Chapter 6
Feeds for Parabolic Dish Antennas
Paul Wade W1GHZ © 1994,1997,1998,1999

Section 6.2 — Dipole and Wire Feeds

6.2.1 – Dipole feeds

One of the simplest and most popular antennas is the half-wave dipole, so it is not surprising that it was one of the earliest[1] feed antennas for a parabolic dish. A dipole antenna has a simple radiation pattern that most hams are familiar with – in free space, it looks like a donut with the dipole through the hole. If it is near ground or a reflector, the pattern in the plane perpendicular to the dipole (**H**-plane) is distorted to emphasize radiation away from the reflector. The distance between the dipole and reflector influences the shape of the radiation in this plane, while the shape of the radiation in a plane parallel to the dipole (**E**-plane) does not change significantly. Thus the pattern might be adjusted somewhat by varying the reflector spacing.

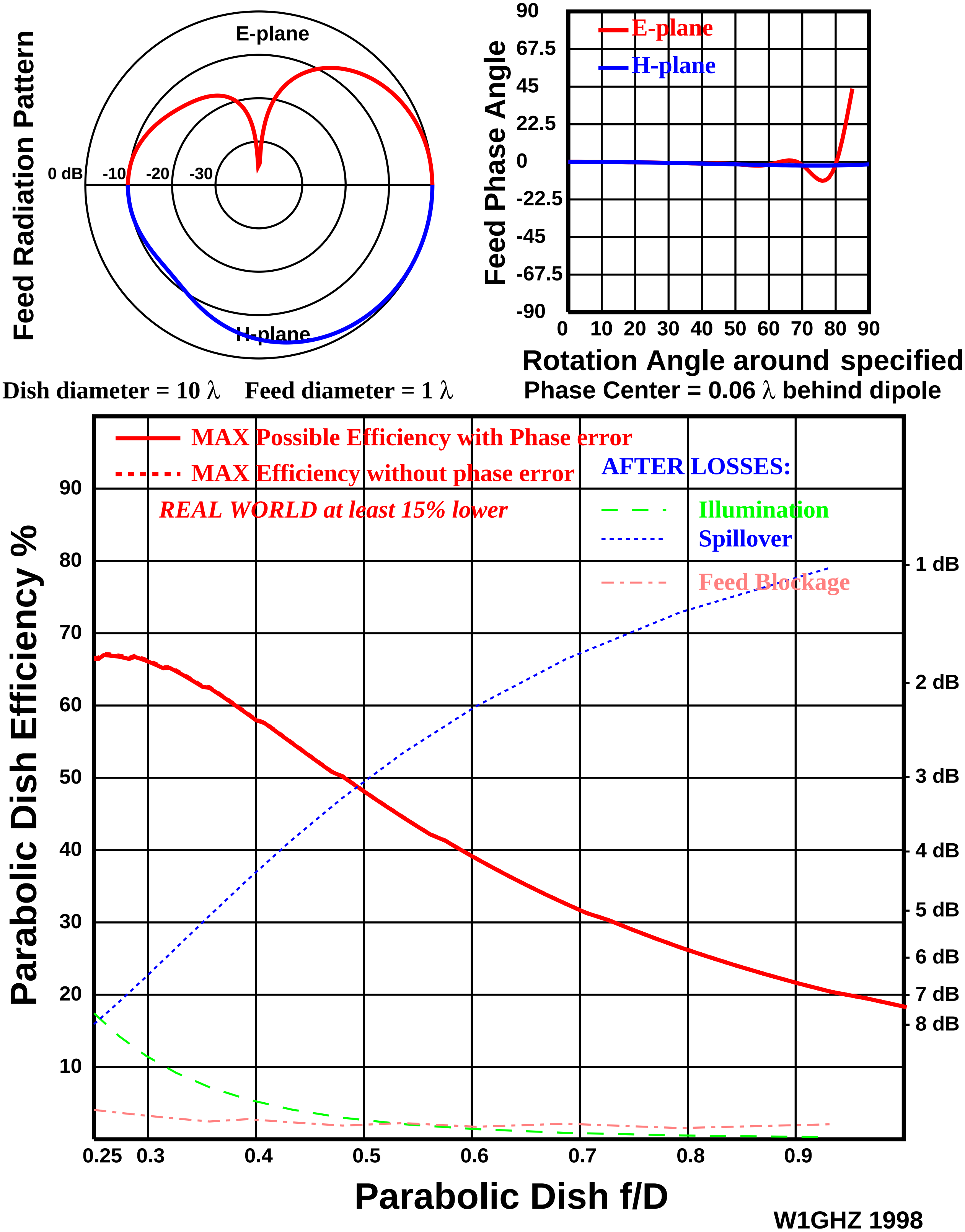
Figure 6.2-1 shows the radiation pattern calculated using **NEC2** for a dipole with a simple rod reflector spaced 0.24λ, which can also be described as a 2-element Yagi-Uda antenna. The radiation patterns in the **H**-plane is much broader than the **E**-plane, and the front-to-ratio is poor, only about 10 dB. These two factors result in the mediocre efficiency shown in the lower plot in Figure 6.2-1; a calculated dish efficiency of about 66% would probably result in about 50% efficiency in practice. We can also see that the dipole feed is better for very deep dishes, with best ***f*/D** around 0.25. The calculated phase center is 0.06λ behind the dipole (toward the reflector). An intuitive phase center would be at the center of the dipole, which is close enough so that the error is small.

A version of the dipole feed that is frequently seen has a round disc reflector rather than a simple rod. Does this make the radiation pattern more symmetrical? Figure 6.2-2, for the version described in the RSGB *Microwave Handbook*[2], shows almost no difference from the version with the rod reflector. The small difference is due to a different reflector spacing, 0.3λ, rather than the shape of the reflector. The calculated phase center is 0.11λ behind the dipole, not far from the published starting point of halfway between dipole and reflector.

However, increasing the size of the reflector will affect the radiation pattern. A dipole feed spaced 0.25λ from a larger reflector, 1.25λ square, is plotted in Figure 6.2-3. The larger reflector narrows the pattern, so best ***f*/D** is around 0.35 to 0.4, and the front-to-back ratio is improved, raising the efficiency slightly. However, the **E**- and **H**- plane patterns are still not symmetrical. An unexpected

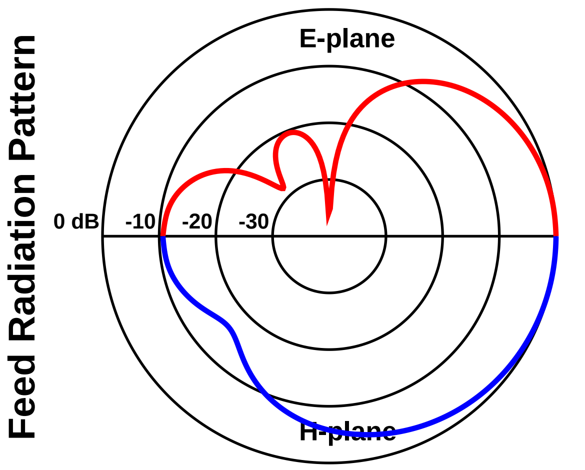
Dipole with rod reflector spaced 0.24λ, by NEC2

