A LOW WINDLOAD BROADBAND FLAPS™ ANTENNA FOR TELEMETRY TRACKING SYSTEMS

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ABSTRACT

The use of low windload FLAPS™ antennas in telemetry tracking systems yields sizable savings in system cost due to the reduced requirements imposed on the pedestal assembly and on the underlying support structure. Traditionally the use of these antennas has been limited to applications in which frequency bandwidths did not exceed 10-13%. This paper describes a variation of the FLAPS™ technology which allows operation over bandwidths in excess of 35% and makes it usable in broadband systems. Two new applications are feasible: one for a ground based telemetry system operating in the 1435-1850 or 1750-2400 MHz band and one for a shipboard satellite communication system operating in the 4000-6000 MHz band.

Keywords: FLAPS™ reflector, broadband operation, telemetry tracking, communication system.

INTRODUCTION

The use of low windload FLAPS™ antennas "Flat Parabolic Surface" in telemetry and communication systems operating at frequencies below 8 GHz yields sizable savings in overall system costs due to the reduced requirements imposed on the pedestal assembly and on the underlying support structure. These savings are a direct result of the 60-80% reduction in the magnitude of wind generated forces experienced by the pedestal when an open structure FLAPS™ reflector is used instead of a conventional solid or mesh parabolic reflector.

Traditionally, because of their frequency response, the use of standard FLAPS™ reflectors has been restricted to applications involving bandwidths not exceeding 10-13%. This paper describes a variation of the standard FLAPS™ technology which allows operation over bandwidths in excess of 35%. Two new applications are feasible: one for a ground based telemetry system operating in the 1435-1850 or 1750-2400 MHz frequency band and one for a shipboard satellite communication system operating in the 4000-6000 MHz frequency band.

GAIN VS FREQUENCY CHARACTERISTICS

The operating range of an antenna/feed assembly is typically specified in terms of the minimum required values for its gain and/or G/T over a specified range of frequencies. In the case of a conventional parabolic reflector/feed assembly the achievable values of gain and/or G/T increase as a function of the operating frequency. The gain vs frequency characteristics of the assembly is dominated, if not entirely determined, by the behavior of the feed illuminating the reflector and is independent of the actual implementation of the reflector itself. The RF performance of a typical telemetry tracking system operating in the 1435-2400 MHz band decays at the lower end of the band because the feed itself approaches cutoff and is limited at the upper end of the band as a consequence of the excessive taper in the feed primary pattern.

The gain vs frequency response of a FLAPS™ reflector/feed assembly exhibits a different behavior and is a combination of the response of the FLAPS™ surface and of the feed. In most applications, the FLAPS™ surface is the dominant factor and the gain vs frequency characteristics shows a gradual and symmetrical decrease on each side of the center frequency. In this case, bandwidth is defined as the range of frequencies over which the response is no more than 1.5 dB down from its peak value.

STANDARD FLAPS™ TECHNOLOGY

The FLAPS™ reflector concept is based on the premise that a geometrically flat surface can be designed to behave electromagnetically as though it were a parabolic reflector (figure 1.1). As shown in figure 1.2 this effect is achieved by introducing an appropriate phase shift at discrete locations on the flat surface.

A typical implementation of this concept consists of an array of dipole elements positioned above a ground plane in such a way as to allow incident RF energy to set up a standing wave between the dipole and the ground plane. Each dipole element possesses an RF reactance which is a function of its length and thickness. This combination of standing wave and dipole reactance causes the incident RF energy to be re-radiated with a phase shift which is controllable through variation of the dipole parameters. The exact value of this phase shift is a function of the dipole length, thickness, its distance from the ground plane, the dielectric constant of the intervening layer and the angle of incidence of the RF energy. Typical dipole lengths vary over the range of 1/4 to 3/4 of a wavelength and ground plane spacings are set between 1/16 and 1/8 of a wavelength. Figure 2 shows an S-band FLAPS™ reflector in which the various dipole lengths required to emulate the parabolic surface are clearly visible. Table 1 lists the specifications for a 3 meter FLAPS™ reflector operating in the 2200-2400 MHz frequency range; it illustrates the behavior of the FLAPS™ surface as a function of frequency.

