Single- and Dual-Band FSS With Switchable Characteristics

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***Abstract*—In this work, we propose an FSS that electrically reconfigures its transmission spectrum. The FSS is formed by elements based on the four-arms star geometry, and it uses PIN diodes as active components. Three states of configuration of the FSS panel are analyzed. By biasing the entire panel with the voltage, either forward or reversed, the structure shows single-stopband response, while when half of the panel is forward biased and the other half is reserved biased, it shows dual-stopband response.**

I. INTRODUCTION

Frequency-selective surfaces (FSSs) are arrays of periodic structures, formed by patch or aperture elements etched on a dielectric substrate, providing filtering properties of the incident electromagnetic waves [1]. In certain applications altering the FSS' frequency response is a requirement. The reconfigurable FSS (RFSS) has proved to be an alternative to provide mechanical and/or electrical tuning. In the electrical reconfiguring method, active components, such as PIN diodes [2] and varactors [3] are incorporated on the FSS to manipulate the magnitudes and phases of the reflection and transmission coefficients by altering the element's geometry and effective size.

In this work, an FSS with reconfigurable properties is proposed. Three states of the FSS panel are evaluated: entirely forward biased, entirely reverse biased, and two different states of biasing voltages. The structure can present single-stopband response with different resonant frequencies, or dual-stopband response.

II. PIN-DIODE-SWITCHED FSS DESIGN

The reconfigurable FSS based on the four-arms star geometry is used in this paper, following the design procedure described in [4], which consists of the four-arms star with a gap separating the upper and lower arms and bias lines added to all arms in the horizontal direction to apply voltage to the PIN diodes (Fig. 1). The diode is inserted in the center of the unit cell, which can electronically connect and disconnect the arms. The RFSS is designed to operate at 4 GHz when the diode is in the on-state. The dimensions of the structure are a_p = 12 mm, b_p = 2 mm, g = 1 mm, p_p = 22.5 mm, s_p = 3 mm, and w_b = 1 mm, and considering a dielectric substrate with dielectric constant (ϵ_r) of 4.4 and thickness of 1 mm.

Three state configurations to bias the FSS' rows are considered and they are described in Table I. The number of rows in the FSS panel is divided in half, which are represented by row#1 and #2. Furthermore, by controlling the states of row#1 and row#2, the RFSS can be easily switched between state-11 (on-state), state-10 (intermediate state), and state-00 (off-state).

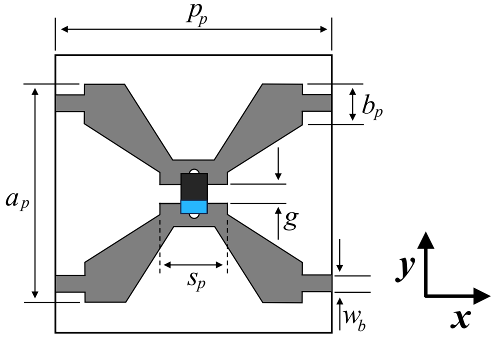


Fig. 1: Geometry and parameters of proposed RFSS with bias lines and diode.

TABLE I: Switching states of the FSS' rows.

	State-11	State-10	State-00
Row#1	ON	ON	OFF
Row#2	ON	OFF	OFF

III. PERFORMANCE VALIDATION

The numerical characterizations of the structure in all states are obtained through the commercial software package CST Microwave Studio. Experimental characterizations of the proposed RFSS were performed to examine the scattering properties and validate the numerical results. The prototype was manufactured on a single-layer low-cost FR-4 fiber-glass dielectric substrate and one-sided metallization, with ϵ_r = 4.4, thickness of 1.0 mm, and loss tangent of 0.025. The fabricated diode-mounted RFSS has 8 × 8 elements and overall dimensions of 18 cm × 18 cm, and a total of 64 diodes soldered on it (Fig. 2). The surface-mountable Infineon BAR 64-03 PIN diodes in SOD323 package, with parasitic inductance of 1.8 nH, are used. The package length and width are 1.7 mm and 1.25 mm, respectively. When forward biased, these diodes offer low resistance with typical value of 1.35 Ω at 100 mA and 0.95 V. When reverse biased, they can reach low capacitance as 0.2 pF at 0 V [5].

