Investigation on Convex Conformal Reflectarray Antennas exploiting double parameter technique

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***Abstract*—In this paper, some results about the design and the full-wave analysis of Printed Conformal Reflectarray Antennas, able to work in the Ka band, using non-conventional re-radiating elements are presented. They introduce an improvement of the radiation characteristics, and in particular an enhancement of the bandwidth.**

***Index Terms*—Conformal antennas, Printed Reflectarrays, Conformal Reflectarrays.**

I. Introduction

The use of printed Reflectarray Antennas (RAs) [1], [2] is quite interesting in practical applications, because they combine the good characteristics of both array and reflector antennas, overcoming their disadvantages. For what concerns the advantages, RAs exhibit low profile, cost and weight, and do not require a feeding network that may be responsible of severe losses, and quite difficult to design.

In recent years, the interest of designing antennas conformal to bent structures has been increased: for example, they can reduce the visual impact of the antenna, when this has to be mounted on a wall with non conventional shape, or for the enhancement of the aerodynamics when the antenna has to be mounted on the fuselage of an aircraft. The advantage of a Conformal Reflectarray Antenna (CRA) is that it can fit both concave and convex structures, properly arranging the re-radiating elements in order to take into account the effect of the curvature, and can therefore have a more flexible use.

A preliminary study [3] on Conformal Reflectarray Antennas has been carried out showing the possibility to compare two structures both in the convex and in the concave configuration, demonstrating the features of these latter. In the concave configuration, re-radiating elements have a distance from the feed lower than the planar case, and for this reason this CRA exhibits even better performances, because it is more similar to a parabolic reflector. For what concerns the convex geometry, it has a larger number of potential applications and it is more interesting from a research point of view.

A full-wave analysis on Convex Conformal Reflectarray Antennas was reported in [4] and [5], investigating the possibility to bend different CRAs on various cylindrical surfaces with different radii of curvature. From those results, it appears that the most critical drawback of CRAs is the bandwidth, firstly due to the narrow bandwidth of the patch elements themselves, and then because the distance between the feed and the elements on the perimeter of the reflector is greater than in the planar case, because of the curvature of the surface.

The use of non conventional re-radiating elements with more than one degree of freedom is pointed out in [6],[7] underlining the improvement of the radiation characteristics in planar RAs, allowing the enhancement of the bandwidth. In [5] this idea was presented for CRAs, but with few results of the designed antenna.

In this paper, some results on the full-wave analysis of CRAs, using concentric double square rings as re-radiating elements, are presented, and compared with other CRAs with the same size and geometry but with square patches as re-radiating elements, showing an improvement also in this case with elements that exploits more than one degrees of freedom.

II. Design Technique

In [6], [7] it is proved that more complex re-radiating elements improve the radiation features of a RA. If a double square ring is used, it is possible to obtain the phase variation of the reflected field as a function of two parameters, in this case the outer size of the outer ring (W) and the ratio (p) between the outer sides of the inner and outer rings. In this way it is possible to achieve a total phase variation of more than 360°, because the unit cell has more than one resonance.

In order to obtain the phase surface as in Fig.1, the unit cell, differently from the planar reflectarray approach, is not embedded in an infinite lattice but is printed in a finite curved array consisting of 5×5 elements with a given radius of curvature, as shown in [5].

The main objective in using the double square parameters approach is to compensate not only the delay introduced by the distance between the feed and the elements located at the perimeter of the reflector but also the delay introduced with the frequency variation in the desired band.

