EMSICC-Based Compact Array Antenna Having Switchable Frequency Beam-Scanning Range in Microstrip Environment

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***Abstract*—In this paper, an eighth-mode substrate integrated circular cavity (EMSICC) based beam scanning array antenna having reconfigurable frequency band using PIN diodes is realized at X-band. A single annular complementary split ring resonator (CSRR) is introduced in ground plane of EMSICC and by rotating the ring, a shift of resonant frequency is obtained. Further, to implement the rotation, PIN diodes are incorporated at two positions and depending upon the switching states of these PIN diodes, a frequency-reconfigurable unit cell is designed. Finally, a beam scanning array antenna is designed utilizing that unit cell with reconfigurable frequency band. The band can be shifted by switching the diodes maintaining the scanning range of 36°.**

I. Introduction

With the advancement of wireless communication systems in compact frequency beam scanning antenna applications, the requirement of maximum frequency usable range is equally in demand. Dual-band antennas are one of the alternatives but they suffer from different bandwidth issues and therefore, frequency-reconfigurable antennas can be a promising replacement. Recently, substrate integrated waveguide (SIW) [1] becomes very popular due to its light weight, low loss, low cost, ease of fabrication etc. To make the antenna more miniaturized, several techniques have been developed like EMSIW where cavity size is 1/8th from original SIW [2], composite right/left handed (CRLH) structures [3] etc. Compact dual-band reconfigurable antenna has already been designed in EMSIW [2]. In this paper, a single annular CSRR is realized by a complementary ring resonator with PIN diode and is used in ground plane of EMSICC to switch the resonating frequency. Further, this unit cell is utilized for designing a frequency-reconfigurable beam scanning array antenna in microstrip environment. All the full-wave simulations have been performed using Ansoft HFSS.

II. Unit Cell Design

Firstly, the eighth-mode substrate integrated circular cavity (EMSICC) is designed from original SICC by cutting the SICC through its fictitious magnetic wall as shown in Fig. 1(a)-(d). Then single annular complementary split ring is etched in the

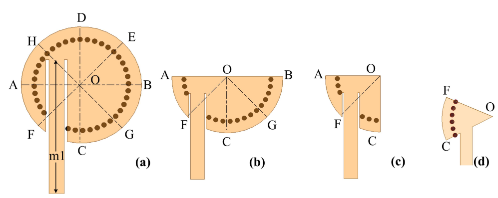

Fig. 1. Transformation of SICC to EMSICC where (a)full-mode SICC (b) half-mode SICC (c) quarter-mode SICC (d) EMSICC.

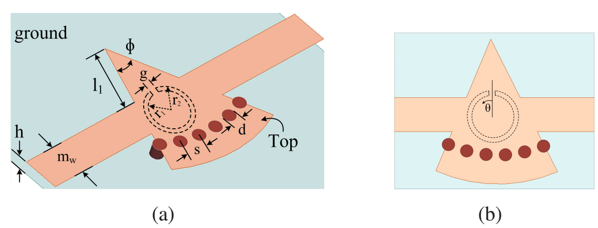

Fig. 2. (a) EMSICC loaded with CSRR on ground plane (b) rotation of CSRR. The dimensions are: l_1=3.86, g=0.45, Φ =23.6°, r_1=1.3, r_2=1.6, s=1.2, d=0.8, m_W=2.32, h=0.787 (mm).

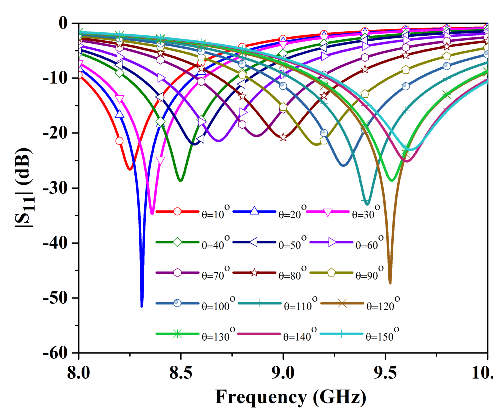

Fig. 3. Variation of resonant frequency of CSRR loaded EMSICC with θ.

