HEMISPHERICAL COVERAGE ANTENNAS FOR SATELLITE MOBILE COMMUNICATIONS

J. Barbero, M.J. Fernández, J.L. Fontecha, A. González, M. Hernanz, C. Martín Pascual, J. Taltavull; I.E.C., C.S.T.C., Serrano 144-MADRID

Introduction

This work is a part of the PROSAT Program of ESA for the development of terminals of low G/T (-24dB/°K) for aircrafts (with coverage over 10° of elevation), land mobiles (elevation over 15°) and ships (elevations over 5° including non stabilized movements of ±30° of the ship, what extends the coverage to 125° in colatitude). The antennas must work in RHCP with an axial ratio better than 5dB and it must pay special attention to the multipath discrimination in the land and aeronautical mobiles. Moreover, this last specification requires that, for low elevations, the main component of the electric field be the vertical one. This characteristic and the need of obtaining high coverages advises the use of antennas consisting in four radiating wires fed in quadrature, such as quadrifilar helices (1), conical spirals (2) or a combination of crossed loops and dipoles (3).

Numerical and experimental study

In order to get the desired coverages, the length of the wires must be of the order of the wavelength, therefore it can be studied by the Moment Methods. Only first order moments with respect to a complete set of Dirac distributions will be taken to simplify the problem. The first step in the design consisted in the optimization of the fundamental parameters of each type of antenna, and the following conclusions have been obtained:

- The conical spirals are discarded, compared to the quadrifilar helices (volutes) of length $\lambda/2$, because those ones have similar radiation characteristics but they are of larger size.

- The only structure with which the maritime coverage is theoretically obtained is the one of the crossed loops in its second resonance. However it was experimentally impossible to excite this mode probably because its radiation resistance is very different of the 50 Ω of the feeding coaxial cable. Once this antenna was discarded, the largest theoretical coverages correspond to the volute $\lambda/2$ of the smallest possible diameter.

- In flush mounted installations (truck and aircraft) the volute $\lambda/2$ is advisable. In the truck, where the antenna can be separated from the body, the volute $3\lambda/4$ is more suitable because it presents better multipath discriminations and due to the dimension of its diameter it is possible the use of a balun and so the matching is achieved.

- In order to control the back radiation and to improve the multipath discriminations metallic structures like ground planes or skirts must be used in the ship and truck.

In the step of optimization and final design the numerical study of the modelling of the balun and socles is included and also that of the die lectric supporting the wires. The existence of this dielectric divides the length of the wire by $\sqrt{\varepsilon_r}$. As far as the interaction between wires through the dielectric is concerned two situations have been considered: in the ca se of opposite wires, ε_r has been taken as the effective value (except when a balun is used) and $\sqrt{\varepsilon_r}$ for contiguous wires according to the expe rience. The most important conclusions are:

- The dielectric does not modify the two general laws of the behaviour of the volutes: a) an increase of the diameter causes an increase of the radiation in the zenith; b) an increase of the fraction of turn of the wi re improves the axial ratio and the efficiency but decreases the coverage and degenerates the polarization to horizontal one.

- The coverage of the antennas with dielectric depends almost exclusively on the diameter. The dielectric affects only to the length of the wires (and therefore to the antenna height) and so, the ratio of the length to the diameter is a function of the permittivity for a given coverage.

- The agreement with the experience is good in RHCP in the upper hemisphere (figs. 1 to 3), and no so good when antennas with the above mentioned metallic structures are considered, what is probably due to the approximation chosen in the modelling (GTD of first order and no consideration of the interaction of four or more wires in the Moment Methods).

Installation on mobiles

Once the use of two antennas (receiver and transmitter) was decided, their mutual coupling should be lower than 40dB (according to the specifications of filters, R/T, etc) what was obtained for a distance of 80 cm between them. The installation on land mobiles will depend only on the dimensions of the roof of the vehicle what is not the case in ships and aircrafts. For the first ones the desired coverage requires to place the antenna in the highest point and it is necessary to predict the reflection effects on the deck and sea over the total Radiation Pattern.To do that, with a GTD model,(fig. 4) the results of figures 5 and 6 are obtained. The main effect is a fluctuation arriving to 8dB by reflections on deck and sea. Taking into account the height of the antenna (25 m), the phase of the reflected rays on the sea varies so fast that the amplitude of that fluctuation measures approximately the actual fading.

