Chapter 6
Feeds for Parabolic Dish Antennas

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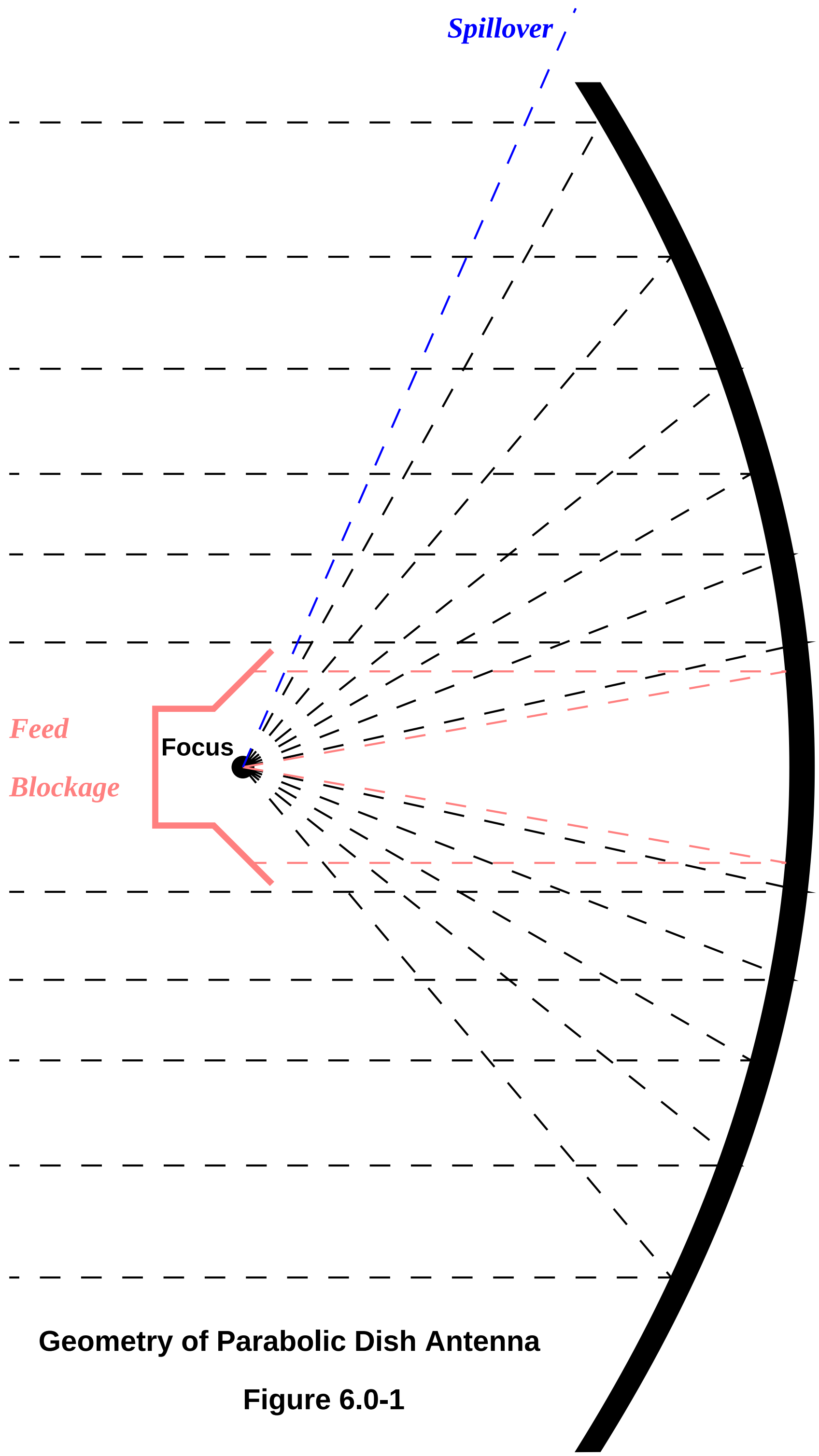
Section 6.0 Introduction

The key to good parabolic dish antenna performance is the feed antenna, the source of radiated energy for the antenna system. There is a bewildering number of choices out there, and an equal number of opinions about which is best. While there is no single best feed, we can choose the best available feed for a given reflector and frequency. If we make our selection based on measured data and proven performance, our probability of good results is much higher.

