Shaped single-offset DBS-reception antenna for multiple satellites

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Abstract. A direct approach to the design of a multi-focal antenna system for the reception from several satellites along the orbital arc is presented. The method is based on optimising the reflector shape until a desired far-field performance, as calculated by using Physical Optics, is achieved. The method is straightforward and makes use of readily available tools for PO reflector design.

Introduction. If TV reception from more than one satellite is desired the customer must have antennas with the capability of providing receive beams of adequate gain in different directions. Several methods are implemented for this purpose: individual antenna systems pointed in different directions; single, mechanically steerable antennas and reflector antennas with several feeds, one for each spacecraft. The first approach is demanding in terms of real estate, and the second suffers from the fact that changing from one program to another may take considerable time until the antenna is pointed correctly and has acquired the new satellite.

The approach with several feeds using the same reflector overcomes the above problems, but suffers from the inevitable scan loss associated with the feeds being displaced from the focus. If a normal parabolic reflector is being used the centre beam will have ideal performance whereas the gain decreases with increasing scan. An improvement is obtained by using a parabolic torus antenna [1], but scan-degradation is still a significant factor.

To further improve the scanning capabilities of the single reflector it is necessary to shape the surface in a more general form than the torus. Rappaport [2] designed an antenna with excellent scanning characteristics by combining, in a least-squares sense, sections of paraboloids each of which defines a beam direction for a particular feed horn. The method was recently employed by Pino et al [3] to shape a DBS antenna for application in Spain, where there are domestic spacecraft located 55º apart.

The idea of combining several paraboloids with different focal points and boresight directions into a single, common reflector is obvious since the paraboloid has the desirable characteristic of focussing a beam in one direction. However, using the surface shape as the goal of the optimisation process (the least-squares fit) provides no guarantee that the resulting reflector is also optimum in so far as the beam performance is concerned. It also becomes necessary to oversize the reflector quite substantially, in reference [3] by as much as 66% in one dimension.

With the reflector synthesis tools available today it becomes more apparent to optimise the reflector shape with the goal of maximizing the gain of the scanned beams directly. This is routinely done in contoured-beam shaped reflector design, where at each step of the synthesis the antenna radiation pattern is analysed in a number of far-field directions using Physical Optics (PO) and the surface adjusted until satisfying performance is obtained. In this method it is possible to control the gain of each beam and either equalize them or place more emphasis on some directions at the expense of others. An example is given in the following.

An example A standard reflector shaping package POS4 [4] has been applied to a specific example, a DBS antenna for reception in Denmark from satellites that are 30º apart. The relative position of a couple of interesting spacecraft are shown in Figure 1, as seen from an antenna that is pointed towards HotBird at 13º E. From East to West the satellites are Astra 2, Astra 1, HotBird, Sirius 3 and Thor 2.

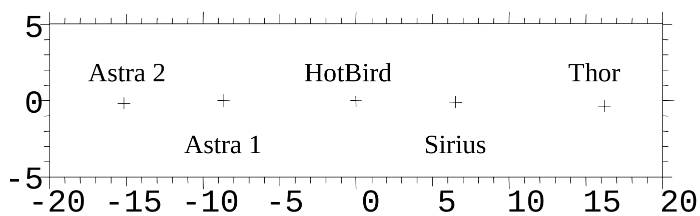


Figure 1. Position of 5 spacecraft along the geostationary arc relative to an antenna pointed towards the centre satellite

As a baseline we have first designed a simple parabolic reflector with D = 0.72 m (30λ at 12.5 GHz), F/D = 1 and an offset clearance of 0.1 m. This size of antenna will give acceptable performance for single-beam operation. The feed positions are initially set by using simple rules of thumb and then optimised using the POS4 program. The resulting directivity values are given in the first column of Table 1 and the geometry is shown in Figure 2.

