A FOLDABLE MULTIBEAM ARRAY FOR SATELLITE COMMUNICATIONS

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1. INTRODUCTION

Future satellites for communications at L-band with mobiles (ship, aircraft, lorries) will require multibeam antennas with at least 10 dB more gain than the present global beam antennas, and with low sidelobes for frequency re-use.
Array fed focussing or imaging reflector systems have been proposed, but they imply unfurlable structures and do not have the efficiency and flexibility of direct radiation active arrays, such as those developed in the seventies in Europe [1], [2] and, more recently, in Japan [3].
These arrays, with beam forming at intermediate frequency (IF), were designed for medium gain, without low sidelobe requirements.
Schemes implying two levels of output powers in the array, associated with a ring arrangement of the elements, have also been proposed to reduce sidelobes [4], but only for applications with limited gain.
It is highly desirable to retain the use of identical amplifier modules, and a solution using unequal subarrays of microstrip patches studied in the case of a circular array with medium gain [4] has shown the potential and the flexibility of this approach which has been retained here to meet specific RF performance and configuration requirements.

2. REQUIREMENTS

The antenna operates in circular polarisation from 1548 MHz to 1556 MHz (transmit) and from 1649 MHz to 1657 MHz (receive). The most critical requirements are the coverage gain (goal 30 dB) and the sidelobe level of -28 dB. Other critical constraints are the use of less than 50 identical transmit/receive amplifier modules and compatibility with a half Ariane class satellite.
The coverage is Europe and its coastal region with, as an option, addition of the North Atlantic Ocean. The number of beams should be minimised and maximum flexibility in channel to beam allocation is required for optimum use of on-board resources.
This latter requirement, together with the 2.5 dB ripple specification, precludes the use of a reflector focussing system with one amplifier module per beam and favors direct radiating or magnified array systems.

3. SELECTED ANTENNA CONCEPT

The minimum gain goal of 30 dB leads to 32.5 dB of peak gain i.e., assuming 50% aperture efficiency as was achieved in multibeam arrays [2], to an aperture of 10.6 m^2. A rigid circular antenna is excluded since the required diameter of 3.7 m exceeds that of the launcher shroud.
Since North South extension is restricted to avoid solar panel shadowing, a rectangular arrangement in 3 panels, one on the earth facing side of the satellite, and two foldable during launch along the satellite East and West faces is preferred, as shown on Fig. 1.
The initial design assumed radiating elements with 2.2 wavelength diameter and 15 dB gain [1], as for instance the short backfire shown on Fig. 2.

Taking into account the available space and the requirement to group elements in subarrays to achieve illumination tapering with identical amplifier modules, the best arrangement found was an array of 15 x 4 elements which can provide elliptical beams with nearly 32 dB peak gain and compatible with the coverage requirements. The chosen configuration, shown in Fig. 1, only allows for a -6 dB East-West illumination taper, in 3 dB steps from subarrays of 4 and 2 elements, not compatible with sidelobe levels below -28 dB. The equivalent tapering can be increased by creating a gap between the outer subarrays and the rest of the elements and this yields excellent sidelobe performance. The array then includes a total of 40 input ports to 4 subarrays of 4 elements, 8 of 2 elements, and to 28 single elements. A simplified block diagram of the payload is shown on Fig. 3.

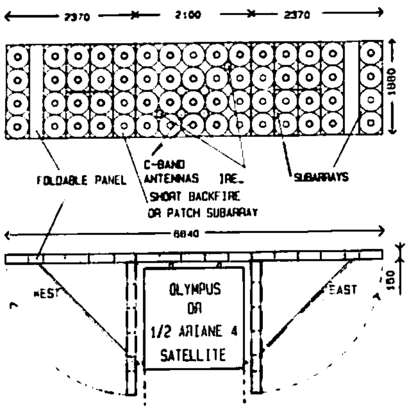

Fig. 1 - Foldable Array Configuration

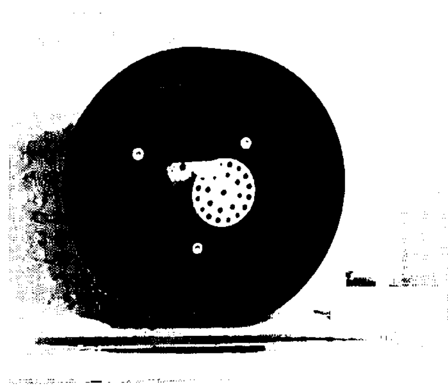

Fig. 2 - Short Backfire Element

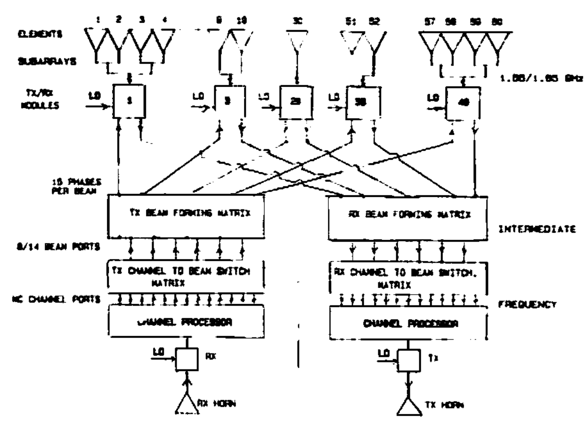

Fig. 3 - Simplified Payload Diagram

The radiating elements can be either short backfires or groups of microstrip patches [3] which might lead to lower cost and mass. It is preferrable for thermal and structural reasons to group the transmit receive modules on the spacecraft North and South walls rather than behind the elements. A low loss transmission line network must be placed at the back of the array. Use of suspended air stripline (or rectangular coaxial line) seems to be a very low loss solution, validated for the SEASAT A SAR and for the SIR-A antennas [5].
Each transmit/receive module includes a diplexer, a linear power amplifier, a low noise amplifier and up and down converters. At least the 12 modules connected to subarrays must have built-in redundancy to limit sidelobe degradation in case of failures.
The beam forming matrices operate at IF, and provide 8 to 14 beams depending on the coverage. Their structure is simplified by the fact that all phases can be multiple of the same increment and that the even numbered beams (as well as the odd numbered ones) are quasi orthogonal to each other. The technology for these matrices and for the channel processors is already developed.

