DESIGN OF A DUAL BEAM SPACECRAFT ANTENNA FOR SIMULTANEOUS ELLIPTICAL AND CIRCULAR COVERAGES AT 11/14 GHZ

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Introduction. In order to provide flexible communications service in the K-band (10.95 GHz-12.50 GHz for transmit and 14.00-14.50 GHz for receive) INTELSAT has implemented two fully steerable spot beams on the INTELSAT V and VI spacecraft. On INTELSAT V the West Spot is circular and the East Spot is elliptical, while on INTELSAT VI both beams are elliptical. They are required to be independently steerable and thus cannot be realized by one single reflector antenna but must be implemented using two separate, movable systems.

For future applications the two elliptical coverages defined as S1 and S2 in Table 1 are of interest. However, in addition to these two beams a third, circular K-band coverage must be provided for particular orbital locations of the spacecraft in the Pacific Ocean Region. It can be assumed that the S2-beam will then be pointed towards Japan, and the circular S2A-beam shall cover Southern Australia, as illustrated in Figure 1.

	Inner Coverage	Outer Coverage
S1	1.3° x 2.7°	1.9° x 4.3°
S2	2.0° x 3.5°	3.0° x 5.4°

Table 1. Definition of the S1 and S2 Elliptical Coverages.

Because the S2-beam pointing remains fixed whenever the S2A-beam is active it is possible to integrate the two beams into one antenna system. This paper presents one approach to designing the S2/S2A antenna with the design objective being to optimize the transmit performance, and to avoid any blockage introduced by the additional feed needed for the S2A-beam. It is shown that while the S2 reflector is designed to produce an elliptical beam, the scanned beam generated from the S2A-feed actually turns out to be almost circular and better focused than the S2-beam.

Design of Elliptical Beam Reflector. A number of methods exist for generating elliptical beams. One which has been applied successfully in the past on INTELSAT V and VI spacecraft involves the shaping of a reflector with a circular aperture, and illuminated by a corrugated horn. The circular aperture ensures that the reflector will be efficiently illuminated by the feed, with a minimum of spill-over loss. The primary function of the shaping is to introduce a phase error which will spread the beam out in one plane while maintaining it focused in the orthogonal plane. A detailed description of the design of the INTELSAT V East Spot Beam may be found in [1].

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The size of the S2 elliptical beam is different from the INTELSAT V and VI beams, and therefore a redesign is required. However, the principles remain the same. Figure 2 shows a cut through the reflector in the plane of offset. The intersection curve is parabolic, with the feed being placed at the focus. To produce the elliptical beam, the rest of the reflector is generated from the parabolic curve in the following way: An axis is defined orthogonally to the axis of the parabola, and in the plane of offset, as indicated by R_0 in Figure 2. The parabolic curve is rotated around this axis to generate a barrel-shaped reflector with a circular aperture. By chosing the distance from the apex of the parabola to R_0 appropriately, the required ellipticity will result. The equation for the surface in the coordinate system given in Figure 2, is:

$$z(x,y) = -\sqrt{((y-y_0)^2-4F*R_0)^2-(4F(x-x_0))^2}/4F + R_0$$

where (x_0,y_0) are the coordinates of the center of the aperture.

Depending on whether R_0 is greater than or smaller than twice the focal length, the aperture phase error will be negative or positive. This corresponds to either converging or diverging rays, similar to the elliptical versus the hyperboloidal subreflector in a dual reflector system. The same ellipticity may be obtained from both choices; however, it was found that the better performance was achieved with a value of R_0 smaller than 2F, and initially converging rays.

In the narrow plane, the beamwidth is diffraction limited due to the parabolic shape of the cross section, and has been found to depend very litle on the shaping in the orthogonal plane. Thus well-known methods can be applied to optimize the reflector diameter. In the present example, a 0.75 m diameter yields a 3-dB taper at the inner coverage, and is considered close to optimum.

Design of the S2A Beam. Having realized the reflector for the S2 beam, the S2A beam is generated by placing a feed identical to the primary at the appropriate position. Because the S2-beam is symmetrical it may be rotated 180 degrees and provide the same coverage. This leaves two different possibilities for positioning the S2A-feed relative to the S2-feed, as has been indicated in Figure 3 (a) and (b). In one case it is impossible to avoid blockage by the S2A-feed unless a very large offset angle is chosen, and the other solution is selected for the present study.

