LARGE SATELLITE ANTENNA DEVELOPMENTS AT ESA

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1. ABSTRACT

A review of large satellite antenna developments in Europe is presented. Typical application requirements for future European space missions are outlined. Then European mesh and inflatable antenna concepts are described, as well as a large reflector with foldable tips.

2. INTRODUCTION

In the past decade, a number of future missions requiring unfurlable satellite reflector antennas have been proposed. These cover as diverse applications as land mobile communications, direct broadcasting and very long base interferometry. Antenna diameters range from 3 to 150 meters, wavelengths from 1 to 40 centimeters. A review of future missions for large antennas and related technologies is given in [1]. This paper is based on the above reference but concentrates on the most recent European developments. Also [2] includes a review of ESA large satellite antennas developments. Offset and symmetrical reflector configurations are envisaged.

Typically, the missions with offset configurations imply multiple beams with low sidelobe and/or low cross polarization requirements to allow for multiple re-use of the same frequencies. For these applications, the choice of reflector diameter is constrained by the angular separation of frequency re-use zones and, for a given diameter and frequency, the number of gores or facets and their tolerances are directly derived from acceptable sidelobe level degradations.
Specifying the overall r.m.s. surface tolerance is generally not sufficient in these cases, since different surface error distributions with the same r.m.s. deviation value can have very different effects on sidelobe levels and location.

On the other hand, for missions with symmetrical reflectors, operation is normally in the single beam mode and peak gain is the parameter of concern. The diameter and surface tolerance can be traded-off since the same peak gain can be produced by a small but accurate reflector or by a larger less accurate one.

As an indication, in flight rms tolerance goals typically range from 1/100th to 1/25th of the wavelength. Moreover, the reflecting surface has to provide quasi perfect reflection, i.e. with minimum ohmic loss, minimum depolarization and negligible passive intermodulation product (PIMP) generation in cases with transmit /receive operation on the same antenna.
In addition to meeting requirements derived from RF specifications, unfurlable antennas must survive the severe launch and space environmental conditions and maintain their surface profile over the life-time of the payload. For this reason the bulk of the design, manufacturing and testing problems is in the structural and thermal areas.

3. EUROPEAN DEVELOPMENTS AND CONCEPTS

3.1 Foldable radial-rib antenna (MBB - D)

The development of this offset unfurlable mesh antenna started in 1983, following earlier definition studies. The technology is applicable to reflector diameters ranging from 3.2 to 12 meters with surface errors between 0.2 mm and 1.4 mm rms.

