The SIW Cavity Backed Tunable Planar Antenna

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Abstract — **A substrate integrated waveguide cavity backed active slot antenna is presented in this paper. The antenna operating frequency band is tuned by varying the capacitance of the three varactor diodes connected across the radiating slot. The overall dimensions of the fabricated antenna prototype are 29.6×34.8×0.508 mm^3. The tuning process does not change the antenna radiation pattern.**

Keywords — **reconfigurable antenna, SIW, varactors, frequency agility**

I. INTRODUCTION

In recent years, rectangular waveguide technology has been used for the design of high performance passive circuits and systems [1]. Nevertheless, these bulky and heavy structures have not been appropriate for integration and low-cost mass production. Substrate integrated waveguide (SIW) technology that have been introduced by Deslandes and Wu in [2] exhibits many advantages like low loss, electrical isolation due to the shielding via posts, and facility of integration with all kinds of passive and active components. For those reasons, it has been widely applied in the design of various microwave components such as antennas [3], oscillators [4], filters [5] and leaky wave antennas [6].

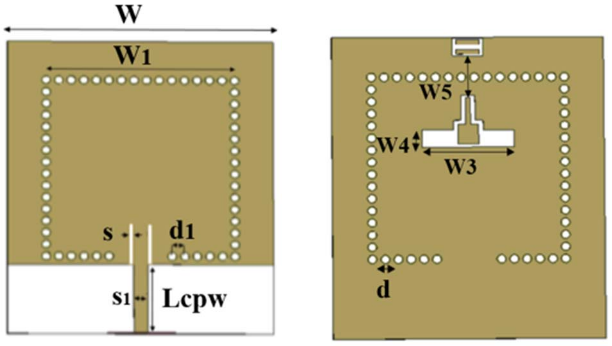
On the other hand, frequency reconfigurable antennas have gained a significant interest in the last decades due to their capability of multiple performance functions which are suitable for many multi-band wireless communication systems [7-8]. The cavity-backed SIW tunable antennas are widely used for their gain and narrow bandwidth. Due to their nature, they exhibit wide tunable frequency range. Many techniques have been used in the design of frequency tunable SIW cavity backed structure. A SIW cavity-backed antenna with interdigital capacitor (IDC) has been investigated in [9]. The tuning of varactor diode embedded across the IDC slot has allowed to vary the resonant frequency of the zeroth-order resonance in the range from 4.13 to 4.5 GHz. A miniaturized switchable SIW antenna based on composite right/left-handed metamaterial has been proposed in [10]. Pin diode has been used to adjust the operation frequency between the positive- and negative-order resonances while the frequency is changed between 1.83 GHz to 4.93 GHz. Two biased ferrite slabs have been inserted into an SIW cavity backed bowtie slot antenna to design the X-band resonant frequency tuned from 9. 23 to 10.69 GHz in [11].

In this communication, we propose the design of the SIW cavity backed antenna that can be tuned in a wide frequency band by loading three varactors across the radiation slot graved in the ground plane. By simulations and experiments, we validated that the designed structure has a tuning range of about 900 MHz with high gain values and a stable unidirectional radiation patterns. The central frequency is 9.4 GHz.

This paper is organized as follows. Section II presents the architecture of the frequency reconfigurable SIW cavity backed antenna. Section III shows the measured and simulated results of the proposed structure. Finally, Section IV draws some brief conclusions.

II. RECONFIGURABLE SIW CAVITY ANTENNA: ARCHITECTURE, DESIGN, CHARACTERIZATION

The architecture and the photograph of the fabricated grounded coplanar waveguide (GCPW) fed reconfigurable SIW cavity backed antenna are depicted in Figs. 1 and 2, respectively. The antenna is built on Rogers RT Duroid 5880 substrate with 0.508 mm thickness and permittivity equal to 2.2.

