Non Conventional Reflectarray and Transmitarray Configurations for Next Generation Applications

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Abstract

Reflectarrays (RAs) and transmitarrays (TAs) represent an efficient alternative to reflectors and arrays as high-gain antennas, since they posses nice features making them potentially suitable for several different applications. In view of these, some non-conventional, dielectric-only RA and TA configurations are here discussed.

1. Introduction

The next generation of wireless communication networks are demanded to offer and to support services such as virtual and augmented reality, portable video streaming, Internet of Things and on move communication, that also affect the radiating sub-system, and for this reason many effort are spending to face the challenge of designing innovative antenna configurations suitable for obtaining the required features. Among the different possible solutions, there are also those based on the use of Reflectarray (RA) [1, 2] or Transmitarray (TA) [3] technologies: they have been extensively studied, to develop configurations showing features as a broad-band behaviour [4, 5] and beam-scanning capabilities [6]. From the technological point of view, different solutions are considered, with the aim of improving the antenna performance, keeping as low as possible its complexity and the manufacturing cost. For this reason, the design of metal-only [7] or a completely dielectric structure [5, 9] are recently considered. In particular, this last solution gained interest since antennas of this type can be manufactured with 3D printing techniques, that allow to realize non-conventional shapes with a reduced cost. In the following, some recent results relatively to dielectric-only RAs and TAs designed to provide wide bandwidth, high efficiency and beam scanning capabilities, are discussed.

2. Dielectric-only RAs and TAs

In the following, two Additive Manufacturing (AM) techniques are addressed for the realization of RAs and TAs: the PolyJet and the FDM ones. The first one guarantees good resolution, important to manufacture structures at high frequencies, as the Ka-band considered here, but the material suitable for this type of 3D printers are characterized by rather high losses and low relative constant. The accuracy provided by FDM techniques depends on the size of the adopted nozzle, but in any case is lower; as a counter part, FDM-based printers can also work with materials showing lower losses and higher value of their relative dielectric constant.

Table 1: Performance of three different dielectric-only antenna configurations.

structure	thickness	max. Gain [dBi]	1-dB BW [%]	aperture efficiency [%]
TA unit-cell [8]	$3.3\,\lambda_0$	30.7	21.5	38.6
RA unit-cell [10]	$0.8\,\lambda_0$	31.3	24.5	39.3
RA unit-cell [11]	$0.31\,\lambda_0$	31.9	15.4	54.5
TA unit-cell: 2 cylinders + square base	$0.74\,\lambda_0$	32.0	16	51.6

Four different antennas are discussed here, two of which (a transmittaray and a reflectarray) are realized with PolyJet technique, using a material characterized by $\varepsilon_r = 2.77$ and $\tan\delta = 0.021$ at $f_0 = 30\,\text{GHz}$ while the unit-cell consists in a dielectric layer with a central square hole [10], eventually located between other two layers, presenting a pyramidal hole, acting as matching circuits and adopted to increase the bandwidth of the TA [8]. Both the antennas have an aperture size of $15.6\lambda \times 15.6\lambda$, at the design frequency $f_0 = 30\,\text{GHz}$; as it appears from the first two rows the data summarized in Table 1, the low value of ε_r forces to increase the thickness of the unit-cell, to reach good performance. The other two configurations are still a reflectarray and a transmitarray, both with size $15\lambda \times 15\lambda$ at f_0, designed to be manufactured with FDM technique, using a dielectric material with $\varepsilon_r = 10$ and $\tan\delta = 0.004$ [11]. Thanks to the high value of ε_r, the unit-cell, that consists in a cylindrical resonator over a square base in the case of the RA, while for the TA another cylinder is added on the other side of the base, is much thin, as it emerges from the first column and the rows 3, 4 of Table 1.

2.1. Bandwidth and efficiency

As it is shown from the data summarized in Table 1, all the four considered antennas are characterized by a wide band-

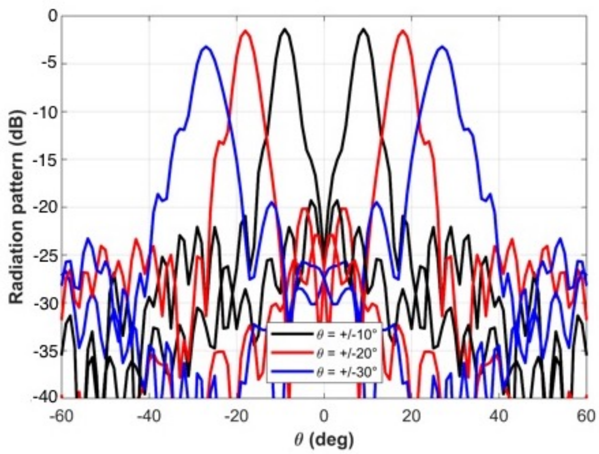

Figure 1: Radiation pattern of a beam-scanning RA, designed using the unit-cell in [10].

width and good efficiency. In particular, the RA and the TA manufactured with the PolyJet printer have a very large bandwidth, compensated by a lower efficiency. The other RA and TA have a smaller bandwidth, even though significantly larger than that obtained with more conventional configurations, but are characterized by two features that make them particularly attractive for many applications, i.e. their extremely reduced thickness, some flexibility that can be exploited especially in case of RAs, if it is convenient to mount them on a curved surface, and the efficiency, higher than $50\,\%$.

2.2. Beam-scanning capabilities

To reduce the complexity and the cost of beam-scanning RAs and TAs, a configuration in which the active part is just limited to the feed, keeping the reflecting/transmitting surface passive is more convenient. To improve the antenna performance, two aspects must be considered. The first one is the use of a proper unit-cell, as low as possible sensible to the direction of arrival of the field radiated by the feed: this improves the performance of the antenna, since it contributes to keep it constant over a large scanning range. An example of such a unit-cell is that introduced in [10], that is used to design a RA, in which the beam scanning is obtained changing the position of the feed. The obtained radiation patterns are plotted in Fig. 1: they stay almost the same over the entire scanning range, with a reduction of the maximum gain no larger than 1.8 dB. The steering beam capabilities of a passive RA or TA can be further enhanced through a suitable approach for their design; as described in [2] a possible solution is that of designing a non-parabolic phase aperture, as for instance a bifocal one: in this case, the antenna performance increase in proximity of the maximum scan angle, but at a cost of its degradation near the central direction of maximum radiation. To overcome this drawback, the use of a suitable optimization technique can be adopted [12].

3. Conclusions

Innovative solutions for the design and manufacturing of dielectric-only transmitarrays and reflectarrays are introduced, discussing their main advantages and drawbacks. Further results will be shown at the Conference.

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