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FEATURES AND TECHNOLOGIES OF  
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## ABSTRACT

The paper describes features and technologies of planar waveguide array antennas developed for spaceborne microwave sensors. Such antennas are made from carbon fibre reinforced plastic (CFRP) employing special manufacturing and metallisation techniques to achieve satisfactory electrical properties.

Mechanical design enables deployable antenna structures necessary for satellite applications (e.g. ESA ERS-1). The slotted waveguide concept provides high aperture efficiency, good beamshaping capabilities, and low losses. These CFRP waveguide antennas feature low mass, high accuracy and stiffness, and can be operated within wide temperature ranges.

## I. BACKGROUND AND CONCEPTUAL APPROACH

In view of mutual cooperative interests in the field of SAR antenna development, the German and Swedish space administrations agreed to sponsor a common antenna technology programme in 1980. Overall technical responsibility was given to Dornier System, whereas Ericsson was responsible for all electrical aspects. This programme has proven the feasibility of CFRP technology for space-borne antennas. This technology is currently being applied to two SAR missions for different carrier frequencies, but having a number of mechanical parameters in common:

- The synthetic aperture radar, to be flown on the first ESA remote sensing satellite ERS-1, has a 10 m x 1 m deployable array for C-band operation, and
- X-SAR, conceived for cooperative missions together with SIR-C, employs a 12 m x 0.5 m planar array for the 9.6 GHz frequency band.

ERS-1 mission requirements, visible during the course of the technology programme, suggested an antenna concept as outlined in Table 1: Planar array, subdivided into appropriate mechanical and electrical subpanels, employing slotted waveguides made from carbon fibre reinforced plastic. The panels are supported by a lightweight deployable truss structure having a minimum number of bars. CFRP technology is applied wherever reasonable, particularly for all parts of significant dimensions. This concept provides lightweight deployable structures with good planarity maintained under severe environmental conditions.

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Table 1. Conceptual approach

Requirement	Solution
Large deployable structure, one long dimension > 10 m	Planar array, stiff-mounted centre panel with wings comprising 2 or more outer panels
High stiffness, high alignment accuracy, locking function	Deployable supporting truss structure with thin tabular bars
Low mass, thermally stable	Carbon fibre reinforced plastic (CFRP)
High aperture efficiency, low losses, beam-shaping requirements	Slotted waveguide array with coupling guides and waveguide distribution network

## II. WAVEGUIDE TECHNOLOGY

The CFRP material offers considerable performance advantages when compared to aluminium: The specific stiffness to mass ratio of suitably designed CFRP is about three times that of aluminium, which leads to structures of markedly lighter weight. The coefficient of thermal expansion of CFRP is 1/25 that of aluminium. Even though a CFRP construction is likely to experience higher thermal differentials in a changing environment due to its lower thermal capacity and conductivity, an order of magnitude advantage still remains. The electrical conductivity of CFRP is unfortunately far from adequate. Thus coating processes with highly conductive materials have been developed.

Waveguide metallisation, especially of the internal walls, required extensive experimental work. Of the numerous metallisation processes available, the indirect technique has provided superior adhesion. Here mandrels are metallised prior to CFRP lay-up. A special surface treatment is applied to the metal which assures excellent adhesion of the metal layer to the cured CFRP. This process can be applied to straight mandrels, which can be extracted and reused after CFRP manufacturing. It can also be applied to sacrificial mandrels for more complex components. These mandrels are made from aluminium, and chemically decomposed after each use. Metallisation after final machining and slot cutting is accomplished by silver paint with a stable binder. This indirect metallisation technique has been space qualified for temperatures ranging from -70 to +115 degrees centigrade.

## III. ANTENNA DESIGN

As illustrated in Fig. 1, the antenna consists of horizontal radiating waveguides having longitudinal slots on the broad side. A subarray is fed by a vertical coupling waveguide. Radiating and coupling waveguides

are operated in resonant mode. This requires careful design with respect to VSWR, sidelobes, and bandwidth, but avoids beam squinting during emission and reception of the chirped radar pulse. Bandwidth limitations of the resonant guides, and the need for a suitable mechanical subdivision for folding, led to 1 m long subarrays for the ERS-1 antenna. Each pair of subarrays is combined into one mechanical panel. This can be seen in Fig. 2, which depicts the mechanical configuration of the deployable antenna and shows panels together with the supporting truss structure. The waveguide distribution network on the rear side of the panels has been omitted.