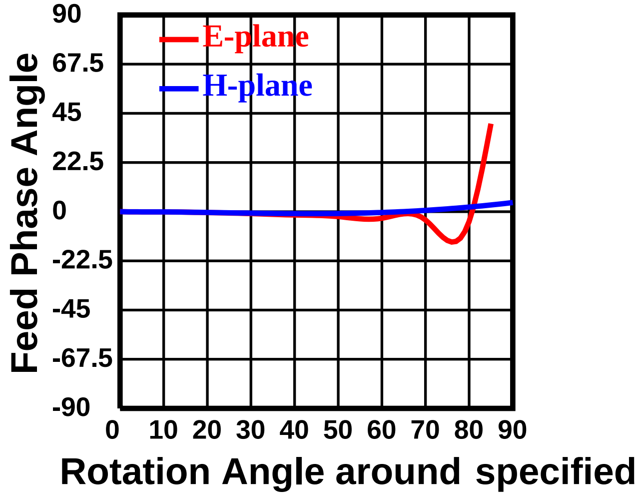
Figure 6.2-1



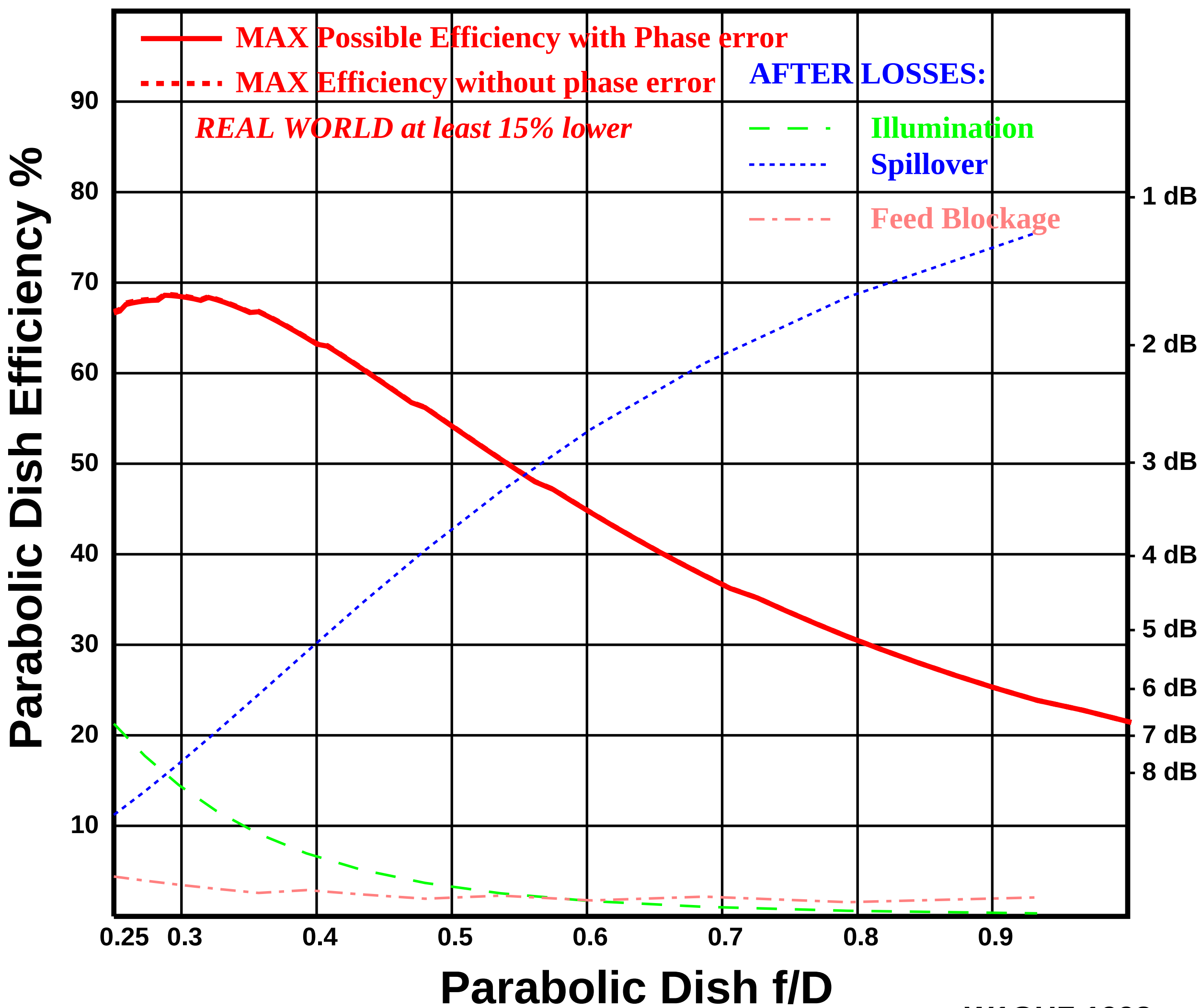
RSGB dipole-splashplate feed, by NEC2

Figure 6.2-2





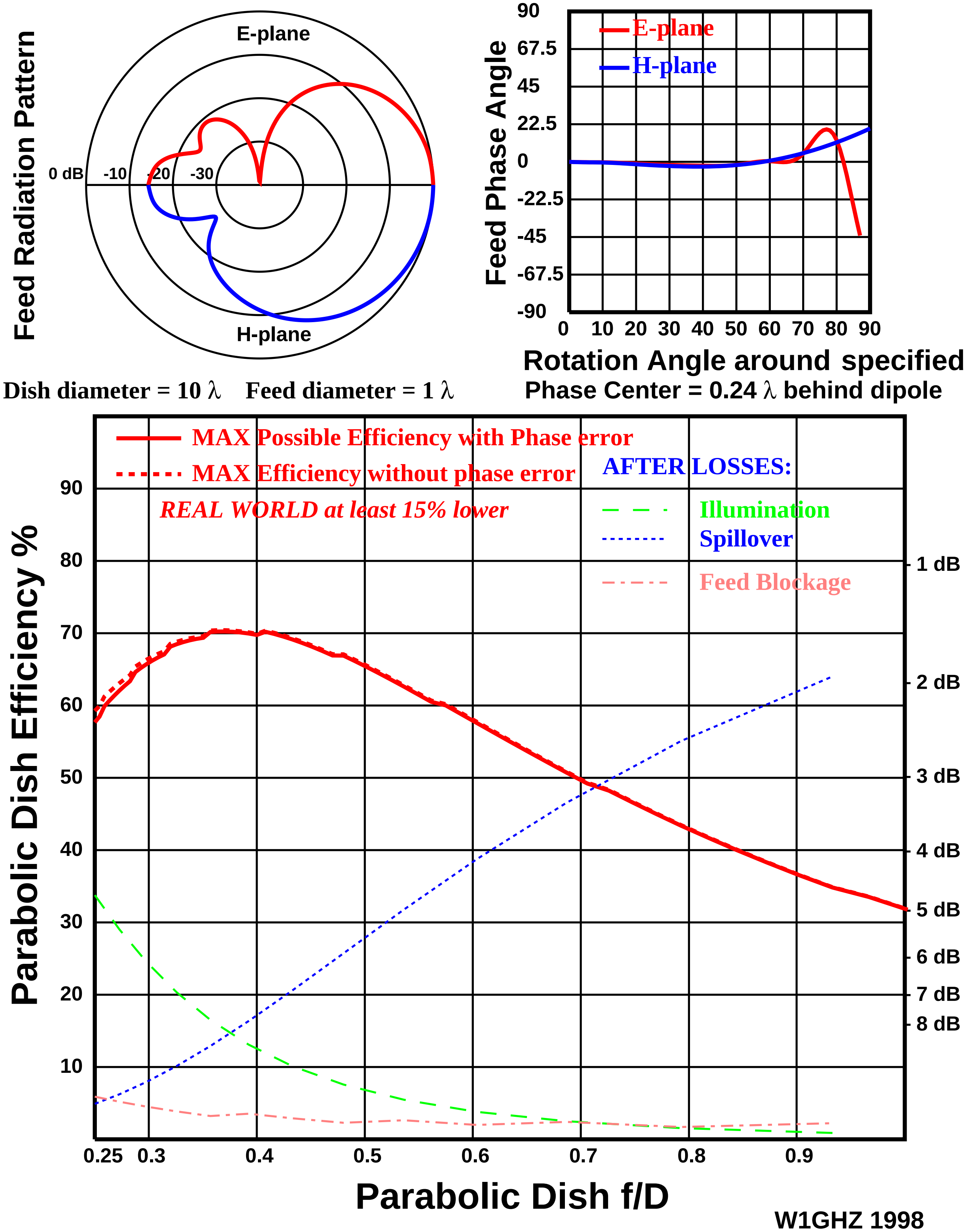
Dish diameter = 10 λ Feed diameter = 1 λ Phase Center = 0.11 λ behind dipole



W1GHZ 1998

Dipole over 1.25λ square reflector, by NEC2

Figure 6.2-3



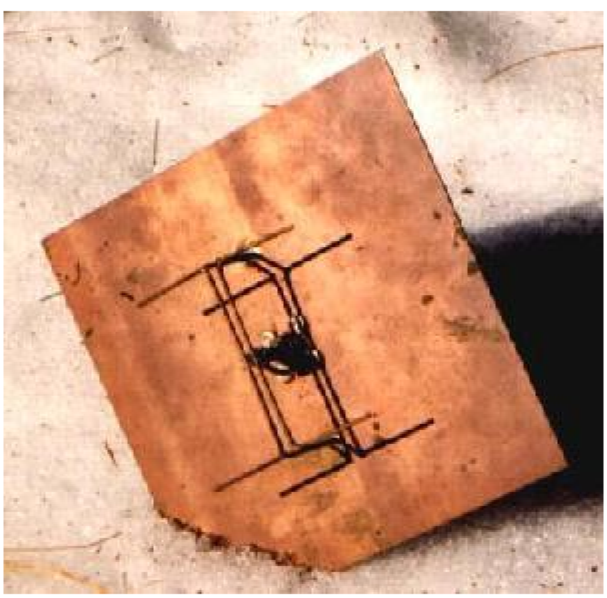
result is the calculated phase center, 0.24λ behind the dipole, or just above the reflector.

Another technique for improving a dipole feed was described[3] by W1YLV and KB1QV. They bent the dipole into a **V**-shape toward the rod reflector to improve the symmetry by broadening the **E**-plane pattern, using **MININEC** to model the result. This feed was used with a 12-foot TVRO dish with ***f*/D** = 0.3 for EME at 432 MHz. The radiation pattern calculated using **NEC2** is plotted in Figure 6.2-4, showing a small improvement in efficiency for very deep dishes. The calculated phase center is 0.11λ behind the center of the dipole.

In summary, simple dipole feeds can provide reasonable performance with very deep dishes, which are difficult to feed effectively. However, it is difficult to make a dipole at the higher microwave frequencies which is not buried in the supporting structure, so a dipole should only be considered for UHF and lower microwave frequencies. Most dishes at these frequencies are electrically small, so the small size of the dipole feed helps reduce loss due to feed blockage.

6.2.2 – EIA dual-dipole feeds

All of the single dipole feeds above have the same basic weakness — the **H-**plane pattern is much broader than the **E-**plane. One solution is to narrow the **H-**plane pattern by adding a second dipole, parallel and in-phase with the first. One implementation[4] of this is based on the EIA standard-gain reference antenna[5], with two dipoles a half-wave apart spaced λ/4 above a one-wavelength square ground plane; the dipoles are supported by λ/4 stubs of heavy open-wire feedline. Variations of this feed have been used for many of the UHF and lower microwave bands. An example I built for 1296 MHz is shown in Figure 6.2-5, the photograph below.