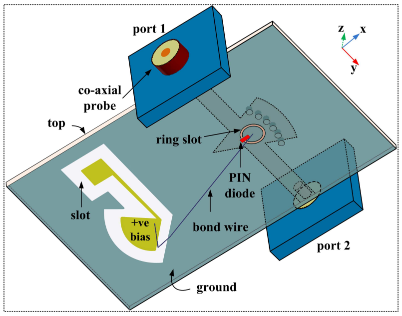

Fig. 4. Realization of CSRR using PIN diode with proper biasing.

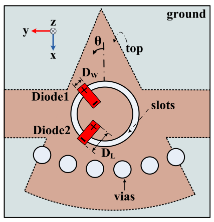

Fig. 5. Realization of frequency switching using two diodes (bottom view), dimensions are: D_W= 0.45mm, D_L= 1.15mm.

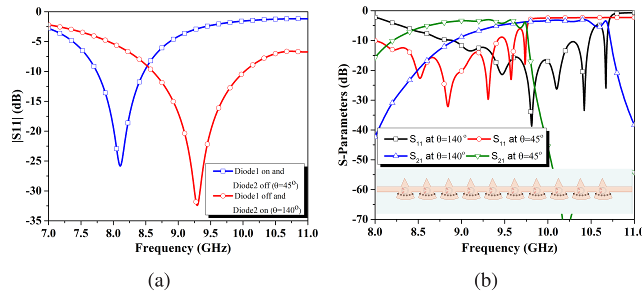

Fig. 6. (a) Variation of S-parameter with resonant frequency of unit cell shown in Fig. 5, (b) variation of S-parameter with frequency for the proposed antenna where frequency range shifting is observed.

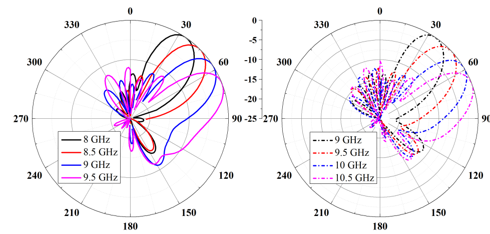

Fig. 7. Radiation patterns of the proposed antenna for two different switching states.

ground plane as shown in Fig. 2 and by rotating (θ) the ring, the shifts in resonant frequency are observed which are shown in Fig. 3. The range of shift in frequency with rotating CSRR (θ =10° to θ =150°) is 1.37 GHz (8.25 GHz to 9.62 GHz). For excitation, microstrip feeding is used through the radiating edges of the EMSICC. Then to make it re-configurable, a PIN diode (MA4SPS402) is mounted [4] in the position of split/gap in the ring resonator and suitable biasing is depicted as shown in Fig. 4. Further, for practical realization of two different angles, two PIN diodes are used named Diode1 and Diode2. When Diode1 is ON and Diode2 is OFF, the SRR is tilted at 45°. In similar way, it is tilted at 140° when switching conditions of diodes are reversed. The schematic is shown in Fig. 5 and the responses are shown in Fig. 6(a) where the shift of resonant frequency is observed from 8.1 GHz to 9.3 GHz. No significant changes are observed when tilt angle is greater than 180° because the ring would not be excited by the current element.

III. Antenna Design

The unit cell of Fig. 5 is placed periodically with a periodicity of p = 9.7mm such that the antenna scans with frequencies in forward quadrant. The scanning angle of the proposed antenna depends upon n^{th} spatial harmonic β_n and free space wave number k_0 [5]. Based on the switching conditions of the PIN diodes, the operating range of the antenna is shifted. When all SRR's are tilted at θ =45°, the proposed antenna scans within the frequency range of 8-9.5 GHz with the scanning range of 36°. Similarly, for θ =140°, the antenna scans within 9-10.5 GHz with the same scanning range. Simulated S-parameters of the proposed antenna and the radiation patterns in yz-plane are shown in Fig. 6(b) and 7 respectively. The proposed antenna contains 10 unit cells and is designed on Rogers RT/duroid 5880 substrate having the dielectric constant of 2.2, loss tangent (tanδ) of 0.0009 and thickness of 0.787 mm.

IV. Conclusion

In this paper, a frequency-reconfigurable EMSICC unit cell is designed using PIN diodes which have been used to switch the scanning range of frequency beam scanning array antenna. The proposed antenna provides a scanning range of 36° for both the switching cases where the shift of frequency range is observed from 8-9.5 GHz (for θ =45°) to 9.5-10.5 GHz (for θ =140°). This antenna can be a promising candidate in switched-beam smart antennas and several low power radar applications.

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