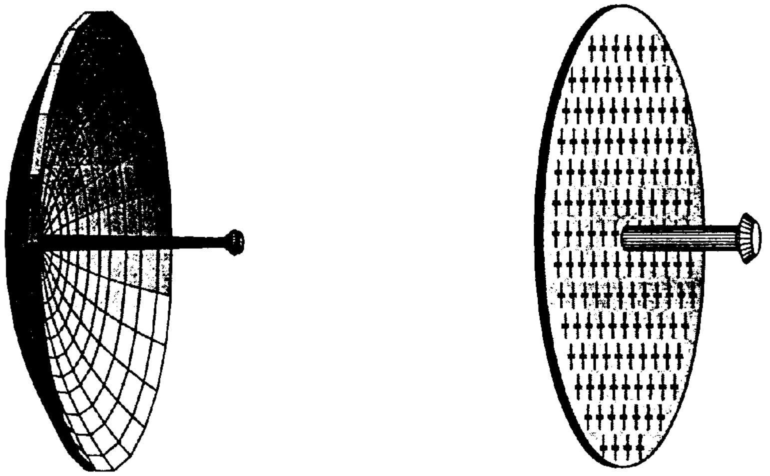
Table 1: FLAPS™ Reflector Gain vs Frequency

Parameter		Specification
Antenna Size		3 meters
Antenna Gain	2200 MHz	≥ 33.8 dBi
	2300 MHz	≥ 34.2 dBi
	2400 MHz	≥ 33.6 dBi

In the standard planar configuration the bandwidth of a FLAPS™ reflector is limited by either one of two completely independent and diverse phenomena: The first one is associated with the bandwidth of the individual dipole elements forming the reflecting surface and it limits the 1.5 dB bandwidth to 10-13%. It is independent of the frequency of operation or of the size of the reflector. The second phenomenon is caused by pathlength dispersion and is inherent to the geometry of a planar reflector. Its effect is entirely dependent on the value of the ratio of its focal length divided by its diameter; i.e., f/D.

Dipole Element Bandwidth. The bandwidth of an individual dipole element used in a standard FLAPS™ reflector is similar to that of a shorted dipole above a ground plane. Its behavior as a function of frequency can be derived from the theoretical expression for its impedance. This derivation is subject to a number of assumptions and it will not be presented here. Instead, actual data showing the relative average gain response of a number of FLAPS™ reflectors is introduced in figure 3.

The shape of the response curve in figure 3 is entirely attributable to the dipole elements and is both a function of the phase vs frequency behavior of individual dipole elements across the FLAPS™ surface and of the distance of each element from its ground plane. In a typical implementation of a small to medium size standard FLAPS™ reflector a useful 1.5 dB bandwidth of 10 to 13 percent is achievable on a repeatable basis.



