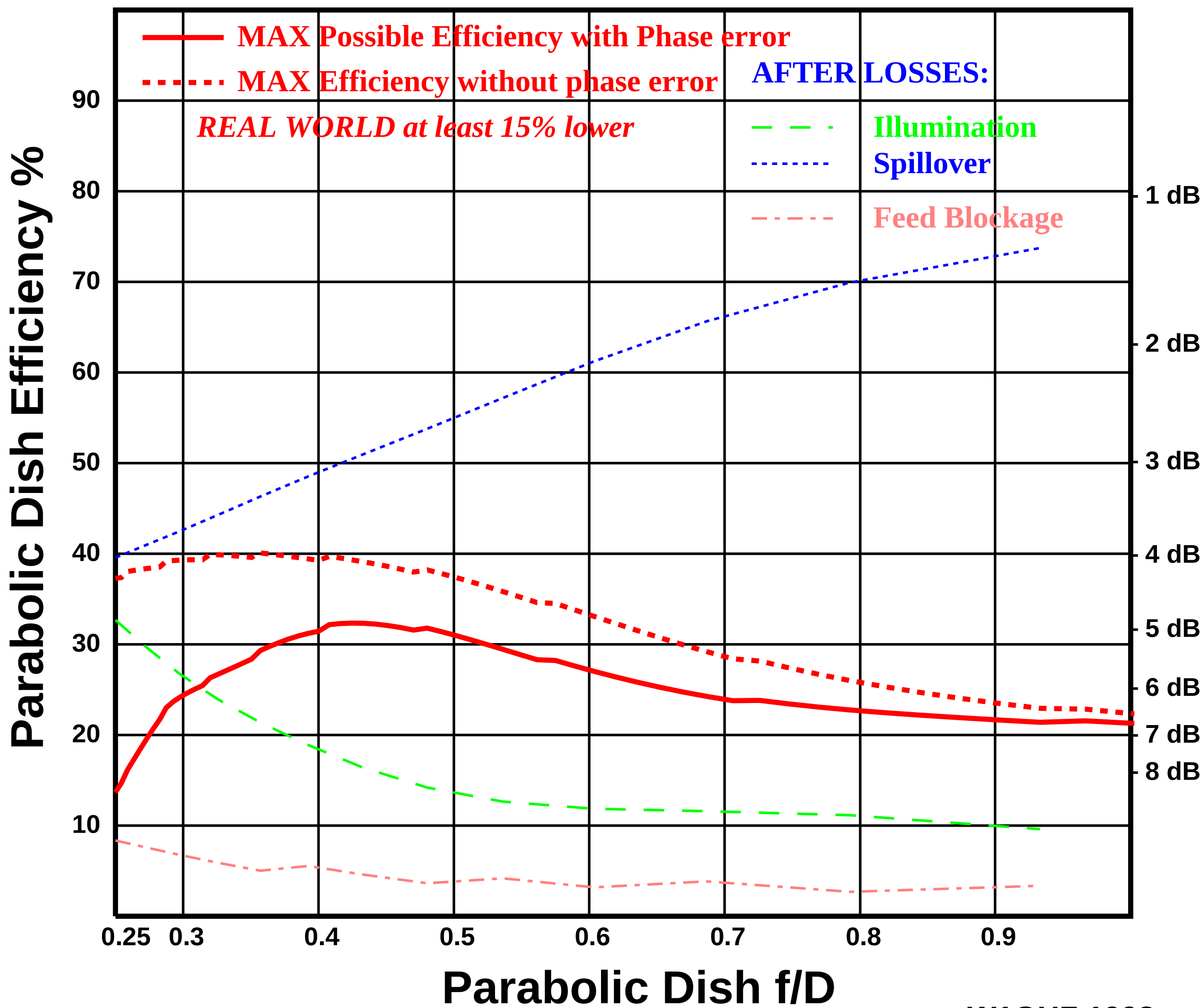
Figure 6.7-18





Dish diameter = 20 λ   Feed diameter = 2 λ

Rotation Angle around specified
Phase Center = 1.1 λ inside aperture



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provide gain of 20 to 25 dBi, as much as a small dish with a rear feed, and the horn is no more unwieldy. For gain higher than a horn alone can easily provide, a dish with a higher performance feed is required — or a much larger dish with the poor feed! To feed the dish from behind, a "shepherd's crook" arrangement may be used with the higher performance feedhorn. The version in Figure 6.7-19 made by N2LIV[14] uses copper water pipe as circular waveguide, formed into a shepherd's crook as described by WA6EXV[15]. Occasionally a formed J-bend in rectangular waveguide may be located as surplus, but the waveguide need not pass through the center of the dish — KB1VC simply runs waveguide over the top of the dish, as shown in Figure 6.7-20.

Finally, if the waveguide bends seem like too much plumbing, ordinary semi-rigid coax may be used. A ½ meter length of RG-141 is plenty for a small dish, and has roughly one dB of loss, a much smaller penalty than the 3 to 5 dB penalty incurred by the backward feeds. For larger dishes, you would be crazy to use an inefficient feed when a smaller dish with a good feed can provide the same gain!

Better still is an offset dish — since the feed is not in the main beam, the electronics can be right next to the feed for minimal loss.


Figure 6.7-20

6.7 References

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