
Feed design and selection for microwave antennas

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While many of us may take microwave antenna design for granted, there is a long history of experimentation and improvements leading to the current generation of microwave antennas. By understanding these different designs and their tradeoffs, one can best choose the appropriate feed for a particular application.

Initial design and experimentation with microwave antennas began more than 100 years ago, reaching back to that key pioneer of well-known fame, Guglielmo Marconi. Microwave system work using parabolic antennas grew significantly during the 1930s. During World War II designs such as pencil-beam and shaped-beam antennas were developed for radar systems used by the Allies. While many advances were made at this time, it was in the 1950s that terrestrial microwave communication systems were deployed and parabolic reflector designs were utilized on these commercial systems. Over time, numerous feed designs have been developed, some more optimum than others.

This article will explain basic feed design and selection for microwave antennas.

A basic schematic for a microwave antenna can be seen in Figure 1. A feed system is placed with its phase center at the focus of the parabola. Ideally, all the energy radiated by the feed will be intercepted by the parabola and reflected in the desired direction. To achieve maximum gain, this energy would be distributed such that the field distribution over the aperture is uniform. Because the feed is small, however, such control over the feed radiation is unattainable in practice. Some of the energy actually misses the reflecting area and is lost; this is commonly referred to as “spillover.” Also, the field is generally not uniform over the aperture, but is tapered: maximum signal at the center of the reflector, less signal at the edges. This “taper loss” reduces gain, but the field taper provides reduced sidelobe levels. Optimum performance is generally considered to be achieved with a -10 dB edge illumination taper.

A common way to define a parabolic dish shape is with the F/D ratio, where F is the focal length and D the diameter of the dish: the smaller the ratio, the “deeper” the dish. Most commercial microwave antennas use an F/D ratio of .25 to .38, with .32 to .36 the most common. The F/D ratio for a reflector can be determined by measuring the depth of the dish from the plane of the rim to the vertex at the center and using the basic equation for a parabolic curve. Typically, only measurement from the vertex to the rim is required, since a parabola of revolution consists of the same shape curve for all radial sections.

One of the simplest feeds for a microwave antenna is the dipole. Due to its simplicity, the dipole was the first to be used as a feed for reflector antennas. While easy to design and implement, the dipole feed has inherently unequal E and H plane radiation patterns, which do not illuminate the dish effectively and thus reduce efficiency. Another disadvantage of the dipole feed for some applications is that due to unequal radiation patterns cross-polarization performance is not optimal. Small sub-reflectors of various designs located behind the dipole will improve the feed pattern performance and gain. The dipole feed also may be used as feeds for non-symmetrical grid parabolas as in Figure 2. The usage of a corner reflector behind the dipole also can enhance pattern performance and gain in many designs. The dipole feed is generally used for frequencies of less than 5 GHz.

The open-ended waveguide is another type of simple feed. Like the dipole feed, it has inherently unequal E and H plane radiation patterns, which leads to poor radiation patterns and efficiency. By flaring the waveguide opening into a horn shape, the patterns in both planes can be equalized. The flare must be gradual such that the E and H plane phase centers are reasonably close to each other. Some designs also use circular openings, or various arrangements of “chokes” or “baffles” attached to the outside of feed to improve performance.

These rectangular waveguide feeds are often designed by bending solid waveguide into a curve so that the waveguide input is at the vertex of the dish and the feed is located at the focal point of the parabola. The “button-hook” (or J-hook) design in Figure 3 has been a staple of commercial microwave antenna design for decades. This style of feed can provide excellent VSWR performance, which was important with older generation analog microwave radios. However, scattering off the waveguide and feed support structures causes radiation pattern distortion. Also, bending waveguide is an expensive operation requiring highly skilled labor. Special techniques must be used for dual linear or circular polarization.

During the 1980s the need became greater for a lower profile microwave antenna that also exhibited superior pattern performance. Two forces drove this requirement. One was the need to reduce the visual impact of radio communication installations. The other was the need to place more and more microwave “links” in the same geographic area.

In 1988, Radio Waves introduced one of the first hybrid-Cassegrain sub-reflector type feeds for high frequency commercial microwave antennas. This design is a modification of the classical Cassegrain feed system. In a Cassegrain system, a feed is mounted in the dish and energy is radiated toward a sub-reflector.

With a hybrid Cassegrain system, the energy is transported through a circular waveguide that radiates into a reflective surface at the focal point. This reflected energy is then prorogated through a carefully shaped dielectric lens mounted between the sub-reflector and waveguide tube. The dielectric lens is typically made from a piece of rexolite, which has a dielectric constant of 2.54. An illustration of this feed is shown in Figure 4 and a picture in Figure 5.

At times, this design is mistakenly referred to as a “back-fire” feed system. A back-fire feed does not incorporate the dielectric lens and suffers from poor side lobe performance relative to the hybrid-Cassegrain style feed.

This hybrid-Cassegrain design has several benefits over the button-hook design, including higher antenna efficiency. Because the hybrid-Cassegrain feed is shorter than the J-hook feed, the entire antenna has a lower profile and lower wind loading. The feeds use a circular waveguide that provides inherent dual-polarization capability. Polarization is determined by the orientation of the input device (rectangular to circular transition or omt) that can be rotated easily to change polarization. Modern electromagnetic simulation software allows the reflecting surface of the feed to be shaped to provide superior control of radiation pattern. Due to the fact that these feeds are self-supporting, there is no scattering off the feed support system as in the button-hook design.

One slight disadvantage of these designs is that they have higher VSWR than button-hook feed designs. However, with today's digital radios, this does not cause degradation in performance. These “back-fire” feeds are generally used for frequencies of 5 GHz to 60 GHz. For modern radio systems requiring high efficiency in a smaller package, the hybrid-Cassegrain feed reflector antenna is most applicable.

There are many other techniques that can be used to optimize microwave antennas for best performance in a particular application. Some of these include the usage of reflector shrouds and absorber material to improve pattern performance and shaped reflectors to improve pattern

performance or gain. These concepts may be dealt with in a future article.

In summary, hybrid-Cassegrain feed antennas provide optimum mechanical and electrical performance for modern high frequency digital microwave radio systems. Applications that still use older analog radios requiring very stringent VSWR specifications are best served by antennas using buttonhook feed systems. Dipole feed system can be used for applications below 6 GHz that require a low cost antenna and that do not demand the most robust pattern performance. However, for modern high-frequency microwave radio systems requiring high efficiency in a smaller package, the hybrid-Cassegrain feed reflector antenna is most applicable.

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