6.1.5 Dish Patterns with Axial Displacement Error

When I first talked about axial displacement error, one of the first questions that arose was "Where does the power go when the gain is reduced?" The best way to answer this is by example, by calculating patterns for a dish with various feed displacements, using Physical Optics. For this example, we will use a simple feed horn, 1.2λ in diameter; any larger diameter could support additional waveguide modes. The feed radiation pattern and predicted dish efficiency, about 72% for an ***f/*D** = 0.5, is shown in Figure 6.1-15; experience suggests that efficiency on a real dish would be perhaps 15% lower than predicted. Figure 6.1-16 shows the calculated radiation pattern for a 0.5 ***f/*D** dish, 20λ in diameter, when illuminated by this horn with the phase center of the horn at the focus of the dish. Calculated gain, neglecting feed blockage, is about 34.4 dBi, for an efficiency of about 70%, very close to our prediction, and the 3-dB beamwidth is about 5°.

The axial displacement error for this feed is shown in Figure 6.1-17, so that we may choose some other interesting locations for closer examination. With an axial displacement of 0.5λ, gain is reduced by less than one dB, but one wavelength displacement produces a huge reduction, so an intermediate point of ¾ λ might be interesting. There is an apparent null at about 1.5λ displacement, and very poor performance with further displacement.

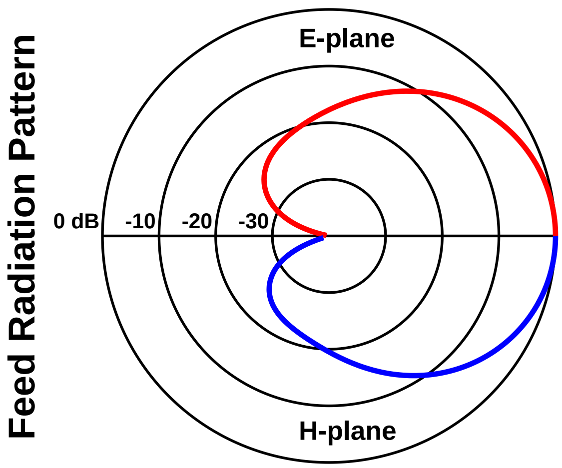
To examine the effect of axial feed displacement at the points chosen above, we calculate dish radiation patterns at these displacements as the feed is moved axially toward the reflector. Figure 6.1-18 shows the patterns at the chosen displacements. In Figure 6.1-18a, at 0.5 wavelength of axial displacement, gain has dropped by about 0.5 dB. As the feed is moved further toward the dish, gain decreases further, by about 1.3 dB at 0.75λ in Figure 6.1-18b, 2.5 dB at 1λ in Figure 6.1-18c, and 6.6 dB at 1.5λ displacement in Figure 6.1-18d. Feed displacement in the other direction, away from the reflector, produces similar results. The dish patterns show gain and efficiency decreasing with axial displacement, with the lost energy going into a broadening of the near sidelobes; the 3-dB beamwidth of the main beam remains constant at about 5° for displacements less than about one wavelength.

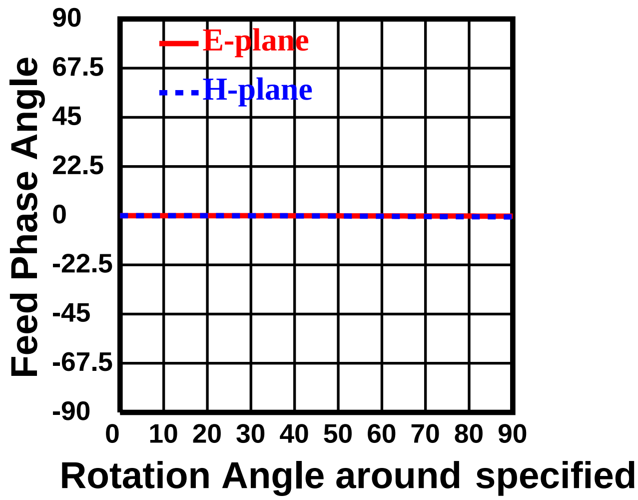
Larger axial feed displacements are even worse. Figure 6.1-19 shows the dish radiation patterns for displacements of two and three wavelengths in each direction. All the larger displacements result in large gain reductions, more than 10 dB, and ugly patterns. The patterns in Figure 6.1-19a and 6.1-19d have a dip on boresight – try and visualize a donut-shaped main lobe, with a hole in the middle. Peaking up a signal would be difficult with this antenna pattern.