6.0.1 Feed Review

As we saw in Chapter 4, an optimum feed antenna for a parabolic dish reflector would have a radiation pattern which completely illuminates the reflector in both **E-** and **H-** planes with minimal spillover, as shown in Figure 6.0-1. A good feed also has the same phase center in both planes. A feed antenna must have a broad radiation pattern to illuminate a dish, much broader than the pattern of an antenna with reasonable gain. While the **HDL_ANT** program will do the calculations, it may be easier to understand the relationships visually. Figure 4-8 illustrates the desired illumination patterns for various ***f*/D** reflectors, and Figure 6.0-2 is a graph of illumination angle vs. ***f*/D**. Note that the relationship is not linear: the illumination angle for an ***f*/D** = 0.6 is not half the angle for an ***f*/D** = 0.3.

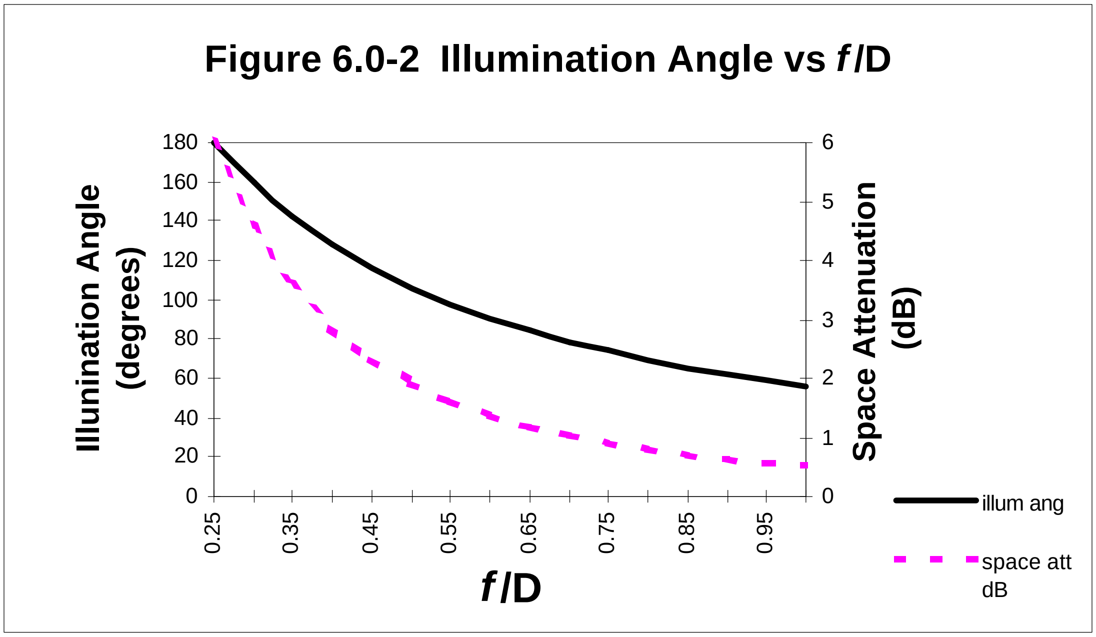
The illumination provided by most feeds is not uniform; less energy is available at the edge of the dish than at the center. Typically, a feed provides best efficiency when the energy at the edge, or edge taper, is about 10 dB lower than at the center. A larger taper, 13 to 16 dB, is sometimes used to optimize for **G/T.** We can choose a feed to provide the desired taper as an approximation — in Chapters 11 and 12, computer analysis of feed patterns by pattern integration provides more accurate results. To achieve the desired taper, we must account for space attenuation, since the edge of a parabola is farther away than the center from the focus. Since radiated power diminishes with the square of the distance (inverse square law), we can calculate the additional space attenuation at the edge. Figure 6.0-2 also plots space attenuation vs. ***f*/D**.



