A Reconfigurable Radiation Pattern Microstip Patch Antenna with High Mode Purity

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***Abstract*—A single-layer, dual-mode circular microstrip patch antenna is presented to achieve reconfigurable radiation patterns with high mode purity. The broadside radiation pattern is achieved by a central circular patch, whereas conical radiation pattern is realized through a concentric shorted ring patch. With the simultaneous excitation of the two operating modes, the proposed antenna can generate self-scanning and self-nulling radiation patterns. The proposed antenna was fabricated and tested. Simulated and measured results show that the antenna produces stable broadside and conical radiation patterns with high mode purity at the design frequency of 10 GHz.**

Keywords—Dual-mode; circular microstrip patch; ring patch; pattern re-configurability.

I. Introduction

The popularity of reconfigurable array antennas in the field of wireless communication, remote sensing and radar systems has increased exponentially due to their ability to modify the antennas' operating frequency [1], radiation pattern [2] as well as polarization [3]. In pattern reconfigurable antennas, the direction of the main lobe and null locations can be controlled to avoid the interfering signals and noise sources as well as improve system security and generate highly directive radiation patterns. A variety of techniques have been developed to achieve reconfigurable patterns in microstrip patch antennas as they are low profile, light weight and can be easily incorporated in different array configurations [4]-[5]. The multi-mode stacked circular microstrip patch antenna in particular has the ability to steer the main beam location as well as mitigate the grating lobes by exciting the higher order modes along with the fundamental mode at the same frequency [6-8]. However, the stacked nature of the multimode antenna along with its complicated feeding network makes the design bulky and expensive.

To alleviate the antenna design, the authors proposed a single-layer compact dual-mode circular patch antenna in [9]. The operating modes are the TM_{11} and TM_{21} modes, excited in the central circular patch and the concentric short-circuited ring patch, respectively, at the frequency of 10 GHz. In this paper, the radiation reconfigurability of the antenna in [9] is further investigated to demonstrate its self-scanning and nulling capabilities. To ensure mode purity and reduce the cross polarization, the unwanted orthogonally-polarized modes are effectively suppressed by loading horizontal and arc slits in the ring patch. The dual-mode circular patch antenna was analyzed using the finite-element based full-wave solver ANSYS HFSS [10] and fabricated using the printed circuit board technology.

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II. Antenna Structure

The geometric configuration of the proposed dual-mode circular microstrip patch antenna [9] is depicted in Fig. 1. The antenna is designed on a single-layered substrate (Roger RT/duroid 5880LZ) with a thickness of 1.27 mm and a dielectric constant of 1.96. The dual-mode antenna comprises of a circular patch and a ring patch, exciting the TM_{11} and TM_{21}, respectively. To improve the isolation and reduce the mutual coupling between two modes, 16 metallic vias were used to short-circuit the inner circle of the ring patch with the ground plane. Four symmetrical arc-shaped slits are engraved on the ring patch to help improve the TM_{21} mode purity, which were originally inspired by its current distribution. To suppress the unwanted orthogonally-polarized TM_{11} mode, two horizontal slits are etched on the ring patch. Finally, three vertical slits are cut on the TM_{11} circular disc to miniaturize its size.

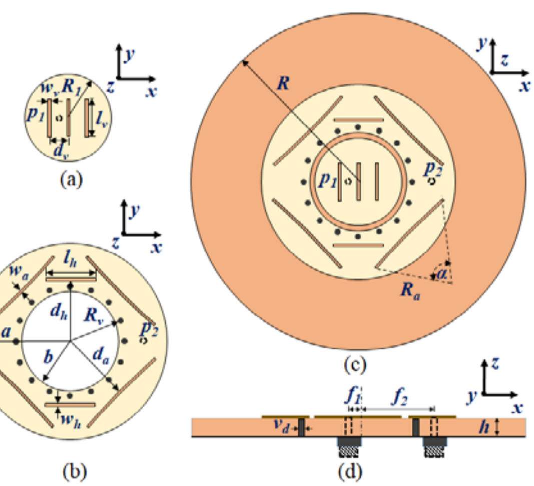


Fig. 1. Configuration of the dual-mode patch antenna [9] (a) Top view of TM_{11} circular patch (b) TM_{21} ring patch (c) dual-mode circular microstrip patch antenna and (d) side view; R_1=5mm; a = 11.56mm; b = 5.84 mm; R = 20 mm; h = 1.27 mm; w_v = w_h = 0.25mm; l_v = 4.4 mm; R_v = 6.4 mm; v_d = 0.4 mm; d_v = 2.2mm; l_h = 5.8 mm; d_h = 7.4 mm; R_a = 55 mm; w_a = 0.2 mm; d_a = 8.15 mm; f_1 =1.1 mm; f_2 = 8.97mm.