Those readers astute enough to calculate efficiencies will have noticed that the efficiency found in the radiation patterns does not drop off quite as quickly as shown in Figure 6.1-17 with axial displacement, probably due to the different approximations used. Since the main value of the axial displacement plots is to accurately locate the best phase center for a feed, I'm not concerned about small errors in the undesirable regions.

Test horn for dish examples, 1.2λ diameter, by P.O.

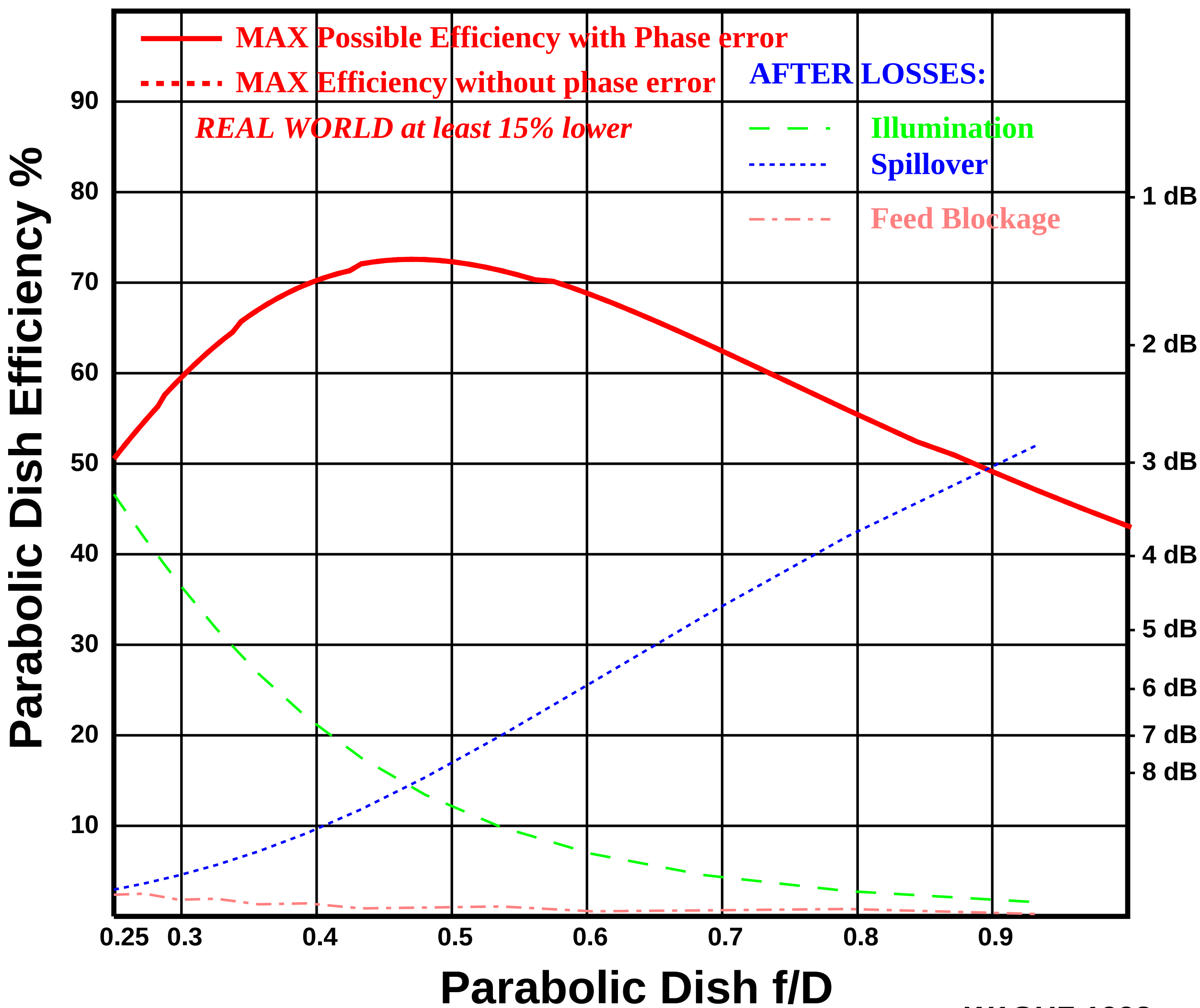
Figure 6.1-15





Dish diameter = 20 λ Feed diameter = 1.2 λ

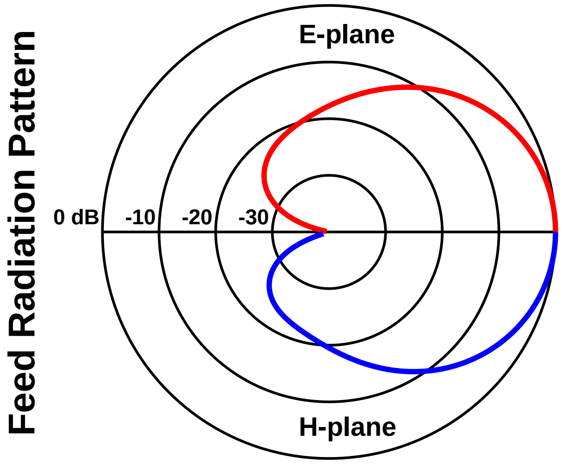
Phase Center = 0 λ beyond aperture

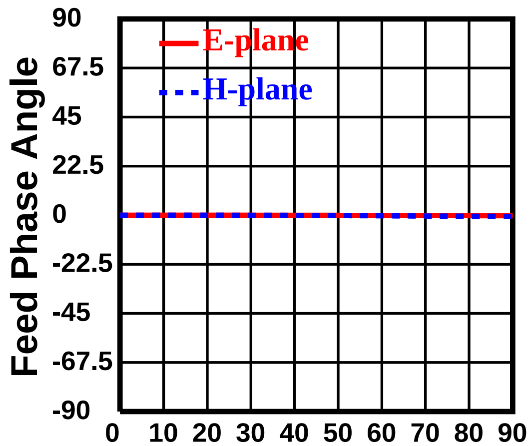


W1GHZ 1998

Test dish with feed at focus, by P.O.

