ELECTRONIC CIRCUITRY FOR AN ACTIVE DIRECT RADIATING PHASED ARRAY

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INTRODUCTION

The Direct Radiating Array (DRA) is often employed as a versatile antenna for various applications, including radars; however, its on-board use for satellite communication links has been so far very limited.

The present study, carried out under a European Space Agency contract, investigates the feasibility of an active array at Ku- band for the down-link of a geostationary communication satellite covering Western Europe. In particular, this paper is centered on the possible solutions to be adopted for the circuitry associated with the transmitting section of the array.

The consequences on the design philosophy of the active nature of the DRA are evaluated, taking into consideration the new possibilities opened up by the recent advances in solid-state technology.

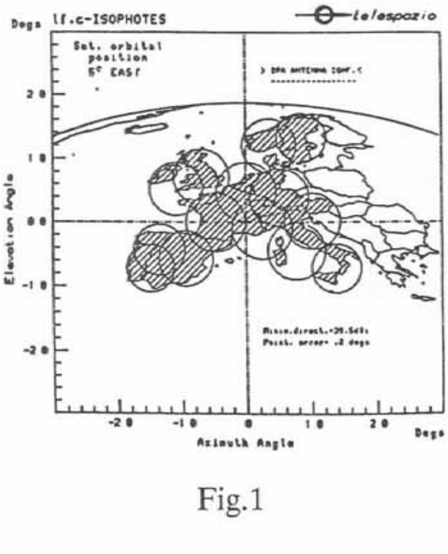

Fig.1

SYSTEM OVERVIEW

The array is designed to cover Western Europe (Scandinavia and Greece included) (fig.1, after [1]) using the 12.5 - 12.75 GHz band; such coverage is obtained by overlapping 14 beams pointed to smaller sub-regions, while no frequency reuse is allowed in order to avoid interference. All the beams are simultaneously generated by all the feeds of the array, which is divided into 19 sub-arrays of 19 feeds each, for a total of 361 feeds (fig.2).

The beam pointing is obtained by properly phasing the different sub-arrays, whose feeds are fed in-phase; the amplitude of the radiated signal is uniform over the whole array. The beam forming network must therefore combine the 14 beam signals so to provide each sub-array with the combination of all them, each one with the appropriate phase.

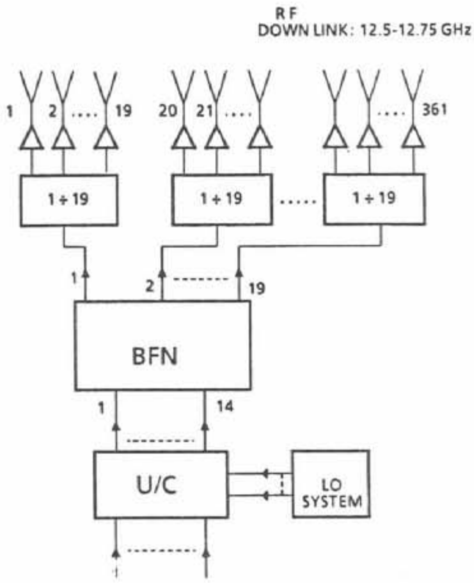

Fig.2

The satellite is supposed to perform IF signal processing; the beam signals are however up-converted before the BFN, so to avoid the tight phase synchronization of the up-converting chains that would otherwise be required, were they placed after the beam forming. A BFN at radio-frequency, moreover, has smaller size and weight with respect to an IF implementation, while the increase in losses is easily compensated by the successive power amplification. The final division by 19 for each sub-array completes the signal routing.

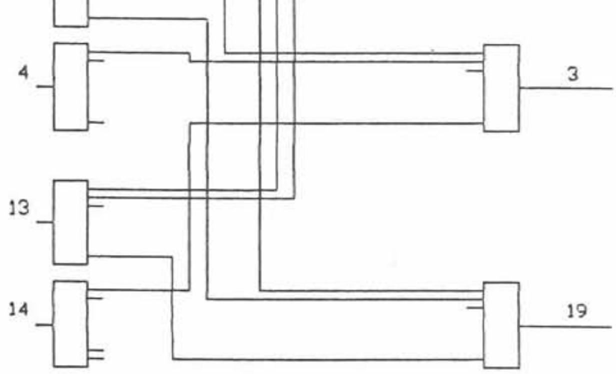

Fig.3

UP-CONVERTING SECTION

The up-converting chains are formed by means of low intermodulation passive mixers, that ensure a good reliability and signal purity. The local oscillator system is a triple phase-locked-loop oscillator, thermally stabilized by an oven, with a high frequency stability; the signal is divided by 14, preamplified and sent to the mixers. The IF also is amplified before the mixing. The circuitry can be implemented in planar technology.

BEAM FORMING NETWORK

The Beam Forming Network (BFN) is composed by two sections: in the first one, each of the 14 beams is divided into 19 equal parts; in the second one, these signals coming from the 14 beams are combined with the proper phase to feed each of the 19 sub-arrays. The first section is therefore formed by 14 19-way dividers, the second by 19 14- way combiners; the topology of the complete BFN is shown in fig. 3.