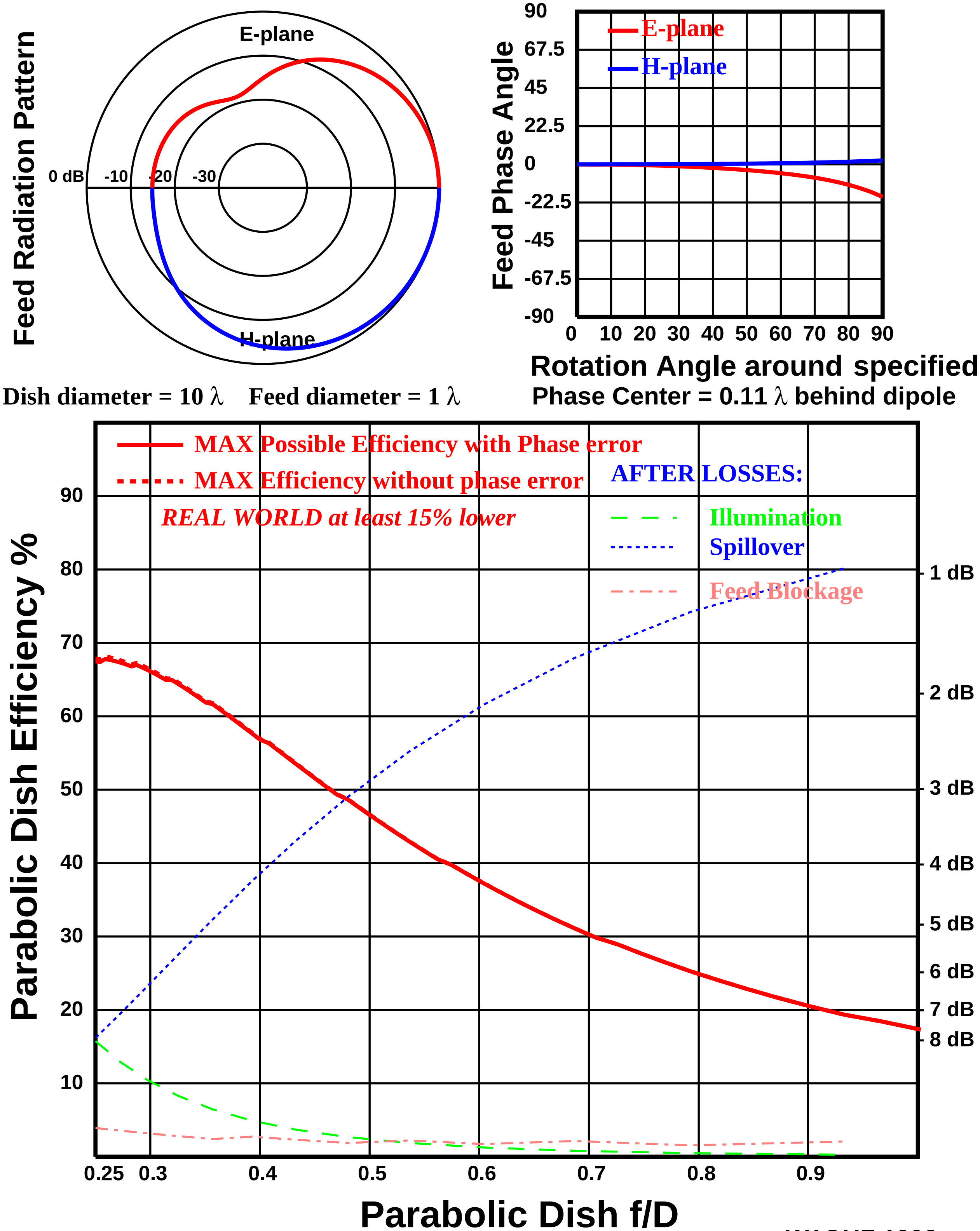
The radiation pattern calculated by **NEC2** for an EIA dual-dipole feed is shown in Figure 6.2-6. The forward part of the **E-** and **H-**planes are well matched, and the efficiency plot shows very good efficiency for ***f*/D** around 0.5. The calculated phase center is 0.15λ behind the dipoles, centered between them.

This feed is very popular for 432 MHz EME and has been used successfully by many stations. It is easy to build and adjust — spreading or squeezing the open-wire transmission line between the dipoles will usually minimize the VSWR. Circular polarization is possible by adding another pair of dipoles[6] on the same reflector at right angles to the first pair, with the ends of the dipoles bent to minimize interaction.

The EIA standard dimensions were chosen to provide an easily duplicated reference antenna for gain measurements — strict adherence is only necessary if the gain of the antenna is important. As a feed antenna, the whole radiation pattern is important, not just the axial gain, and we might choose to adjust the dimensions to provide better illumination for a specific parabolic reflector. KF4JU described[7] his attempts to adjust the EIA dimensions to better illuminate a 0.37 ***f*/D** reflector, using

W1YLV & KB1QV bent-dipole feed, by NEC2

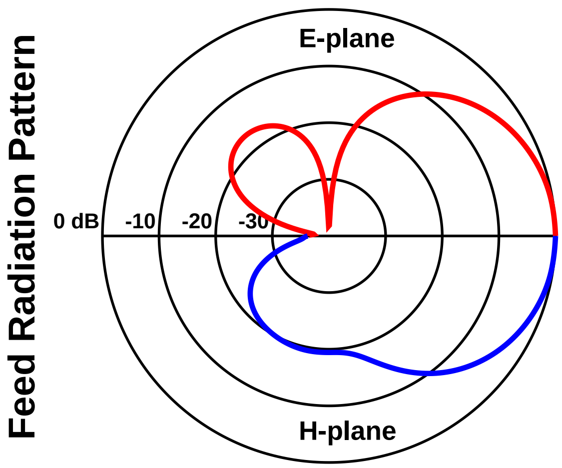
Figure 6.2-4

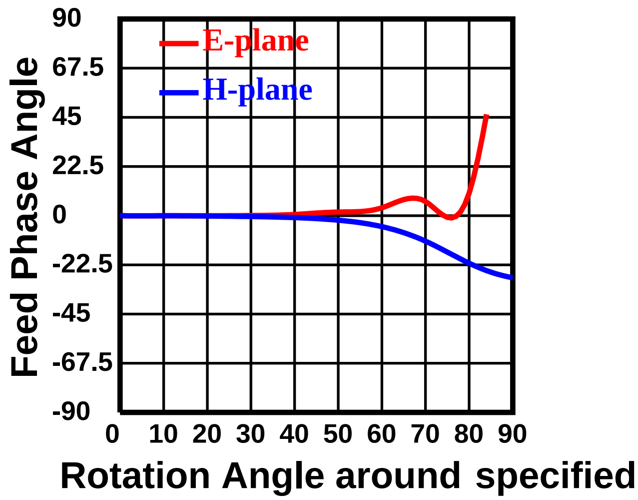


W1GHZ 1998

EIA dual-dipole reference antenna as feed, by NEC2

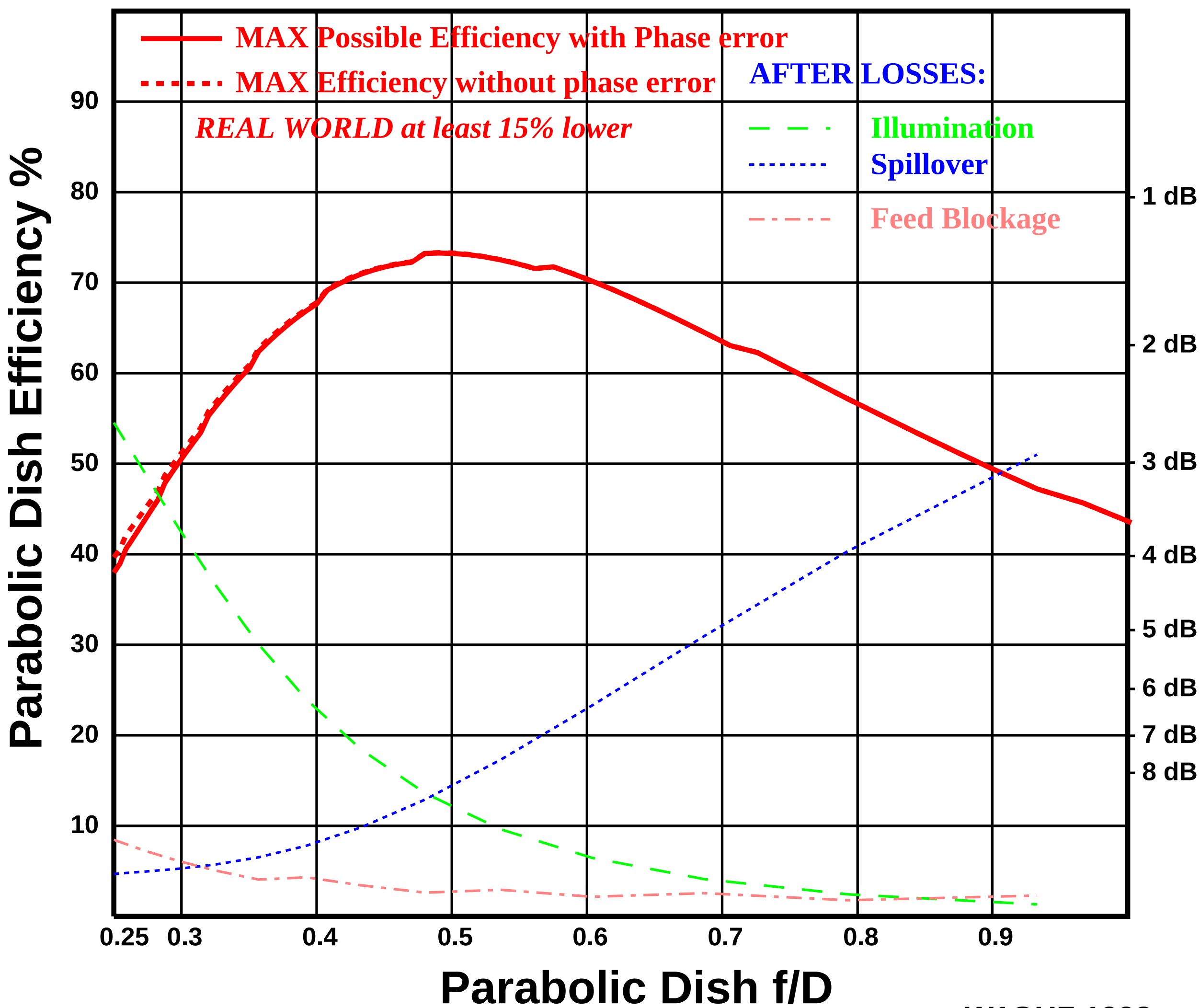
Figure 6.2-6





Dish diameter = 10 λ   Feed diameter = 1 λ

Phase Center = 0.15 λ behind dipoles



W1GHZ 1998

MININEC for the pattern calculations. He started with the basic EIA dimensions, with a larger 1.25λ square reflector, and referred to it as an NBS feed. (A common practice among hams is to erroneously refer to the EIA reference antenna as the "NBS" antenna; the NBS reference antenna[4] has different dimensions: two 1λ dipoles above a 1.6λ x 2λ plane. KF4JU is following this practice.)

The radiation pattern calculated by **NEC2** for the KF4JU "NBS" feed is shown in Figure 6.2-7. As we might expect, it is very similar to the EIA feed in Figure 6.2-6. The larger reflector raises the best ***f*/D** slightly, to about 0.55, and moves the phase center further from the dipoles.

Since the ***f*/D** of the target dish is 0.37, a broader pattern is needed for proper illumination. The first modification is to move the two dipoles closer together, to broaden the **H-**plane pattern. The resulting pattern, shown in Figure 6.2-8, is a small step in the right direction. Next, the spacing of the dipoles from the ground plane is increased to 0.405λ to further broaden the pattern in both planes. Optimizing this dimension results in very good efficiency peaking close to the desired ***f*/D**, as shown in Figure 6.2-9.

