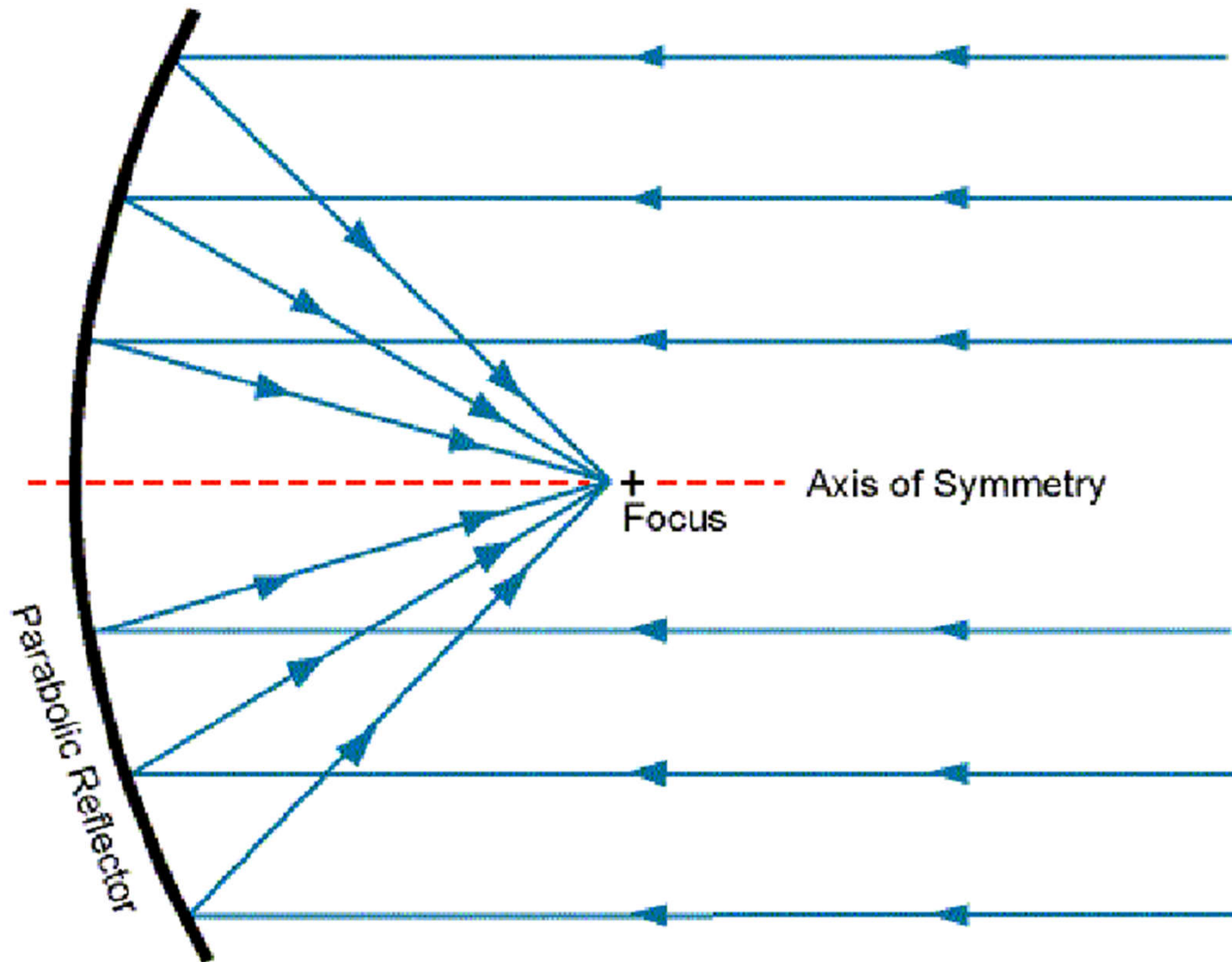


**CHAPTER FIVE:**  
**SATELLITE RECEIVING ANTENNAS**

The satellite dish is a parabola of revolution, that is, a surface having the shape of a parabola rotated about its axis of symmetry (Figures 5-1 and 5-2). The resulting paraboloid shares one key property of optical lenses: it is able to form an image of whatever object is placed in front of it. The largest optical and radio telescopes employ the parabolic reflector to gather and concentrate electromagnetic radiation. Any

antenna surface irregularities or any departure from the precise parabolic shape will degrade the image resolution. As is more often the case, however, low-resolution performance is the result of the installer's failure to grasp the importance of using good antenna assembly techniques.