Figure 6.1-16

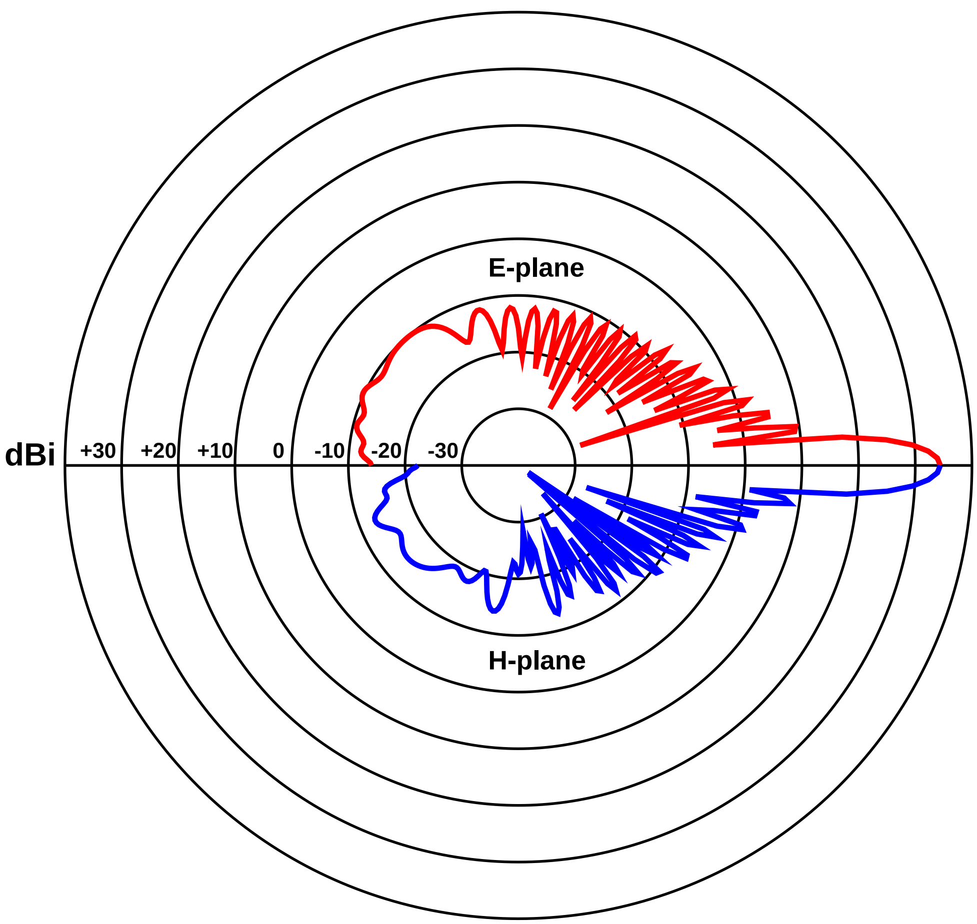




Dish diameter = 20 λ   Feed diameter = 1.2 λ

Rotation Angle around specified

Phase Center = 0 λ beyond aperture

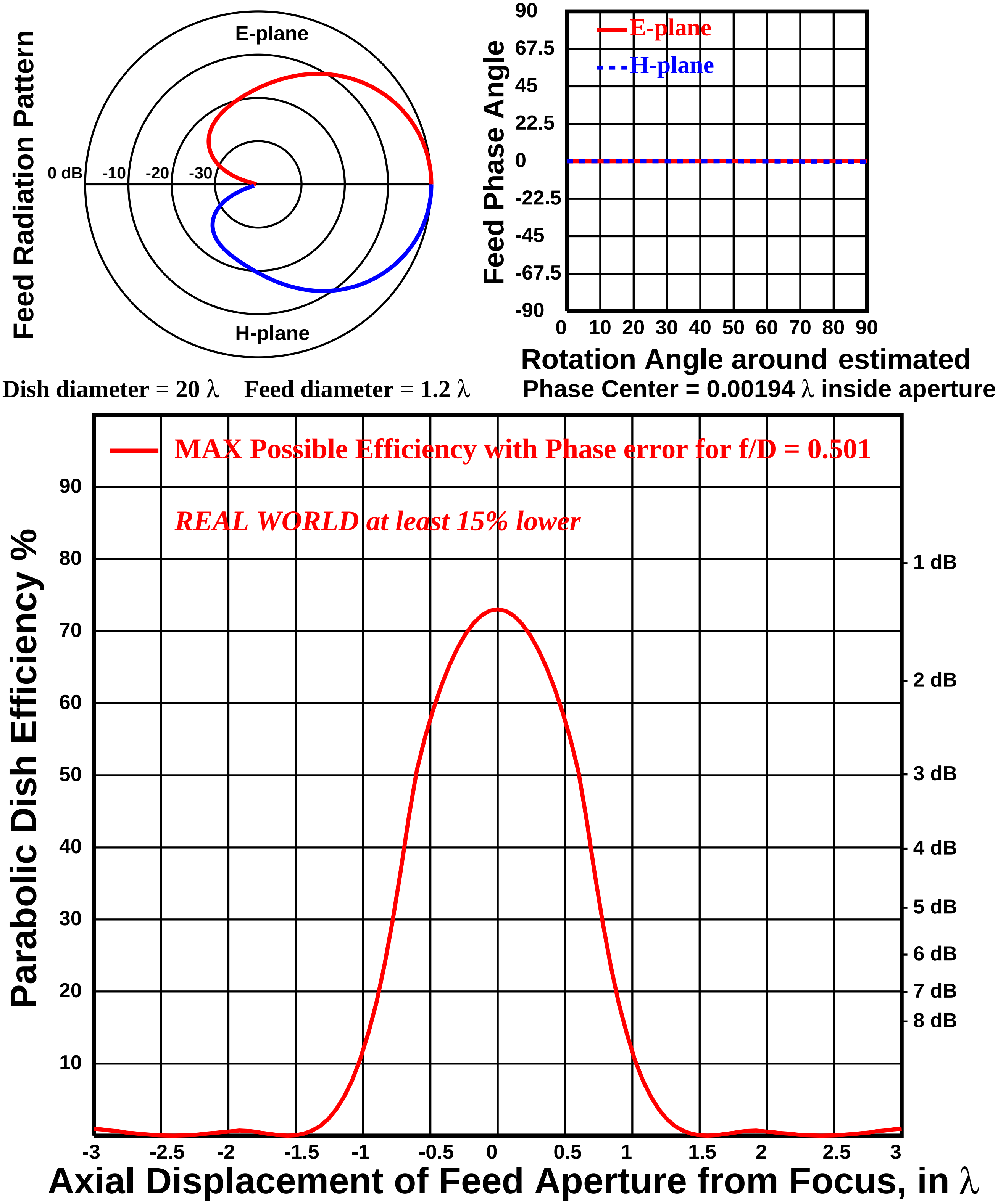