Geometry of Parabolic Dish Antenna

Figure 6.0-1

The total edge taper is the sum of the feed taper, radiation pattern of the feed at the edge of the dish, and the space attenuation. For example, a dish with an ***f*/D** of 0.35 has 3.6 dB of space attenuation and an illumination angle of 142 degrees. To provide an edge taper of 10 dB, a feed must have a pattern that is 6.4 dB down at the edge, 90° from the axis, so that the sum of the pattern and the 3.6 dB space attenuation is 10 dB. Since the feed pattern is only 6.4 dB down at the edge, some spillover is inevitable, as illustrated in Figure 4-8e.



6.0.2 Feed Comparisons

In this chapter we will be examining a number of different feeds. Since all dishes with the same ***f*/D** have the same geometry, a feed that is optimum for a given reflector is also optimum for all reflectors with similar ***f*/D.** Thus, feed comparisons should be made at the same ***f*/D**; ideally, the ***f*/D** for which they are best suited.

For analysis and comparison of feeds, we will use measured gain data where available, particularly the measurements in Chapters 9 and 10. We will also use computer analysis by pattern integration of measured and published radiation patterns for various feeds, using the **FEEDPATT** software described in Chapter 11. For many of the feeds, we will also use calculated radiation patterns, as described in Chapter 12. The calculated radiation patterns provide phase information, which not only enhances the efficiency calculation but also enables phase center calculations. The **PHASEPAT** software described in Chapter 12 makes these calculations. Where data is lacking, I may add some personal opinion.

To eliminate some variables and ease comparisons, efficiencies for most feeds are calculated using a reflector diameter that is ten times the feed diameter. This diameter ratio makes feed blockage pretty much the same for all feeds. However, in practice, this is not the case — for small dishes, the feed blockage of a physically large feed may outweigh any potential performance advantage. If possible, the efficiency curve should be recalculated for the actual feed and reflector diameters.

Offset-fed dishes typically have almost no feed blockage, so for those feeds intended for offset dishes, I specify a feed diameter much smaller than the actual diameter so that blockage loss not significant. Lower feed blockage is a significant advantage for offset dishes.

Finally, wherever possible, dimensions are specified in wavelengths, so that comparisons are not frequency dependent. Almost all feeds will work at other frequencies if all dimensions are scaled proportionally.

6.0.3 Antenna Efficiency

The criterion for performance comparison is antenna efficiency. For a given aperture, higher efficiency equates to higher gain. While a larger aperture can also provide more gain, it makes sense to get as much performance as possible out of a smaller dish before struggling with the narrower beamwidth, increasing wind loading, and mechanical difficulties associated with larger dishes.

For EME, the dish is usually as large as possible, so increased efficiency is the only way to improve antenna performance. At 10 GHz, antennas larger than about 5 meters in diameter have beamwidths narrower than diameter of the moon, so increasing size will not improve performance; the only avenue left is to maximize dish efficiency.

While measured gain obviously accounts for all losses, the **FEEDPATT** program only accounts for the losses that are unavoidable: illumination loss, spillover loss, and feed blockage loss. There are several other losses found in a real dish:

- phase error – *new* **PHASEPAT** program includes phase error
- feed not at focus
- diffraction from the edge of the dish
- polarization shift due to reflector geometry
- blockage by feed supports
- surface error in the parabolic reflector
- feedline loss
- feed VSWR

These losses occur in greater or lesser amounts in a given antenna, so that the real efficiency is *always* lower than the maximum possible efficiency shown in the curves. The best antennas I have measured have efficiencies perhaps 15% lower than the curves, while others are significantly worse. A typical efficiency for a moderate-sized dish is about 50%, for a gain 3 dB below the theoretical gain for a given aperture size. A really good dish has an efficiency of 60% or so, about 1 dB better than a typical dish, while a poorly chosen feed or a poor installation can make the gain several dB worse. One dB difference may not seem like much, but it is a huge difference for an EME station that can't squeeze another dB from the preamp or power amplifier.

