A dual reflector system with a reconformable subreflector

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Abstract. The paper describes the design of a dual reflector spacecraft antenna with a circular main reflector aperture, shaped to produce an elliptical beam. A design is made with two different subreflector shapes which, when used with the same shaped main reflector, will generate elliptical beams rotated 90° with respect to each other. During the design optimization it is assumed that the subreflector is fully reconformable, i.e. any desired shaped can be accomplished. The impact of using a particular implementation of a reconformable surface with a specified number of control points, implying that the desired shape can only be met with a particular tolerance, is assessed.

Introduction. Elliptical beam antennas are widely used on communications satellites, since many coverages on the earth can be well approximated by an ellipse. Most often these antennas are steerable by means of a two-axis gimbal system, such that they can be pointed to almost any location on the ground. However, the orientation of the elliptical beam axes remains fixed in such systems. The extra flexibility of being able to rotate the beam around the beam axis may come at a large price. For example it could be necessary to introduce moving waveguide components such as rotary joints.

An alternative which becomes attractive due to innovative developments in software as well as hardware is to employ a reflector surface, the shape of which can be changed via commands from the ground [1], [2]. The primary beam-shaping action in a contoured antenna normally comes from the main reflector, whether the system consists of one or two reflectors. Thus it would be desirable to be able to control the shape of the main surface; however, since the subreflector is usually much smaller, it seems attractive to investigate the extend to which the beam can be changed by employing only a reconformable subreflector surface.

In the following we will first briefly describe the shaping technique and present the dual reflector geometry which has been further investigated. Then we present results of optimizing such system for two elliptical coverages (90° with respect to each other) subject to the constraint that only the subreflector surface can be modified. Finally, the optimized subreflector shapes are fitted by surfaces which could be realized by a reconformable surface consisting of a mesh of curved, interwoven flexible wires. The shape of this surface is defined by the position of a number of control points, and it will be shown that a very attractive performance can be achieved by a limited number of points.

The shaping. A special version of TICRA's dual reflector shaping program POD has been developed, which makes it possible to simultaneously optimize the main reflector and several subreflectors, such that different coverage requirements are fulfilled by different subreflectors, whereas the main reflector attains the same shape in all cases (this shape being part of the optimization). In the present case there will be two distinct coverages, ellipses with their main axes at 90° relative to each other. During the optimization the radiated field from the system is calculated by using PO on both the sub- and the main reflector surfaces.

The geometry. A system with typical dimensions for spacecraft applications at Ku-band (10-14 GHz) has been chosen. The geometry is shown in Figure 1.

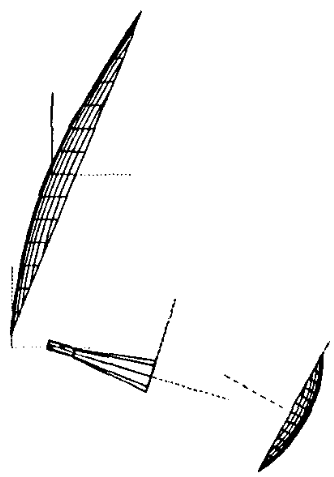

Figure 1. Geometry of dual offset reflector system

Before shaping, the system is a regular Gregorian dual antenna with a main reflector aperture of 1.2 m and a focal length of 0.8 m. The subreflector has an eccentricity of 0.3, an interfocal distance of 0.3 m and an aperture with a radius of approximately 0.25 m. The entire system is offset with a choice of angles that fulfil the condition of minimum cross polarization.

The coverages. Two elliptical beams are required. Both have major and minor axes of 1.8° by 1.15°, respectively, but one has its major axis aligned with the plane of offset for the antenna whereas the other is rotated 90°. It is expected that if a system with a reconformable subreflector surface can meet the requirements for these two extremes it will also be possible to generate elliptical beams rotated at any other angle in between.

