THE EFFICIENCY PROBLEM IN SMALL TELEMETRY COLLECTION SYSTEMS

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ABSTRACT

Small telemetry antennas (under ten feet) are popular on many ranges due to ease of handling and low cost. Unfortunately spillover, taper loss, diffraction loss, aperture blockage and feed efficiency can combine to reduce overall antenna efficiencies under ten percent. Even for a low cost antenna system, these are unacceptable losses.

This paper characterizes these losses and introduces an efficient feed with a scanning acquisition beam specifically for small reflectors.

INTRODUCTION

Antenna efficiency is discussed below with emphasis on those factors which contribute major losses in the 1.4 to 2.4 GHz frequency range for small reflectors. Feed configurations are discussed which reduce the impact of these loss factors and a novel tracking and acquisition feed is presented.

MAJOR LOSSES

Diffraction - Diffraction loss results from scattering at the reflector boundaries and increases dramatically with reduction in reflector sizes below ten wavelengths in diameter. Diffraction theory has not yet yielded a handbook solution for parabolas with diameters between one and ten wavelengths. However, many designers use parabolas with diameters between five and ten wavelengths based on empirical data. For these reflector sizes, diffraction alone accounts for an additional 1 or 2 dB reduction in gain.

Spillover and Taper Losses - Figure 1 shows curves indicating typical spillover and taper losses. Spillover loss is defined here as the amount of energy radiating from the feed that misses the main reflector. Taper loss is the amount of loss due to amplitude taper across the aperture (i.e., zero taper loss assumes constant amplitude across the dish). From Figure 1, it can be seen that most reflectors will exhibit spillover and taper losses of approximately 2 dB. For a low cost antenna system, 2 dB for combined spillover and taper loss is reasonable.

Aperture Blockage - The ratio of feed blockage area to the reflector area can be used as an approximation to the loss in gain due to feed blockage. Figure 2 shows that the effects of aperture blockage increase as reflector size decreases. For a small reflector in the low frequency telemetry band, the effects of aperture blockage and diffraction loss are exacerbated by the fact that these phenomena also create higher sidelobes. Aperture blockage is the more severe problem because it substantially increases the first sidelobes, which in turn degrade the angular limits over which the system can track or acquire automatically.

Feed Losses - In the 1.4 to 2.4 GHz band, a three channel monopulse feed with waveguide beam former can be built with less than 1 dB of loss for the entire feed. Unfortunately, this scheme requires several cubic feet of volume at the feed location and is only applicable to large reflectors. If the beam former is composed of stripline or microstrip, the losses will increase by 1 or 2 dB. If the system is converted at the output of the beam former to a single channel system, additional losses of 1 or 2 dB will be incurred in the scan converter. At this point the system is no longer attractive relative to a con-scan feed with smaller aperture blockage and lower losses. Feed loss and blockage are the principal reasons for the utility of con-scan feeds on small reflectors.

Feed Configurations - After review of the foregoing data, a reasonable designer will frequently choose to investigate alternate configurations. He may try to eliminate feeds in front of the reflector which require arrayed elements since larger feeds substantially degrade both the acquisition and tracking beams. If he has a requirement for automatic acquisition he may decide to separate the tracking and acquisition functions. The designer may use a single conically scanned antenna for the tracking beam and mount the acquisition feed on the edge of the reflector or utilize a compound acquisition and tracking feed mounted back-to-back. The disadvantage in mounting the acquisition feed on the edge of the dish is that the relatively wide beam of the acquisition feed is likely to be asymmetrically perturbed by the primary feed unless it is mounted separately from the main reflector. In the back-to-back configuration, the designer is still under pressure to keep the aperture blockage down. At this juncture, the designer still has a number of options for a ten foot antenna; however, smaller size rapidly reduces the number of options. For small, mobile, collection systems severe performance tradeoffs are required.

Con-Scan Squared Feed - S.T. Research Corporation is currently developing a configuration which allows the designer to include automatic acquisition and maintain high efficiencies on low cost systems. The approach is so simple it is probably not new. However, it is so easily integrated with state-of-the-practice systems it warrants a new look.

The concept is shown in Figure 3. It consists of two back-to-back circular waveguide elements of slightly different designs. The tracking antenna achieves its conical scan from lateral displacement as it rotates. The acquisition antenna develops a con-scan beam from a slanted aperture.