Another way to adjust the pattern of a dual-dipole feed was described[8] by W7PUA, bending the ends of the dipoles toward the reflector so that they will not radiate toward the dish. Since the two ends of a dipole are always out of phase, bending the ends of the dipole parallel to each other tends to cancel the radiation in unwanted directions. The smaller remaining part of the dipole still illuminating the dish will have a broader pattern. He used the **EZNEC** program to analyze the effect of the bends.

W7PUA calls this feed the Double Handlebar, since it resembles a bicycle handlebar, and he described[6] two versions with different bend points. The pattern for the Type A double handlebar feed, with an effective dipole length of about 0.2λ, is shown in Figure 6.2-10; best ***f*/D** is around 0.38, and the phase center is about 0.17λ behind the center of the dipoles. The Type B version has the bend point closer to the center of the dipole, to make the effective dipole radiators smaller (0.125λ) and provide a broader pattern. Figure 6.2-11 shows that the best ***f*/D** for this version is around 0.32; peak efficiency is slightly lower, but is good for such a deep dish. The phase center for the Type B is about 0.185λ behind the dipole centers

The W7PUA double handlebar feeds have a simple wire reflector rather than a plane reflector, reducing the size and weight. Thus, this feed might be a good choice for lower frequencies where the other feeds might require more metal so that size and weight become unattractive. Construction of the feed does not appear difficult.

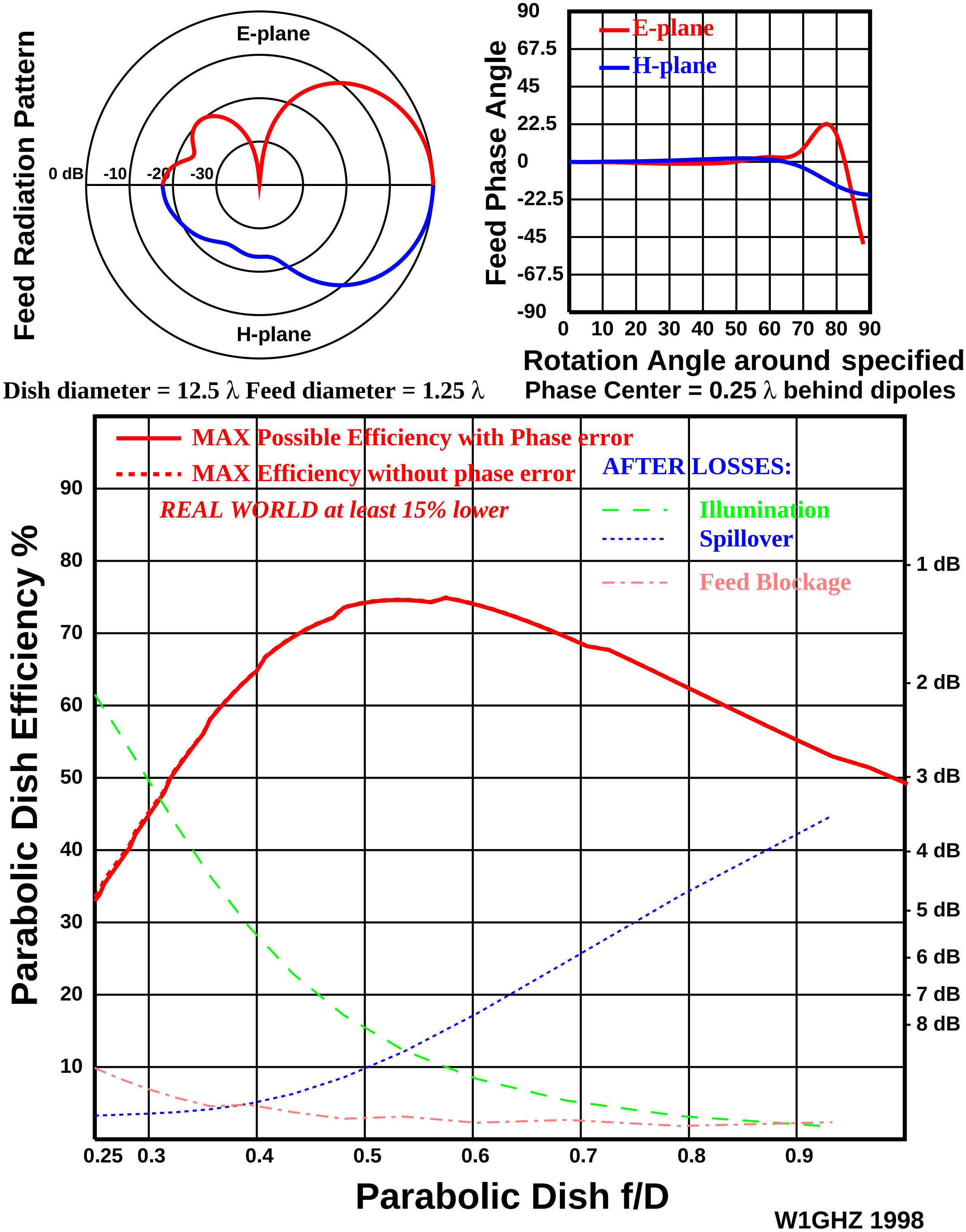
6.2.3 – Loop feeds

Another variation on a dual dipole feed is to bend the two dipoles toward each other until the ends are joined, making a full wavelength loop. One advantage is that a loop may be fed at a single point instead of needing to phase two dipoles. However, the **NEC2** calculations showed a slight skewing of the pattern with a single feedpoint, so I stuck with two feedpoints to simplify plotting. In practice, the effect is probably negligible.

KF4JU experimented with optimizing this loop feed[7] as well as the dual-dipole described above. He started out with a square loop, 0.25λ on a side, spaced 0.25λ from a 1.25λ square groundplane; he called this a Quad loop feed. Figure 6.2-12 shows the **NEC2** results for the quad loop feed, with

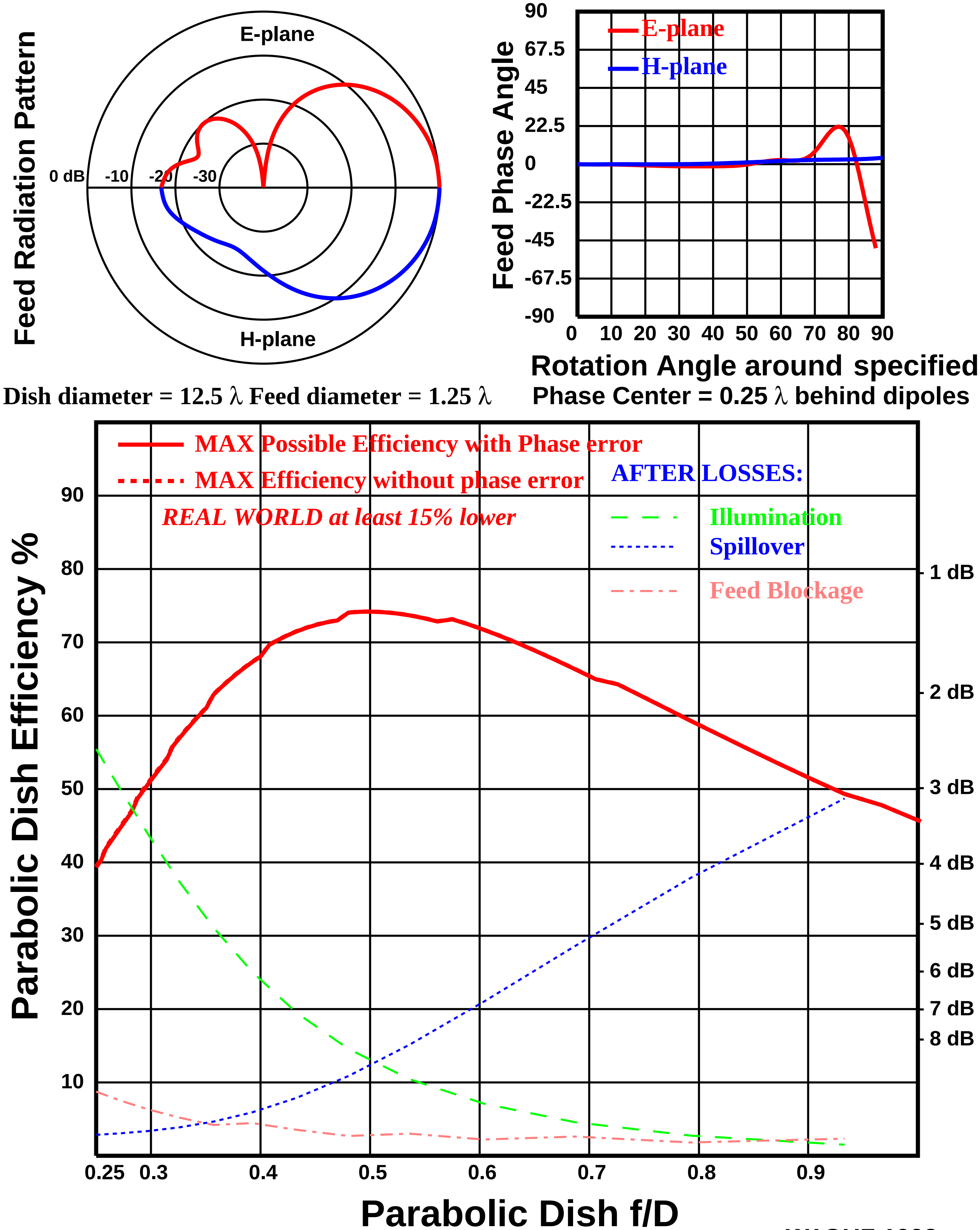
KF4JU "NBS" dual-dipole over 1.25λ reflector, by NEC2