Radiation Pattern for Dish with above Feed

W1GHZ 1998

Test horn for dish examples, 1.2λ diameter, by P.O.

Figure 6.1-17



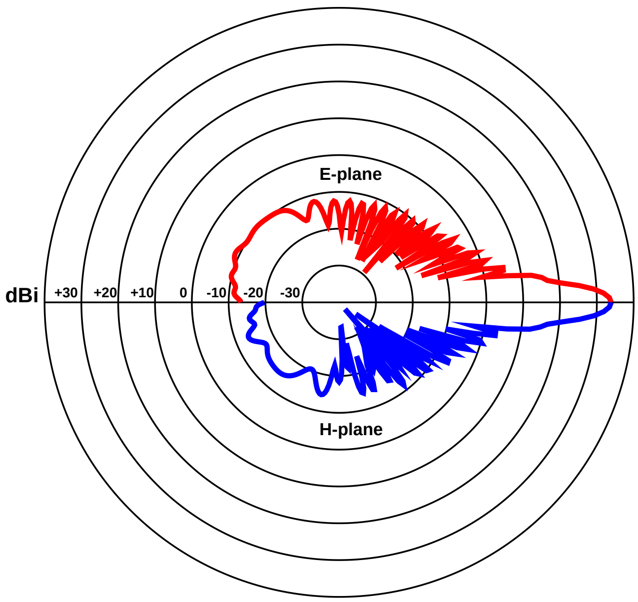
W1GHZ 1998

Dish patterns with feed displaced axially from focus, by P.O.

