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Role of spillover and illumination efficiency in case of parabolic antennas

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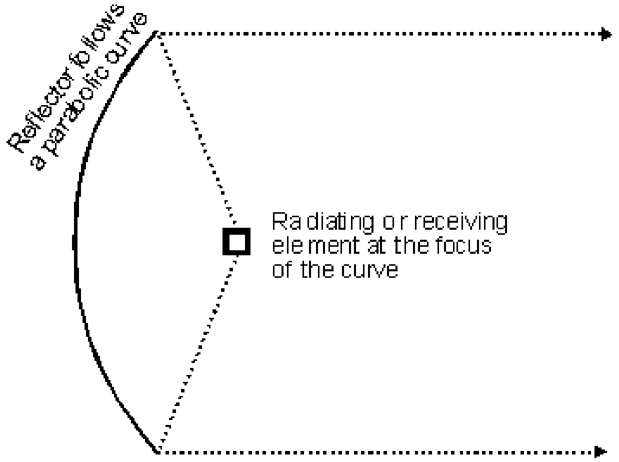
Abstract

In receiving mode when an antenna gets signal from space, like satellite , it is known that there is a very little back ground noise emanating from sky, compared to noise generated by the warn 300 Kelvin earth during terrestrial communication . It is true that most of the noise received by an antenna pointed at the sky is earth's noise arriving through feed spill, which can be reduced by increasing edge taper.

Introduction

It is well known fact that dish antenna can provide extremely high gains at micro wave frequencies.[1,2] A 2 ft dish at 10 GHz can provide more than 30 dB of gain and it is only limited by the size of the parabolic reflector these high gains are only achievable if the antennas are properly implemented and dishes have more critical dimensions than horns and lenses.

A dish antenna work the same way as a reflecting optical telescope. Electromagnetic waves either light or radio waves arrive on parallel paths from a source and are reflected to a common point called focus as shown in fig below.



Parabolic reflector antennas, often called parabolic dishes are normally used in applications where gain and directivity are of paramount importance. Satellite TV reception, microwave links and other satellite links are prime examples of where parabolic reflector gain is used.

The parabolic reflector antenna is ideal for high gain applications. At microwave frequencies where these antennas are normally used, they are able to produce very high levels of gain, and they offer a very convenient and robust structure that is able to withstand the rigours of external use, while still being able to perform well. Many other types of antenna design are not practiceable at these frequencies.

High gain parabolic reflector antennas come in a variety of sizes. The most commonly seen are those used for satellite television reception. However parabolic antennas are used in many other applications. Parabolic reflector antennas are also often seen on microwave towers for communications. Larger ones still can often be seen on TV broadcast stations where signals need to be transmitted up to a broadcast satellite and where performance is paramount. Even larger antennas may also be used for other communications or even space research applications. Some these parabolic antennas are many tens of metres across.

The one common feature of all these examples is the parabolic antenna gain, or parabolic dish gain. While the larger antennas have greater levels of parabolic antenna gain, the performance of all these antennas is of prime importance.

There are a number of factors that affect the parabolic antenna gain. These factors include the following:

1. Diameter for the parabolic reflector antenna reflecting surface
2. Surface accuracy
3. Quality of illumination of the reflecting surface
4. Frequency or wavelength of the signal being received or transmitter

The parabolic antenna gain can easily be calculated from a knowledge of the diameter of the reflecting surface, the wavelength of the signal, and a knowledge or estimate of the efficiency of the antenna.

The parabolic reflector antenna gain is calculated as the gain over an isotropic source, *i.e.* relative to a source that radiates equally in all directions. This is a theoretical source that is used as the benchmark against which most antennas are compared. The gain is quoted in this manner is denoted as dBi.

The standard formula for the parabolic reflector antenna gain is:

$$\text{Gain } G = \frac{10 \log_{10} k (\pi D) 2}{\boxed{\lambda^2}}$$

where

G is the gain over an isotropic source in dB

k is the efficiency factor which is generally around 50% to 60%, i.e. 0.5 to 0.6 D is the diameter of the parabolic reflector in metres

lambda is the wavelength of the signal in metres

From this it can be seen that very large gains can be achieved if sufficiently large reflectors are used. However when the antenna has a very large gain, the beamwidth is also very small and the antenna requires very careful control over its position. In professional systems electrical servo systems are used to provide very precise positioning.