4. PERFORMANCE DATA

Analysis has been performed for the array, using element data measured on short backfires. Very similar results would be obtained using instead subarrays of seven microstrip patches [3]. Fig. 4 shows 30 dB isodirectivity contours and a global beam (from 8 elements) with a scheme for frequency re-use. Pattern cuts are shown on Fig. 5 for 8 beams indicating that two to three time re-use of the frequency is possible. Contours for extended coverage are shown on Fig. 6.
The 30 dB objective for gain is not quite met since a feed line loss of 0.5 dB and pointing and excitation error losses of 0.5 dB are expected to bring down the gain to 29 dB at the edges of the coverage.

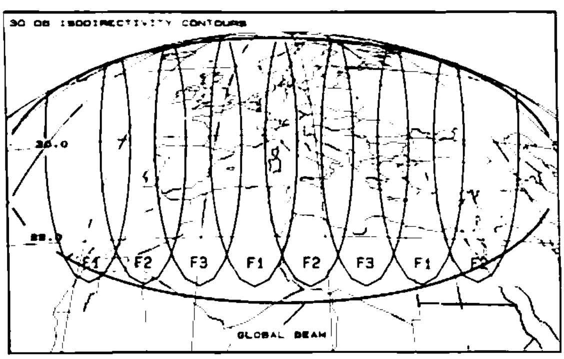

Fig. 4 - 30 dB Isodirectivity Contours - Europe

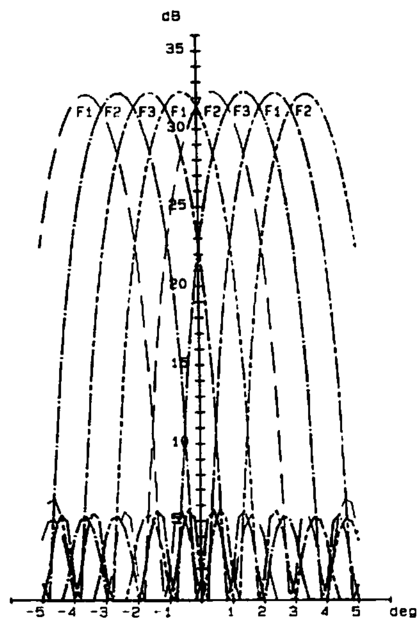

Fig. 5 - West-East Pattern Cut

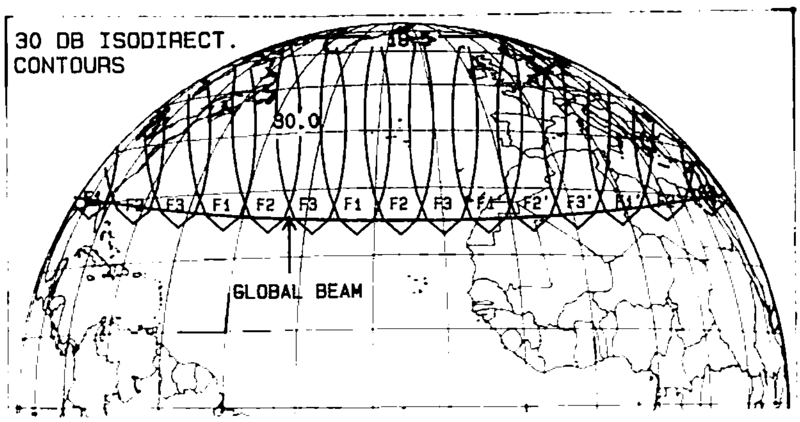

Fig. 6 - 30 dB Isodirectivity Contours
Extended Coverage

5. CONCLUSION

Results obtained during the development of the Multibeam Array Model [2] and from the above design exercise, show that a very compact and effective multibeam front end for communications at L-band with mobiles, with low sidelobes (-28 dB) for frequency re-use and high minimum gain (29 dB), can be designed for a half Ariane class satellite.
A rectangular foldable array, including subarrays fed by identical modules and with beam forming at IF seems to be a very performing antenna, which could readily be implemented without major technological development.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] A. Anderson, P. Bengtsson, A. Molker, A. Roederer, "Short Backfire Antenna Arrays for Space Communications" IEEE AP-S Int. Symp. Stanford 1977, pp. 194-197.

[2] R. Coirault and W. Kriedte, "Multibeam Generation at L-Band: A Phased Array Approach", ESA Journal 1980, Vol. 4.

[3] T. Teshirogi and N. Goto, "Recent Phased Array Work in Japan", ESA/COST 204 Phased Array Antenna Workshop, June 1983, ESA SP-204.

[4] A. Roederer, A. Molker, J. Forrest, P. Sheehan, "L-Band Arrays for Mobile Communication Satellites", ESA/COST 204 Phased Array Antenna Workshop, June 1983, ESA SP-204.

[5] H.A. Nitschke, J.W. Kierein, T.A. Metzler, "Definition Study of the Shuttle Imaging Radar-A (SIR-A) Antenna", Proc. SAR Technol. Conf. Las Cruces 1978, pp. IV-2-1 to IV-2-9.