Conventional Reflector FLAPS™ Reflector

Figure 1.1 Conventional vs FLAPS™ Reflector

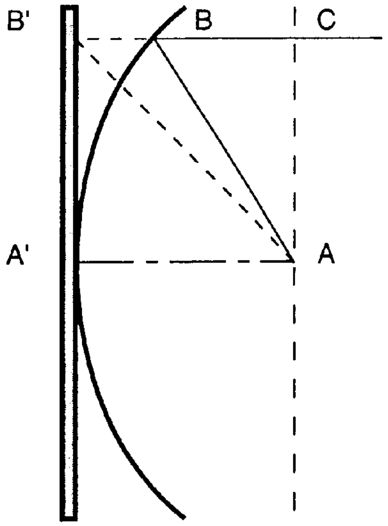


Figure 1.2 Geometry for Planar FLAPS™ Reflector

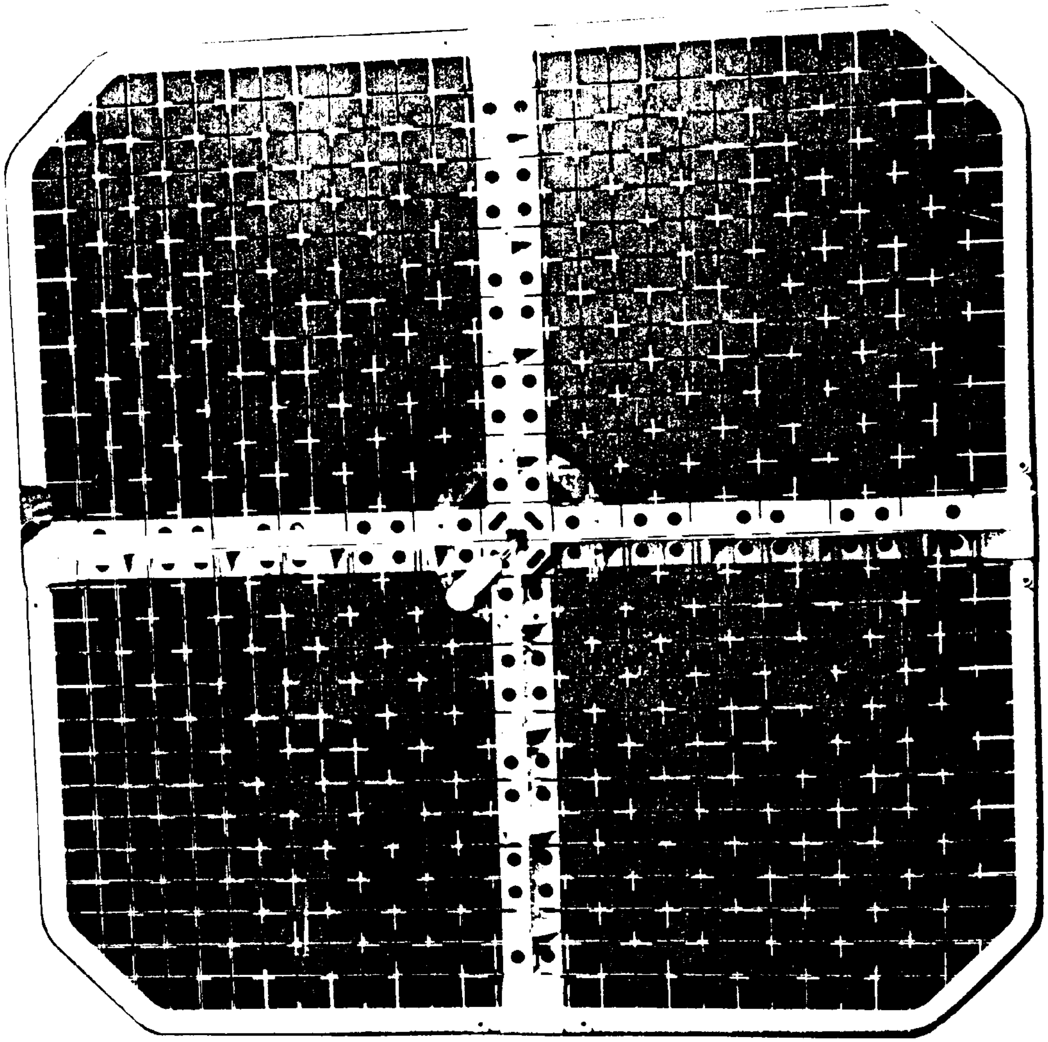


Figure 2 S-Band FLAPS™ Reflector

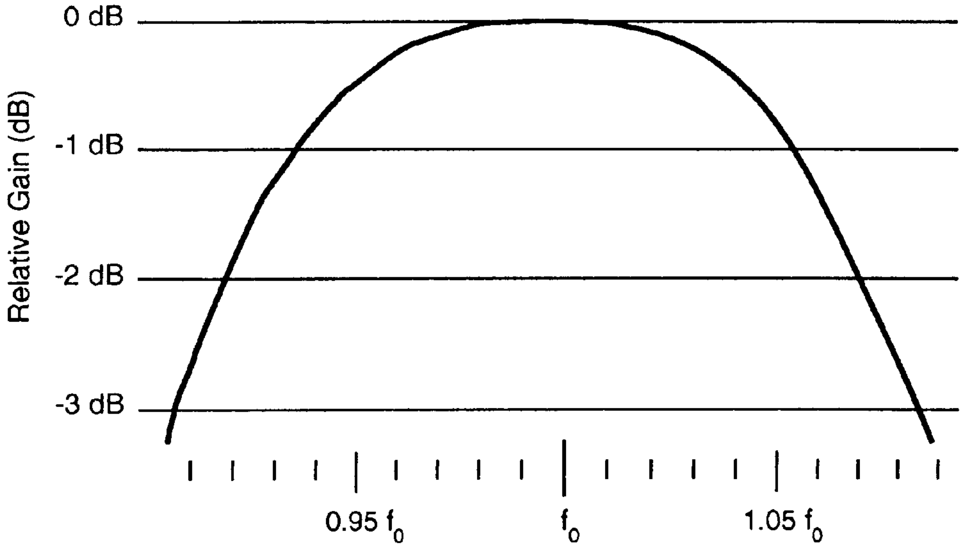


Figure 3 Dipole Response vs Frequency

Pathlength Dispersion. The pathlength dispersion phenomenon is a direct result of the method used by the FLAPS™ reflector to simulate the operation of a parabolic reflector. A conventional parabolic reflector provides equal pathlengths between the feed and any point on a flat reference plane in front of the reflector via reflection points on the parabolic surface. This is the property that makes a conventional parabolic surface frequency independent. In a planar FLAPS™ reflector the reference plane is located at the reflector surface and the pathlengths between the feed and points on the surface vary monotonically; they are shortest at the center and slowly increase as the reflection point moves out toward the perimeter. At the center frequency of operation the phase of each individual dipole is adjusted to exactly compensate for the varying pathlengths and provide the necessary conditions to assure a collimated beam. As the