

## ANTENNA TECHNOLOGY FOR ADVANCED MOBILE COMMUNICATION SYSTEMS

DR. EMMANUEL RAMMOS, DR. ANTOINE ROEDERER, MR. ROGER ROGARD,  
European Space Agency, ESTEC, Noordwijk, The Netherlands

EUROPEAN SPACE AGENCY  
Postbox 299, 2200 AG Noordwijk  
The Netherlands

## ABSTRACT

The onboard antenna front end is the key subsystem conditioning configuration and performance of mobile communication satellites. The objectives of this paper are to demonstrate this key role and to review L-band satellite antenna technology for earth coverage and regional applications.

Multibeam arrays, are first discussed, then unfurlable and inflatable reflector antennas are described.

These technologies are now qualified in Europe for future mobile systems, for which the optimum choice of antenna technology has been found to be the key to efficient use of spectrum and power resources.

## INTRODUCTION

Although studies on mobile communication satellites were initiated in the late sixties, it is only recently that, thanks to the creation of INMARSAT, the availability of satellites in orbit has allowed to test and evaluate new system concepts. The limitations of global beam earth coverage have also been evidenced and this has led to the understanding that multibeam (array) systems were the only solution to cope with increased traffic and smaller terminals. Multibeam arrays represent a quantum jump with respect to single global beam payloads as MARISAT and MARECS. The antenna optimisation so strongly influence the overall system concept and performance that system design for multibeam payloads must involve in depth antenna engineering from the onset. This is illustrated in the next sections where the interaction between antenna and system designs is highlighted.

## ANTENNA RELATED SYSTEM REQUIREMENTS

In view of the limited frequency bandwidth available and of the increase in traffic, frequency re-use and therefore multibeam operation are mandatory to progress. In addition, traffic distribution is far from being uniform. Some areas, such as the North Atlantic region, carry such a large percentage of the traffic, that dedicated multibeam systems for these areas could be considered, the remaining ones being covered by simpler systems. In addition, introduction of electronically - steerable beams could be an efficient means to cope with traffic

fluctuations and/or to reduce the amount of redundant beam forming hardware.

Optimum choice of beam number, shape and lattice also has a large impact on overall system performance, and several iterations are required before detailed payload specifications can be firmed up. For instance, whereas linear arrays can be used in regional applications (Canada, Conus, Europe) with performance advantages and hardware simplification, a global beam requirement for earth coverage seriously constraints the antenna configuration and spotbeam shapes.

Another example of the dependance of system design on antenna optimisation is the spreading of intermodulation products in multibeam arrays (and not multibeam focussing reflector antennas) which strongly affects the required system linearity and its efficiency. Similarly, the required signal dynamic range has a large effect on system performance. This figure not only depends on the mix of terminals in the system, but also on spacecraft and mobile antenna specifications.

Frequency re-use requirements have a direct impact on satellite antenna size and illumination. They affect differently the forward and return links and beam decoupling factor specification is very complex and system dependent. Typical values are 20 dB on the forward link and 25 dB on the return link, in a one satellite system. They are increased in a multisatellite environment with small terminals.

For historical reasons (MARISAT using helices), single circular polarisation has been considered until now. The use of two circular polarisations might be envisaged, since it can provide, at the cost of no or little added complexity, much needed isolation between transmit and receive and/or between adjacent coverage areas. As will be shown in the next section, the required flexibility both in antenna design and technology, is indeed available to cope with the next generations of mobile communication satellites.

## ARRAY ANTENNA TECHNOLOGIES

A typical block diagram of a multibeam array front end is shown in fig. 1. Each element chain includes a radiator, a diplexer, transmit and receive amplifiers and frequency converters. The beam forming matrices create a different phase (and possibly amplitude) front for each beam and operate at IF (100 to 200 MHz). A few agile beams can be included for redundancy and/or to increase flexibility in traffic allocation to different areas. Each beam port is connected to the channel to beam switching matrix which allows to vary the number of channels available to beams. Note that the power in each beam originates from all the element amplifiers.