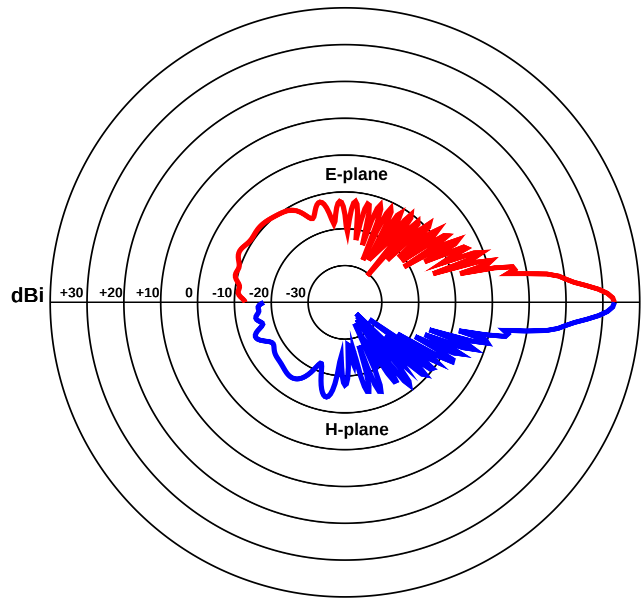
Figure 6.1-18

Dish diameter = 20 λ, *f*/D = 0.5

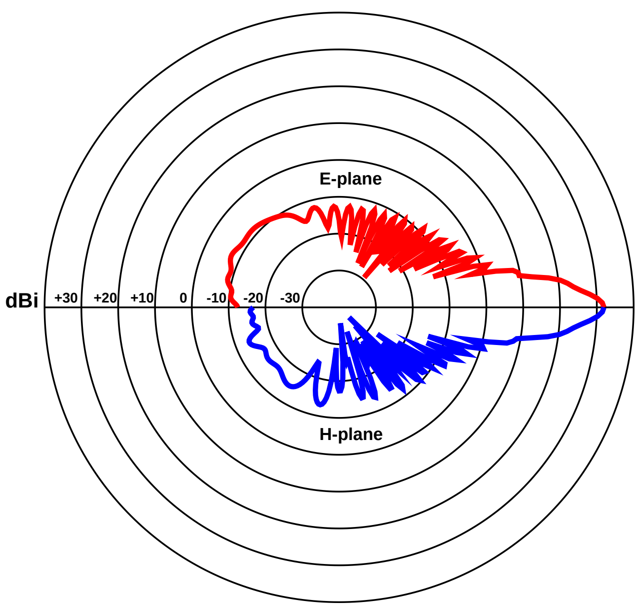
Feed diameter = 1.2 λ, Phase Center at feed aperture