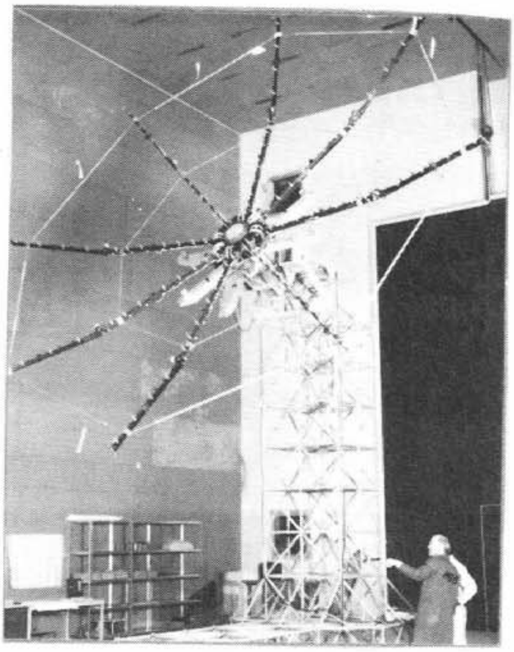

Fig. 1 - MBB (D) - 5 m engineering model of the foldable radial rib antenna

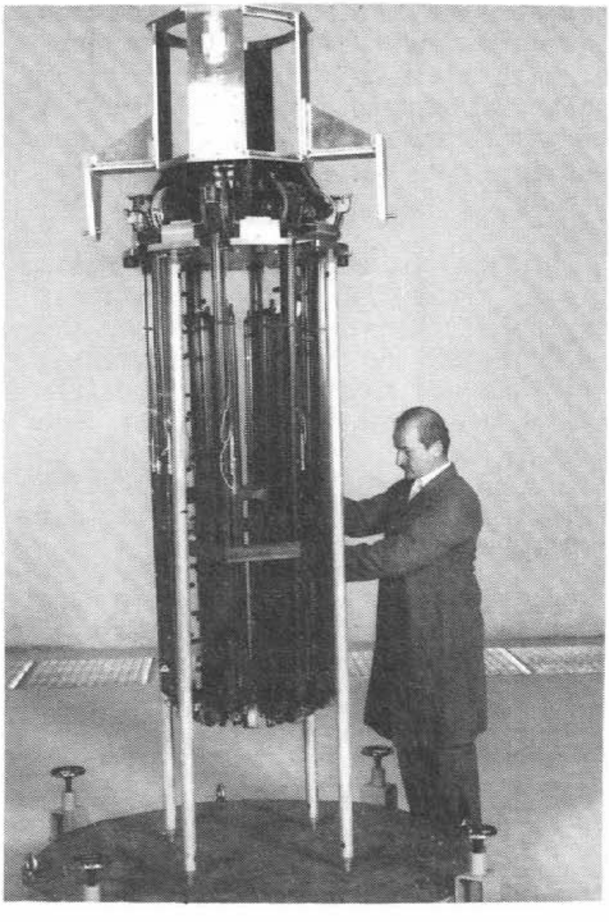

Fig. 2 - MBB-(D) - Folded 5 m engineering model

The reflecting surface consists of a knitted gold plated molybdenum wire mesh supported by foldable CFRP ribs. One originality of the design is the introduction of thin surface shaping intermediate ribs, between the main load carrying ribs, resulting in a considerable mass saving for a good surface accuracy. The main ribs are hinged to a central hub, also made of CFRP, which carries a deployment and retraction actuator. The parabolic intermediate ribs (flexible CFRP ribbons) are tensioned at deployment by means of cables attached to the lower edges of the main ribs.

A five meter engineering model shown on fig. 1 has been designed, manufactured and tested to meet mobile communications requirements at 1600 MHz. Fig. 2 shows the same antenna folded. The model has a true diameter of 6.15 meters and includes 16 foldable ribs. Manufacturing tolerances have been tightened to meet more stringent requirements compatible with multiple beam operation at C-band (requiring more ribs).

The main characteristics of the 5 meter offset reflector are:

Projected aperture diameter: 5 m
Focal length: 3.125 m
Number of ribs: 16
Mass: 22,5 kg

The electrical design and analysis of this family of antennas uses novel techniques developed by TICRA. More details on this development can be found in reference [3].

3.2 Prismatic truss antenna (AEROSPATIALE - F)

This development aims at offset antennas in the 5 to 10 meter diameter range, later extendable to larger sizes. The basic configuration is illustrated on fig. 3. The structure is a regular hexagonal and spherical truss made of the assembly of triangular prismatic cells.

Each cell consists of 3 crossing bars perpendicular to the reflecting

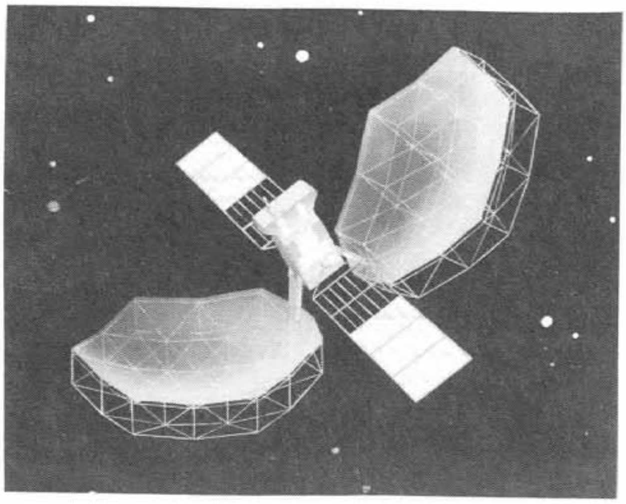

Fig. 3 - AEROSPATIALE (F) Prismatic truss antenna

surface and 6 articulated bars, each with a spring actuated central hinge, that cause the deployment and lock themselves when open. All tubes are made of CFRP. The mechanical parts are made of aluminium alloy. The skin is made of triangular mesh gores. Inside each triangle the parabolic profile is achieved by a few catenaries.

A 9 meter functional model has been successfully developed and deployed more than 20 times. A 5 meter RF model has been built and tested. All components including the mesh are at the space qualified level. Deployments in zero-g conditions have also been conducted.

A 7 meter diameter offset configuration for operation at 2 GHz, has been evaluated in detail. The reflector includes 24 triangular prismatic cells, each cell having 6 surface adjustment cables. The overall on-orbit rms accuracy is about 1.5 mm. The reflector mass including supporting arm is evaluated to be 54 kg. The frequencies of the structure are 35 Hz and 3 Hz in the stowed and deployed configurations respectively. More details on this development are given in reference [4].

3.3 Space-rigidized antenna (CONTRAVES - CH)

This development started in 1980 and aims at reflectors of 12 meters for Land Mobile Communications [5] [6], 15 to 20 meters for QUASAT [7] and higher aperture diameters. The basic lay-out is illustrated on fig. 4. The inflatable space rigidized reflector is manufactured out of prepreg gores precut and joined together. The reflector can be divided in three parts:

- A torus used to stabilize and stretch the structure.
- Reflector/radome membranes to seal the structure and support RF reflecting/transparent surfaces.