frequency of operation is changed from its center value a quadratic phase dispersion is introduced due to the varying pathlengths and the fact that, to a first order, the dipole phases are frequency independent.

This phenomenon limits the bandwidth of a planar FLAPS™ reflector and its 1.5 dB bandwidth can be calculated as:

$$BW\ (\ 1.5\ DB\ ) = 1.15 \times C/D \times \sqrt{(\ 1 + 12 \times (\ f/D)^2\ )}\ Hz$$

Where: C = velocity of light = 3×10^8 meters /sec
D = antenna diameter in meters
f = focal distance in meters
BW = total bandwidth in Hz to the 1.5 dB points.

For an f/D of 0.5 the expression becomes:

BW (1.5 DB) = 2.3 x C/D Hz.

For an f/D of 1.0 the expression becomes:

BW (1.5 DB) = 4.14 x C/D Hz.

Bandwidth values for two standard FLAPS™ reflectors (f/D = 0.4 and f/D = 1.0) are plotted in figure 4. These curves show the primary relationship between bandwidth and reflector size and also highlight the secondary dependence of bandwidth of the value of f/D. Figure 5 presents values of bandwidth vs frequency for a 1 meter, a 3 meter and a 5 meter reflector. This figure shows that the pathlength dispersion phenomenon severely limits the bandwidths of these reflectors when operating at frequencies above 4.0 GHz, 1.8 GHz and 1.0 GHz respectively.