In order to determine the spinal position of the antennas in the aircrafts, the power density of the creeping waves versus elevation was calculated (fig. 7); from this, the shielding of the multipath versus the wing position (sliding in fig. 7) was evaluated. The power intercepted by the wing versus the position of the antenna is shown in figure 8. That po sition was fixed in the maximum on the right hand. By means of a modelling of GTD (fig. 9) the final Radiation Patterns of figures 10 and 11 were obtained. It can be observed that the most important fluctuations (though acceptable) are due to the diffraction on the outer edges of the wings.

Acknowledgements

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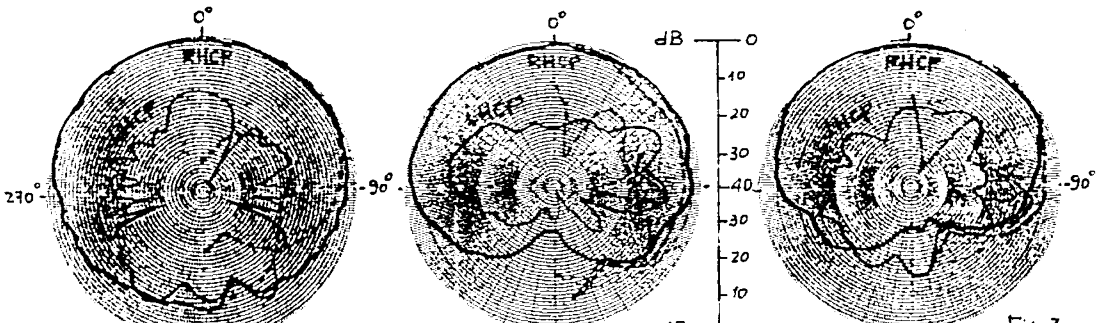


Fig 1 Fig.2 Fig.3

Radiation Pattern of experimental(——) and theoretical(---) antenna. 1) Aeronautical mobile; 2) Maritime mobile; 3) Land mobile.

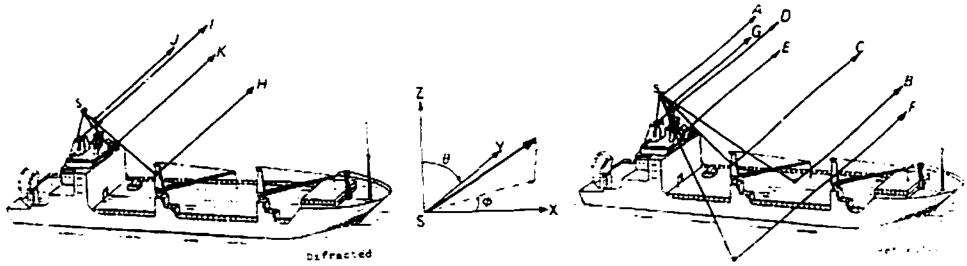
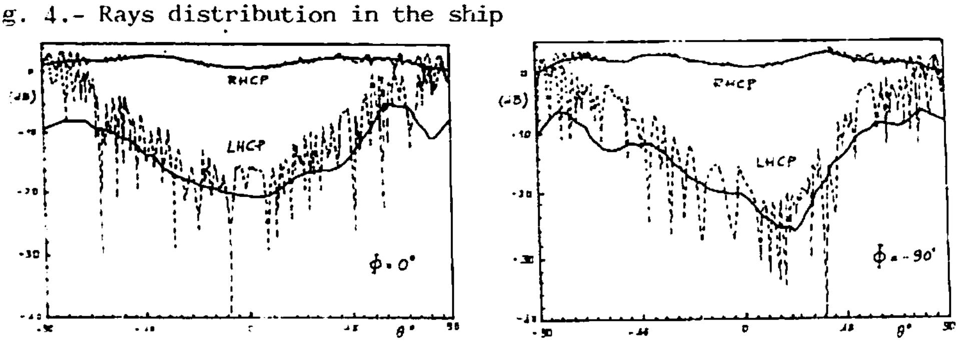


Fig. 4.- Rays distribution in the ship



Figs. 5 and 6.-Two different azimuthal cuts (ϕ =0º and ϕ =90º) of the radiation pattern of the maritime mobile antenna.