Figure 6.2-7



KF4JU modified "NBS" dual-dipole feed, by NEC2

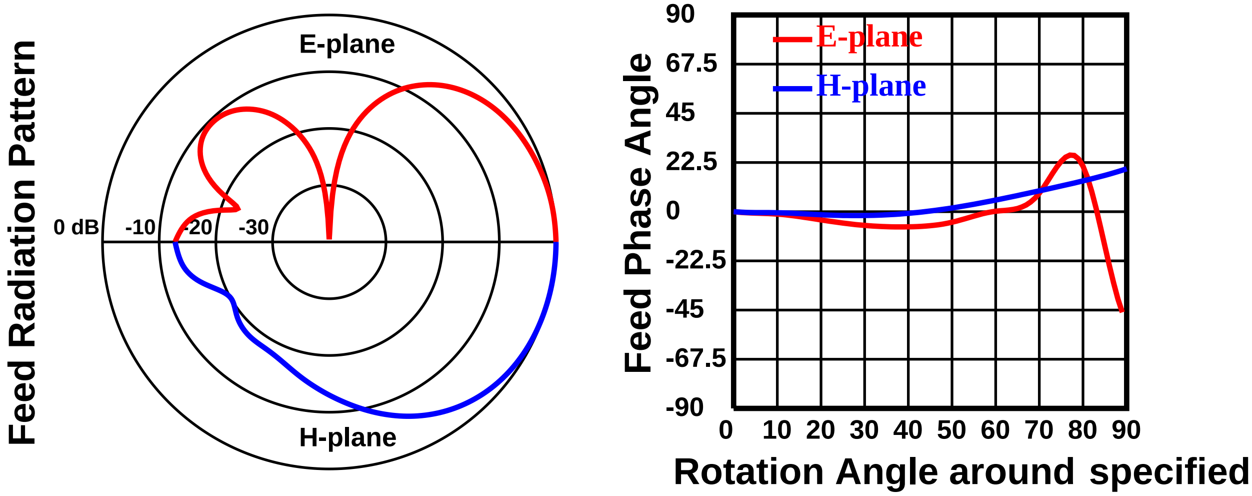
Figure 6.2-8



W1GHZ 1998

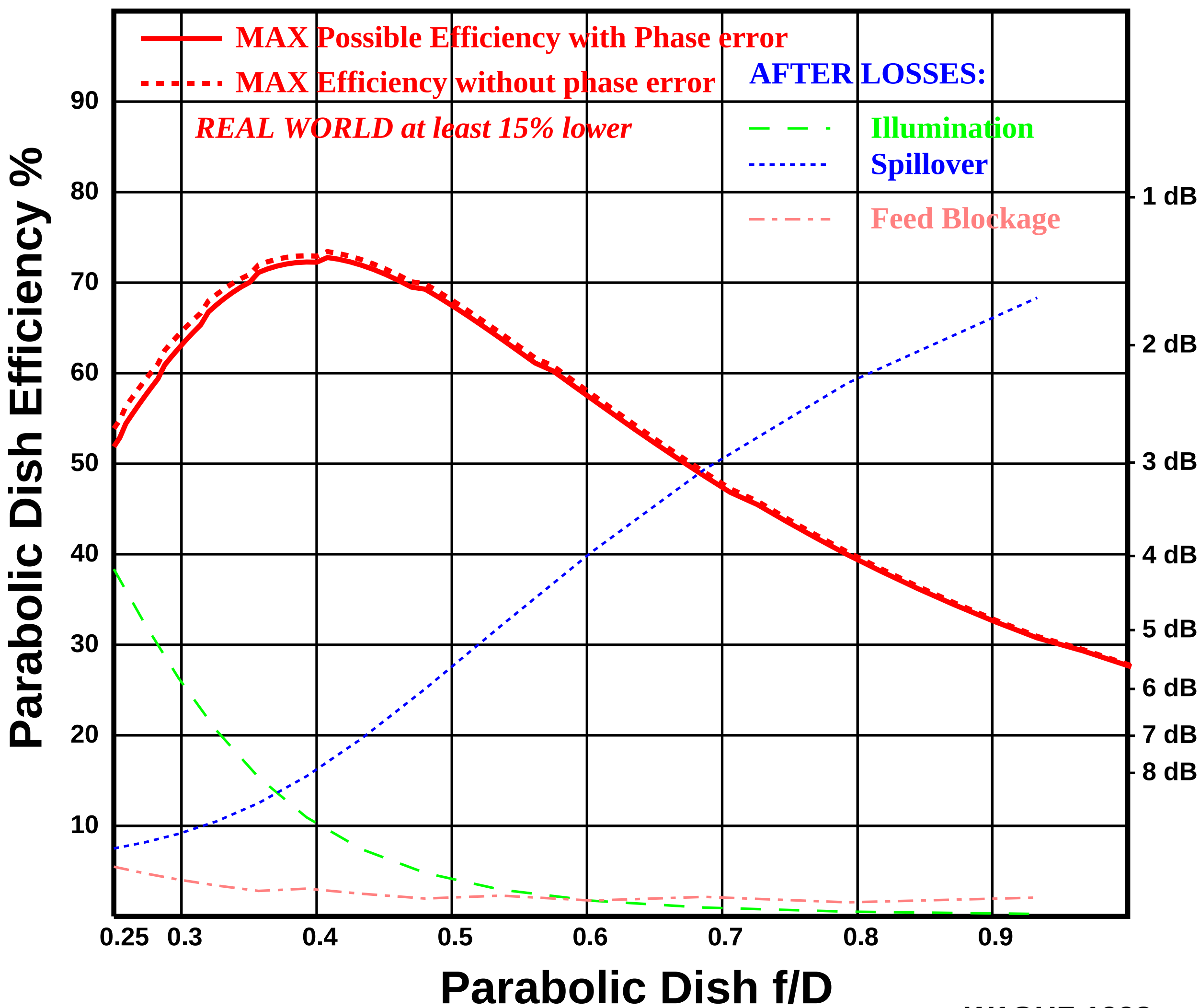
KF4JU optimized "NBS" dual-dipole feed, by NEC2

