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A DUAL ASTIGMATIC REFLECTOR ANTENNA FOR A DIRECT-TV SATELLITE

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For direct TV transmission from a satellite to small home receivers, a high-performance satellite antenna is needed. At L M Ericsson, we have designed such an antenna for the European heavy satellite project (an experimental direct-TV satellite for the European Space Agency).

The antenna requirements are:

- two elliptical beams, $0.8^o \times 1.4^o$ shall be produced at transmit frequencies (12.1-12.6 GHz)
- the two beams shall be combined into one at receive frequencies (14.0-14.5 GHz)
- the polarization shall be circular (different senses at transmit and receive)
- rf sensing shall be used for attitude control with a beacon station, transmitting at 14.25 GHz, arbitralily located in one of the transmit beams
- the transmit, receive and rf sensing functions shall be combined into one antenna
- the relative position of the two beams shall be defined one year before launch, with very small beam separations possible
- repointing shall be possible

To obtain a good circular polarization in elliptical coverage areas represents a difficult problem. The elliptical beams require elliptical reflectors, and thus a feed horn with an elliptical circularly polarized beam. One of the horns is also required to handle rf sensing modes. Since no good candidate for such a horn has been found, we have settled for a feed horn with a circular beam. In order to transform the symmetrical beam into an elliptical illumination of the main reflector, we use a subreflector with different magnification ratios in the two principle planes. The main reflector is then properly shaped to give a co-phased aperture. We call this an astigmatic reflector system. The aperture efficiency of the astigmatic system is thus not reduced compared to a normal dual reflector system, as is the case with a single shaped reflector.

The principle is similar to the optimum shaping of circularly symmetric Cassegrain-earth station antennas. The non-symmetry of the astigmatic system gives rise to a much more complicated situation, however. Rays from the focus will, after reflection on the subreflector, not seem to originate from the main axis. Only in the two principle planes can the conventional design principles with choice of magnifications etc. be used.

The dual reflector system is of the Cassegrain type, and is open in order to avoid blockage. The lay-out is shown in figure 1. The small shield, mounted on the subreflector, is used to avoid signals to reach the feed horns directly from the earth, without passing the reflector system. Repointing is performed with a positioner below the main reflector. The design parameters of the system have been chosen as a compromise between several requirements:

- the limited space available on the spacecraft
- limited tower height for mechanical reasons
- sufficiently large subreflector to keep diffraction effects small
- sufficiently large feed horns in order to minimize the influence on the beam separation by the corrugations, to allow good pattern control and propagation of higher order modes, used for rf sensing
- good repointing capability

When all these constraints are taken into account, the remaining design freedom is rather small. The main reflector is 1.3x2.3 m, which is the maximum size allowed. The subreflector is 16-19λ in diameter. This small size is the main drawback of the design, since it introduces diffraction losses and cross polarization contributions. On the other hand a great advantage of the dual reflector system is that waveguide and electronic parts are mounted in the controlled environment inside the spacecraft.

Square corrugated horns are used as feed horns. They give better efficiency for close beam separation than circular ones, and they allow the use of a square waveguide mode coupler. The schematic in figure 2 shows the waveguide components of the system. One feed horn is equipped with a narrowband square mode coupler, which couples the H_{02} and H_{20} modes. The fundamental mode input is connected to a polarizer with a dielectric vane, and an OMT is used to separate the orthogonally polarized receive and transmit signals. The beacon sum signal is filtered out from the receive signal via a circulator and a bandpass filter, and is used to normalize the difference (rf sensing) signals (the extracted H_{20} and H_{02} modes).

The other feed horn is equipped with a polarizer and an OMT, and the receive signals are combined in a magic tee (combiner), in order to produce a combined coverage.

The design and optimization of the reflectors have been done with a computer program, using geometrical optics for the subreflector and physical optics for the main reflector. The diffraction effects were checked with a spherical mode expansion of the subreflector radiation. The size and offset structure of the system made these calculations rather expansive. Later, we have therefore used GTD for the subreflector diffraction calculations.