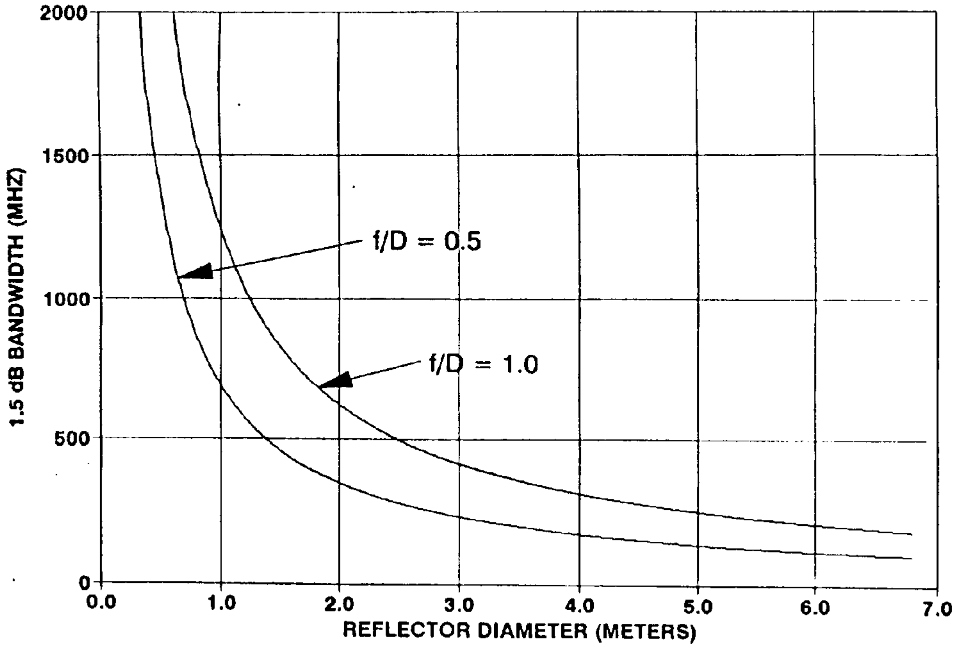


Figure 4 Bandwidth vs Size

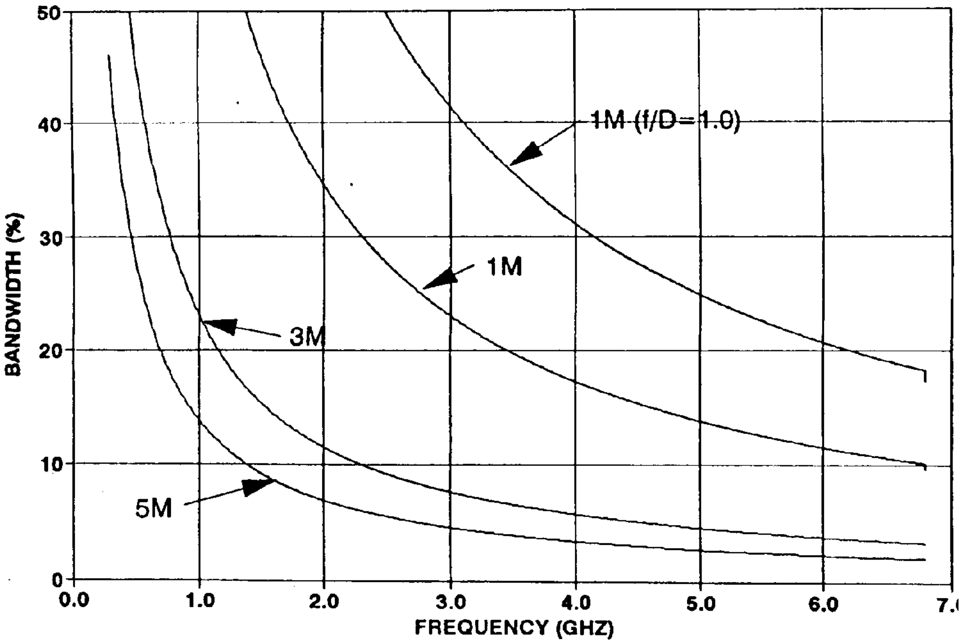


Figure 5 Bandwidth vs Frequency

BROADBAND FLAPS™ TECHNOLOGY

The approach used to broaden the operational bandwidth of the FLAPS™ reflector addresses the two limiting factors described above. The bandwidth of both the individual dipole elements and of the planar FLAPS™ surface is extended in such a way as to make their combined bandwidth exceed the 35% requirement.

First the individual dipole configuration is modified by the addition of a second radiator located in front of the standard element. It is mounted on a third support grid and it adds two more degrees of freedom to the design of the dipole and to the tailoring of its response curve. The best results achieved to date show that bandwidths in excess of 35% are feasible both at S-Band and at C-Band and work is in progress to extend this limit up to the 50% range.