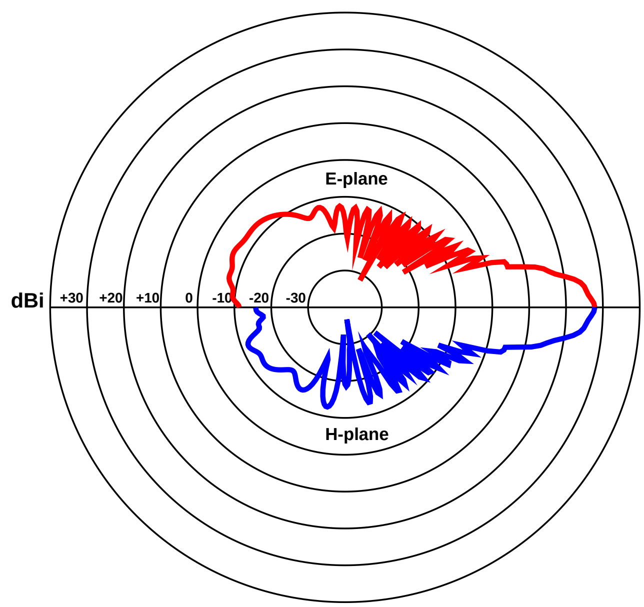
a: Feed 0.5 wavelengths toward dish



b: Feed 0.75 wavelengths toward dish



c: Feed 1.0 wavelengths toward dish



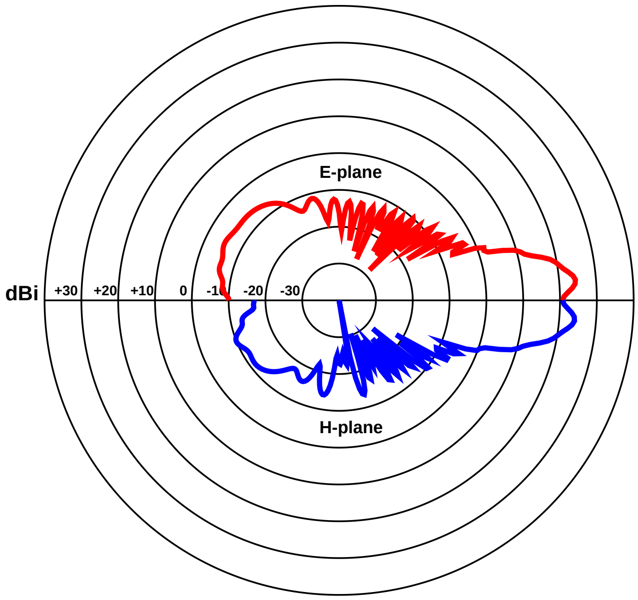
d: Feed 1.5 wavelengths toward dish

W1GHZ 1998

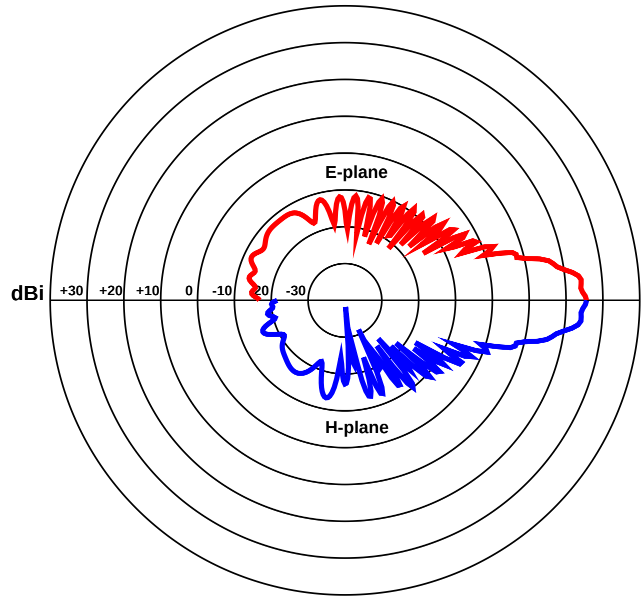
Dish patterns with feed displaced axially from focus, by P.O.

Figure 6.1-19

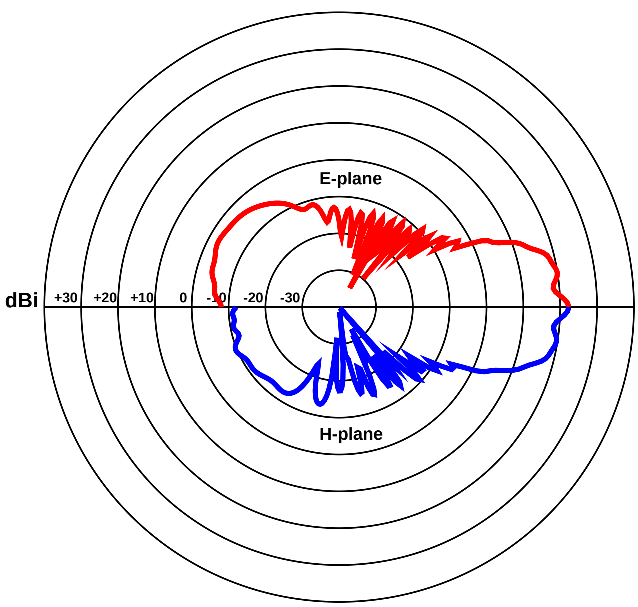
Dish diameter = 20 λ, *f*/D = 0.5 **Feed diameter = 1.2 λ, Phase Center at feed aperture**