The advantages of active arrays over focussing reflector antennas are the increased flexibility in channel to beam allocation, the lossless generation of overlapping beams, and the relatively graceful degradation of performances with element chain failures.

Different array configurations are envisaged for multibeam earth coverage with a global beam requirement and for regional applications. Fig. 2 shows a possible configuration used to generate the beams of fig. 3 in the "ARAMIS" system, and a global shaped beam. The array is arranged in 21 non identical subarrays of microstrip patches. Arrays of short backfire elements or of short horns are also considered. Fig. 4 shows a foldable array, oriented E-W, proposed to generate the beams

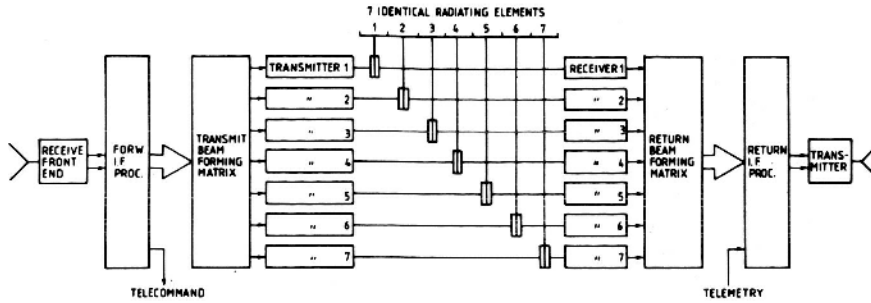


Fig. 1 Multibeam array payload block diagram

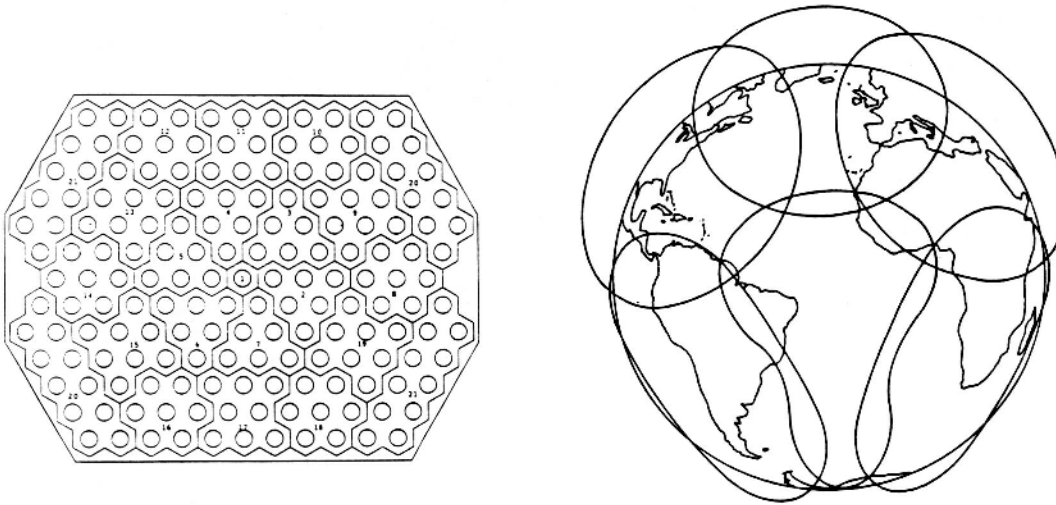


Fig.2 Array for global earth coverage Fig.3 Multibeam earth coverage

of fig. 5. Subarrays are oriented N-S and low sidelobes are achieved by a gap and a power taper at the outer elements. Larger arrays are considered to generate more beams [1]. Elements are microstrip patches.

Short backfires have been developed [2] as elements for non foldable arrays. An engineering model is illustrated in fig. 6.