The numerical and measured results of the RFSS transmission spectra are shown in Fig. 3 and Fig. 4. For vertical (y) polarization, numerical and measured results are presented in Fig. 3a for the off- and on-states. In the on-state, the PIN

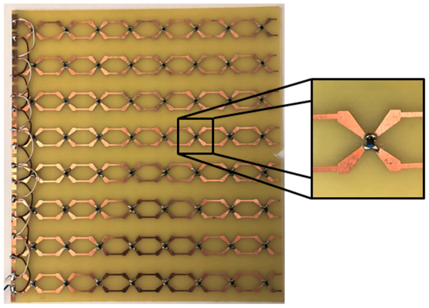
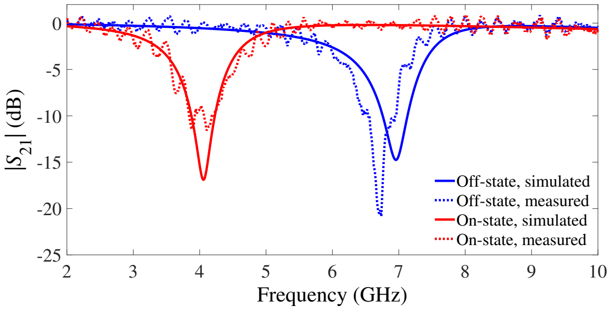
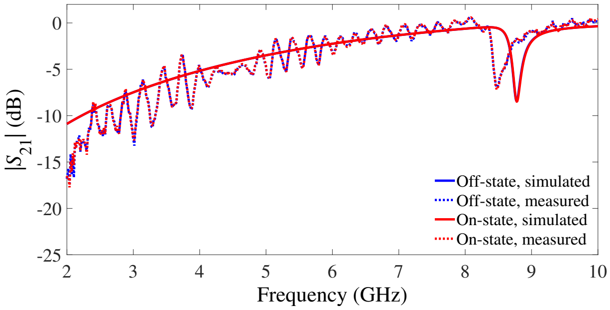


Fig. 2: Fabricated RFSS with close-up view of its unit cell.

diodes in all FSS' rows are forward biased, presenting resonant frequencies at 4.06 GHz and 4.1 GHz for the simulated and measured results, respectively, with minor differences observed. When the PIN diodes in all rows are in the off-state, i.e., they are reverse biased, the RFSS' resonant frequency switches to 6.96 GHz (simulated) and 6.73 GHz (measured). The soldering process of the PIN diode in the unit cell may lead to minor modifications of the PIN diode footprint, hence a slight difference between the simulated and experimental results are observed. Fig. 3b presents the results of horizontal (x) polarization for the off- and on-state; in this case the resonant frequencies for both states are approximately the same: 8.78 GHz (numerical) and 8.47 GHz (experimental). This is due to the fact that the electric field in this polarization is perpendicular to the PIN-diode leads, thus the switching operation is of hardly any effect.



(a) y-polarization.



(b) x-polarization.

Fig. 3: Simulated and measured frequency response of RFSS in the on- and off-state.

The state-10 is a state where half of the rows in the FSS panel have their PIN diodes forward biased, while the other half is reserve biased. In this state, the FSS frequency response is a combination of the one for the on-state FSS and off-state FSS. Fig. 4 shows that in the y-polarization, the FSS presents two resonant frequencies, one at 4.12 GHz and 4.15 GHz, and another at 6.84 GHz and 6.44 GHz, for the simulated and measured results, respectively, which are the transmission nulls originated from the on- and off-state FSSs. When the RFSS is in state-10, the power is divided between the resonant frequencies, thus reducing the magnitudes in S_{21}. The results for x-polarization is not presented for this state because they are the same as those shown in Fig. 3b.

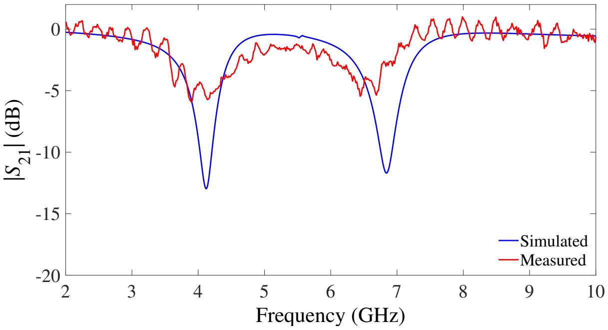


Fig. 4: Simulated and measured frequency response of RFSS in the state-10.

IV. CONCLUSION

A polarization-dependent reconfigurable FSS with single- and dual-stopband response, achieving reconfigurability by using only a single PIN diode per unit cell, is presented. The proposed structure consists of a single dielectric substrate with single metallization layer, and immersed biasing network. By changing the bias state of the diodes in the FSS panel, the FSS can be configured into single-stopband for forward (∼4 GHz) and reverse (∼7 GHz) biasing in all rows, and dual-stopband (∼4 and 6.6 GHz) when half of the FSS panel is forward biased, and the other half is reversed biased.

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