For most of the feeds, the analysis and plots are for a feed diameter one-tenth of the reflector diameter, so that feed blockage is comparable for all feeds. Also, dimensions are given in wavelengths to remove any frequency dependency. However, the actual blockage is a function of dish diameter — a small (in λ) dish might have better performance with a physically small feed that has less loss due to blockage. Running the **FEEDPATT** or **PHASEPAT** analysis programs for various feeds with actual reflector and feed diameters could be illuminating.

6.0.4 Reverse Feeds

Reverse feeds, where the feedline and the radiation direction are the same, have an obvious attraction — the feedline can pass through the center of the dish for minimum length and loss. Waveguide feed lines can also support the feed, minimizing blockage by struts and support structure. The G4ALN "Penny feed" described in Section 6.7 is a popular reverse feed.

Unfortunately, there are few high-performance reverse feeds. Most feeds suitable for configuration as reverse feeds, like dipole feeds and the Penny feed, are best suited for very deep dishes with low ***f*/D**, and offer rather mediocre performance. So we are left with a tradeoff of feed performance vs. feedline loss (note that common semi-rigid coax has a loss on the order of 2 dB per meter at 10 GHz).

For high performance, we must find a way to have a good feed *and* low feedline loss — one way is to mount amplifiers at the feedpoint. Another way is to use a "shepherd's crook" arrangement of low-loss waveguide, like the one shown in Figure 6.0-3. A third solution is the offset-fed dish, where the focus is not in the main beam, so the electronics may be mounted next to the feed.

6.0.5 Dish setup and adjustment

Finally, Appendix A6 describes a simple procedure for setting up a dish and feed to make a working antenna system.

6.0.6 Feed Index by Name

Since there are a large number of feeds available for discussion, with plots and graphics for many of them, this chapter will be broken into several files. The grouping will be by families of similar feeds. The following alphabetical index of feed names may be used to locate the section that contains a description for a given feed, or to select suitable feeds for a particular ***f*/D**:

FEED	Best *f*/D	Section
Backfire Helix		6.6
Backward feeds	—	6.7.2
Cassegrain		6.10
Chaparral	0.3 – 0.45	6.3.4
Circular waveguide rear feed	0.3 – 0.4	6.7.4
Clavin	0.3 – 0.4	6.7.1, 6.7.2
Coffee-can	0.25 - 0.4	6.3.1
Conical horn	≥ 0.4	6.4.2
Corrugated horn	≥ 0.4	6.4.3
Cylindrical horn	0.25 - 0.4	6.3.1
Diagonal horn	≥ 0.3	6.5.3
Diffraction Loss	—	6.7.3
DC3QS	0.25 – 0.3	6.7.2
DK2RV	0.3 – 0.4	6.7.4
Dual-mode horn (W2IMU)	0.5 – 0.8	6.5.1
Dipole	0.25 – 0.35	6.2.1
EIA	0.4 – 0.6	6.2.2
G4ALN (Penny)	0.25 – 0.3	6.7.2
Handlebar	0.3 – 0.5	6.2.2
Helix		6.6
Indirect rear feed	—	6.7.2, 6.7.4
KF4JU	0.35 – 0.5	6.2
Koch		6.8
Kumar	0.3 – 0.45	6.3.3
Loop	0.35 – 0.5	6.2.3
Love (diagonal horn)	≥ 0.3	6.5.3
NBS (see EIA)	0.4 – 0.6	6.2.2
Penny (G4ALN)	0.25 – 0.3	6.7.2
Pillbox	~0.3	6.7.2
Potter		6.5.2
Procom	~0.3	6.7.2
Pyramidal horn	≥ 0.45	6.4.1
Rear feeds	—	6.7.2
Rectangular horn	≥ 0.45	6.4.1
RSGB	—	6.7.2, 6.7.4
Scalar		6.8

Shepherd's Crook	—	6.7.5
Sletten	0.25 – 0.3	6.2.1
Turrin (W2IMU)	0.5 – 0.8	6.5.1
VE4MA	0.3 – 0.45	6.3.3
WA9HUV	0.3 – 0.35	6.3.2
W1YLV	0.25 – 0.3	6.2.1
W2IMU	0.5 – 0.8	6.5.1
W7PUA Double Handlebar	0.3 – 0.5	6.2.2
Waveguide		6.3, 6.4