Results. The radiation pattern for the S2/S2A-antenna at 10.95 GHz is shown in Figure 4. The gain is equalized at the inner S2 coverage and the S2A-coverage with a power division ration of -2.3 dB to S2 and -3.9 dB to S2A. A high efficiency is achieved in the S2-beam, as seen in Table 2 summarizing results. Note that the gain-area products does not take the power splitting between the two beams into account, but does assume a 0.5 dB loss in the feed and waveguide run.

The coverages utilized above are similar to the requirements for the INTELSAT VII spacecraft, and the feasibility study has thus shown that a single, shaped reflector with two feeds is one potential candidate for the S2/S2A antenna system.

	Transmit		Receive	
	Directivity	Gain Area Product	Directivity	Gain-Area Product
S2 inner	32.6	10520	32.8	11015
S2 outer	29.6	11550	29.9	12380
S2A	34.2	--	34.3	--

Table 2. Edge-of-coverage directivities of S2 and S2A beams in dBi, and associated gain-area products in square degrees

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References.

[1] P. Bielli, P. De Vincenti, G. Doro, A. Saitto: "Design of 11/14 GHz Elliptical Beam Reflector Steerable in a Wide Angular Zone", AIAA Conference on Communications Satellites, San Diego, 1978.

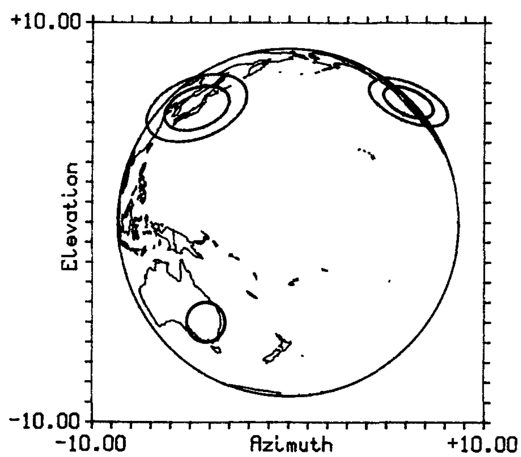


Figure 1. Definition of the S1, S2 and S2A coverages at one particular orbital location.

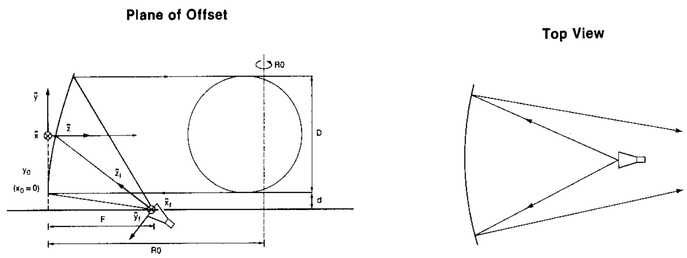
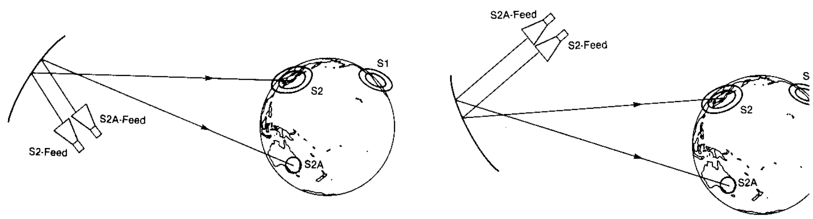


Figure 2. Definition of shaped reflector antenna coordinate system.



(a) Design with inherent blockage (b) Blockage-free design

Figure 3. Illustration of two different principles for realization of the S2A beam.

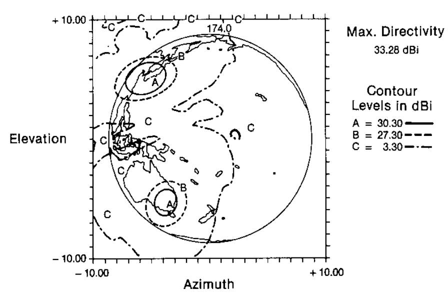


Figure 4. Radiation pattern of S2/S2A-antenna at transmit (10.95 GHz).