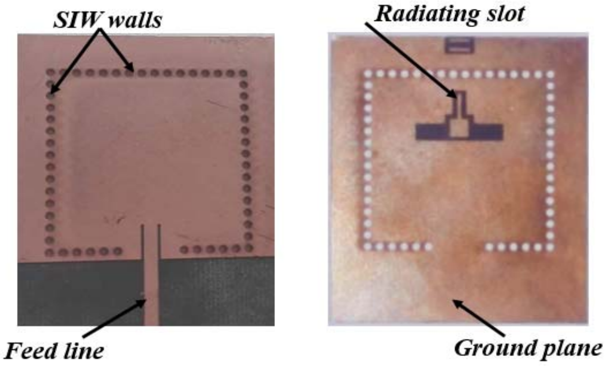


(a) (b)

Fig. 1. Architecture of reconfigurable SIW cavity backed antenna (a) top view, (b) bottom view (W=29.6mm, W1=21.6mm, W3=6mm, W4=3mm, W5=5mm, S=0.2mm, S1=1.56mm, Lcpw=8.2mm, D=1mm, d1=1.4mm)

The cavity is realized within SIW metal via arrays. The condition $d/d_p \geq 0.5 \; and \; d/\lambda_0 \leq 0.1$ must be satisfied to make the SIW cavity equivalent to the conventional metallic cavity. The length and the width of the SIW cavity are calculated from relations given in [12]. For antenna excitation, a GCPW feed line located at one edge of the SIW cavity is used.

50 Ω microstrip line is attached at the end of the GCPW to facilitate the measurements procedure. The radiating slot is loaded by three varactor diodes. A continuous frequency tuning is performed by changing the capacitance value of the diodes by changing the DC bias. Fig. 3 shows the location and the equivalent circuit of the diodes (SMV1430-040LF) in the antenna structure [13].



(a) (b)

Fig. 2. Photograph of the fabricated reconfigurable SIW cavity backed antenna (a) top view, (b) bottom view.

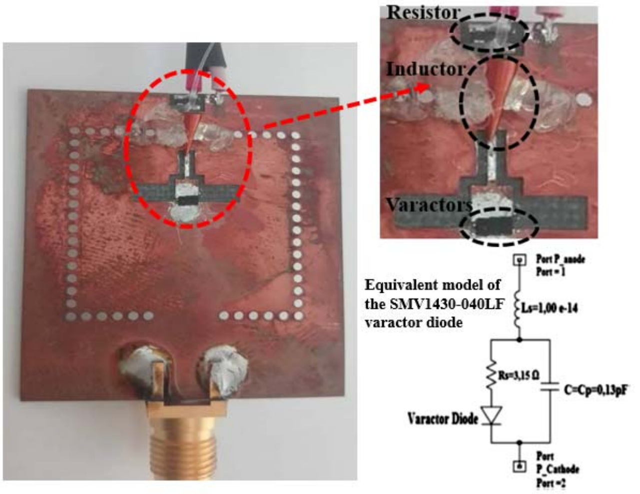


Fig. 3. Location of the varactors and the lumped elements in SIW cavity backed antenna.

III. RESULTS DISCUSSION AND EXPERIMENTAL DEMONSTRATION

The reflection coefficient of the proposed frequency reconfigurable antenna has been simulated and measured by using a CST full-wave simulator and Agilent vector network analyzer (Rohde Schwarz ZVA 67) in a laboratory environment.

The reflection coefficient of the SIW cavity backed antenna is shown in Fig. 4. Relatively good agreement is visible between the simulated and measured results. A slight upward frequency shift is observed in the measured characteristic. It is mainly due to manufacturing tolerances and SMA connector soldering.

Fig. 5 presents the measured and simulated resonant frequency taken over the variation of the reversed bias voltage from 0 to 30 V. Good correlation is observed between both results showing a wide frequency range from 8.9 till 9.8 GHz (900 MHz). Fig. 6 compares the S_{11} matching level results obtained from simulation and measurement for all studied cases. Unfortunately, high matching level of S_{11} is noted in measured data in all varied bias voltages that has not been found by the measurements of the structure without varactors and lumped elements (Fig. 4). This explains the fact that a high disturbance can be figured out by the soldering of those elements as well as the dielectric constant and the tolerances on the substrate thickness that can also change the S_{11} results.