The bandwidth limitation associated with the pathlength dispersion phenomenon is strictly a function of the size of the FLAPS™ reflector in use and of its f/D. Inspection of the data presented in figure 4 and figure 5 shows that the bandwidth of a fixed size reflector can be increased by changing its f/D. It also shows that, for a given operating frequency, the bandwidth of a reflector can be increased by reducing its size. Eliminating this bandwidth limitation is straightforward and involves the modification of the planar geometry to the "cupped" geometry of figure 6. The size of the individual panels is chosen to yield an individual bandwidth of at least 60% and the form factor is determined by the need to have equal pathlengths between the feed and the center

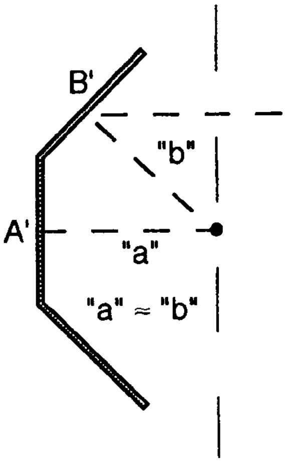


Figure 6 Cupped FLAPS™ Reflector Geometry

point of each of the panels. It is an easily implemented solution which, for all practical applications, essentially eliminates the pathlength dispersion phenomenon as a bandwidth limiting factor.

Figure 7 shows the actual geometry of a broadband 3 meter S-Band FLAPS™ reflector.

CONCLUSION

Broadband implementations of the FLAPS™ technology are now allowing the deployment of antenna systems in environments and locations which so far have precluded the use of such systems because of restrictions on weight and/or on support structure. It is now feasible to quickly deploy and operate a 5 meter shipboard communication system (4000-6000 MHz) without the need for heavy moving equipment or the installation of permanent substructure. It is also practical to mount a large telemetry tracking system (1435-1850 or 1750-2400 MHz) on a lightweight trailer that can be towed with a small vehicle and/or airlifted aboard a medium size aircraft.

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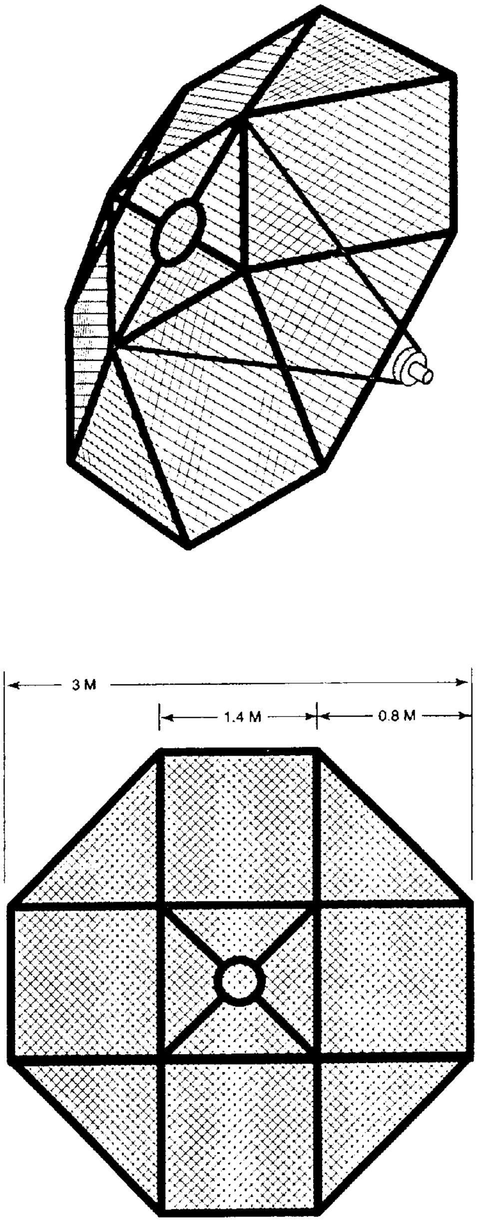

Figure 7
3 Meter C-Band Cupped FLAPS™ Reflector