*Figure 5-1. The parabolic curve has the property of reflecting all incident rays arriving along the antenna reflector's axis of symmetry to a common focus located to the front and centre.*

The parabolic reflector receives externally generated noise along with the desired signal. When

the "cold" sky, the antenna noise temperature is at its lowest level. If the antenna must tilt downward to receive a low-elevation satellite, however, the antenna's noise temperature will increase dramatically because it is now able to intercept the "hot" noise temperature of the Earth (Figure 5-3). The actual amount of noise increase in this case is a function of antenna  $f/D$  ratio and diameter. Minimum antenna elevation angles of 5 degrees, for C-band, and 10 degrees, for Ku-band, above the site location's horizon usually are recommended.

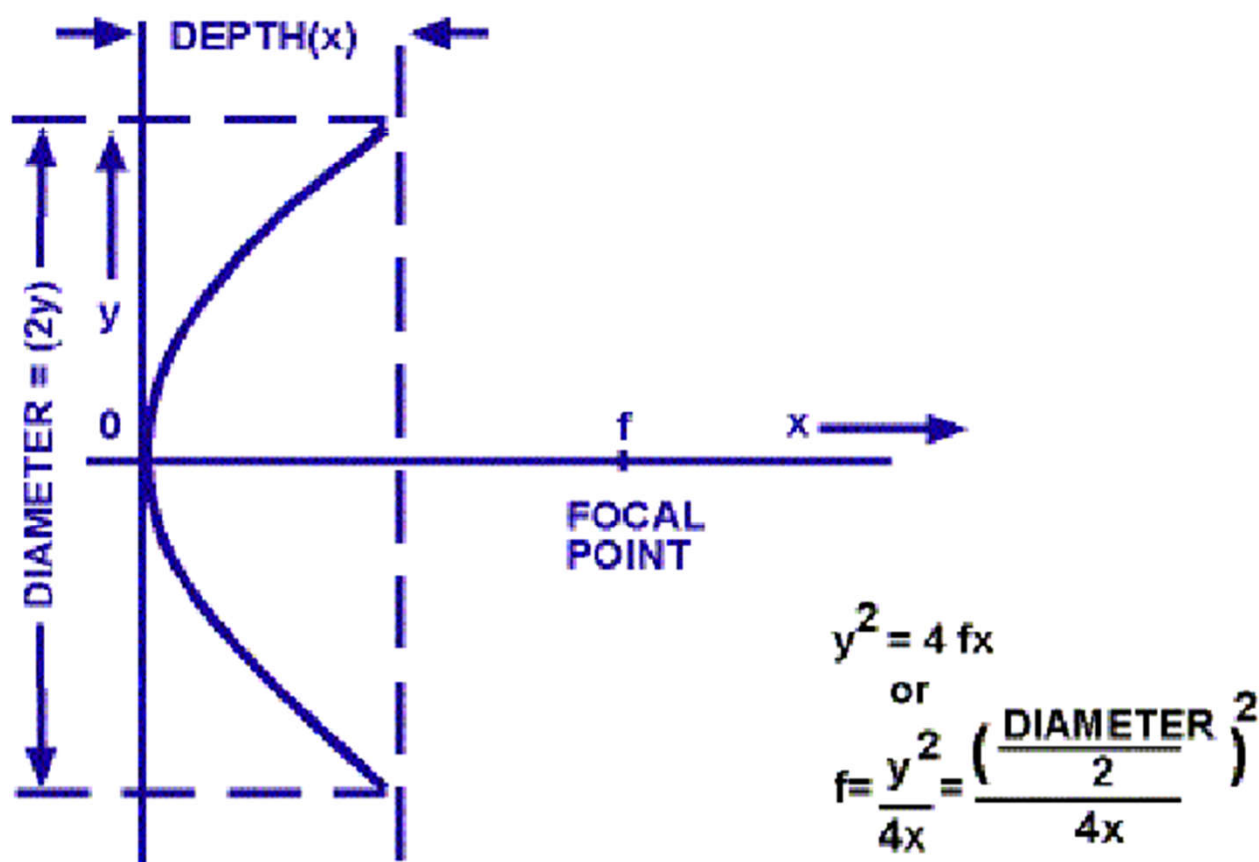


Figure 5-2. Calculation of the parabolic curve. (Courtesy H. Taylor Howard.)