Figure 6.2-9



Dish diameter = 12.5 λ Feed diameter = 1.25 λ

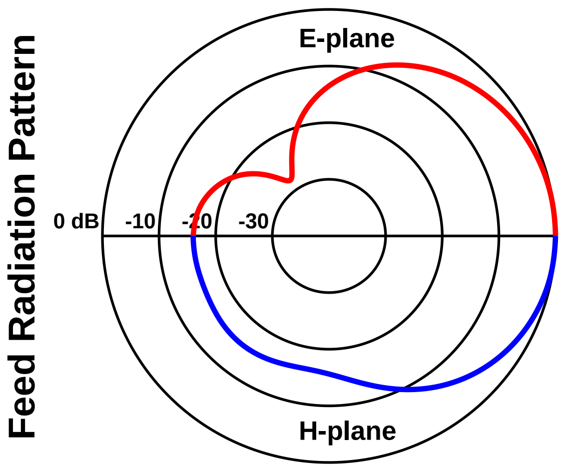
Phase Center = 0.46 λ behind dipoles

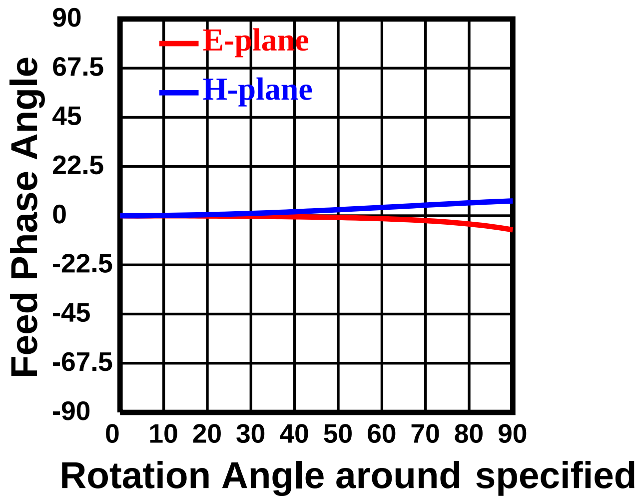


W1GHZ 1998

W7PUA Double Handlebar feed - Type A, by NEC2

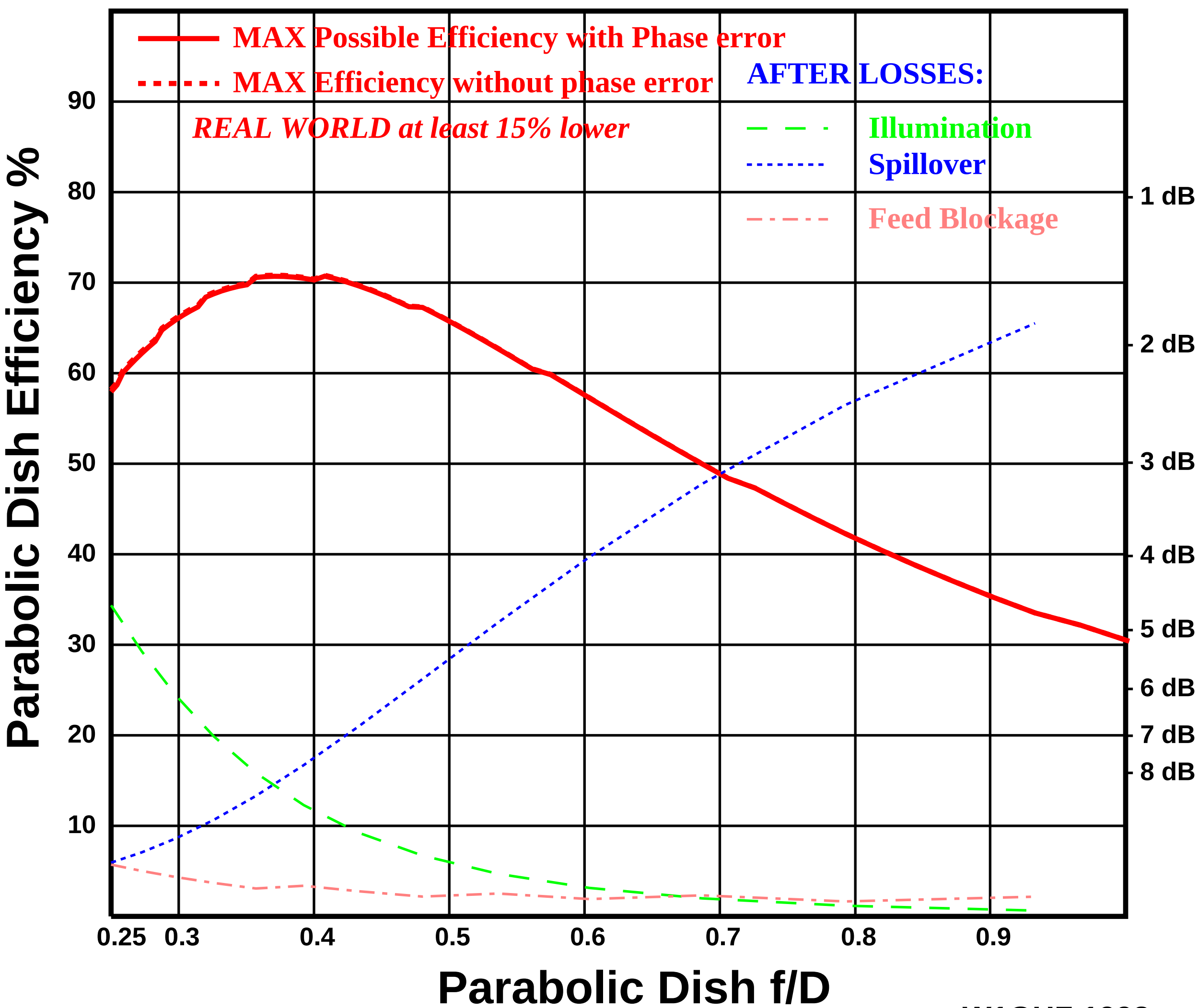
Figure 6.2-10





Dish diameter = 10 λ Feed diameter = 1 λ

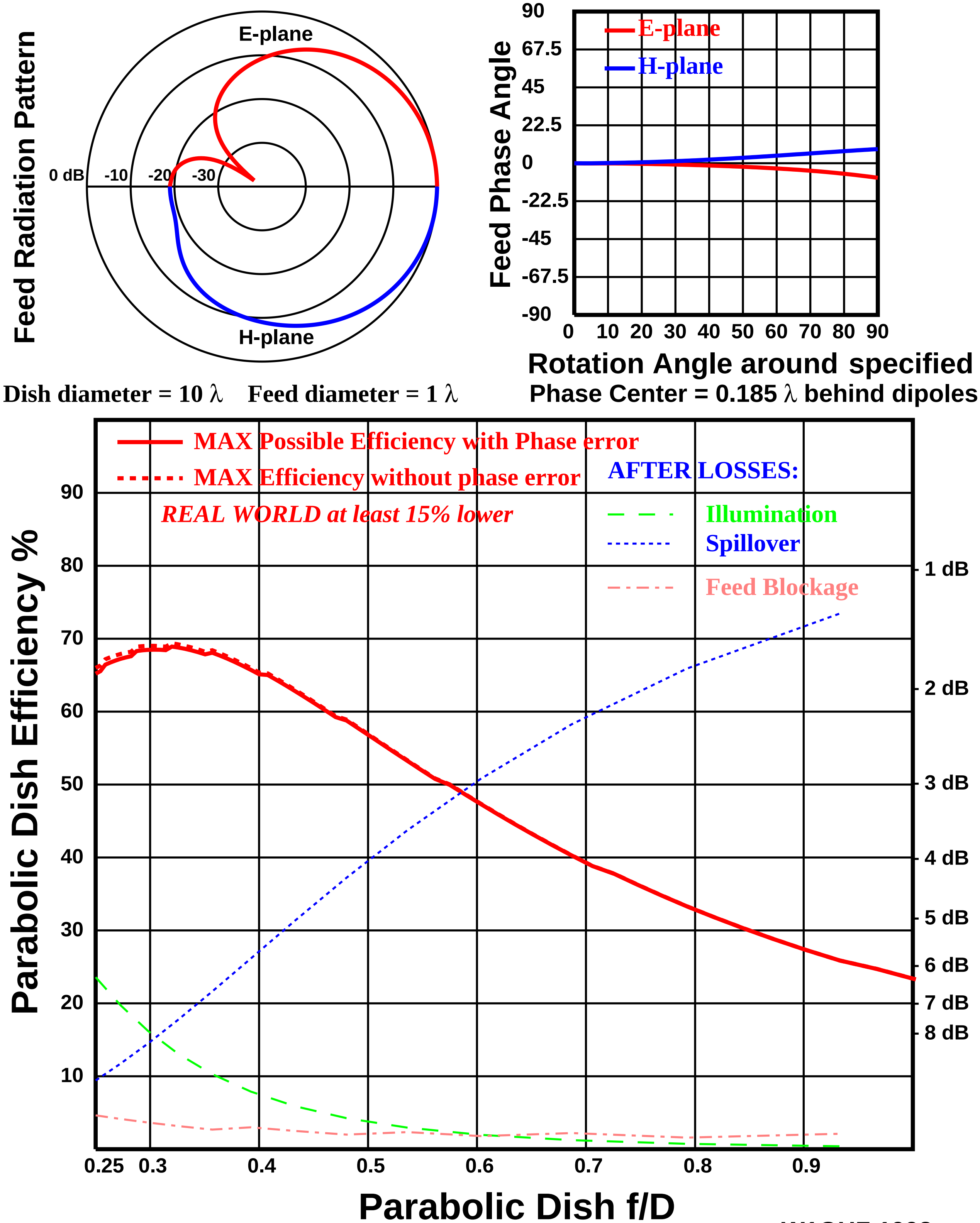
Phase Center = 0.17 λ behind dipoles



W1GHZ 1998

W7PUA Double Handlebar feed - Type B, by NEC2

Figure 6.2-11



W1GHZ 1998

good efficiency and best ***f*/D** around 0.42. The phase center is 0.25λ behind the center of the loop, at the center of the ground plane. Although the square loop is physically symmetrical, the **H-**plane pattern is broader than the **E-**plane.

Since the target ***f*/D** for this feed was again 0.37, KF4JU adjusted the dimensions using **MININEC**. The first modification was to narrow the **H-**plane without changing the circumference by making the loop rectangular, 0.404λ by 0.095λ, resulting in higher efficiency as shown in Figure 6.2-13. However, the best ***f*/D** moved in the wrong direction, to about 0.48. The final optimization was the same as for the dual-dipole feed, to adjust the groundplane spacing, increasing it to 0.385λ. Figure 6.2-14 shows the result of the optimization — very high efficiency at the desired 0.37 ***f*/D**. The phase center has moved back, to 0.43λ behind the loop, so that the feed must be closer to the dish to have the phase center at the dish focus.

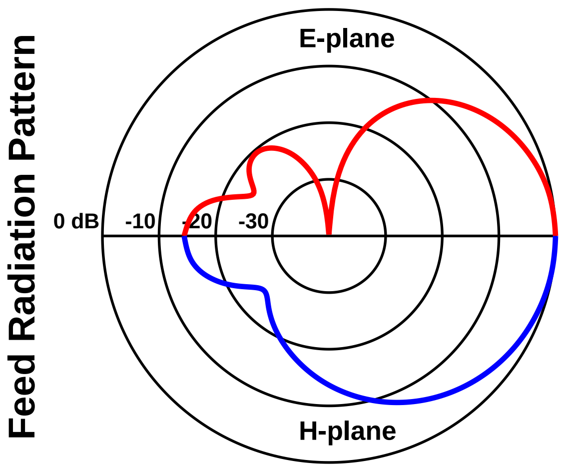
There is no reason a loop must be rectangular. DL4MEA sent me a picture of the round loop feed[9] he uses for 1296 MHz and 13 cm., shown in Figure 6.2-15, at right. He modeled this feed using **NEC4WIN95** by approximating the round loop with an octagon — using more sides would be a slightly better approximation. The loop is one wavelength in circumference, spaced approximately λ/8 from a half-wavelength diameter reflector. The pattern calculated by **NEC2**, in Figure 6.2-16, shows good efficiency for an ***f*/D** range around 0.36 to 0.42, with a phase center just behind the center of the loop. Like the square quad loop above, the **H-**plane pattern is broader than the **E-**plane. Even so, this feed has an attractive simplicity.

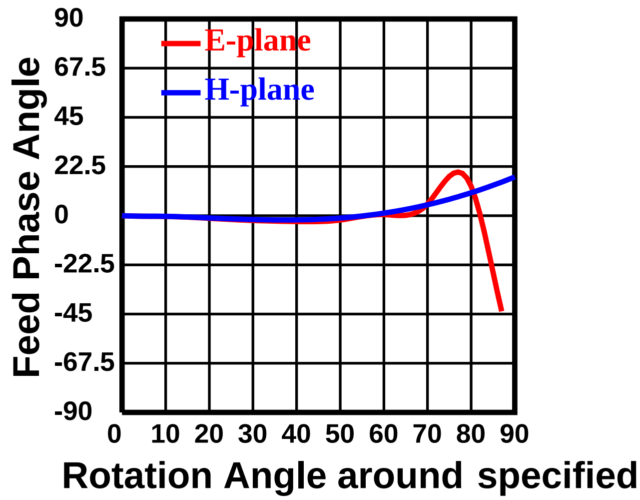
6.2-4 Note on pattern calculations

The radiation patterns shown here were all calculated using **NEC2**. They do not agree exactly with results in the original articles referenced below because of differences in the models and in the different **NEC** programs. The other versions were derived from **MININEC**, a **BASIC** code derived from the original **NEC2**. **NEC2** is a double-precision **FORTRAN** code provides more accurate calculations than the **BASIC** code of many of the derivatives, and is capable of calculating much larger models. Also, the phase output needed for efficiency and phase center calculations is not available in many of the derivatives. W4RNL[10] has discussed some of the differences in *antennaX*. The major disadvantage of **NEC2** is the primitive user interface, but the better accuracy and the phase information are worth the trouble. See Chapter 12 for a brief discussion of **NEC2** modeling, and the **NEC2** manual[11] for all the gory details.