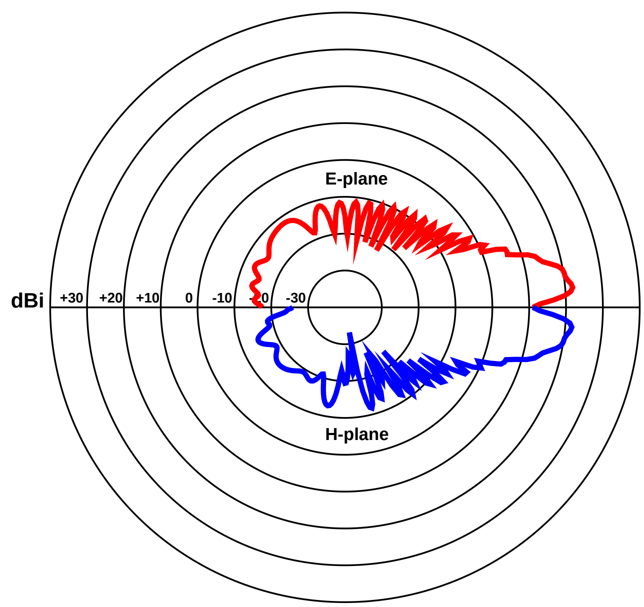
a: Feed 2.0 wavelengths toward dish



b: Feed 2.0 wavelengths away from dish



c: Feed 3.0 wavelengths toward dish



d: Feed 3.0 wavelengths away from dish

W1GHZ 1998

The radiation pattern of a dish is quite sharp, and it can be difficult to find signals if the direction is not accurately known. I have heard of hams who deliberately move the feed inward to defocus the dish, as a zoom control. Since we found that 3-dB beamwidth does not change for small axial displacements, this strategy obviously does not work. The beamwidth does become broader at large displacements, but the resulting gain is much lower and the pattern is dirty, so it would still be difficult to locate and peak weak signals. I think that being able to aim a dish accurately would be more effective in locating weak signals. For the very sharp beamwidths available at the higher microwave bands, scheduling or liaison on lower frequencies is often necessary.

6.1.6 Phase Summary

The ability to calculate antenna patterns with both amplitude and phase allows us to more accurately estimate performance of various parabolic dish feeds. It also provides the ability to calculate phase centers of the feeds and to see the effects of axial displacement errors. Graphical presentation enables us to visualize this data and use it to optimize the performance of our dishes.

As we concluded in Chapter 4, optimum dish performance is realized by matching the feed to the ***f*/D** of the dish and aligning the phase center of the feed at the focus of the parabola. Computer analysis is useful in both choosing the best feed and calculating its phase center.

Acknowledgements

The NEC models for many of the feedhorns were derived from models for the VE4MA and W2IMU feeds provided to me by Peter Beyer, PA3AEF. The NEC2 program was compiled to run under **linux** on an Alpha™ PC by Matt Reilly, KB1VC.

6.1 References

1. J.D. Dyson, “Phase Centres,” in *The Handbook of Antenna Design* (A.W. Rudge, K.Milne, A.D.Olver, & P. Knight, editors), Peter Periginus Ltd., 1986, p. 657.

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

3. L. Diaz & T. Milligan, *Antenna Engineering Using Physical Optics*, Artech, 1996.

4. W.V.T. Rusch, “A Comparison of Geometrical and Integral Fields From High Frequency Reflectors,” *Proceedings of the IEEE*, November 1974, pp. 1603-1604.

5. G. A. Evans, *Antenna Measurement Techniques*, Artech, 1990, p. 82.

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

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

8. D. Turrin, W2IMU, “A Paraboloidal Reflector Antenna for 1296 mc/s,” *Crawford Hill Technical Report #5*, 1971

9. R.C. Johnson, *Antenna Engineering Handbook*, McGraw-Hill, 1993, pp. 15-23 to 15-25.

10. P. Wade, N1BWT, “More on Parabolic Dish Antennas,” *The ARRL UHF/Microwave Projects Manual, Volume 2*, ARRL, p. 1-30 to 1-38.

11. J.D. Kraus, (W8JK), *Antennas*, McGraw-Hill, 1950, p. 376.