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Dual-Polarized Reflectarray Cell for 5G Applications

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Abstract

A fractal-based reflectarray configuration is investigated to achieve a dual-polarization operation mode, on a same working frequency. The proposed single-layer cell offers an independent phase tuning for each polarization, on a very thin structure with small size. Due to its technical features, a reflectarray configuration realized with the proposed cell could be very attractive for satellite systems and future 5G applications.

1 Introduction

Fifth generation communication systems (5G) are expected to offer higher data rates, lower latencies, and more connectivity [1]. To address these demands, 5G will use millimeter wave (mmw) frequencies, as recommended by the World Radiocommunication Conference.

Microstrip reflectarray antennas can represent an attractive solution in the development of mmw-antennas for 5G, being able to assure large gains/directivities, thanks to the adopted spatial feeding approach [2]-[4]. Additionally, reflectarrays can offer several engaging capabilities [3]-[6], such as beam-steering, multi-beam patterns, multi-band functions and polarization diversity, useful for improving end-user throughput, capacity and coverage.

In this work, the potentialities of a fractal-based single layer reflectarray configuration, preliminary proposed by the authors in [7], [8] for dual-band operations, are illustrated and specifically exploited to operate in a dual polarization mode within the Ka-band (at f=28 GHz), which is under consideration for 5G technology.
The designed single-frequency/dual-polarized cell offers an independent phase tuning mechanism for each polarization, ensuring a dual-polarization behavior with high isolation and polarization purity.

Despite existing dual-polarized reflectarray configurations [9], [10], the proposed cell allows to achieve enhanced features, namely:
- it is able to provide a simpler and thinner structure with respect to multi-layers configurations [9];
- it offers smaller unit cell sizes with respect to other single-layer configurations, thus preserving the ability to point the main beam at large scan angles [10].

Furthermore, the above features make the proposed reflectarray configuration a potential alternative also for space antennas in satellite systems working in transmit–receive (Tx–Rx) operation, with a dual-polarization mode.

2 Unit Cell Geometry and Design

The layout depicted in Fig. 1 is adopted to design a single-layer dual-polarized reflectarray cell. It is composed by two alternately arranged pairs of linearly polarized fractal patches, operating at the same resonant frequency and rotated each other by 90°, in order to achieve the desired dual-polarization mode.

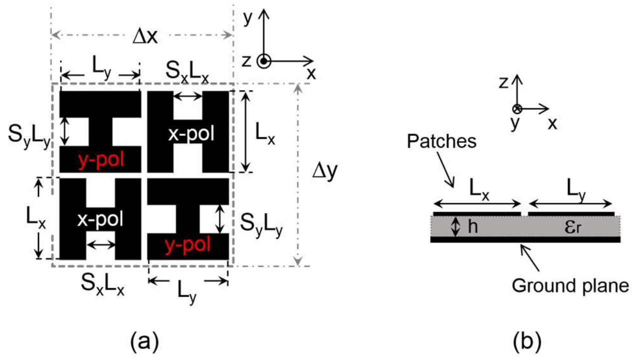

Figure 1. Fractal-based reflectarray cell.

The single patch embedded into the cells is derived from the 1st iteration miniaturized fractal patch, proposed by the authors in [11, 12]. It is characterized by a beginning square element of dimensions $L_p \times L_p$ (p= x, y in Fig. 1). A smaller $S_pL_p \times S_pL_p$-square is removed from the center of the resonant sides of the beginning patch, where S_p is the scaling factor. The reflection phase is tuned by varying the factor S_p from 0 up to 0.45, for each polarization (i.e. along x or y-axes – see Fig. 1). As demonstrated in [11, 12], the adopted fractal radiator allows to allocate a greater electrical length into a smaller area, thus a smaller patch length, with respect to the standard square patch, is needed to obtain the desired working frequency. Taking into account the above considerations, the single fractal patch is accurately synthesized to resonate at the chosen frequency, whilst the prescribed polarization is achieved by a proper patch orientation (Fig. 1).

In order to give a preliminary validation of the proposed structure, a 28GHz prototype is designed and simulated. A Diclad880 substrate (ε_r=2.24, thickness h=0.254mm) is considered and a periodicity equal to $\Delta x=\Delta y= 0.4\lambda$ at 28 GHz is fixed. A commercial full-wave code, based on the infinite array approach (Ansoft Designer), is adopted for unit cell analysis. A normally incident plane wave is considered. Following the design procedures outlined in [11], the following dimensions are obtained: $L_x= L_y=2$ mm, $S_x=S_y=0.357$.

A very low cross-polarization level (<-40dB) is achieved around 28GHz (Fig. 2), whilst a full phase variation range is obtained for each polarization, by varying the corresponding scaling factor S_p from 0.15 up to 0.45 (see Fig. 3).

Finally, Fig. 3 depicts the phase variations of the reflection coefficient component R_{xx} *vs* S_x, for different S_y-values (Fig. 3(a)) and the phase of the R_{yy} component *vs* S_y for different S_x-values (Fig. 3(b)). From the above curves, an independent phase tuning mechanism for each polarization can be identified. As a matter of the fact, a quite constant reflection phase can be observed in the R_{xx}-component, by varying S_y for a fixed S_x-value (Fig. 3(a)). Similar considerations can be extrapolated from Fig. 3(b), thus demonstrating the effectiveness of the proposed dual-polarized configuration.

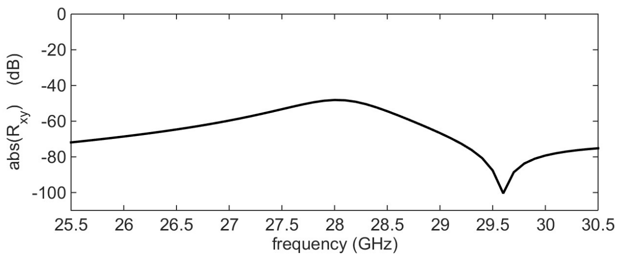

Figure 2. Magnitude of the cross-polar component (i.e. R_{xy}) in the unit-cell reflection coefficient.

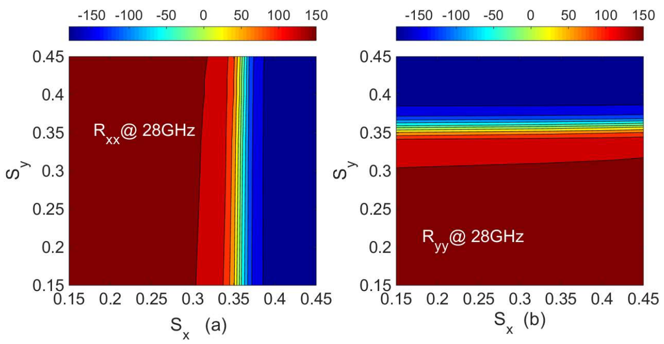

Figure 3. Simulated reflection phase *vs* S_x and S_y: (a) R_{xx} component; (b) R_{yy} component.

3 Conclusions

A novel dual-polarized reflectarray cell has been introduced. The proposed configuration provides a very thin single-layer structure, as well as very small cell sizes. A parametric analysis of the unit cell has been performed, thus demonstrating the independence between the two different polarizations. As future developments, the proposed configuration will be further optimized for designing a dual-polarized mmw-reflectarray prototype.

4 References

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