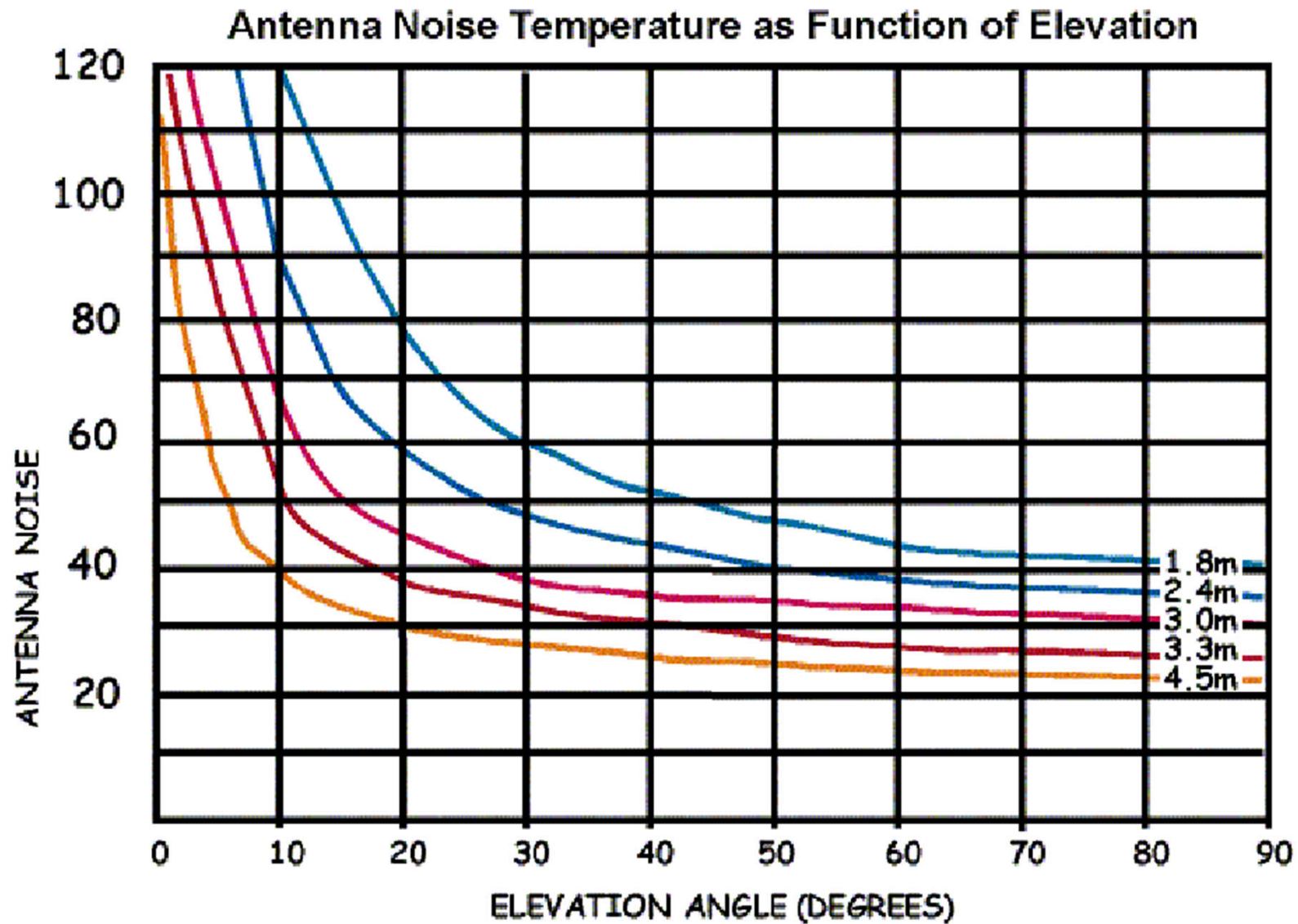


Figure 5-3. Antenna noise temperature is a function of the antenna  $f/D$  ratio and diameter as well as the elevation angle of the dish as it points toward the geostationary satellite's location in the sky.

## Dish Materials and Construction

The reflector's surface material must be constructed out of metal in order to reflect the incoming microwave signals. Some antenna reflectors appear to be manufactured out of plastic or fiberglass; however, these dishes actually have an embedded metal mesh material that reflects the incoming satellite signals to the front and center of the dish.

The solid one-piece metal antenna is most always the dish with the best performance characteristics because there can be no assembly errors and the reflector normally will maintain its precise shape over the lifetime of the system. Solid petal antennas constructed out of four or more metal panels are generally the next best performance value, as potential assembly errors are limited to variations along the seams between panels. The installer can visually inspect these seams during assembly to ensure that there are no variations in the surface curve from one petal to the next. Installation errors almost never occur when this type of antenna is assembled face-down on a flat, level surface.

Both one-piece and petal antennas also are available in a perforated form. The desired diameter of the perforation holes is a function of signal wavelength: too small to pass or resonate with the wavelength of the incoming microwave signals, but large enough to pass light in order to minimize the antenna's environmental impact.