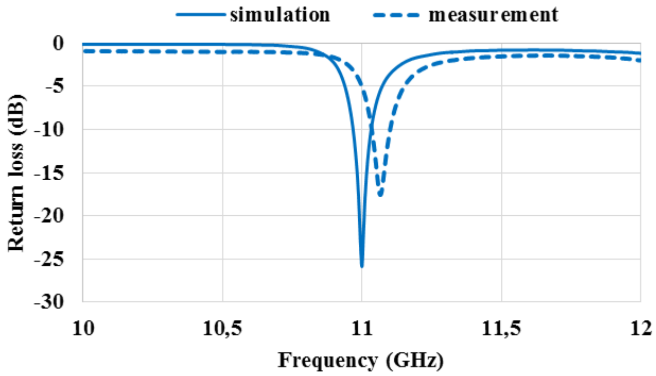


Fig. 4. Measured and simulated S11 results of the SIW cavity backed antenna

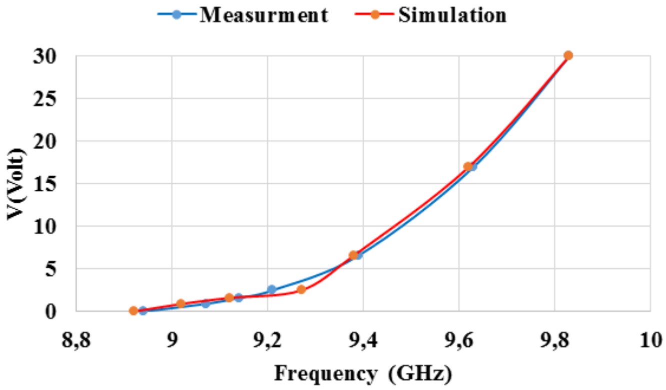


Fig. 5. Measured and simulated resonant frequency versus DC voltage.

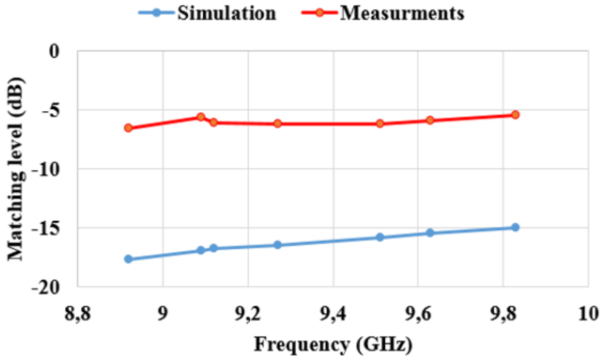


Fig. 6. Measured and simulated S11 matching level over frequency

Besides, measured gain values are lower than simulated results which can also refer to the same reasons. Simulated gain shows a stable value around 5 dBi within all capacitance variation while the measured results present an average gain around 3.5 dBi in all reversed bias voltage altering as presented in Fig. 7.