Satellite	72 cm paraboloid	82 cm paraboloid	72 cm shaped	72 cm shaped, optim. feed pos	82 cm shaped, optim. feed pos
Thor	36.7 dBi	37.4 dBi	37.1 dBi	37.3 dBi	38.5 dBi
Sirius 3	37.9 dBi	39.0 dBi	37.5 dBi	37.3 dBi	38.5 dBi
HotBird	38.5 dBi	39.7 dBi	37.7 dBi	37.3 dBi	38.5 dBi
Astra 1	38.2 dBi	39.3 dBi	37.7 dBi	37.3 dBi	38.5 dBi
Astra 2	36.5 dBi	37.1 dBi	37.1 dBi	37.3 dBi	38.5 dBi

Table 1. Optimised directivity performance

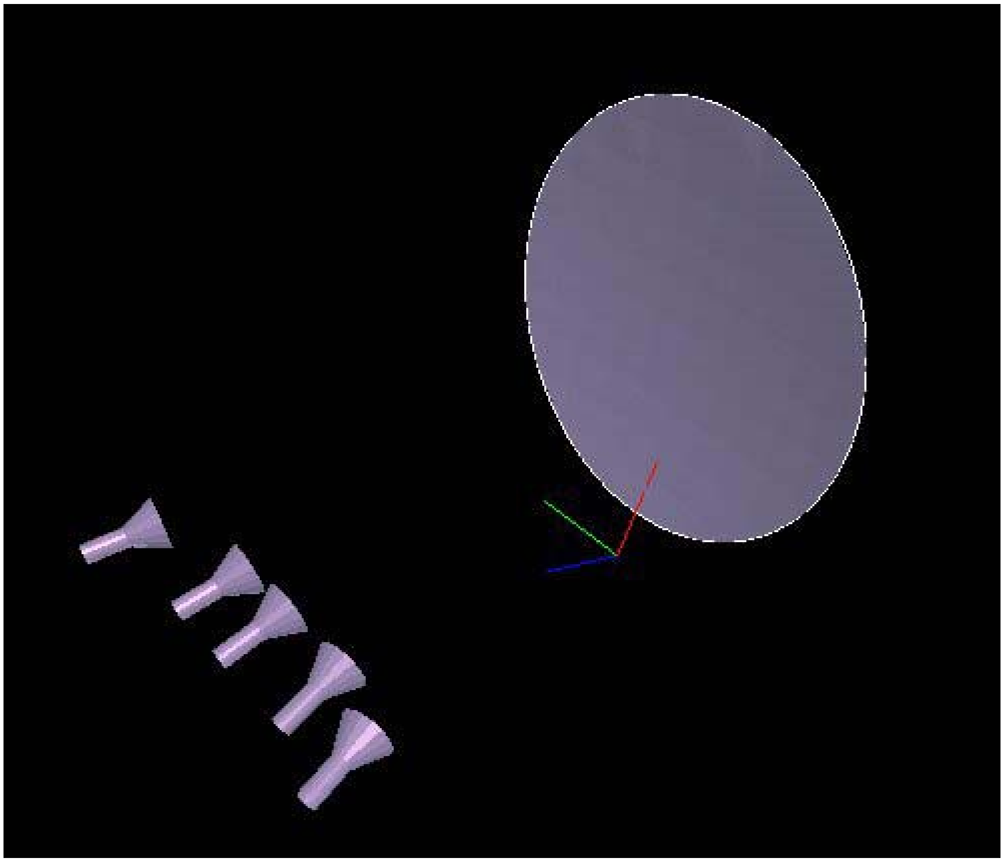
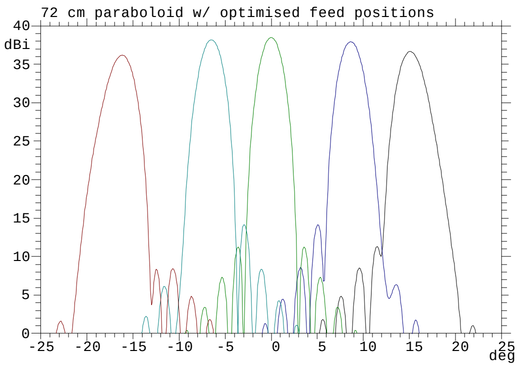


Figure 2.Optimised geometry

In Figure 3 one can observe the typical performance of the paraboloid where the scanned beams exhibit a gain degradation and a sidelobe increase. The patterns to the right show the effect of also shaping the surface.