Mesh antennas are the most susceptible to construction errors. The two-part construction process consists of the building of a support frame, onto which is laid flexible mesh panels. The installer attaches the mesh material to the frame using a series of metal clips or sheet metal screws. This type of antenna is susceptible to construction errors because it must be assembled face up with no level surface to act as a jig to hold the reflector in place.



Mesh antennas also are highly susceptible to environmental effects. Heavy windstorms, for example, can loosen the clips holding the mesh to the frame and distort the curve from its original shape, or even blow out one or more of the mesh panels.

The installer should examine the antenna at intervals during the installation process. In the case of petal antennas, close attention should be paid to how the various panels fit together. The reflector surface should appear to be continuous, with little or no variation from petal to petal and few noticeable bumps or waves along the surface of mesh antennas.

Antenna symmetry is also very important. Improper construction of a petal antenna can warp the reflector curvature. The installer should sight along a side view of the reflector from the near to far edge of the rim. If the near and far rims of the dish do not line up in parallel with each other, then the installer will need to loosen the bolts holding the petals together and retighten them in such a way that the reflector conforms to the manufacturer's intended shape. Another way to detect a warped dish is to run a series of strings across the face of the antenna (Figure 5-4). All strings should lightly touch over the center of the dish. Any gaps between strings indicate a deviation in the parabolic curve.




*Figure 5-4. Stringing the dish is one method of visually verifying correct antenna construction. It also allows the installer to measure the antenna's depth.*

## Prime Focus Antennas

The "prime focus" antenna places the feedhorn at the focal point of the paraboloid reflector so that it looks back into the dish. The reflector focuses the incoming planar wavefront to converge at the phase center, which occurs just inside the mouth of the feed, to optimally excite the chosen mode in the waveguide. Aperture blockage by the feedhorn is minimal, but the location of the focus can be inconvenient, requiring the installer to mount the LNB also at prime focus, where it is inaccessible for adjustment and exposed to the direct and reflected rays of the sun as well as other adverse environmental effects.

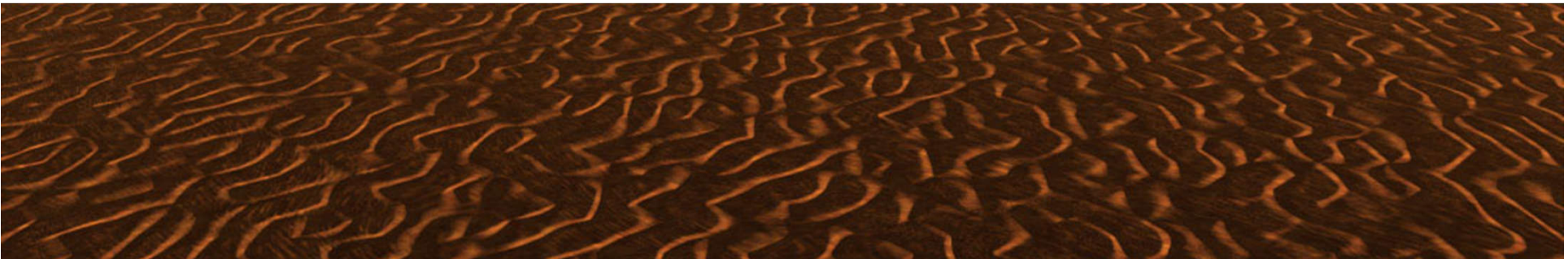
Prime focus antennas are easy to construct and point toward the desired satellite. However, there are two main design disadvantages. The feedhorn and feed support structure block part of the reflector surface, and the feedhorn must look back at the dish at such an angle that it can also intercept noise from the "hot" Earth located directly behind the reflector. The way that the feedhorn illuminates the antenna must be tapered so that the noise contribution is minimized, as the feed looks outward toward the rim of the dish. This design necessity acts to reduce the maximum efficiency level that the antenna can attain. This is why prime focus antennas typically only achieve an efficiency level of 55-60 percent.



Prime focus antennas use two different types of feedhorn support bracket. A bracket with multiple support legs (either three or four legs) provides a rigid support structure for the feedhorn and LNB, placing them over the center of the dish and at the distance specified by the manufacturer. The main disadvantage of this structural approach is that it may be difficult to make minor variations in the focal length, that is, the distance from the reflector center to the lip of the feed opening.

The buttonhook structural design uses a single support member to position the LNB and feedhorn. This tubular leg usually can be slid in and out of a clamp or bracket at the center of the dish, allowing the installer to fine-tune the focal length quickly and easily. However, the buttonhook support may not always position the feed at the precise center of the dish, especially in those instances when the feedhorn is weighted down by more than one LNB.

