Design of terrestrial sector-beam antennas using advanced spacecraft contoured beam synthesis software

Hans-Henrik Viskum
TICRA, Kronprinsens Gade 13, DK-1114 Copenhagen K

Abstract. The design of a sector-beam antenna is described. The azimuth and elevation patterns are subject to stringent requirements on gain and isolation. A PO based synthesis method is applied to generate a shaped reflector surface that radiates the desired pattern when illuminated by a corrugated horn. A centre-fed as well as an offset design is presented. The designs fulfil the requirements, except for side lobes caused by the feed spillover effects. This cannot easily be incorporated into the synthesis, but may be dealt with by extending the rim of the reflector.

Introduction. Reflector antennas have been used for the generation of shaped-beam antennas since the 1940's, as surveyed by Silver [1]. One of the most famous is the classical cosec-squared design by Dunbar [2] used extensively in airborne surface radars. The designs are based on ray optics principles and hence the performance will only approximate the requirements as a consequence of the finite aperture size of the antenna. Nevertheless, the achieved results have been sufficiently well within the specified limits to justify the approach.

Spacecraft communications antennas are also required to produce shaped beams matching the contour of the desired coverage area when seen from orbit. In this case the beam size is only somewhat larger than the beam from a comparable focused aperture, and a design based on ray optics is impossible. Advanced software was therefore developed in the 1990's to optimise the shape of reflector surfaces using diffraction techniques such as Physical Optics (PO). When PO is used during each iteration of the synthesis optimisation the performance of the final design will be in very close agreement with the predictions, much closer indeed than the case is for a ray-optics based design. The disadvantage is the computation time, which in the early days was prohibitive long. Improved numerical techniques and the advent of very powerful PCs have alleviated this problem.

It is obvious to apply the methods now routinely being employed in the space segment to terrestrial shaped-beam antenna design. One case where the advanced software could result in an improved design is the sector beam antennas used for point-to-multi-point communications, for example to provide last mile access service. A flat beam is required in azimuth over a prescribed angular region whereas the elevation pattern should be narrow. Low side lobes and sharp gain roll-off in the azimuth beam are prerequisites for efficient frequency reuse among adjacent sector beams. We will show an example of two designs for a 90º-sector beam, one centre-fed and one offset design.

Centre-fed design. A centre-fed antenna has been optimised to generate a 90º-sector beam at 30 GHz. The diameter is 30 cm (=30λ) and the system is fed by a corrugated horn providing 18 dB taper at the edge. First the design is optimised to give as much gain as possible inside the 90º-sector. The resulting azimuth pattern is shown in Figure 1 where the desired pattern envelope is also indicated.

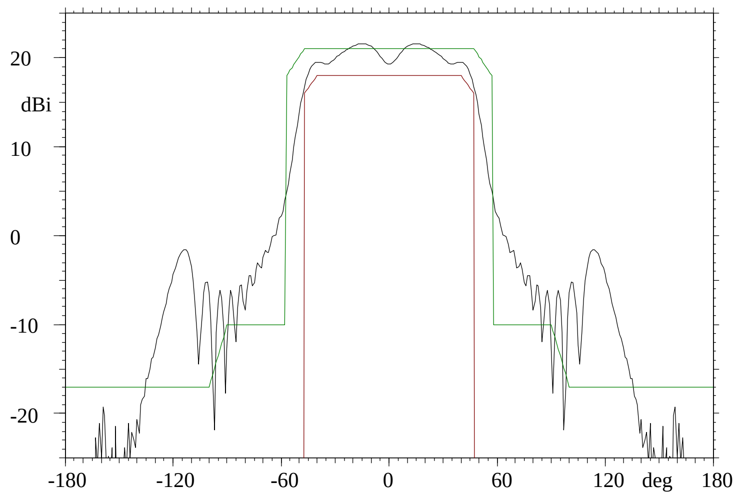


Figure 1. Azimuth pattern for centre-fed antenna, without imposing side lobe constraints during the optimisation

Two distinct features are visible in the pattern: the gain roll-off is too slow, and the side lobe level around 120º is way too high. The first problem is caused by diffraction and can be remedied by including the envelope in the optimisation. The origin of the far-out side lobes is spillover from the feed and cannot be dealt with in the optimisation; it may be possible to reduce it by adding a shield around the edge of the reflector.