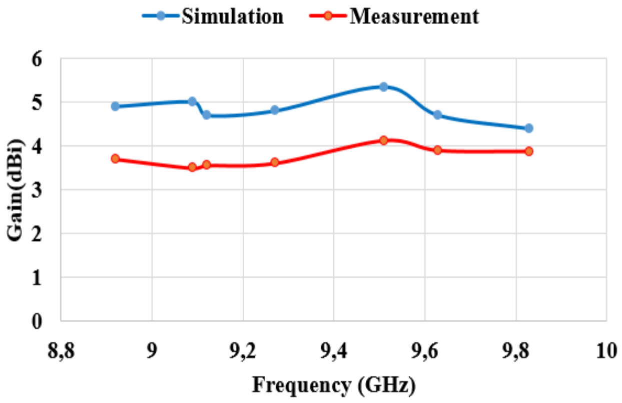
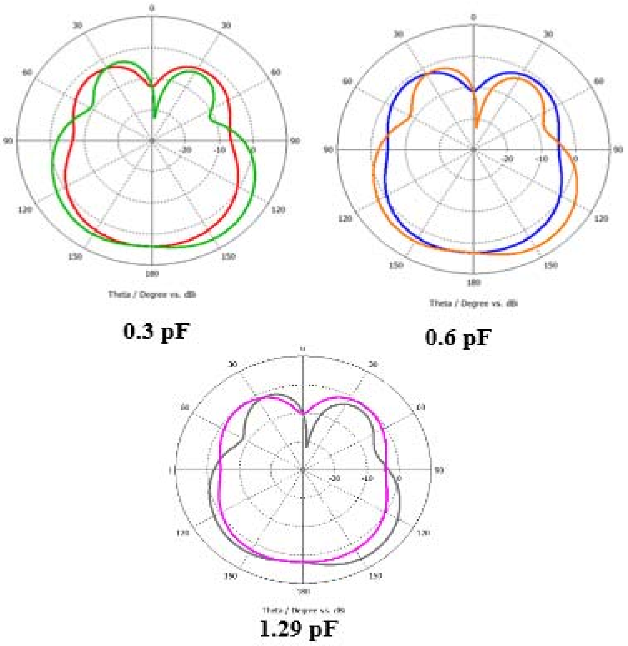


Fig. 7. Measured and simulated gain over frequency

Fig. 8 presents the simulated E- and H- plane radiation patterns in different states. Fig. 9 presents measured radiation patterns at all biasing cases. It can be observed that the antenna displays unidirectional radiation patterns in all states. Moreover, a symmetry radiation patterns are exhibited in all cases which is suitable for many wireless communication systems.

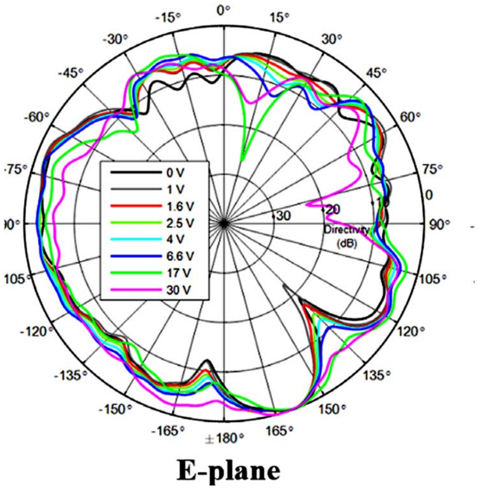


0.3 pF

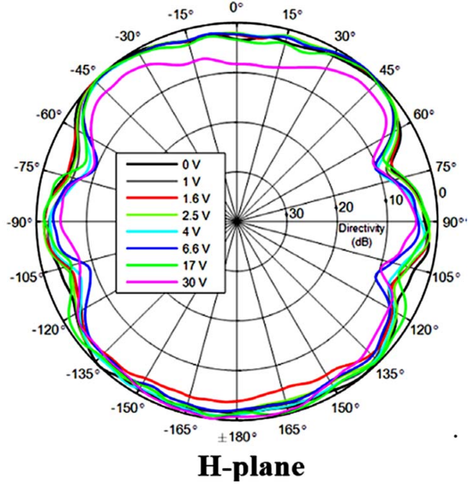
0.6 pF

1.29 pF

Fig. 8. Simulated 2-D radiation patterns (E- and H- planes) of the frequency reconfigurable SIW cavity backed antenna at different capacitance values: 0.3 pF, 0.6 pF, 1.29 pF.



(a)



(b)

Fig. 9. Measured E- and H-plane radiation patterns of the proposed antenna with varying the bias voltage from 0 to 30 V.

IV. CONCLUSION

A novel frequency reconfigurable SIW cavity-backed slot antenna has been studied, designed, fabricated, and measured. Results show that a stable unidirectional pattern and a tunable operating frequency can be realized.

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