Motorized dishes may experience feedhorn movement when the antenna moves from one satellite to the next; heavy windstorms can also temporarily move the feedhorn away from the antenna's focus. Guy-wire kits are available that the installer can use to provide additional structural rigidity to the buttonhook support if required for a given installation.



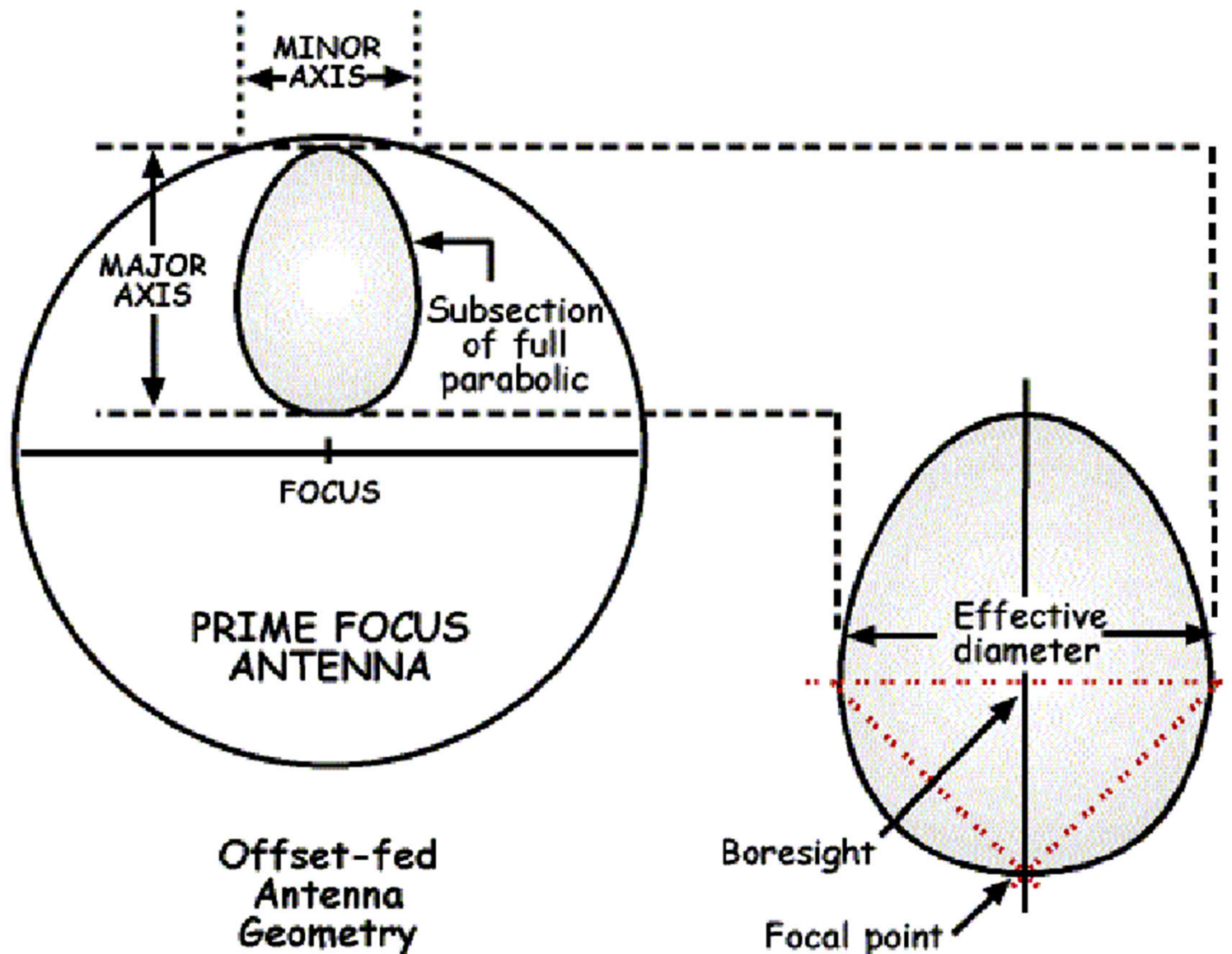


Figure 5-5. Offset-fed antenna geometry

## Offset-fed Antennas

One oval dish design that is the antenna of choice for most digital DTH satellite TV service providers is called the offset-fed antenna (Figure 5-5). Here the manufacturer uses a smaller subsection of the same paraboloid used to produce prime focus antennas (see Figure 5-6), but with a major axis in the north/south direction, and a smaller minor axis in the east/west direction.