Both antennas can be produced with stationary wave launchers by rotating the waveguide and using a simple waveguide choke between the waveguide walls and the stationary wave launchers. The waveguides are directly coupled to external rotor, brushless, DC motors which weigh less than three quarters of a pound each. It should be emphasized that no switches, hybrids, or phase shifters are required to develop either beam. The gain in these tracking and acquisition feeds are, therefore, likely to be 2 to 4 dB higher than single channel monopulse and sequential lobing schemes which require scan converters and beam forming matrices.

If orthogonal wave launchers are used (e.g., crossed dipoles), these elements can produce dual linear or dual circular polarization depending on systems specifications. The dual circular polarization can be produced by addition of a single hybrid for each feed with less than one-half dB additional loss. Figure 4 shows the relationship between acquisition and tracking beams. Performance of prototype feeds are shown in Figure 5.

Advantages and Disadvantages - The disadvantages of most con-scan systems are reduced by virtue of the stationary feeds and the automatic acquisition system. The stationary feed and choke flange eliminate the need for a rotary joint, thereby increasing system reliability. The automatic acquisition function allows the designer to reduce the scan angle of the tracking feed. For small reflectors the scan modulation can be reduced to less than one-half dB on boresight. This also results in lowering the effect of scanning on sidelobes.

The problem of low angle tracking encountered with small reflectors must be dealt with on this system. Most producers of telemetry systems employ some type of processing to reduce the effects of multipath during low angle tracking. On the Con-Scan Squared system, multipath discrimination is used on both the tracking and acquisition beams.

The advantages of this system are very substantial:

a. The total antenna efficiency is high - approaching fifty percent for both beams.

b. The same scan demodulator is used for both beams.

C. The patterns are cleaner and sidelobes are lower since the blockage of the combined tracking and acquisition feeds is very small.

d. On small reflectors, the ratio of tracking beam gain to acquisition beam gain is fortuitously about 13 to 16 dB. The acquisition system can work with signals close to system noise level. When the system switches to the tracking beams, a comfortable carrier-to-noise level of about 13 dB is encountered.

CONCLUSION

In summary, the antenna problems encountered with small reflectors for mobile collection of telemetry signals can be minimized by using a conically scanning tracking antenna. In addition, if automatic acquisition is desirable it can be accommodated in a back-to-back configuration while maintaining reasonable performance. The high efficiencies of this system will enable the designer to use smaller reflectors and pedestals.