III. Preliminary numerical results

In this work two designs of reduced size CRAs with a different number of elements presented, in order to validate

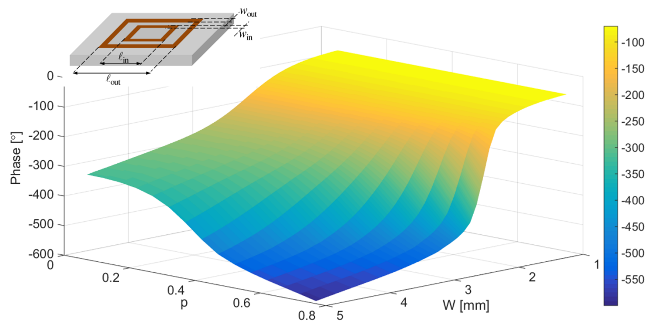

Fig. 1. 3-D plot of the phase of the reflected field versus two parameters at 32 GHz.

the procedure mentioned before. In both designs each cell is square, with a side of 5.5 mm, and the substrate has a thickness of $h_1 = 2.5$ mm and $\epsilon_r = 1.1$; in addition, there is a cover of another dielectric layer with $h_2 = 0.45$ mm and $\epsilon_r = 2.5$, used to have a smoother variation of the phase versus the geometrical parameters.

As for the geometry of the entire CRAs, they consist in 12×12 and 18×18 elements with apertures $D_1 = 66$ mm and $D_2 = 99$ mm for the two antennas, respectively. The geometry is off-set, with a distance from the center of the reflector to the feed $f = D$; the feed is a Potter horn with a maximum gain of 15 dBi, an HPBW of 32.8°, with polarization along the y direction: the (vertical) plane orthogonal to the cylinder axis is therefore the E plane. The radius of curvature of the CRAs is 20λ for both cases, and the CRAs are designed to have a beam tilted to 50°. A sketch of the 18×18 elements configuration, and the view of the cut in $y-z$ plane are shown in Fig. 2.

The radiation features of the two antennas have been computed with the commercial software CST Microwave Studio. The E-plane pattern of the 18×18 elements CRA at the central frequency (32 GHz) and at the two edges of the band are shown in Fig. 3. The main beam remains almost unchanged, while the sidelobes slightly increase moving from the center to the edges of the band. Is also possible to note that there is an asymmetrical spillover effect: in fact, from Fig.2 it is possible to see that, because of the off-set geometry and the alignment of the feed, the lower part of the CRA in the E plane is less illuminated than the upper part. More precisely, the upper and lower edge are illuminated respectively at -1.5 dB and -7.4 dB with respect to the feed maximum, so that the spillover is high, especially in the upper part. Taking into account the different distances to upper and lower edge, the taper unbalance is partially compensated, to about 4.3 dB. For this reason the radiation pattern is asymmetrical, but this is not important at this step because in this work the attention is focused on the design procedure.

Finally, in Fig.4 it is plotted the frequency behavior of the gain for the 12×12 and 18×18 elements antennas: in both cases they are almost constant with the frequency, and this is a further proof of the advantages deriving from the