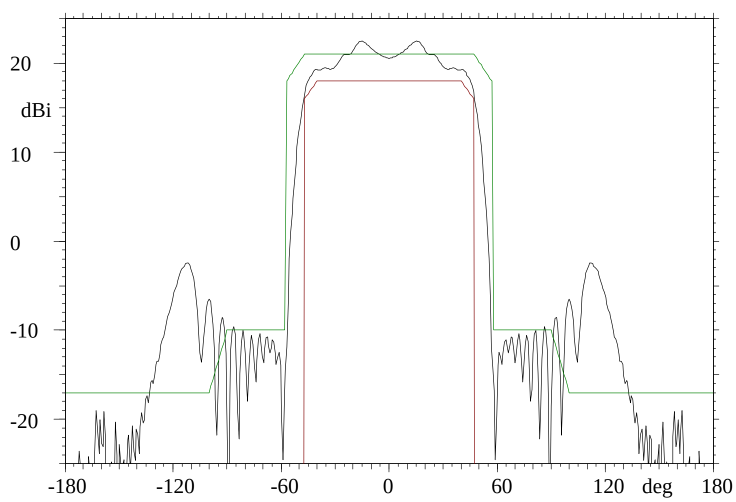


Figure 2. Azimuth pattern for centre-fed antenna, after imposing side lobe constraints

Figure 2 shows how a new optimisation indeed results in an improved gain roll-off, whereas the feed spillover is still present. This can also be seen in the elevation pattern in Figure 3, but it us less important in this plane since there is no interference with other sector beams.

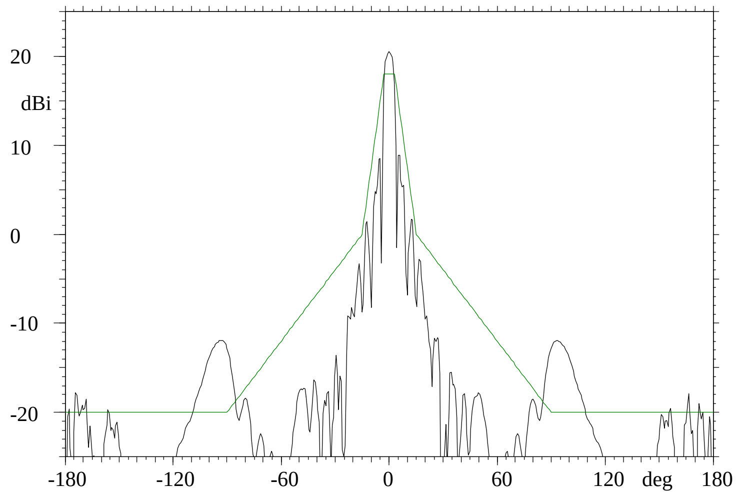
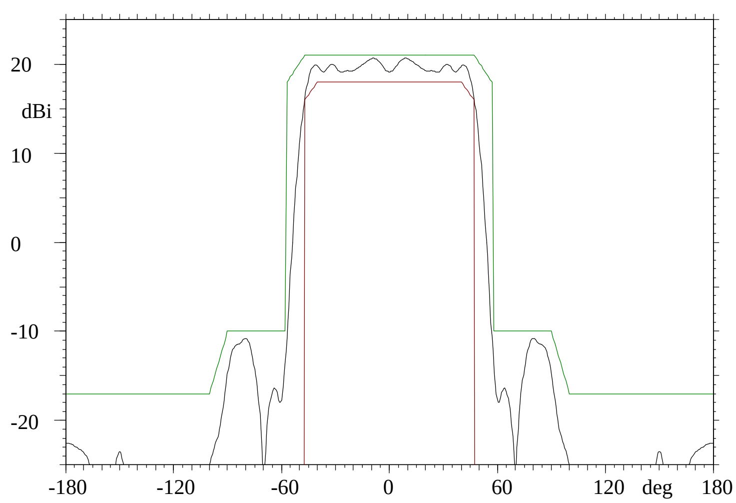