The gain and sidelobe level performance are limited mainly by the small beam separation, which requires high edge illumination. For example, a beam separation of 1.4 beamwidths gives a directive gain of 40.5 dBi at EOC, while 1.8 beamwidths increases this figure by 1 dB. The first sidelobes are about -20 dB.

The incorporation of the rf sensing in the transmit/receive antenna eliminates first-order thermally induced errors. The remaining errors are approximately (3σ values): 0.03° bias, 0.02° daily variation and 0.005° noise. All these errors are given in the worst case.

The reflectors and the subreflector tower are made of CFRP, and the feed horns of aluminium. In order to reduce temperature sensitivity, the mode coupler, polarizer and filters, as well as some waveguides runs, are made of invar.

The presented design principle can also be used in later operational European direct-TV satellites, since all the proposed European coverages are elliptical.

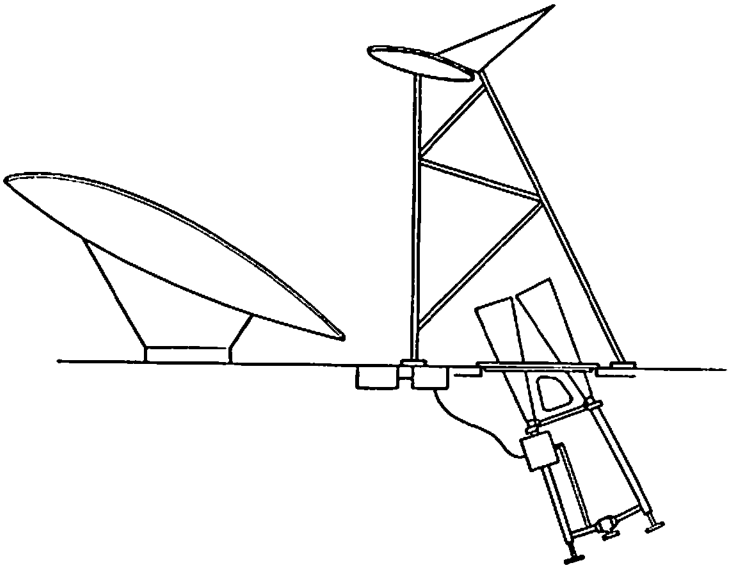

Figure 1. Configuration layout

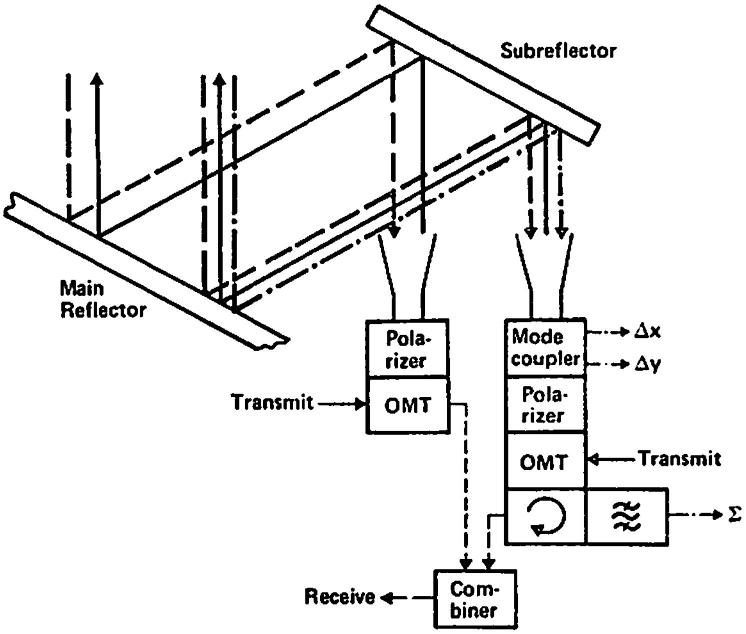

Figure 2. System schematic