THEORY, DESIGN AND APPLICATIONS OF MULTIPLE FEED SYSTEMS FOR PARABOLIC REFLECTOR ANTENNAS

James B. Grabenstein
Senior Applications Engineer

MICRODYNE CORPORATION

With programming source availability changing, real estate restrictions and cost effectiveness in mind, the satellite communication industry has generated the requirement to obtain service from more than one satellite into the same TVRO system. To achieve this goal, additional feeds have to be added to the existing TVRO system or the antenna changed to another type.

This paper is an attempt to outline some of the advantages and applications in changing to a multiple feed system on a parabolic antenna reflector. It covers some of the theory and math that has been incorporated into a computer program that is used to predict the gain and noise generated when the feed point is shifted from normal boresight. This paper will cover some of the data gathered from an extensive testing program that has been done on the multiple feed system in the field. The predicted data and field test data will be compared and analyzed.

The introduction of communication satellites into geostationary orbit has been a revolution to the communication industry. The major impact on the cable television industry has been the availability of revenue producing premium programming. One of the problems with this programming is that not all of the programming originates from the same satellite. We can be assured that this programming will be in constant change for competitive and economic reasons.

As a solution to the problems, the communications industry has asked for a method of adding multiple feed systems to existing antennas. This request is based on sound reasoning; real estate is valuable and hard to obtain for multiple antenna farms and these multiple antenna farms are costly. Today five satellites transmit video signals used by the cable television industry and many more are planned in the next few years. Other services are planned and are being promoted and will require looking at other areas of the geostationary arc.

Over this whole area of requirements looms the unanswered question, what about 2^{o} spacing? One thing I want to state here is that by adding a multiple satellite feed system to a parabolic reflector is not the answer to all of your prayers. It is a tool and your knowledge of this tool and its application depends on the success of the use of a multiple feed system.

A satellite receiving antenna contains two functional parts, the reflector and the feed. Two types of reflectors are used in todays satellite receiving antennas. They are parabolic surfaces and speherical surfaces. The basic difference geometrically of these two reflecting surfaces, is that a spherical surface beam will eventually cross somewhere in space where in a parabolic reflector the beam will remain parallel to infinity. The widths of the beam and the patterns generated by the reflecting surface is determined by three basic functions. The first being the diameter of the reflector, the focal length of the reflector and the frequency in which the reflector is operated. The transformation of the pattern from theoretical to actual depends primarily on the reproduction of the accuracy of the surface in production methods. Most multiple feed antennas in use today that looks at large portions of the geostationary arc are designed around a spherical surface. The spherical surface is less efficient but blends itself easily to multiple focal points. The parabolic reflector has been used as a reflecting surface for satellite communication antennas because of its high efficiency. For that reason, we will address the use of adding additional feeds to the parabolic reflector in this paper.

The most efficient microwave receiving antenna known today is the antenna commonly called a sugarscoop or conical horn. These are offset feeds on a parabolic reflector with high shielding into the focal point producing very low noise and very accurate and predictable patterns. The problem with this type of an antenna is that it is quite costly but in some cases has to be used in the high terrestrial interference environments. The parabolic antenna is an economic antenna to produce and is the most popular in the cable industry today. Adding a multiple feed system to this antenna requires a certain amount of calculations that are predictable and some pattern characteristics that are extremely difficult to predict.

Two basic types of feed systems are used in todays satellite receiving antenna systems. One feed system is the cassegrain feed which requires a subreflector somewhere in the focal plain of the antenna. The other is a prime focus feed and the prime focus feed is a method in which the feed is located at the focal point of the reflector and is aimed at the surface and illuminates the surface evenly just inside of the reflecting surface. When a cassegrain type feed in in an antenna, it has to be removed and replaced with a prime focus feed when the reflector is to be used as a multiple feed system. A conical horn antenna by its design cannot be altered in any way for use as a multiple feed system.

To add a multiple feed system to a parabolic reflector, the geometric functions of the satellite's orbit position to the physical center of the reflecting surface and the focal length of the reflector must be considered. (See Figure 1)

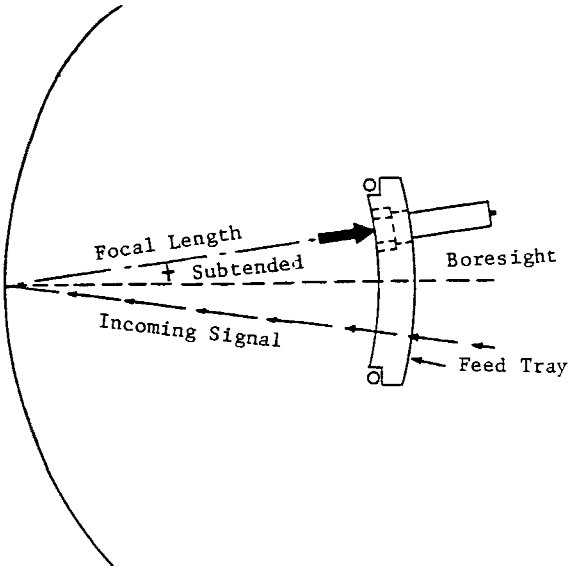

Figure 1

You will note that we treat each satellite as a single beam, the reflector as if it has one point of reflection, to set the angles of the feed in respect to boresight of the reflecting surface. This allows the feeds to be preset for their respective satellite.