The offset paraboloid eliminates aperture blockage, reduces antenna noise temperature, and resists the accumulation of ice and snow by placing the feed below the reflector and angling it upwards. In this case, the reflector acts as if it were a portion of a much larger paraboloid. But because only a portion of this imaginary reflector exists, the feed is designed just to illuminate that portion. The offset-fed antenna then performs just as it would as a part of the larger dish, and directs its beam exactly the same way.

The offset-fed antenna design offers several distinct advantages over its prime focus counterparts. There is no feedhorn blockage, an important consideration when the antenna aperture is less than one meter in diameter. Moreover, antenna designers can reconfigure the required antenna aperture as a flatter, more nearly vertical reflector, with the added advantage of pointing the feed skywards, away from the hot-noise source of the Earth. Because of these advantages, the offset-fed antenna can achieve higher efficiency levels than prime focus antennas normally attain, usually in the 70 percent range.



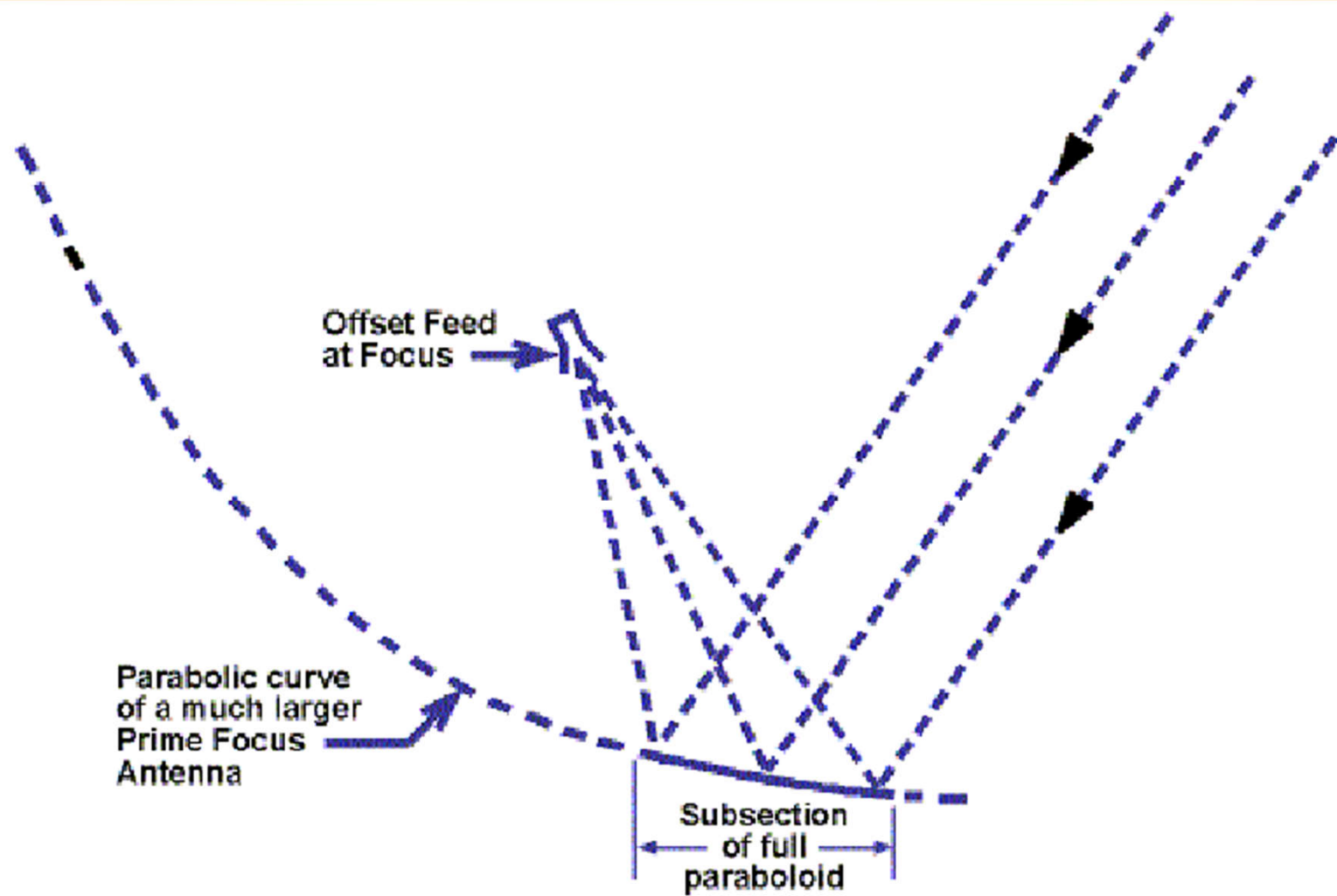


Figure 5-6. The curve of the offset-fed antenna is actually a sub-section of a paraboloid.