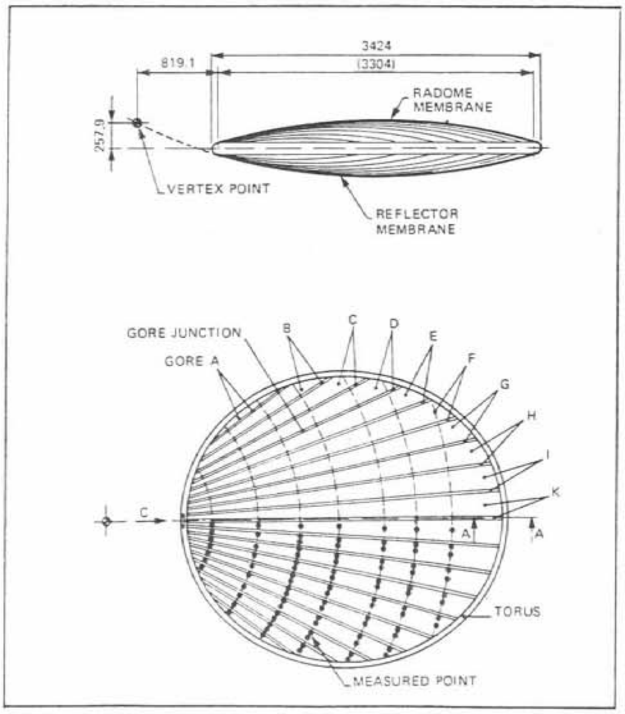

Fig. 4 - CONTRAVES (CH) - Space rigidized antenna configuration

- Structural interface elements to join the reflector to the spacecraft.

The wall of the reflector consists of a thin fiber reinforced composite lamina (Kevlar fibers impregnated with a special matrix) plus a Kapton foil metallized on one side.

After inflation in space (duration up to 10 minutes) solar radiation hardens the matrix by a chemical reaction and rigidizes the structure from which the nitrogen is evacuated 48 hours after deployment.

Several models have been developed and tested including the 6 m model shown on fig. 5 and a 3.5 m model for which an rms surface accuracy of 0.7 mm has been measured. RF modelling and testing have also been performed. A 10 meter model is presently under development. A design has been performed for the QUASAT VLBI mission.

A 72 gore 20 meter symmetrical reflector has an estimated overall in orbit surface accuracy of 0.98 mm rms, a mass of 134 kg and a deployed frequency of 3.2 Hz. More details on this design are given in [7].

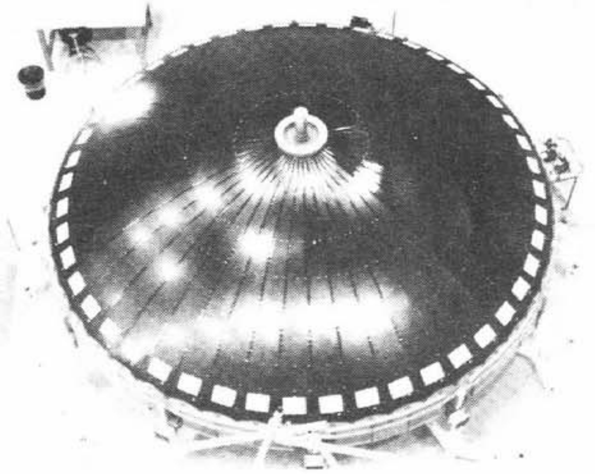

Fig. 5 - CONTRAVES (CH) - Inflatable antenna 6 meter model

3.4 Foldable tips MBA antenna (SELENIA SPAZIO - I)

The development of multibeam antenna (MBA) technology for communications at 20/30 GHz has been a long term efforts. Details on the programme are given in [8].

A foldable-tips reflector is developed for this application. It is composed by 7 mm shell CFRP faces and has two foldable tips. A 3.7 x 4 meter engineering model (folded) is shown on figure 6. The manufacturing accuracy is better than +/- 0.2 mm.

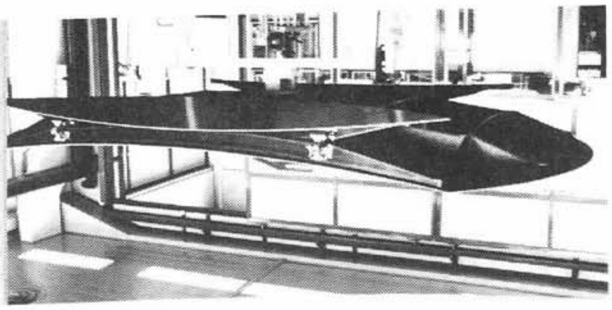

Fig. 6 - 20 GHz MBA 3.7 m reflector with foldable tips (SELENIA SPAZIO - I)

6. REFERENCES

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