Reconfigurable Corner Reflector Using PIN-Diode-Switched Frequency Selective Surfaces

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***Abstract*—This paper presents the development of a reconfigurable corner reflector that uses a PIN-diode-switched frequency selective surfaces (FSS). A reflector aperture angle of 45º is prototyped for application at 4 GHz, and its pattern characteristics are altered by on-off state biasing of the PIN diodes. The numerical characterization of the structure is performed using analysis in CST® tools, and the results are compared with experimentally obtained data. Good agreement between simulated and measured performances is observed, thus confirming the design approach and functionality of the circuit.**

***Keywords*—FSS, reconfigurable antenna, PIN diode.**

I. Introduction

Interest in reconfigurable antenna components has steadily grown due to emerging and ever increasing demand of current and future wireless communication system specifications, e.g. [1]. Reconfigurable antennas can enhance communication qualities by adapting their operation characteristics, such as radiation pattern, resonance frequency, bandwidth and polarization, improving energy efficiency and significantly reducing the effects of interfering signals.

One method for the design of reconfigurable antennas consist in steering the beam by using varactor diodes to change the phase of passive radiators [2, 3]. Other approaches focus on changing the properties of reflective surfaces. For instance, an impedance surface is tuned by mechanically moving two substrate layers against each other [4]. Other techniques involve the use of frequency selective surfaces (FSSs) to reconfigure antenna systems [5-6]. The FSS can be electronically reconfigured by varying the surface characteristics with active devices such as varactor [7] or PIN diodes [8]. This results in the control of the FSS' transmission and reflection properties, and the change of frequency responses by modifying the equivalent geometry, consequently altering the radiation pattern of the antenna system.

This paper focuses on the development of a reconfigurable corner reflector using reconfigurable FSSs as reflector surfaces.

II. FSS Design

The 2D FSS consist of basic elements etched on a dielectric substrate, arranged in a planar periodic structure, and providing filtering properties. The FSS frequency response depends on the substrate thickness h, relative permittivity ε_r, the geometry of the planar circuit and the spacing between the elements within the FSS structure, W_x and W_y, the periodicity and polarization of the incident wave [9].

One of the most adjustable parameters in the design of the FSS is the geometry of the unit cell. In this paper, the reconfigurable FSS (RFSS) is based on the four arms star geometry whose evolution and geometry are shown in Fig. 1. It was introduced in [10] and demonstrated interesting characteristics, such as miniaturization and switch applications. The design and results of the active RFSS with PIN diodes are presented in [11] and thus are not repeated here. The four arms star dimensions are: $W_x = W_y = 22.5$ mm, $L_x = L_y = 12.0$ mm, $d_x = d_y = 2.0$ mm, $S_x = S_y = 3.0$ mm, $ms_x = ms_y = 0.75$ mm, and the gap, $g = 1.0$ mm.

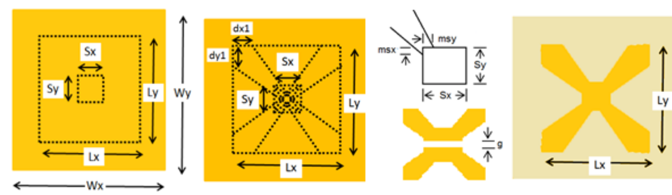

Fig. 1. Four arms star geometry parameters [11]: (a) basic cell with rectangular patch and switch point, (b) lines crossing the centre rectangle from the outside edges, (c) switch point details, (d) four arms star geometry.

The RFSS was manufactured with 8 x 8 elements using the low-cost dielectric substrate FR-4 with $\varepsilon_r = 4.4$, $h = 1.0$ mm, and loss tangent of 0.02. All PIN diodes are Infineon BAR 64-03, inserted at the switch point as shown in detail in the inset of Fig. 2. By biasing the PIN diodes in the ON and OFF states, the geometry's effective length and its respective resonance frequency changes from 6.72 GHz to 4 GHz (Fig. 2). Therefore, the RFSS can replace the metallic plates of an ordinary reflector antenna to work as a reconfigurable reflector.

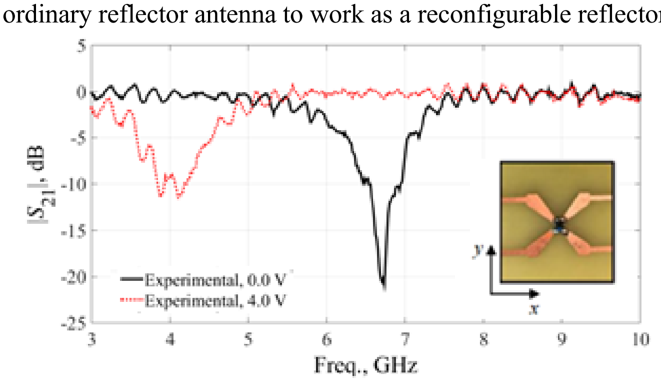

Fig. 2. Frequency response of the RFSS (y polarization).