Figure 3. Elevation pattern for centre-fed antenna

The spillover will appear in all cuts around the antenna due to the centre-fed configuration. Another disadvantage of this design is the blockage caused by the feed. The effect is modelled in the data presented above, but only in an idealised way and there has been no attempt to model any support struts and waveguide feeding which must necessarily be present. Both of these problems are to a certain extent solved in the offset design.

<u>Offset design.</u> The software employed to produce the shaped reflector surface is very general (Sørensen et al [3]), and can accommodate offset as well as centre-fed design task.



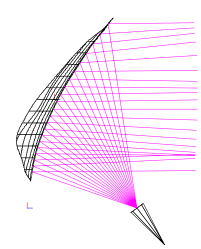


Figure 4. Azimuth pattern for offset antenna

The offset design not only eliminates the feed blockage but it also directs the feed spill over away from the azimuth plane and into areas where it does not interfere with other sector beams. This is shown in Figure 4.

Conclusion. Advanced software designed for spacecraft contoured beams can easily be applied to terrestrial antenna configurations where pattern shape and isolation levels are of importance. Centre-fed as well as offset configurations can be optimised, and results as shown in Figures 5 and 6 are achievable. The offset design significantly reduces the spillover effect in the azimuth plane and provides for a sector-beam antenna with much less interference.

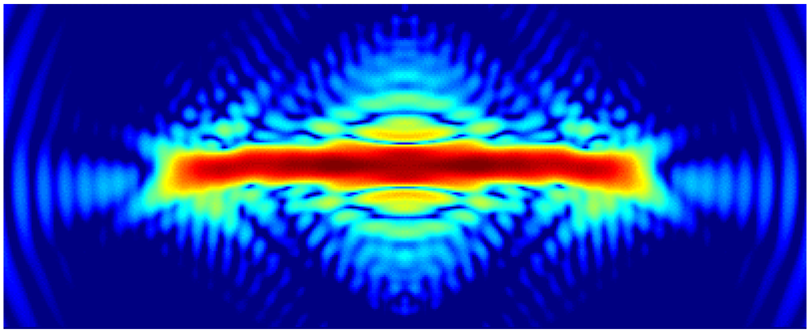


Figure 5. Colour plot of radiation pattern from centre-fed antenna (±90º in azimuth, ±30º in elevation)

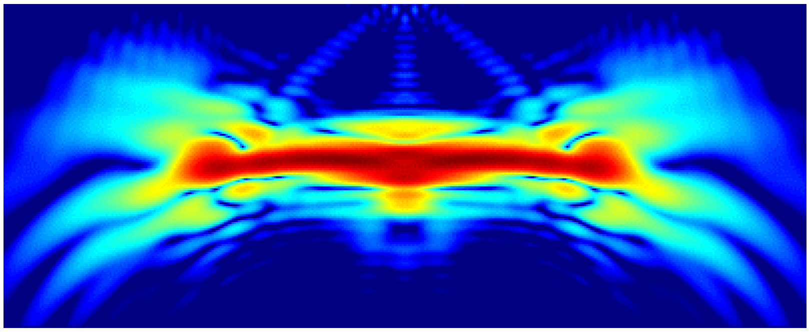


Figure 6. Colour plot of radiation pattern from offset antenna (±90º in azimuth, ±30º in elevation)

References.

[1] Silver, S., "Microwave Antenna Theory and Design", Reprint, Peter Peregrinus Ltd., London, UK, 1984.

[2] Dunbar, A.S., "Calculation of doubly-curved reflectors for shaped beams", Proc. IRE, 36, 1948.

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