Short horns, with typical diameter and length of 0.9 and 0.8 wavelength respectively, have been shown [3] to provide around 9 dB of gain when fed by a strip line incorporated in the radiator. They are a potential candidate for applications where subarraying is required, as in the array of fig. 2. Grouped in subarrays of 4 (Fig. 7), their performances are comparable to those of short backfires. An advantage of the short horns is their low sensitivity to dimensional changes in view of their broadband performance. To limit the array thickness an integrated support structure is included.

Broadbanded microstrip patches have been developed [4]. A technology model with 19 patches is shown in figure 8. The patches have two point excitation and a center post. Broadbanding is achieved by proper choice of ground plane separation and by a special matching circuit. A gain of 8 dB per patch is achieved with cross polarisation isolation better than 20 dB. The design incorporates a NOMEX core bonded to a Kevlar front skin and a copper clad carbon fiber rear skin

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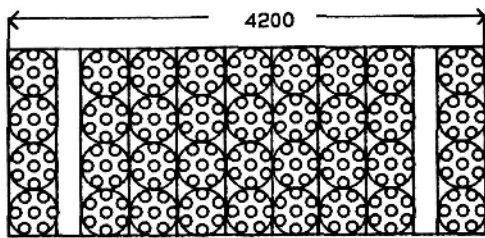


Fig.4 Foldable four beam array

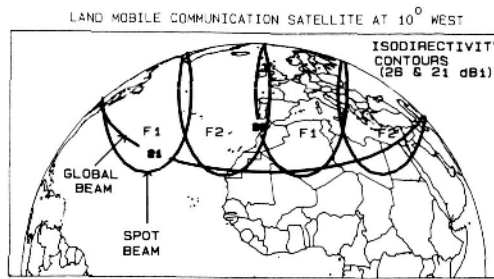


Fig.5 Four beam regional coverage

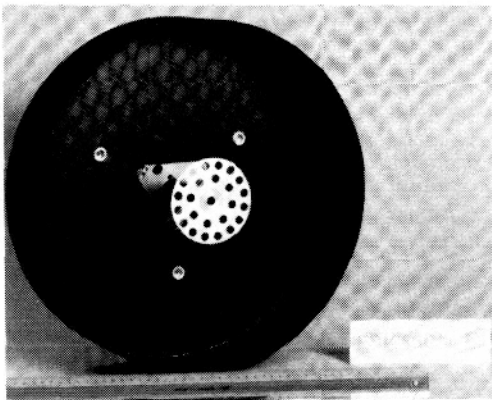


Fig.6 Short backfire element

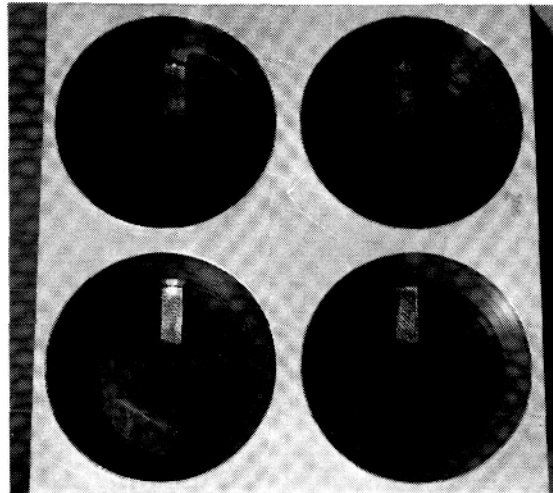


Fig.7 Short horn elements

using film adhesive. The same copper layer is used as ground plane for the patches and as upper groundplane for the triplate power divider. The array of figure 8 has been tested for multipaction and for passive intermodulation product (PIMP) generation.

All other RF components in the front end are space qualified.