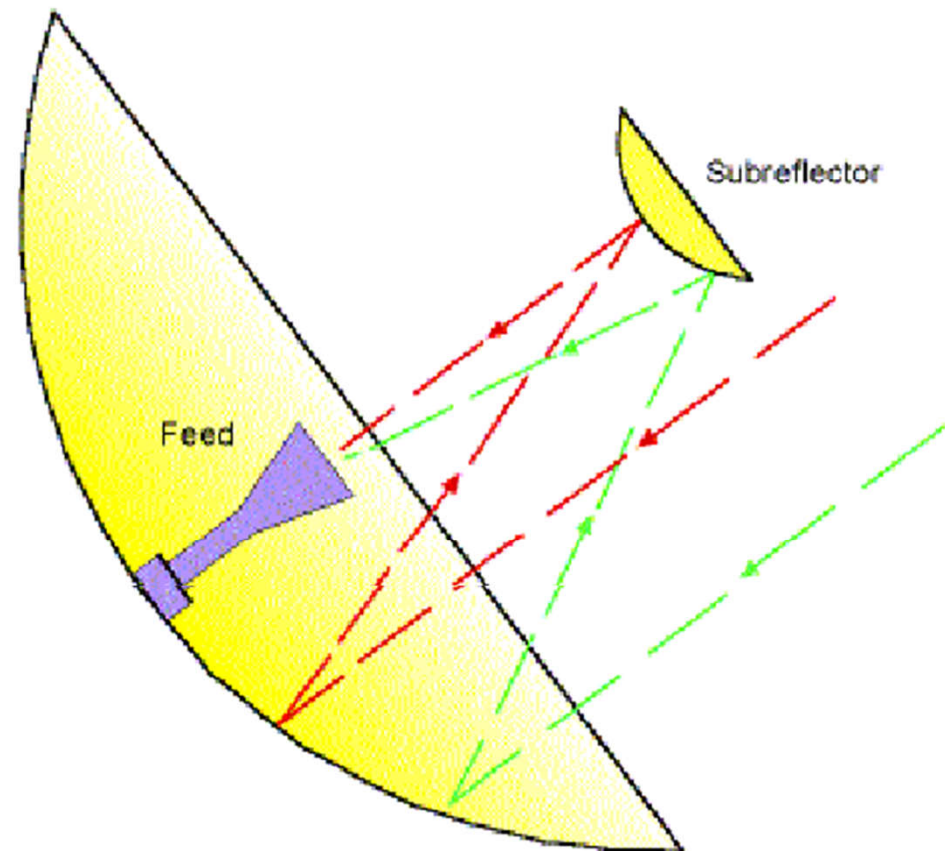
## The Cassegrain Antenna

The cassegrain is a dual-reflector antenna design that primarily is employed at large-aperture uplink earth stations and cable TV head ends. The cassegrain improves aperture efficiency beyond the 55-60 percent that typically is achieved by the prime-focus antennas previously described by matching the feedhorn illumination profile more closely to the antenna aperture. It is characterized by a convex subreflector and a larger feed aperture than the prime focus antenna requires.

*Figure 5-7. Cassegrain antenna geometry. The cassegrain*

*subreflector. The subreflector diameter must be kept small to minimize blockage, but larger than about five wavelengths at the operating frequency to minimize diffraction effects.*

As with the prime focus dish, the cassegrain antenna's view of the satellite is partially obstructed, in this case by the subreflector (Figure 5-7). The subreflector diameter must be kept small to minimize blockage, but larger than about five wavelengths to minimize diffraction effects. Because of this five-wavelength limitation, the cassegrain design approach is not employed for C-band antennas that are smaller than 5 meters in diameter.



When the diameter of the main reflector exceeds 5 meters, however, the amount of subreflector blockage represents only a small percentage of the main reflector's total capture area.