KF4JU Quad loop feed, by NEC2

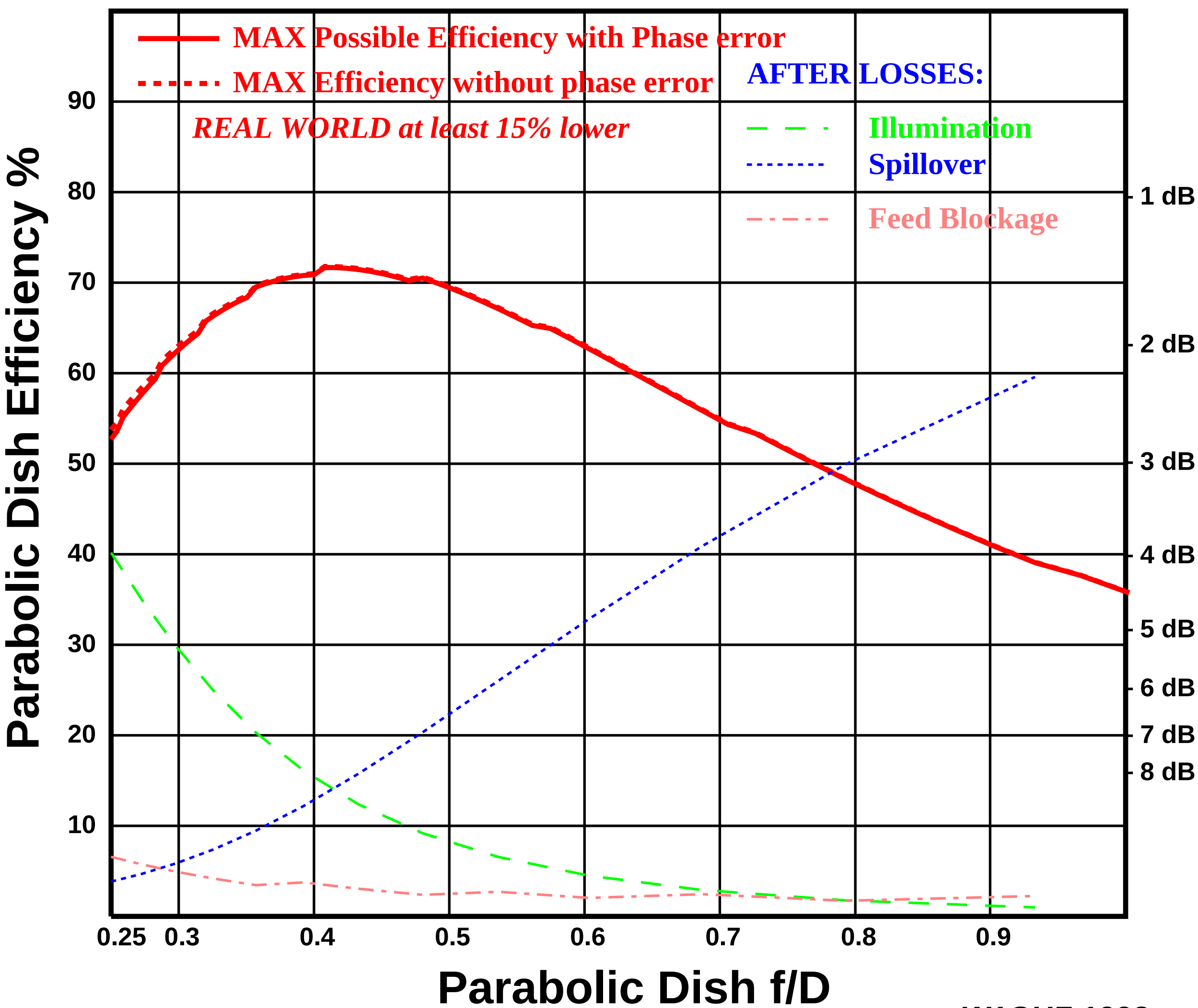
Figure 6.2-12





Dish diameter = 12.5 λ Feed diameter = 1.25 λ

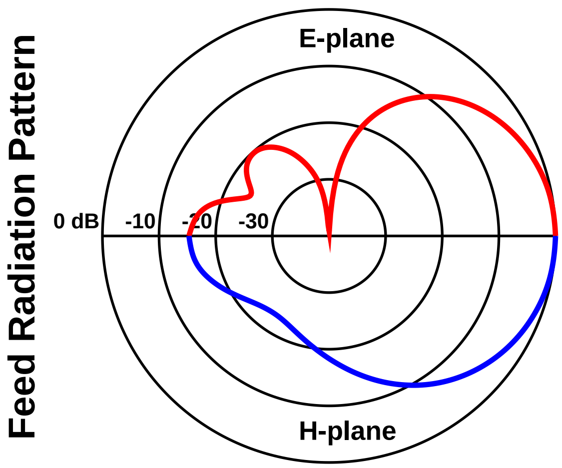
Phase Center = 0.25 λ behind loop

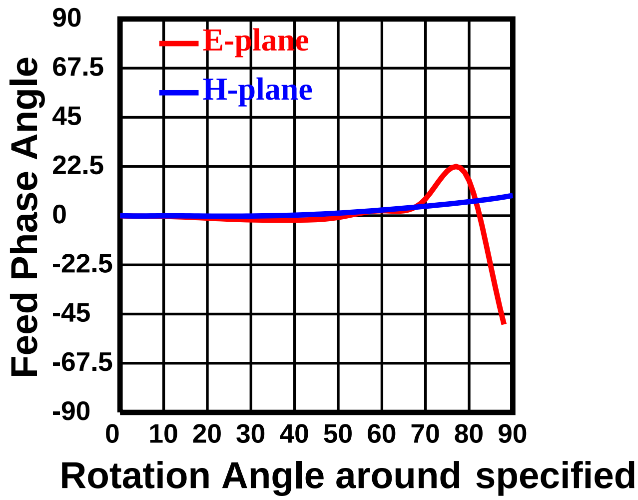


W1GHZ 1998

KF4JU modified quad loop feed, by NEC2

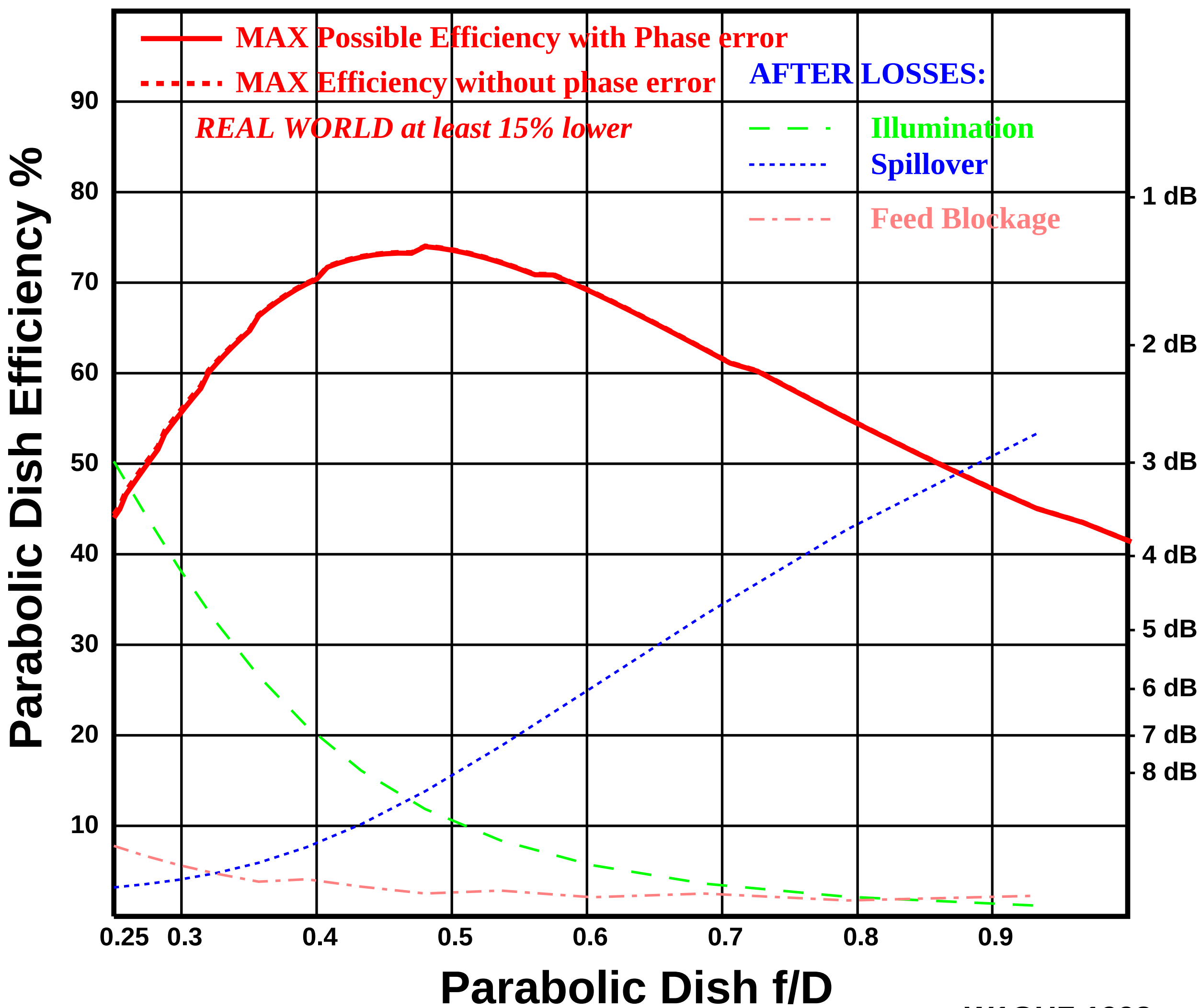
Figure 6.2-13





Dish diameter = 12.5 λ Feed diameter = 1.25 λ

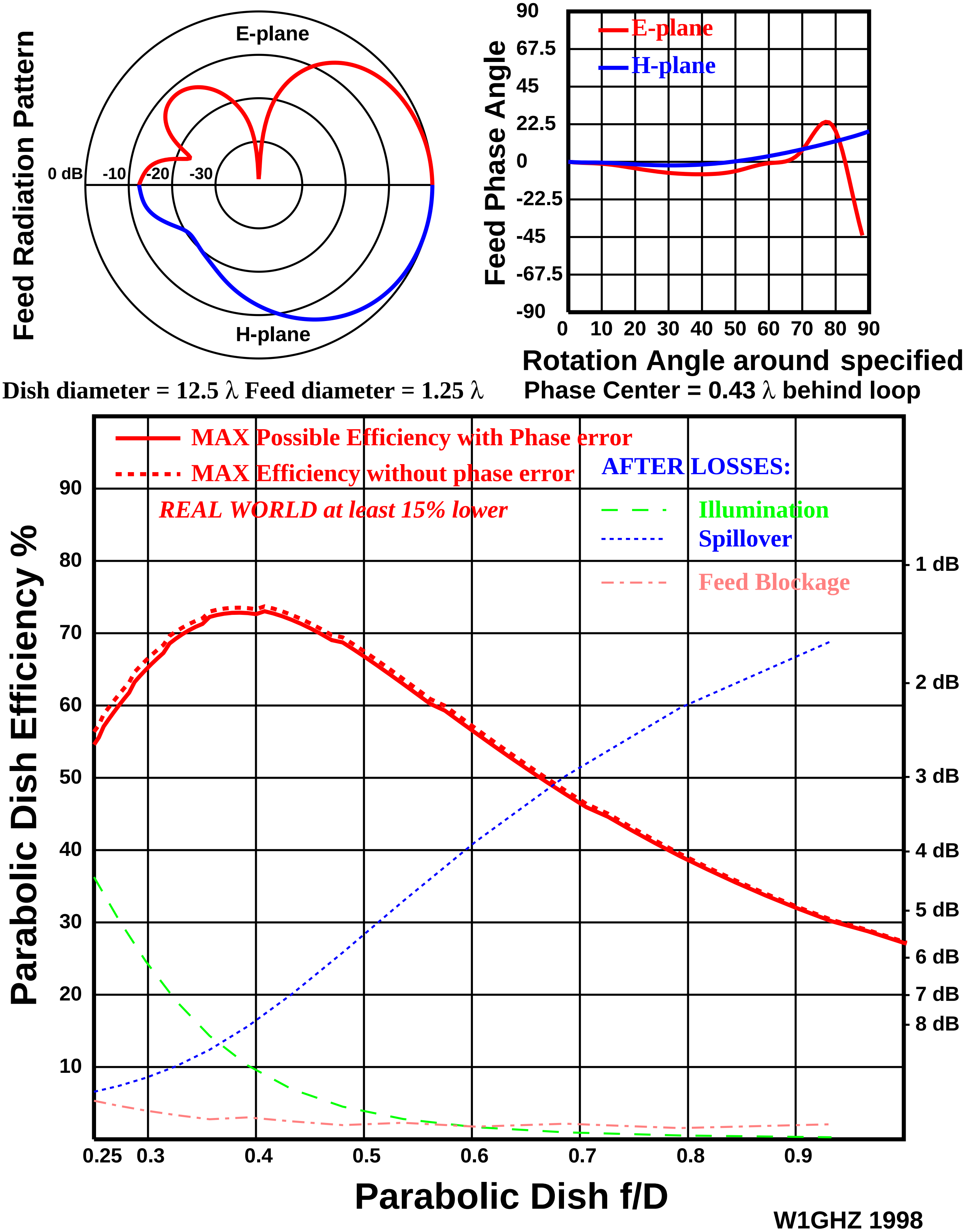
Phase Center = 0.27 λ behind loop



W1GHZ 1998

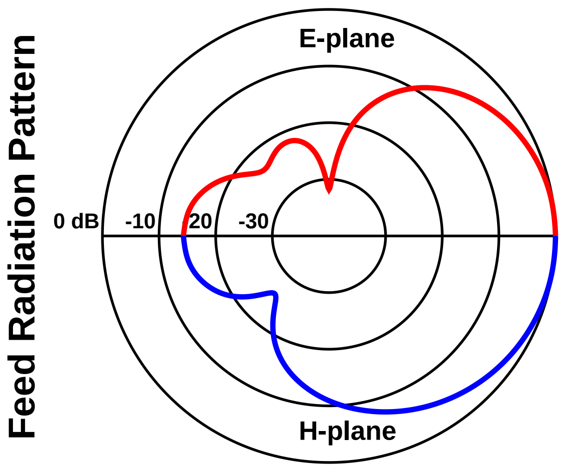
KF4JU optimized quad loop feed, by NEC2

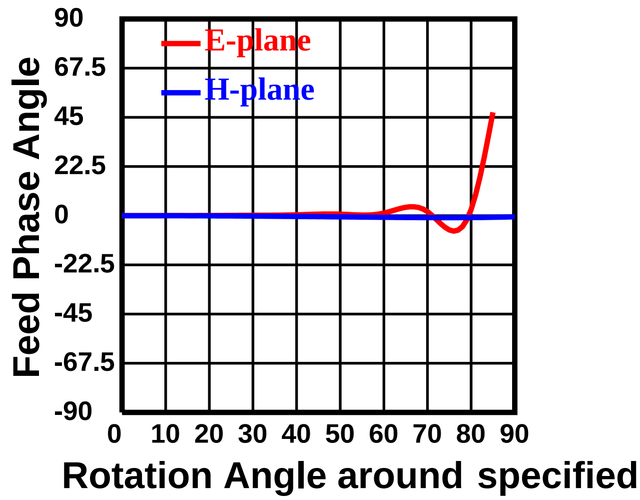
Figure 6.2-14



DL4MEA Full-wave round loop, by NEC2

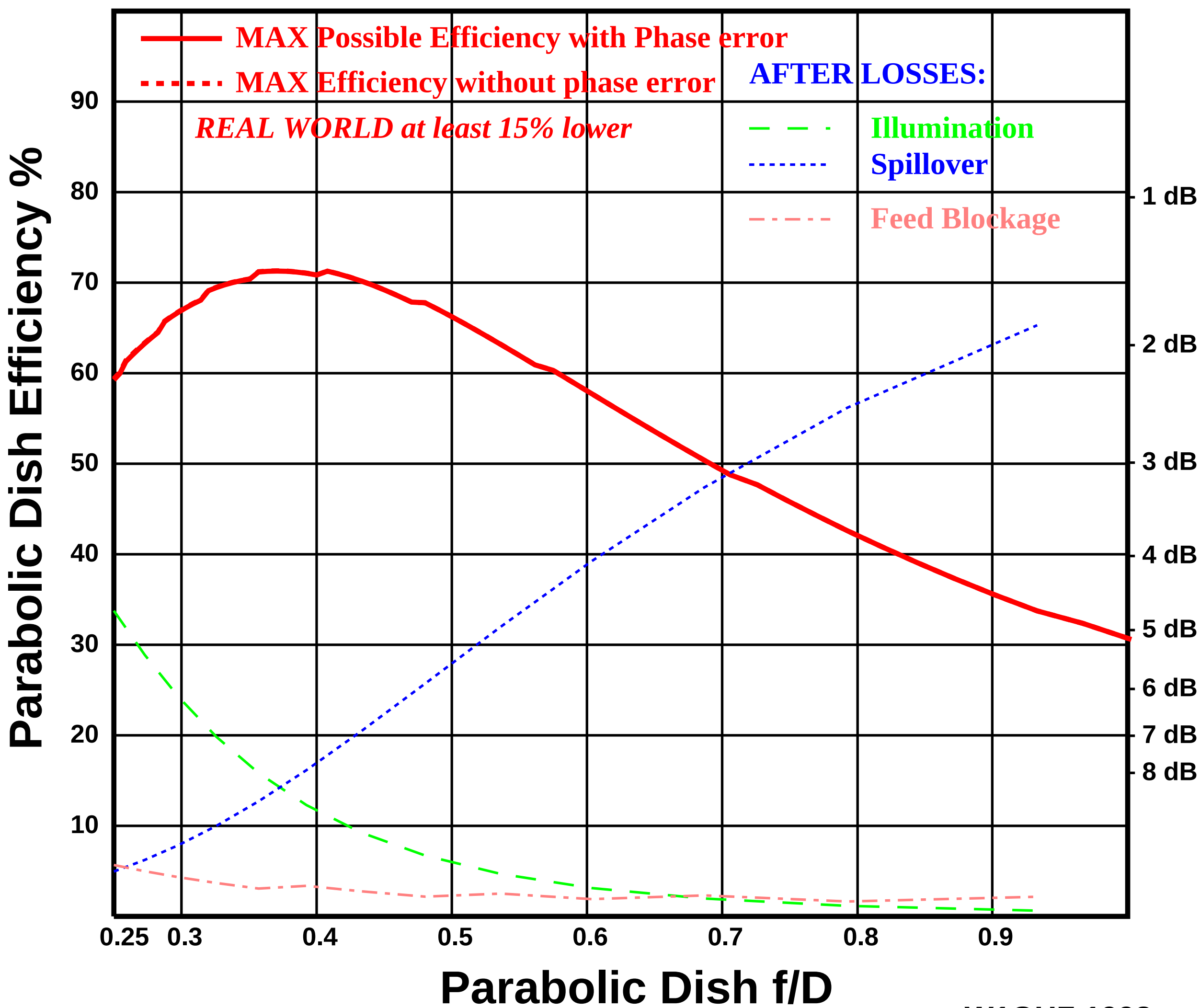
Figure 6.2-16





Dish diameter = 10 λ   Feed diameter = 1 λ

Phase Center = 0.04 λ behind loop



W1GHZ 1998

In spite of the differences and discrepancies, most of the feeds described above were successfully modeled and optimized by their originators using the simpler **NEC** variants. So, if you hear about a new feed or have a great idea, or just want to tweak an existing feed for the exact ***f*/D** of your dish, get hold of a program and have at it. Some of them, including **NEC2**, are even available free for downloading. WB6TPU maintains an unofficial **NEC** website[12] with many of these resources.