III. Results

A prototype of the proposed antenna shown in Fig. 1 was fabricated and measured. Fig. 2 presents the simulated and measured *S*-parameters of the two-port antenna exciting the first and second modes. The mutual coupling between the two modes, S_{12} or S_{21}, is less than -28 dB (VSWR < 1.08). As can be seen, both the modes resonate at the design frequency of 10 GHz with the VSWR less than 1.4.

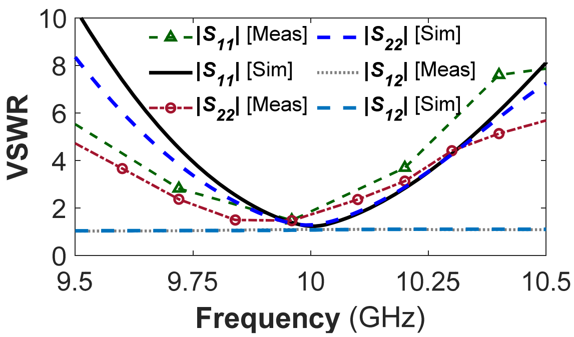
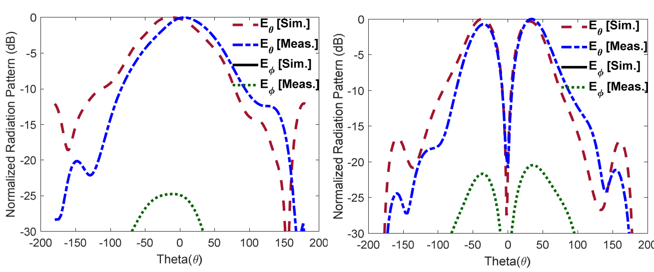


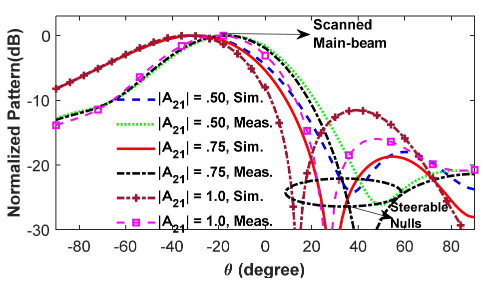
Fig. 2. Simulated and measured VSWR of the proposed antenna versus frequency.

The far-field radiation patterns of the proposed antenna at the design frequency of 10 GHz are shown in Figs. 3(a)-(b). The simulated and measured results are in good agreement. It can be seen that a broadside radiation pattern is obtained with the TM_{11} mode excitation as depicted in Fig. 3(a), whereas a conical radiation pattern with a deep null in the boresight direction is realized in Fig. 3(b) with the TM_{21} mode excitation. For the broadside radiation patterns, the cross-polarization level is about -25 dB in the *E*-plane as per Fig. 3(a). For the conical radiation patterns, the co-polarized patterns in the *E*- plane are symmetric in both simulation and measurement and the cross-polarization level is about -20 dB.

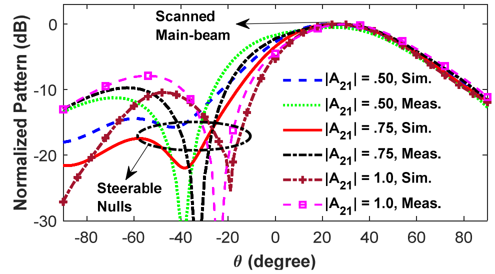


(a) (b)

Fig. 3. Simulated and measured radiation patterns of the dual-mode circular microstrip patch antenna for *E*-plane operating at the (a) TM_{11} mode (b) TM_{21} mode.



(a)



(b)

Fig. 4. Pattern re-configurability of the proposed dual-mode microstrip patch antenna; $|A_{21}|$ is the magnitude of the relative power ratio of TM_{21} and TM_{11} mode, while the phase between the modes is (a) +90°, (b) -90°.

The pattern re-configurability in terms of main-beam scanning and self-nulling of the proposed antenna is demonstrated in Figs. 4(a)-(b), when there is a quadrature ±90° phase shift between the modes. As depicted, the main beam scan angle and the null position in the radiation patterns can be controlled by the magnitude and phase of the two modes, denoted by A_{21} in Fig. 4.

IV. Conclusion

A dual-mode, single-layered circular microstrip patch antenna with reconfigurable radiation patterns is presented. It was shown that reconfigurable radiation patterns could be realized over the course of operation by controlling the vectorial values of the mode content factors to scan the main beams and steer the nulls. The proposed antennas are highly beneficial in reducing grating lobes and sidelobes in phased array antennas.

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