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V.H. Bui[1], P. Pirinoli[2], M. Beccaria[2], M. Orefice[2], F. Yang[3]

***Abstract*—The characteristics of Reflectarray Antennas printed on convex curved surfaces are discussed in this paper. In particular, results will be presented on the radiation performances of Reflectarrays designed to fit cylinders with different radii of curvature, and with different types of radiating elements.**

1 INTRODUCTION

While planar printed Reflectarray (RA) antennas are nowadays well-assessed structures, able to combine the advantages of both conventional reflectors and planar arrays, the extension to their use as curved reflector is still sporadic, even if it could be of practical interest for different applications, as 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.

The results on the analysis of non-planar RAs were first presented in [1], where the entire RA has been designed as an ensemble of planar panels, tangent to a parabolic surface, and in [2], where a preliminary comparison between RAs printed on convex or concave cylindrical surfaces has been carried on. As expected, results in [2] confirm that the printing of the RA elements on a concave surface improves its performances, due to the reduction of the path difference between the central and the lateral printed elements, with respect to the planar case; on the contrary, when the RA is conformal to a convex surface, this difference increases and therefore all the antenna performances are degraded [2]. One of the most significant effects is on the bandwidth, which is always a problem in RAs, since it depends on the path differences for each of the re-radiating elements, whose corresponding phase shift varies with the frequency and cannot be well compensated at all frequencies. The limited bandwidth is a critical issue also for planar RAs, and this is the reason why many possible solutions have been studied (see for instance [3]-[5] and references therein).

In [6], some results on the effect of the curvature for RA designed to be mounted on convex cylindrical surfaces, on the variation of the re-radiated field phase vs. the size of the re-radiating element are shown. Here, additional results of the design and the numerical analysis of three medium-sized convex reflectarrays on cylinders with different diameters, and of other configurations with concentric square patches, are presented.

2 DESIGN OF CONVEX-CONFORMAL REFLECTARRAY

The design of a conformal RA is performed generally following the main steps of the planar RA design procedure, except for the following differences that have to be taken into account:

- the relationship 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, as the frequency and the angle of incidence, that affect the phase variation;
- 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.

- 3 NUMERICAL RESULTS

In order to study the effects of the curvature on the radiation pattern, three different, medium-sized reflectarrays have been designed and analyzed, for which some preliminary results were been presented in previous works [6, 7].

Still considering the same geometry, we can start discussing some further results. By analyzing different RAs conformal to cylindrical surfaces with different diameters (10λ, 20λ and 40λ), and consisting in 29×29 square patches, printed on a substrate with height h = 0.53 mm, ε_r = 2.2 and tanδ = 0.0009; with offset geometry, a comparison can be done on the gain variation vs. frequency.

As expected, the performances of the antenna conformal to the cylinder with the smaller radius of curvature are worse than the others, with a decrease of the maximum gain and an increase of the sidelobe level.

The reduction of the maximum gain is shown in the curves in Fig.1, where the frequency behavior of the gain computed for the three different RAs is reported. Note that when the curvature increases, not only the gain, but also the bandwidth is reduced.

To improve the bandwidth behavior, a new configuration with different elements has been considered, having intrinsically better performances in frequency; concentric square rings have been used that may exhibit more than one resonance and therefore have a wider phase shift range [5].

The concentric square ring geometry has four degrees of freedom, since it is characterized by the inner and outer dimensions of the two rings. Previous works have considered fixed ratios among the sizes, while in this case a free further

[1]ICTEAM Institute, Université Catholique de Louvain, Belgium.
[2] Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy
[3] Department of Electronic Engineering, Tsinghua University, Beijing, China

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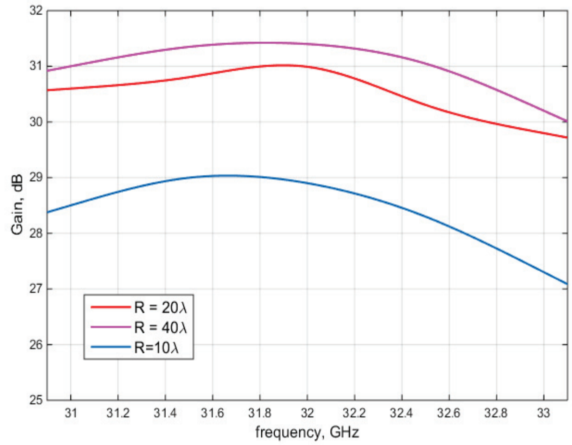

Fig.1: Gain vs. frequency behavior for the three designed conformal RAs.

parameter used is the ratio between the external size of the two rings, that has been varied in the range 0.2 to 0.7. In this way phase curves have been obtained, and example of which is shown in fig.2. In order to have an easily manufacturable and small prototype, a frequency in Ka band was chosen, leading to wavelengths of the order of the centimeter and square ring variable size of few millimeters.

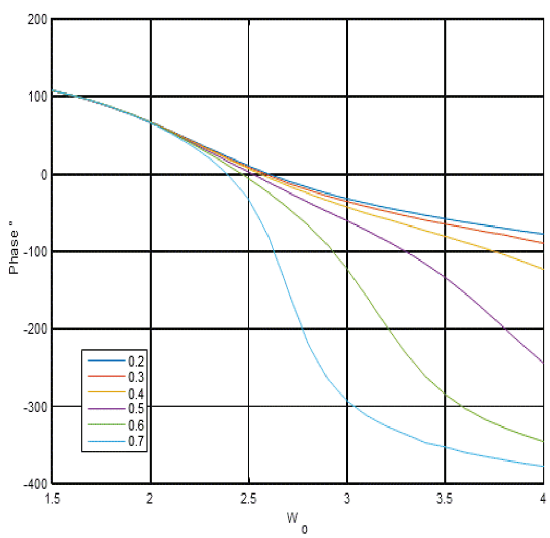

Fig.2: Example of phase curves of the square rings patch. In abscissas, the outer size of the patch. The parameter of the curves is the ratio W_{in}/W_{out}.

Based on these curves, an offset 24x24 elements RA has been designed for a cylinder of 8λ radius, whose layout is shown in fig. 3. The additional parameter has been used in the design to keep constant the variation of the phase difference with the frequency, using the same methodology presented in [4].

4 CONCLUSIONS

In summary, 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 have been used. Results on the use of concentric square rings elements on the characteristics of conformal RAs will be presented at the conference.

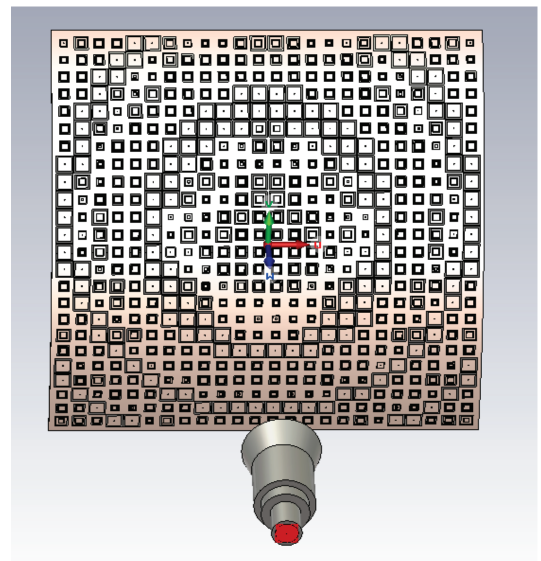

Fig.3: The designed 24×24 RA, conformal to a cylinder of 8λ radius.

Acknowledgments

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