In order to optimum illumination of the reflecting surface, the level of illumination should be greater in the centre than at the sides. and it can be shown that the optimum situation occurs when the centre is around 10 to 11 dB greater than the illumination at the edge and so the lower levels of edge illumination result in lower levels of side lobes.

The reflecting surface antenna forms a major part of the whole system anin many respects it is not as critical as may be thought at first. Often a wire mesh may be used. Provided that the pitch of the mesh is small compared to a wavelength it will be seen as a continuous surface by the radio signals. Now if a mesh is used then the wind resistance will be reduced, which provides a significant advantages.

Parabolic reflector or dish antenna consists of a radiating element which may be a simple dipole or a waveguide horn antenna which is placed at the focal point of the parabolic reflecting surface. The energy from the radiating element is arranged so that it illuminates the reflecting surface and once the energy is reflected it leaves the antenna system in a narrow beam. As a result considerable levels of gain can be achieved[3-4].

Now achieving this is not always easy because it is dependent upon the radiator that is used. For lower frequencies a dipole element is often employed whereas at higher frequencies a circular waveguide may be used. In fact the circular waveguide provides one of the optimum sources of illumination.

Some of the difficulties fond in real antennas are easier to understand when considering a transmitting antenna, but are also in receiving one.

In practical dish antennas we put a point source at the focus, so that energy would radiate in all directions both in magnitude and phase. Now the problem is that energy that is not radiated towards reflector would be wasted[3].

Our main task is that we want a feed antenna that only radiates towards the reflector, and has a phase pattern that appears to radiate from a single point[4].

It has already been known to us that efficiency is a measure of how well we use the aperture and if we can illuminate the whole reflector, then we should be using the whole aperture, and for this our feed horn pattern should as in fig. or(a). But analyzing more closely at the parabolic surface we find that the focus is farther from the edge of the reflector than from the centre. As the radiated power diminishes will the square of the distance, less energy is arriving at the edge of the reflector than centre, which is known as the space attenuation or space taper.

Now in order to compensate we have to provide more power at the edge of dish than at centre by adjusting feed pattern as shown in the fig. in order have constant illumination over the surface of the reflector.

Simple feed antenna like a circular horn that have many horns have used a pattern which can ban approximated by an idealized ^{n}