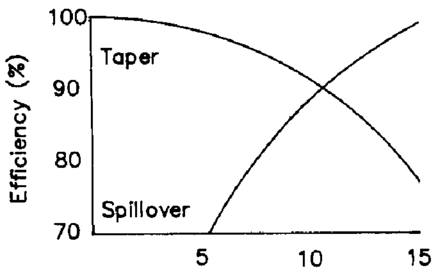

Figure 1. Edge Illumination (dB) Taper and Spillover Losses

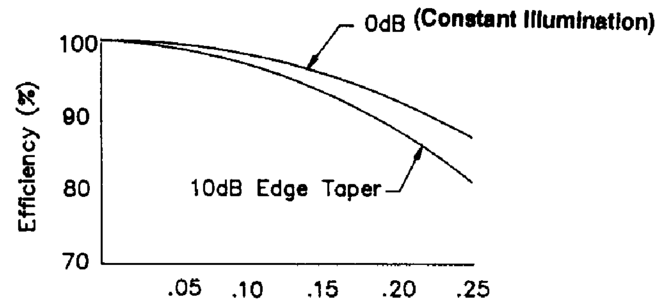

Figure 2. Losses Due to Central Blockage Ratio (Df/D)*

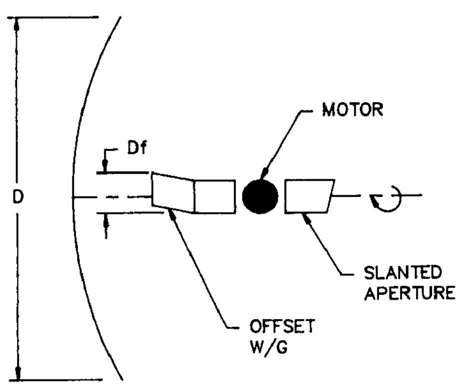

Figure 3. Con-Scan Squared Feed*

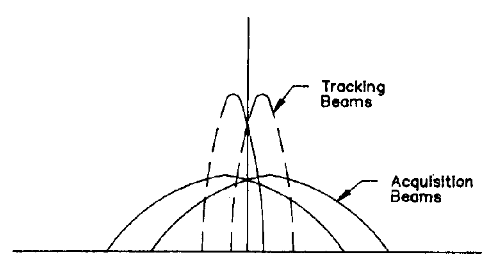

Figure 4. Feed Patterns

*Where Df = Feed Diameter
D = Reflector Diameter

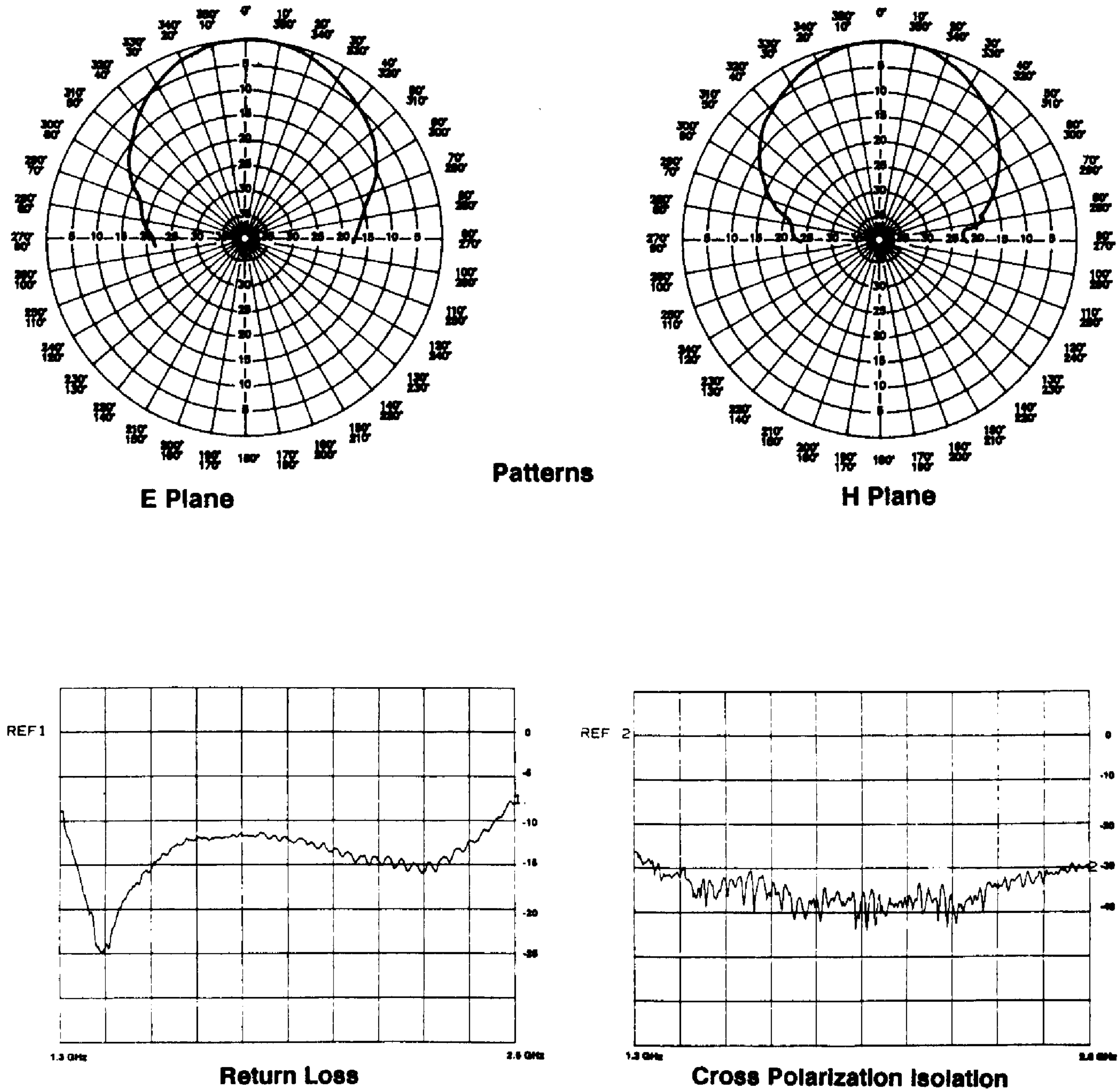

Figure 5. Feed Performance