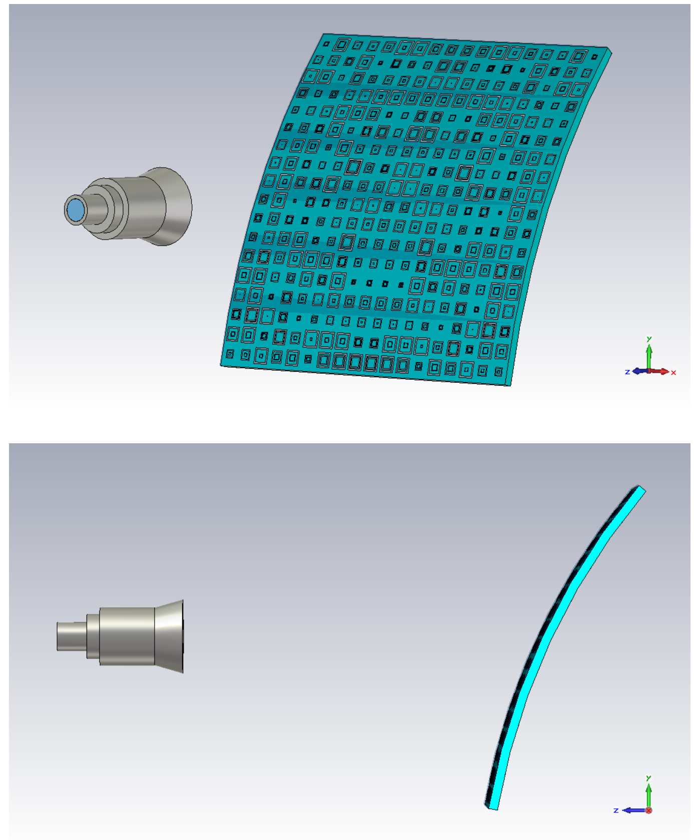

Fig. 2. Layout of the 18×18 elements convex CRA (top) and view in the y-z (E) plane (bottom).

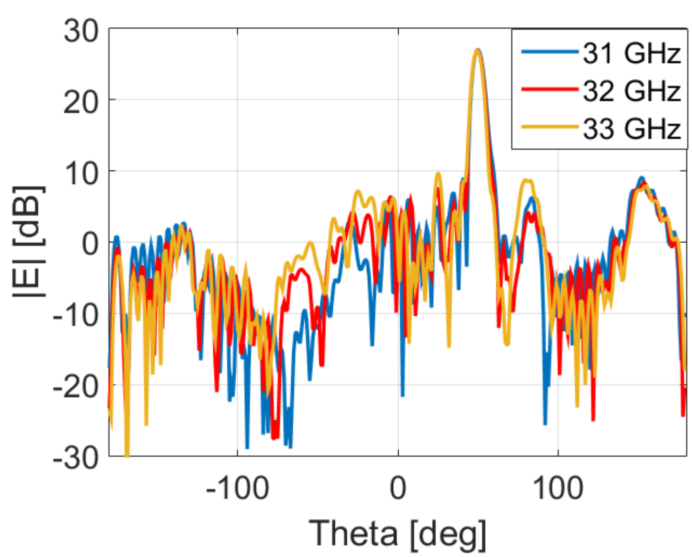

Fig. 3. Radiation pattern in the y-z plane of the 18×18 elements CRA, using double rings, at the working band.

use of two concentric square rings where two geometrical parameters are varied independently. In the same figure the frequency behavior of a CRA with the same configuration of the 18×18 case, but where the re-radiating elements are square patches, is shown. It appears that, even if this configuration is characterized by a higher gain, this varies more sensibly with the frequency.

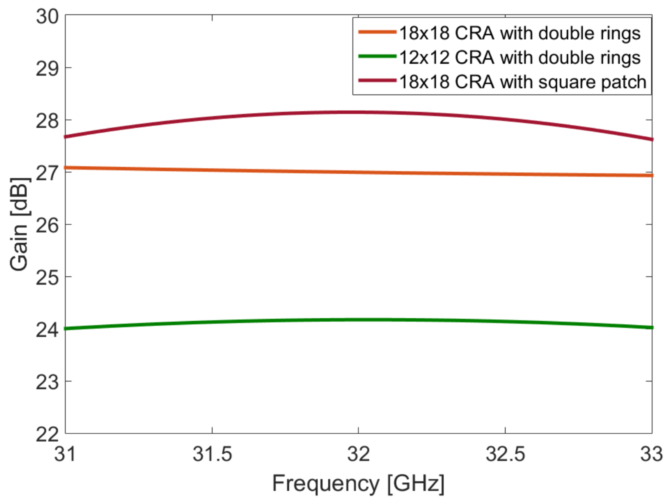

Fig. 4. Frequency behavior of the gain for three different CRAs.

IV. Conclusions

With the square patch, the gain has a more significant variation vs. frequency in comparison to the double rings case. With the double rings, the bandwidth is enhanced because there is the possibility to compensate the delay due to the change of the frequency also in the conformal version of these antennas, in which the phase requirement are more critical due to the curvature of the surface.

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