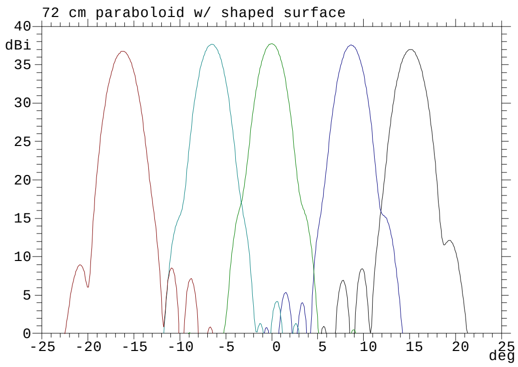


Figure 3. Radiation pattern from a 30λ paraboloid with the feed positions optimised(left) and from a shaped reflector (right)

The first approach to shaping the surface is to keep the feed positions that were found to be optimum for the paraboloid. However, this may limit the degrees of freedom for the design, and is reflected in the fact that the directivity is not the same for all five beams in the third column of numbers in Table 1. If we also allow the feed positions to become part of the optimisation we arrive at the numbers in the fourth column, with the associated patterns shown below. The optimum performance is in this case 37.3 dBi for all beams, which shall be compared to the 38.5 dBi of the baseline, non-scanned beam.

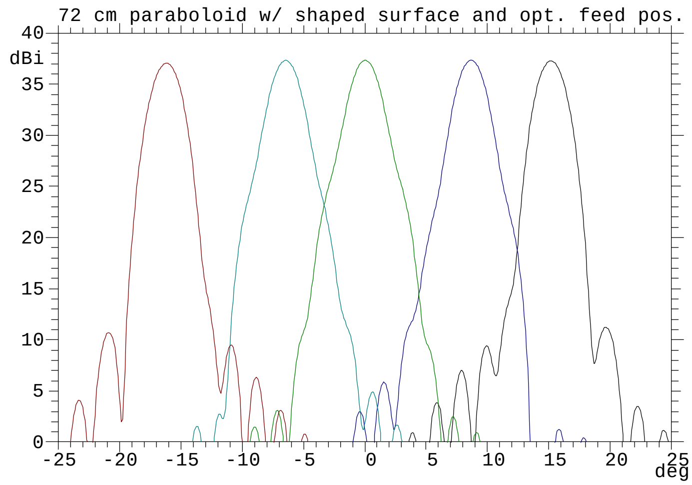


Figure 4. Radiation pattern from a 30λ shaped reflector where the feed positions are optimised simultaneously

A small oversizing of 14% to a diameter of 0.82 m is needed in order to obtain the 38.5 dBi for all five beams. If a non-shaped paraboloid of 82 cm was used the worst-case performance would be as low as 37.1 dBi as shown in Table 1.

Conclusions

Antennas for multisatellite reception can be designed in a straightforward manner using general PO reflector synthesis techniques. Scanning over an orbital arc of 30º can be achieved without any loss compared to a fully steerable antenna if just a small oversizing of 14% is implemented.

References.

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[2] Rappaport, C.M., “A high aperture efficiency, single reflector antenna with 60° scanning”, 1989 IEEE Int. Antennas Propagat. Symp. Dig. vol. 27, pp. 270 - 273, June 1989.

[3] Pino, A.G., Rubiños, J.O., Aria, A.M., Rodriques, A.M. & Ares, F., “Reflector Antenna Solutions for Multisatellite DBS Reception”, 2001 IEEE Int. Antennas Propagat. Symp. Dig. vol. 39, pp. 284 - 287, July 2001.

[4] Sørensen, S.B., Lumholt, M. & Viskum, H.-H., ” Manual for POS4”, TICRA Report S-840-004, TICRA, Copenhagen 1999.