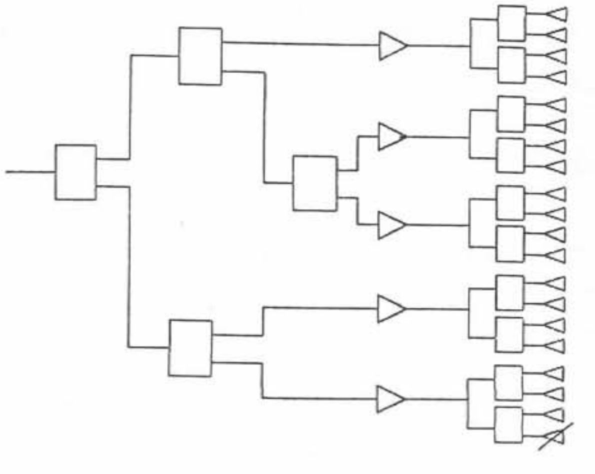

Fig.4 Solution B

As already pointed out, RF losses in the BFN are of lesser importance, hence, both waveguide and planar (stripline) technologies could be suitable for the implementation of the network. Given the high number of dividers and combiners involved, the planar technology seems to be the most convenient in order to reduce size and weight, with still acceptable performances.

POWER AMPLIFIERS

In an active antenna the power amplifiers are placed as close as possible to the feeds in order to minimize the losses at high power level; however, in this case, different solutions are possible, with distinct advantages.

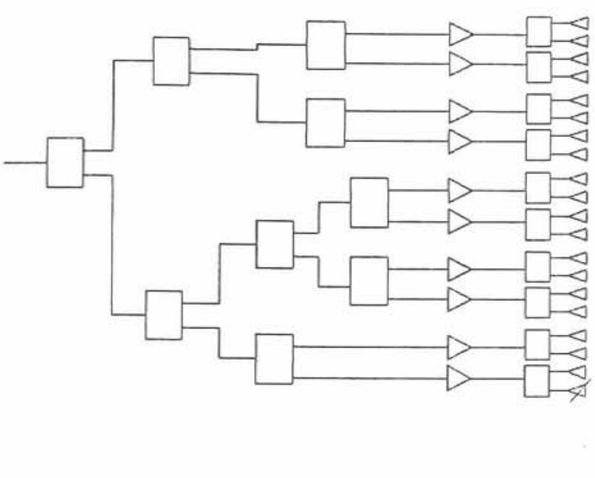

Fig.4 Solution C

In fig.4 the final divide-by- 19 network of a sub-array is shown, with the different levels where the power amplifiers could be placed. If the amplifiers were placed before the division (case A, not shown in figure), only 19 amplifiers would be necessary, but the high output power level required would decrease their efficiency; moreover, they should be redunded to ensure a sufficient level of reliability, and the dividing network should be implemented in waveguide technology to minimize the losses. As a result, weight and power consumption would be high.

In case B, 95 amplifiers would be required, ensuring an intrinsic redundancy and a good efficiency with a limited number of medium power amplifiers and only two power divisions before the feeds. Low weight and power consumption would result.

In cases C and D (i.e., with one amplifier every two or every one feed respectively) reliability and efficiency would be slightly higher, but at the cost of a much higher weight. Therefore solution B results to be the most advantageous one.

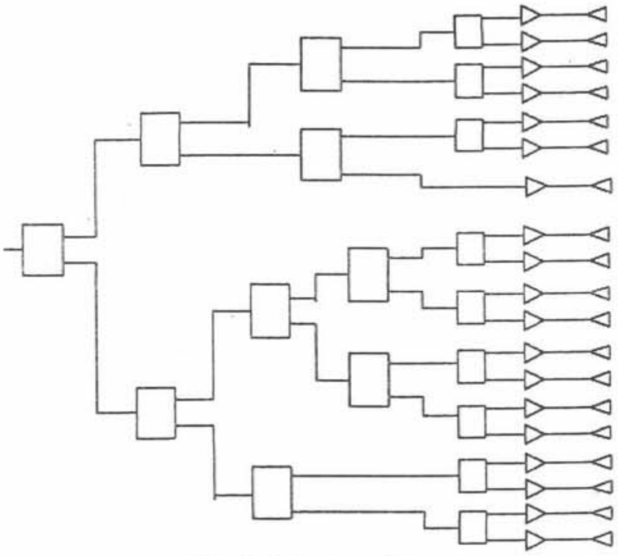
Fig.4 Solution D

CONCLUSIONS

The Direct Radiating Phased Array is a viable solution for Ku-band active antennas for satellite communication.

Strong efforts have to be concentrated in weight and size reduction without sacrifying system reliability. Planar technology is, thus, to be used whenever is possible.

The suitable positioning of power amplifiers has been investigated in terms of both performance required from a single device and influence on the overall system characteristics and behaviour.

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REFERENCES

[1] G.Bartolucci et al. "Comparison of active phased array antennas for communication satellite applications" Proc. of ANTEM 88 , Winnipeg, Canada

[2] R.J.Mailloux, "Phased array theory and technology", Proc.IEEE, vol.70 n.3, March 1982