The design. When optimizing the system under the assumption that the subreflector shape is fully reconfigurable, it is possible to achieve a minimum edge of coverage directivity at the two elliptical coverages of 33.7 dBi, as can be seen in Figure 2. It is emphasized that these two beams are achieved by the same, shaped main reflector but with two different subreflectors. It is also worthwhile noting that if two completely independent designs were made, i.e. where both the sub- and the main reflectors were shaped for each coverage, the minimum EOC directivity would only have been 0.05 dB higher.

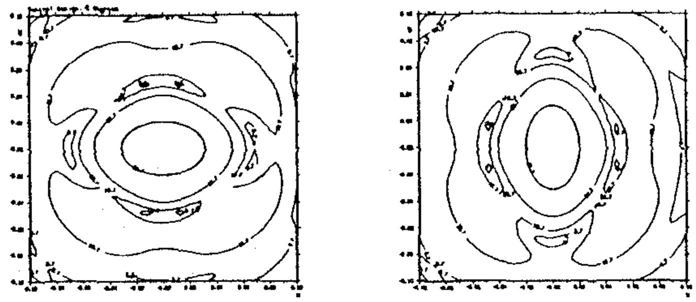

Figure 2. Elliptical beams generated by two dual reflector system with the same main reflector but two different subreflectors. The coverage ellipse is also drawn but cannot be distinguished from the minimum EOC contour. Levels are 33.7, 23.7, 13.7 and 3.7 dBi.

Now, the optimized subreflector surface shapes are assumed to be realized by a mesh which is suspended by a grid of flexible wires [3], see Figure 3. The crosses indicate control points where a force can be applied. A least-square optimization scheme is used to determine the z-displacement at each point in order to fit the surface to the desired shaped subreflectors.

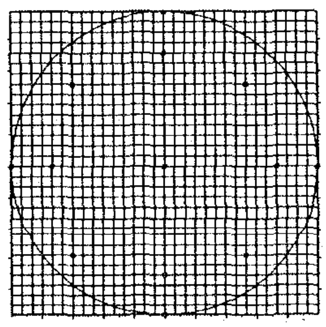

Figure 3. Wire surface seen from top with the position of 9 interior and 4 rim control points shown.

An analysis is performed of the dual antenna system with the two subreflector shapes which can be attained by the reconformable surface, showing a minimum EOC directivity of 33.4 dBi, a reduction of 0.3 dB compared to the optimum solution. This can also be seen from Figure 4 where the beam contour fits the elliptical coverage quite well, but not as close as in Figure 2.

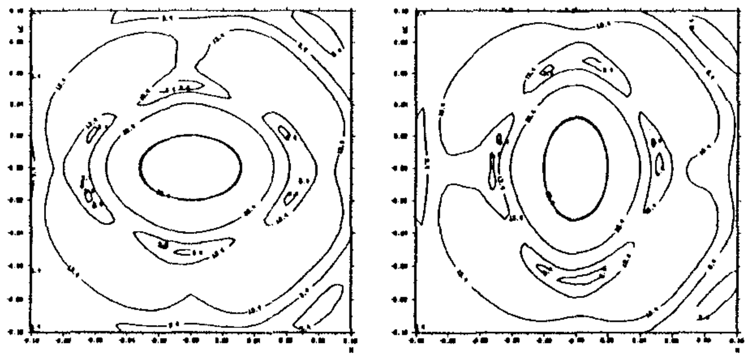

Figure 4. Elliptical beams generated by a dual reflector system with a reconformable subreflector the shape of which is fitted to the subreflector shapes used in Figure 2. Levels are 33.4, 23.4, 13.4 and 3.4 dBi.

Conclusion. The study shows that it is possible to provide reconfigurability in a dual reflector systems by means of a reconformable subreflector surface, and two elliptical beams at a 90° angle can be generated with a reasonably small price in edge of coverage gain performance. It would be possible to further improve the performance if the subreflector surface shape would be constrained already in the optimization. For example, the model for the wire reflector could be incorporated into the POD program, which could then optimize directly on the amplitudes at the control points.

References.

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