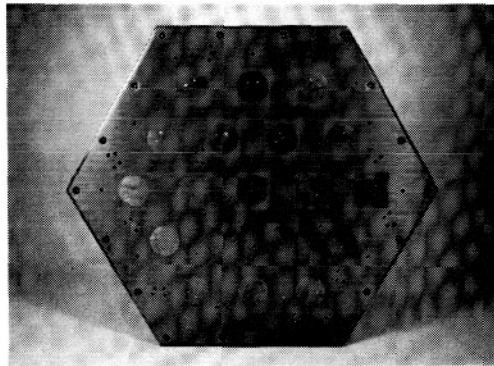


Fig.8 Microstrip patch array

#### REFLECTOR ANTENNA TECHNOLOGIES

To achieve re-use of the frequency with many narrow beams (fig. 9) antenna apertures with dimensions exceeding 10 meters are needed and foldable planar arrays become impractical. Large focussing reflectors, fed by overlapping beam feed clusters (fig. 10) can be used. Then power to beam allocation flexibility is limited by that of the amplifier associated to each beam. To eliminate this limitation, an imaging system (fig. 10) where a small array is magnified by a system of two reflectors can be envisaged. Intermediate configurations with more or less feed array defocussing can also be considered. In

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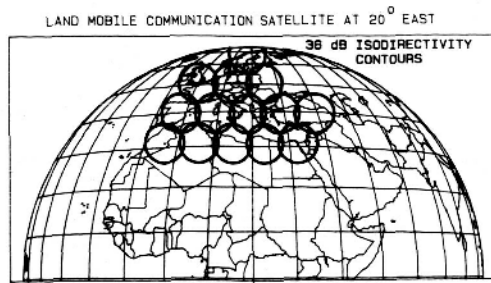


Fig.9 Multibeam coverage

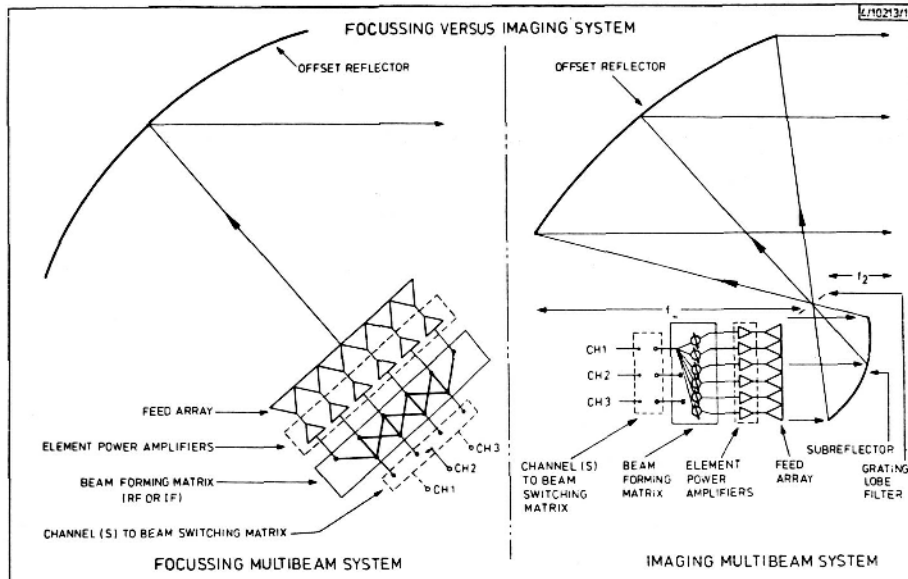


Fig.10 Focussing and imaging multibeam front-ends

all cases a large reflector and numerous feed elements are required. The array element technologies described earlier are also applicable to feeds. Three types of large reflectors are presently available in Europe.

One is a mesh umbrella with radial foldable ribs, under development with ESA funding at MBB (D). A 6 meter engineering model (Fig. 11) is presently under test. The originality of this design is the use of intermediate ribs made of graphite epoxy ribbons and integrated in the mesh between each of the supporting ribs. This provides improved surface control without use of a secondary tensioning system.

Another development, supported by CNES, is ongoing at Aerospatiale (F). It uses a truss structure with spring loaded joints. A functional and an electrical model have been successfully tested and this technology should also be available for flight in the early nineties (Fig. 12).