III. Results

Numerical results were obtained using CST commercial software packages. Measurements were carried out using an

Agilent E5071C two-port vector network analyzer, a Pasternack PE9861-20 horn antenna and a Keysight power supply E3633A. The corner reflector antenna was manufactured using two RFSSs (Fig 3) to reconfigure its radiation pattern. The dipole antenna was manufactured using a Huber & Suhner semi-rigid cable, EZ141TP, designed for the resonance frequency of 4 GHz where the RFSS acts as a reflector when the PIN diodes are in their on-state. The dipole is placed at a distance of $s = 1.20\lambda_0 = 9$ cm from the centre.

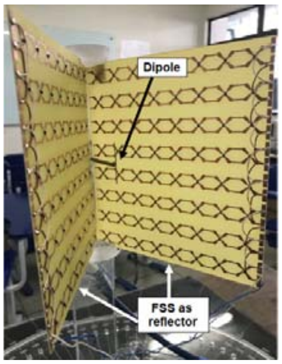

Fig. 3. Reflector antenna manufactured using FSS.

Fig. 4 shows the result of numerical and experimental characterization of the system, when using the RFSSs in the ON state as reflector, with aperture angle of 45°. It is observed in this case that the RFSS behaves as reflector, rendering the radiation pattern directive at $\theta = 0°$, with a gain of 9.16 dB in the experimental results. Simulated and measured results agree reasonably well considering the fact that all diodes have been hand soldered into the FSSs. The same applies for the following results.

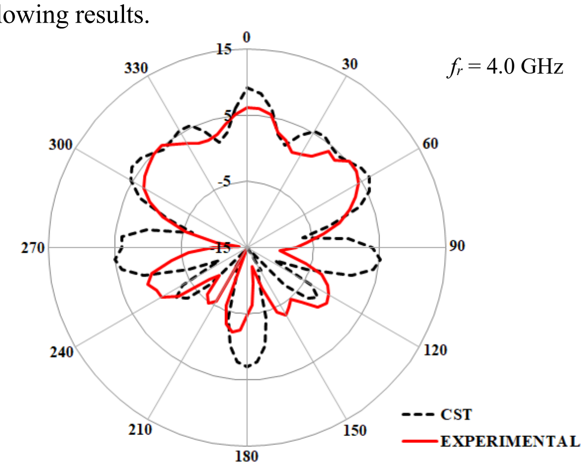

Fig. 4. Non-normalized radiation pattern of antenna using RFSS as reflector, α = 45º, ON state, simulated and measured results.

Fig. 5 shows the respective results when the RFSSs are used in the OFF state. In this case, the RFSSs behave as directors, decreasing the simulated and measured gains at $\theta = 0°$ to -11.73 dB and -5.86 dB, respectively, and putting the main beams towards angles of ≈ ± 60°.

IV. Conclusion

In this paper, the development of a reconfigurable corner reflector using PIN-diode-switched FSSs is detailed. A gain of 12.06 dB for α = 45° is obtained. Active PIN-diode-switched FSSs are used as reflector, and they proved to be a viable option to reconfigure the antenna radiation pattern. When the PIN diode is switched to the ON state, the antenna has its maximum gain at $\theta = 0º$ and nulls in sideward directions. In the OFF state, a null at $\theta = 0º$ is presented with maxima towards other directions. It is observed that the measured gain difference at $\theta = 0°$ is 20.89 dB when ON-OFF state switching occurs.

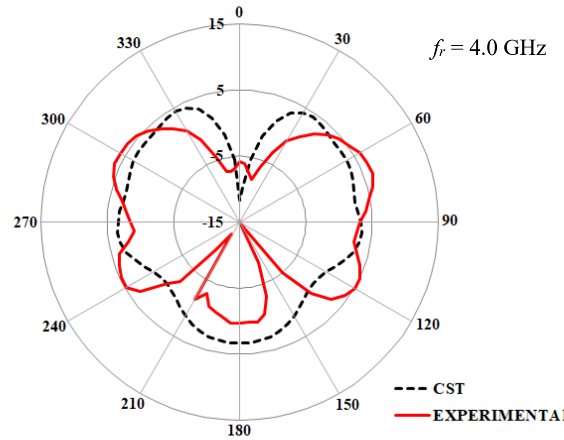

Fig. 5. Non-normalized radiation of antenna using RFSS as reflector, α = 45º, OFF state, simulated and measured results.

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