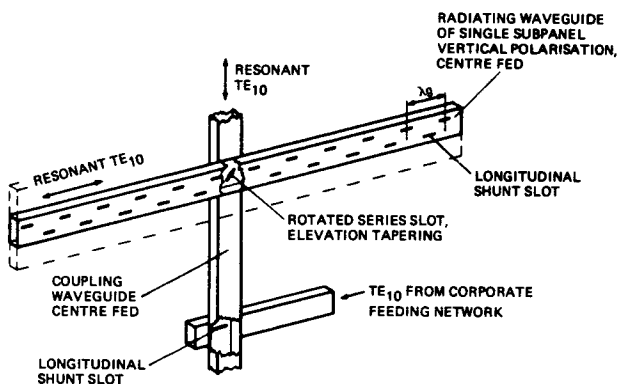


Figure 1. Electrical concept

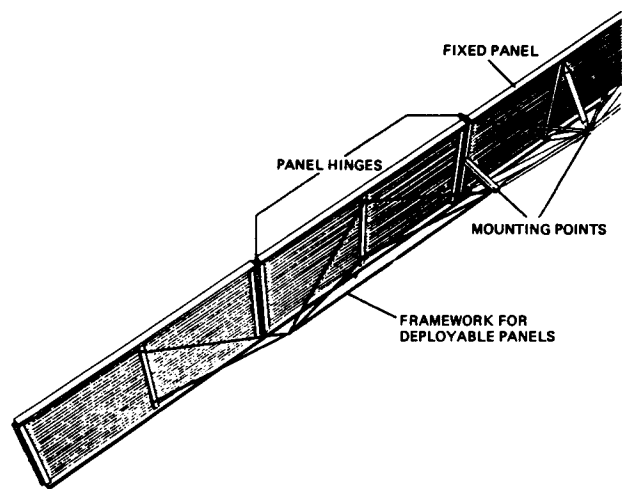


Figure 2. Mechanical configuration

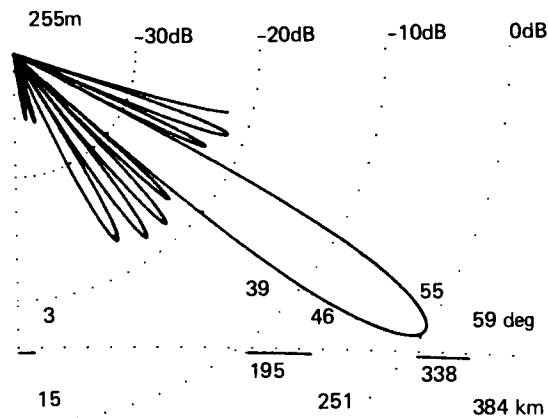
#### IV. SAR ANTENNA FOR ERS-1 (ESA)

The ERS-1 SAR antenna is currently in full production, after completion of all essential design activities. Among these, a 2-panel (4 m x 1 m) functional model was manufactured and tested. A series of deployment tests under simulated zero-g conditions was carried out with this model. Measured out-of-plane distortions were within  $\pm 0.4$  mm peak and  $\pm 0.1$  mm average. The complete 10 m engineering model for ERS-1 will be assembled this summer. Stowed dimensions of this C-band antenna are about 2 m x 1 m x 0.6 m, and its mass is around 68 kg.

## V. X-SAR ANTENNA

X-SAR, a joint project together with SIR-C, is currently in the definition and specification phase. The foldable CFRP slotted waveguide array, to be operated at 9.6 GHz, will be attached to the 12 m long SIR-C antenna support structure. This project will result in the first multi-frequency SAR facility for microwave remote sensing from space. It will illuminate the earth at incidence angles ranging from 15 to 60 degrees.

General features of the X-SAR antenna are included in Fig. 3. This also depicts the ideal antenna elevation diagram, and the computed side-looking geometry for incidence angles around 57 degrees. The useful swath for this specific scenario is between 338 and 384 km from the shuttle ground-track. There are two ambiguous regions, including one around the nadir point. Theoretically the (strong) nadir return could be avoided by suitable timing of the radar (i.e. through selection of appropriate pulse repetition frequency and echo window). However, there are too many uncertainties in the required timing during real flight conditions. As a preventive counter-measure, elevation sidelobes at angles between 30 and 55 degrees off the antenna boresight will be further suppressed.



- 9600  $\pm$  10 MHz frequency band
- Antenna will be mounted onto SIR-C antenna frame
- 12 m long VV polarised antenna
- Peak power is 3 kW
- Elevation sidelobe suppression
- Planarity shall be better than  $\pm$  1 mm

Figure 3. X-SAR antenna features

## ACKNOWLEDGMENTS

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