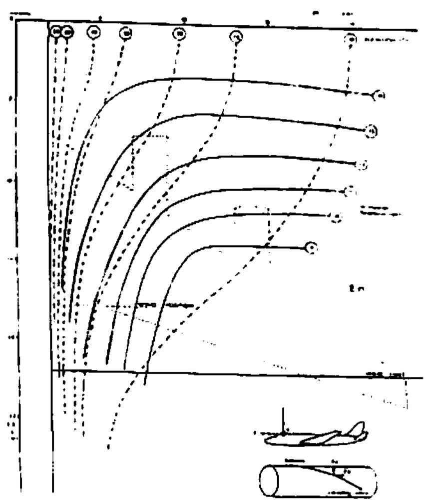


Fig.7.- Attenuation levels of the multipath signals.

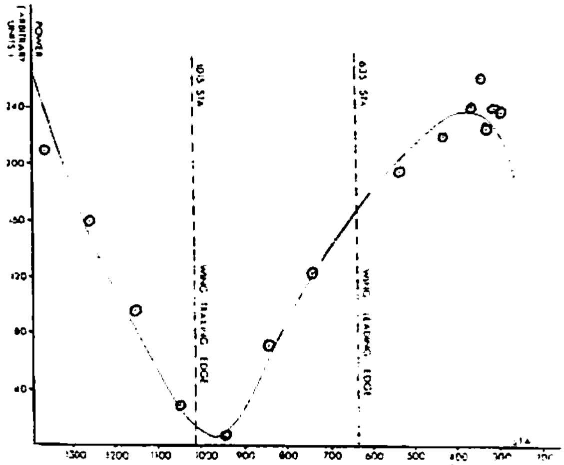


Fig. 8.- Evaluation of the multipath power shielded by wings.

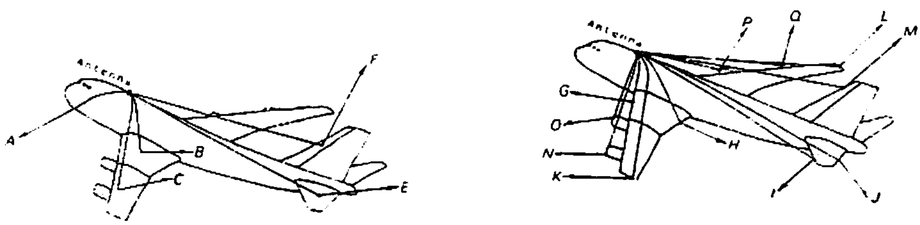


Fig. 9.- Ray distribution in the aircraft: Reflections (left); Difractions (right).

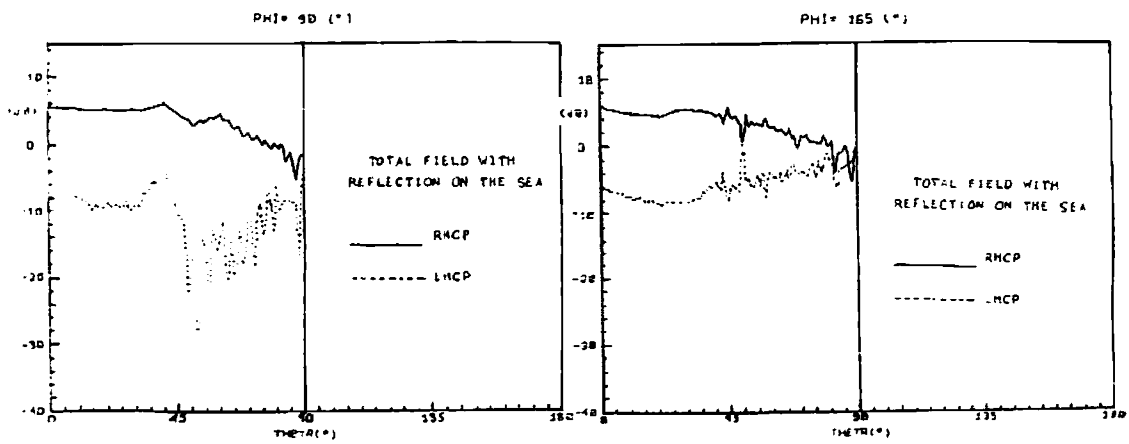


Fig. 10 (cut $\phi = 90º$) and Fig. 11 (cut $\phi = 165º$) of the radiation pattern of the aeronautical mobile antenna.