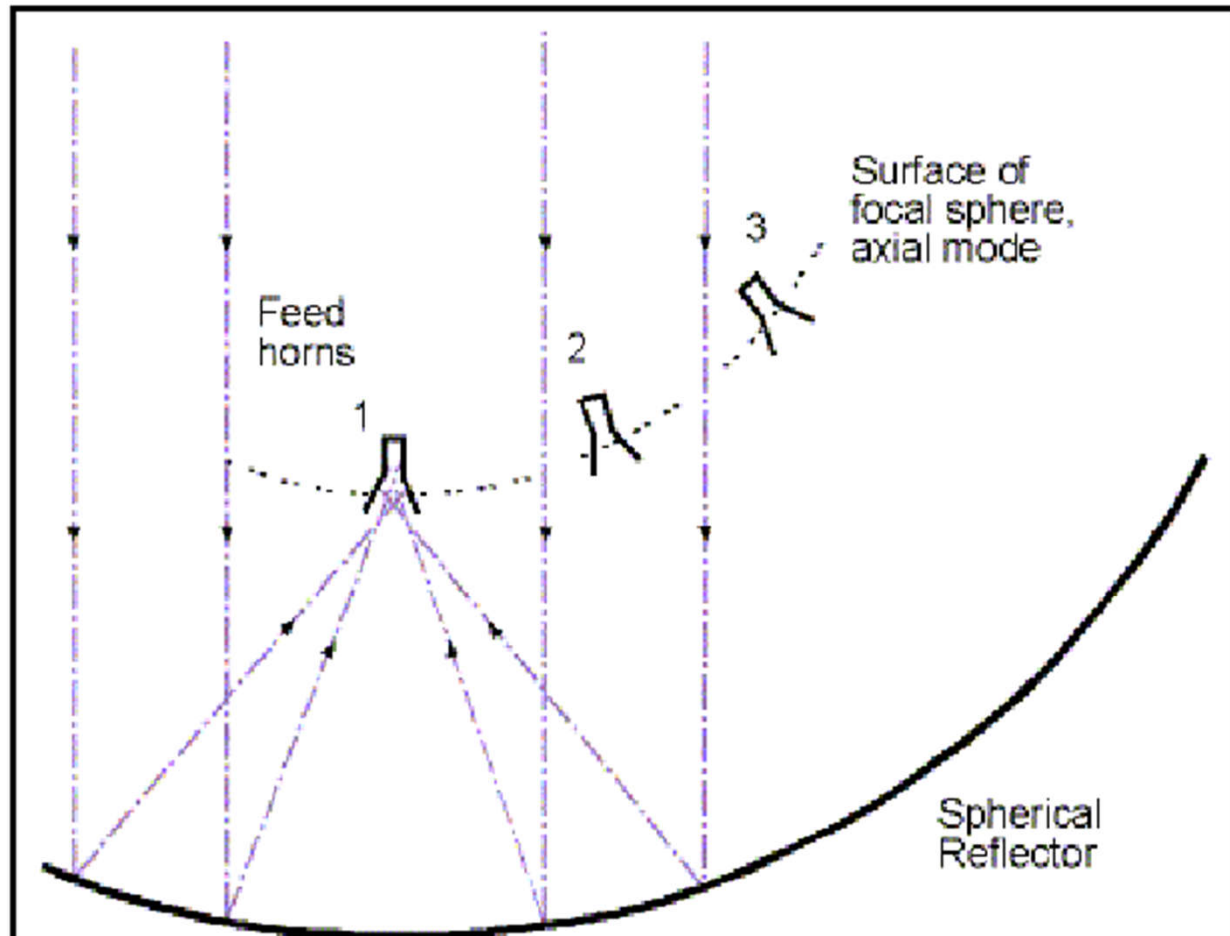
This innovative dual reflector design allows the designer to approximate more closely the ideal of even illumination across the profile of the main reflector without encountering appreciable noise beyond the antenna's rim. To accomplish this, the designer must alter the profile of the antenna's subreflector so it no longer is a true hyperboloid of revolution. This variance of shape alters the feed pattern on the main reflector to favor the region towards the rim, but with a rapid fall-off beyond the rim.

One side effect of this subtle change is that it also destroys the equality of all ray paths from the feedhorn to the far-field region so that waves reflected from different parts of the main reflector no longer arrive at the feedhorn in phase. To compensate for this, the designer must use a computer-derived profile to alter the main reflector from a parabola of revolution. This slight alteration is just enough to bring all points of the aperture back into phase inside the opening of the feedhorn. The result is an increased aperture efficiency of up to 78 percent, or a 1.5-dB increase in gain for a given antenna diameter. The precise manufacturing tolerances required, however, increase the cost of production and add to the complexity of the installation process.

## The Spherical Antenna

Spherical antennas primarily are used for commercial SMATV and cable installations where the customer wishes to simultaneously receive multiple satellites with a single antenna. The spherical antenna design creates multiple focal points located to the front and center of the reflector, one for each available satellite. The curvature of the reflector is such that if it were extended it outward far enough along both axes it would become a sphere (Figure 5-8).

The planar wavefront emanating from a communications satellite



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The planar wavefront emanating from a communications satellite

seen, if these rays approach in parallel to the paraboloid's axis of symmetry, they are reflected to a well-defined prime focus (F). This is the property of the paraboloid that makes it an excellent design choice for a microwave antenna.