6.2 References

1. S. Silver, *Microwave Antenna Theory and Design*, McGraw-Hill, 1949, pp. 239-256.

2. M.W. Dixon, G3PFR, *Microwave Handbook, Volume 3*, RSGB, 1992, p. 14.25.

3. R. Sletten, KB1QV, & C. Sletten, W1YLV, "An Efficient Feed for a 12' EME Dish," *Proceedings of the Eighteenth Eastern VHV/UHF Conference*, ARRL, 1992, pp. 67-70.

4. D. Turrin, W2IMU, "Antenna Performance Measurements, ***QST***, Nov. 1974, pp. 35-41.

5. EIA Standard RS-329.

6. D. Turrin, W2IMU, "Parabolic Reflector Antennas and Feeds," *The ARRL UHF/Microwave Experimenter's Manual*, ARRL, 1990, p. 9-35.

7. J.E. Pearson, KF4JU, "Modified Feed Antennas for Parabolic Dishes," *Proceedings of Microwave Update '91*, ARRL, 1991, pp. 194-204.

8. B. Larkin, W7PUA, "Dipole-Reflector Parabolic Dish Feeds for f/D of 0.2-0.4," ***QEX*,** February 1996, pp. 3-11.

9. http://www.sbs.de/~koellner/ringfeed.htm

10. http://www.antennex.com/w4rnl

11. G.J. Burke & A.J. Poggio, *Numerical Electromagnetic Code (NEC) — Method of Moments*, Lawrence Livermore Laboratory, 1981.

12. http://www.qsl.net/wb6tpu/swindex.html