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Some Preliminary Results on Conformal Reflectarrays

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Abstract— In this paper, the characteristics of Reflectarray Antennas printed on convex curved surfaces are analyzed. In particular, results on the radiation performances of different Reflectarrays designed to be mounted on cylinders with different radii of curvature are presented and discussed.

I. INTRODUCTION

Planar printed Reflectarray (RA) antennas are nowadays well-assessed substitute to both conventional reflectors or planar arrays, thanks to their features, that make them good solutions for several applications, and especially when a reduced visual impact, as in urban areas, or a reduced volume and weight, as in spatial applications, are required.

In some cases, however, it would be more convenient if the antenna, instead of being planar, is able to fit a curved surface. Examples of such applications could be the case where the RA is mounted on the fuselage of an aircraft, with the feed located on a wing, or when the antenna has to be integrated in the wall of a modern building, presenting curved surfaces (see fig.1).



Fig.1: Examples of possible applications of a conformal RA.

In view of these possible extensions of the use of the RAs, it becomes necessary to explore the effect of the ground plane bending on the radiation features of the antenna, and to re-define its design procedure.

In general, a curved RA could be mounted on a concave or a convex surface. In the first case, what it could be expected, and the very preliminary results in [1] confirm it, is that the reduction of the path length between the feed and the printed elements with respects to the planar case improves the radiation performances of the entire antenna. An idea similar to this one, i.e. that of arranging the RA elements on a concave, parabolic-like surface, was already been exploited in [2], where the entire RA has been designed as an ensemble of planar panels, tangent to a parabolic surface. In the opposite situation, i.e. when the RA is conformal to a convex surface, the distance between the feed and the different RA's elements increases with respect to the planar case and therefore the antenna's performances are degraded [1]. In particular, the bandwidth, one of the main drawbacks of RAs, is affected, since it does not only depend on the limited bandwidth of the re-radiating elements, but also on the different path lengths to each of them, whose corresponding phase shift varies with the frequency and cannot be well compensated at all frequencies. The critical issue of the planar RAs limited bandwidth has been the object of many studies, as proved by the large number of papers (see for instance [3]-[5] and references therein) where possible solutions are presented.

In view of the above considerations, and that convex RAs seem to be those with more potential applications, in this work it has been decided to focus the analysis just on them.

In [6], some results on the effect of the curvature on the variation of the re-radiated field phase vs. the size of the re-radiating element are shown. Here, the results of the design and the numerical analysis of three medium-size convex reflectarrays, each of which design to fit a cylinder with a different radius, are presented.

II. DESIGN OF CONVEX-CONFORMAL REFLECTARRAYS

The design of a conformal RA is performed following the main steps of the planar RA design procedure. However, the following differences have to be taken into account:

- the relation between the phase of the re-radiated field and the geometrical parameters of the unit cell has to be

computed considering the single element printed on the curved surface, or adding the radius of curvature among the parameters that affect the phase variation, as the frequency and the angle of incidence;

- in this computation, the single re-radiated element can no longer be considered as embedded in a periodic structure. It is therefore necessary to consider it as an element of a finite size array, printed of the curved surface. The size of the array is determined comparing the phase of its re-radiated field with that computed with the periodicity assumption, for a planar configuration;
- the direction of maximum radiation for the different elements of the RA is no longer the same for all, and therefore, the proper value of the field in the desired direction has to be computed.

III. NUMERICAL RESULTS

In order to check the validity of the above considerations and to study the effects of the curvature on the radiation pattern, three different, medium-size reflectarrays, consisting in 29×29 square re-radiating elements, printed on a substrate with height $h = 0.53$ mm, $\epsilon_r = 2.2$ and $\tan\delta = 0.0009$, have been designed assuming that they must be wrapped around to cylindrical surfaces with radius of curvature equal to 10λ , 20λ and 40λ , respectively. In all the considered cases, the reflector is off-set, with the direction of maximum radiation tilted by 25° in the vertical plane. A schematic of the designed RA in the case of a 40λ radius cylinder is shown in Fig.2.

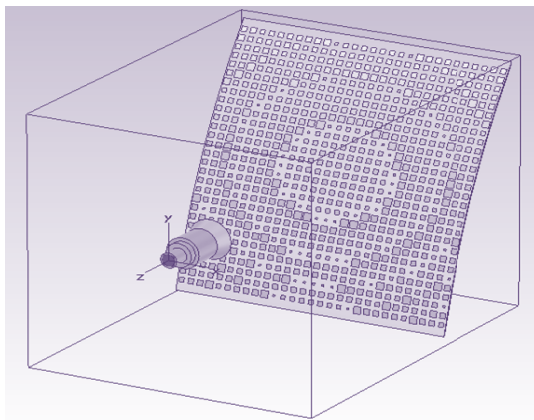


Fig.2: The designed 29×29 RA, conformal to a cylinder with radius of curvature equal to 40λ .

The radiation patterns in the vertical (yz) plane of the three configurations computed at the design frequency of 32 GHz are shown in Fig.3. As expected, the performances of the antenna conformal to the cylinder with the smaller radius of curvature are the worst, with a decrease of the maximum gain and an increase of the sidelobe level.

The reduction of the maximum gain corresponds to a larger HPBW, as it appears from the second column of Table I, where the 1-dB bandwidth of the three configurations is also shown.

Summarizing, it is possible to conclude that the simulations carried out confirm the expected results on the effects of the curvature on the antenna radiation characteristics. For reducing such effects, in particular on the antenna bandwidth, re-radiating elements different from the square ones could be used. Results of the use of other radiating elements on the performances of conformal RAs will be presented at the conference.

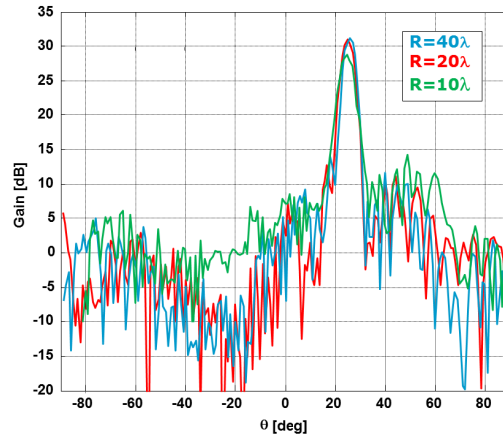


Fig.3: Radiation pattern of the three designed conformal RAs in the vertical plane, at the frequency $f = 32$ GHz.

TABLE I. RADIATION CHARACTERISTICS OF THE THREE DESIGNED CONFORMAL RAS

curvature radius	gain (dB)	HPBW (deg)	1-dB bandwidth
10λ	28.9	5.4	5 %
20λ	31	4.7	7.2 %
40λ	31.4	4.6	7.3 %

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