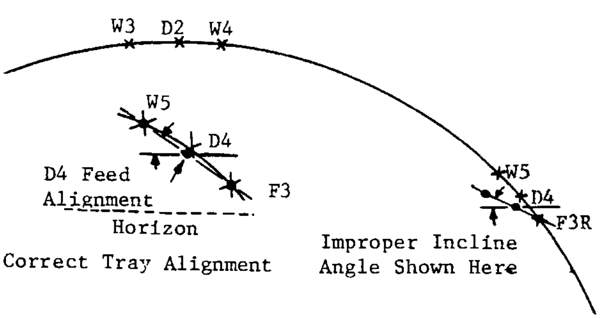

Figure 2

In Figure 2 the geostationary arc changes as it is viewed from different coordinates on earth for each satellite. The sector of the arc generated by the satellites of interest creates a chord that is the incline angle of the feeds. This focal incline angle is predictable and matches the chord between the arc of the extreme satellites. As long as this chord is less than 16 degrees, the satellites of interest will remain in the aperture of the feed system.

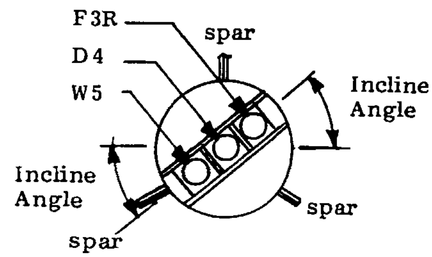

Figure 3

You will note in Figure 3 that the D-4 satellite will be slightly off of the chord of the geostationary arc. These calculations are predictable and usually do not affect the overall operation of the system. The prime consideration of aligning the feeds and the antenna is making sure that the chord of the geostationary arc lines up with the incline angle of the focal plane of the feed. You will also note in Figure 3 that the reflector acts as a mirror image and reverses the angles and the relationships of the satellites.

The relationship of the total gain of the antenna is predictable based upon the antenna diameter, the focal length of the reflector and the type of feed on the antenna. If the antenna is lined up on boresight and the feed placed in a position on that boresight, the gain of the antenna will perform the same as any normal antenna. As you move the feed from boresight, there will be a degrading of the gain of the antenna on a predictable gain loss curve. (See Figure 4) As you move from boresight, the gain of the antenna derates but you will note by Figure 4 that the noise generated within the antenna does not increase appreciably and in fact, you may note that it decreases as you move a couple of degrees off of boresight. The overall carrier to noise of the antenna does increase slightly.

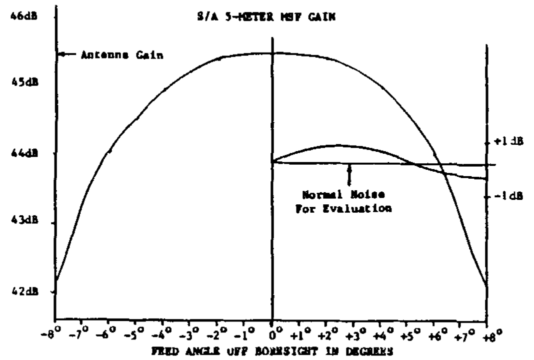

Figure 4

The side lobes of an antenna are the products of the total energy from the reflector not absorbed by the feed and the phase relationship of the electro-magnetic microwaves as they refract from the angular surface of the reflector. As the feed is moved from boresight, these phase angles change causing the level of the side lobes to vary in respect to the boresight gain of the antenna.

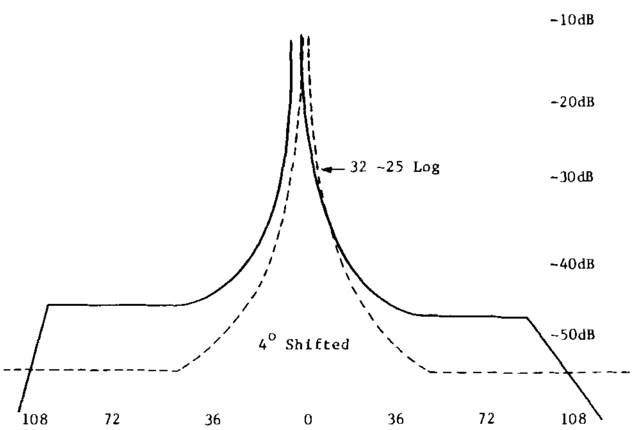

Figure 5

You will note in Figure 5 that the smoothed curves of the antenna radiation pattern degrades as you pull the feeds away from boresight. The side lobes of the antenna become very erratic as you move the feeds away from the boresight of the antenna. For that reason, if you have heavy terrestrial interference, it is not recommended that you try to use an off boresight fed antenna for a multiple satellite feed system. These patterns could be calculated for each angle but the problem is that the calculations would take many days of range time for each antenna system and could be quite costly.

As I mentioned at the beginning, a multiple feed antenna system connected to a parabolic reflector is a tool. This tool has a place in the communication industry, if you need an inexpensive way to view a couple of satellites or if you need a temporary feed system until you find out where the satellite spacing is going to settle. The multiple satellite feed system on parabolic reflectors will lose gains as you move from boresight, but it is predictable. The noise does not increase in some catastrophic manner. The side lobes change but not enough to cause major problems with todays satellite spacing.

The mathematical computations for the angles and spacing of the feeds is covered well in Norman Weinhouse's[1] paper. As a convenience, we have put this into a computer program. This information is available to anyone wishing to run calculations for a particular location in the United States.

If you need a feed system to meet todays needs, don't be afraid to use it.

References: Norman Weinhouse, "Multiple Antenna Feeds"

Thanks to: Jerry Thorne, Microdyne Field Service
Robert Smith, Microdyne Field Service