A different concept is under development under ESA funding at Contraves (CH). The reflecting surface is supported by a torus, inflated in space and rigidized under solar radiation. A photograph of a 3 m model is shown in fig. 13.

It has been demonstrated on several models that tolerances for L-band operation can easily be met. A 10 meter engineering model is presently being manufactured in flight technology.

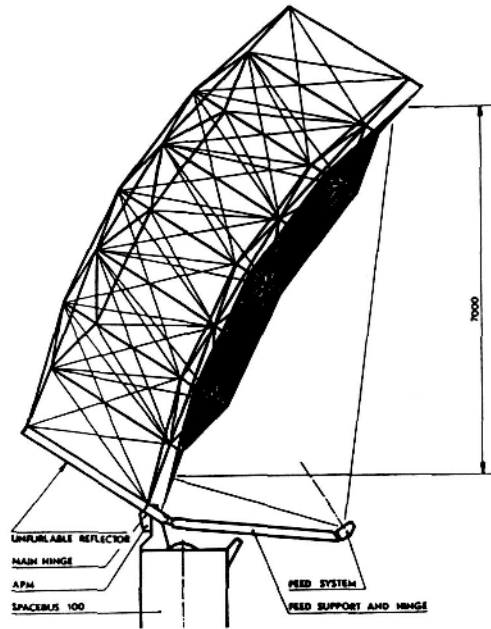
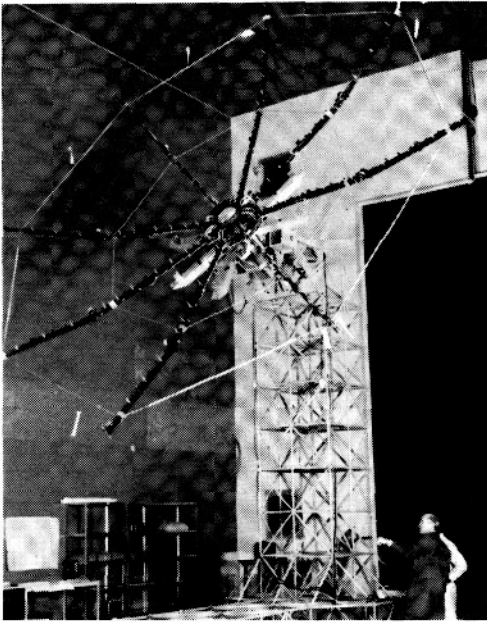


Fig.11 Mesh Umbrella (MBB) Fig.12 Mesh truss reflector (Aerospatiale)

#### CONCLUSIONS

The key technology for the next generation of mobile communication satellites : multibeam active arrays is ready in Europe for flight in the early nineties. Large foldable arrays and array fed reflectors for future regional applications are at a very advanced stage of development for apertures up to 6 meters. A serious additional effort will be required for larger apertures, in particular in the area of test techniques and facilities.

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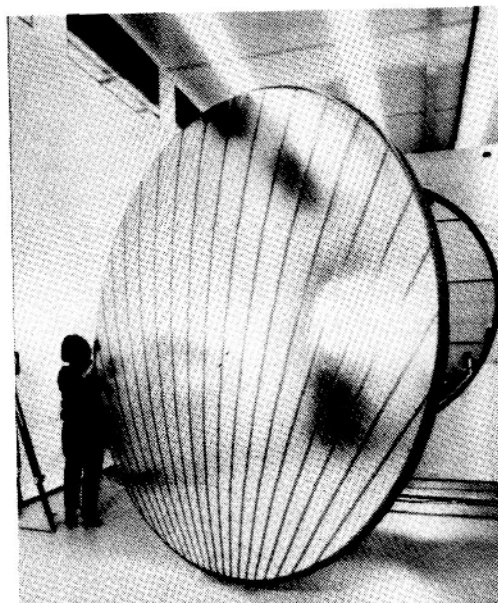


Fig.13 Inflatable reflector (Contraves)