Table A,B,and C

Overall Efficiency

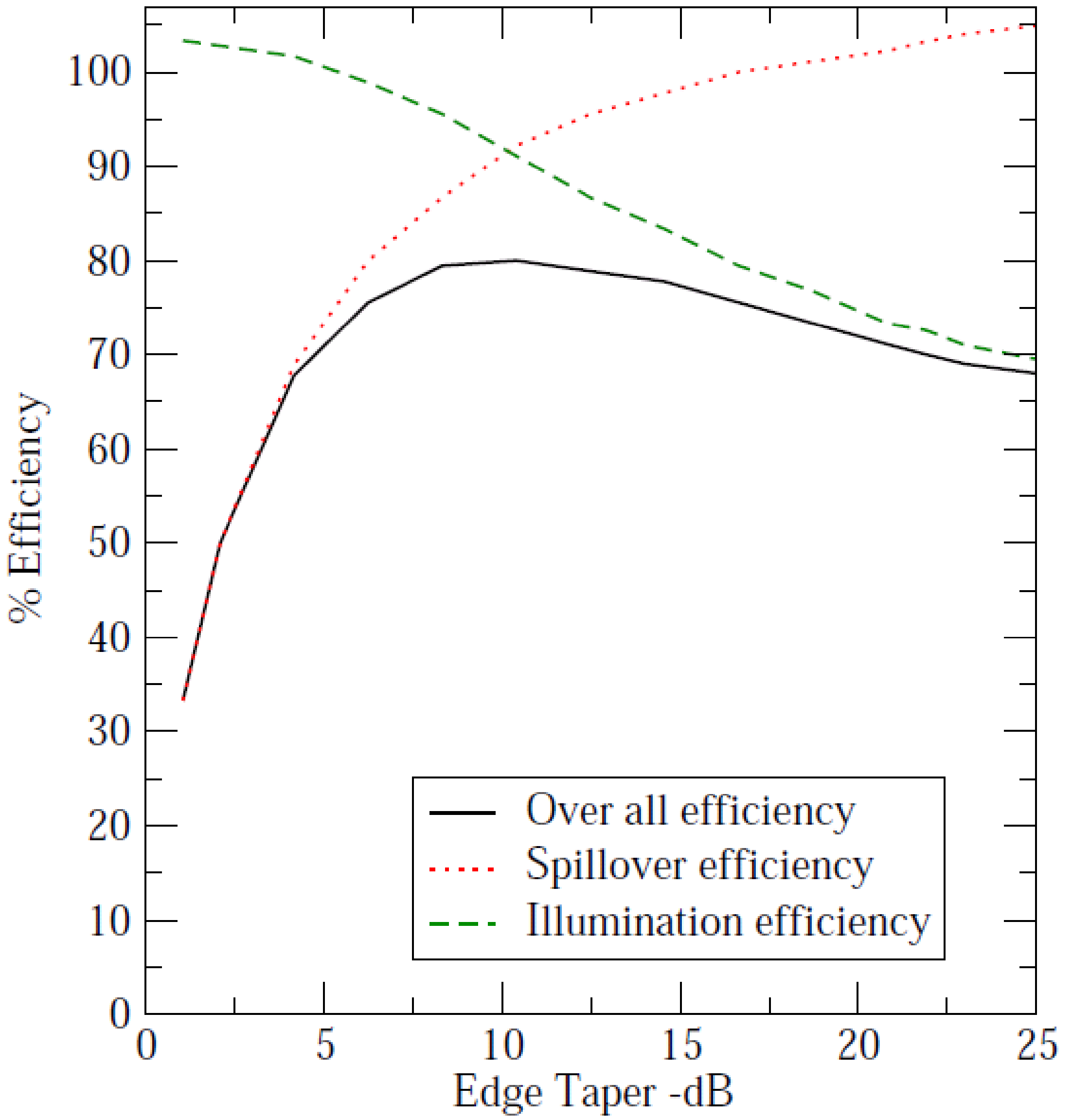
S. No.	Edge Taper (dB)	% Efficiency
1.	1.04	33.3
2.	2.08	49.99
3.	4.16	67.77
4.	6.24	75.55
5.	8.32	79.44
6.	10.4	79.99
7.	12.48	78.88
8.	14.56	77.77
9.	16.64	75.55
10.	18.72	73.33
11.	20.8	71.1

Spillover Efficiency

S. No.	Edge Taper (dB)	% Efficiency
1.	1.04	33.3
2.	2.08	49.99
3.	4.16	68.88
4.	6.24	79.99
5.	8.32	86.66
6.	10.40	92.21
7.	12.48	95.55
8.	18.56	97.77
9.	16.64	99.99
10.	18.72	1010.1
11.	20.8	102.21

Illumination Efficiency

S. No.	Edge Taper (dB)	% Efficiency
1.	1.04	103.32
2.	2.08	102.77
3.	4.16	101.66
4.	6.24	98.88
5.	8.32	95.55
6.	104	91.1
7.	12.48	86.66
8.	14.56	83.33
9.	16.64	79.44
10.	18.72	76.66
11.	20.80	73.33



θ pattern like shown in fig. now as shown in fig. we super impose the idealized pattern on our desired pattern we have too much energy in the centre, not enough at the edge and some misses the reflector entirely. The missing energy at the edges shown as blue are dotted is called illumination we need to increase energy near the edge of the dish and have the energy drop off very quickly beyond the edge.

It is known that all feed horns will provide less energy at the edge of dish than in the centre like the difference in power at the edge is referred to as the edge taper. Which different feed horns, we can vary the edge taper with which a dish is illuminated.

Different edge tapers[5,6] produce different amounts of illumination loss and spill over loss.

Some of the small edge taper results in larger spill over loss, while a large edge taper produces the spillover loss at the expense of increased illumination loss. On plotting these losses verses the energy at the dish, we find the what efficiency of a dish antenna peaks with an illumination tapers so that the energy at the edge is about 10 dB lower than the energy in centre. This often referred to as 10 dB edge taper or edge illumination, often recommended but not explained.

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