A Dual-Band Multilayer SIW Cavity Backed Differential Slot Antenna

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***Abstract*—This paper presents the design of a differential dual-band three-layer substrate integrated waveguide (SIW) cavity-backed antenna. The SIW has three cross-shaped slots and two shorting pins to facilitate radiation and improve impedance matching. The measured fractional bandwidth of 1.2 and 2.06%, peak gain of 5.67 and 6.99 dBi, radiation efficiency of 79.75 and 92.78%, and cross polarization level more than 37.94 dB have been achieved at resonating frequencies of 10.66 and 11.64 GHz, respectively. The proposed antenna is suitable for X-band application by comparing its output parameters with the previously reported results**

***Index Terms*—Differential dual-band antenna, Multi-layer substrate integrated waveguide, Cross-shaped slots, Shorting pins.**

I. Introduction

The differential microwave circuits and devices are preferred in balanced transmitters and receivers due to their high immunity to external noise, extensive dynamic range, wider bandwidth, reduced electromagnetic interference, good linearity, and a lower offset. In addition, unlike the single-ended antennas, the differential antennas facilitate easy integration with other balanced circuits, for example, amplifiers, power dividers etc. Differential antennas eliminate using additional baluns. This, in turn, reduces losses and simplify the design of balanced transceiver systems [1]. Thus, the differential antennas are most suitable alternatives for the baluns resulting in good impedance matching and improvement of system radiation characteristics[2].

In the previously reported works, a compact funnel-shaped slotted antenna with four square-shaped patches was tested for the quarter-wavelength mode which yielded the better impedance bandwidth, and improved radiation characteristic [3]. Another study [4], demonstrated the differential fed dual-mode patch antenna by adding an absorbing stub to obtain the high gain and wide bandwidth. Lately, the dual-band filtering antenna has been investigated for achieving a narrow bandwidth, high isolation, common-mode suppression [5]. Also, a low gain antenna to implement the common-mode feeding [6] was demonstrated.

This paper presents a differential dual-band antenna fed with the rectangular SIW cavity designed with three layers of substrate and cross-shaped slots. The design allows to improve the radiation characteristics like peak gain, radiation efficiency, and cross-polarization level. Two shorting pins on the SIW side allow to improve the impedance bandwidth. The

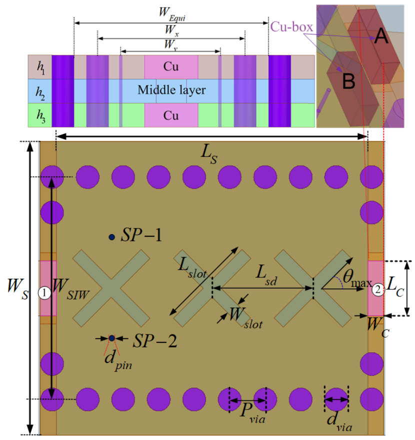

Fig. 1. Geometry and dimensions of proposed antenna.

differential feeds generate the differential signals and excite the TE_{120}-mode at two resonant frequencies (10.66 and 11.64 GHz) obtained using SP-1 and SP-2 pins. The simulations are confirmed by the experimental results measured on the laboratory prototype.

II. Antenna Design and Analysis

Fig. 1 shows the different views (side, top, and enlarged solid copper slabs (top right corner) views) of the proposed antenna. It is designed for X-band (8-12 GHz). Three layers of substrate are used for frequency distance reduction, lower cross-polarization level (CPL), and shorter time transients. The top layer (h_1), with etched bottom and cross-shaped slots for radiation, whereas the bottom of the last layer (h_3), with an etched top act as ground. The copper is removed on the top and bottom of the middle layer (h_2). The slabs are used for contacts with external feeds. In addition, four copper

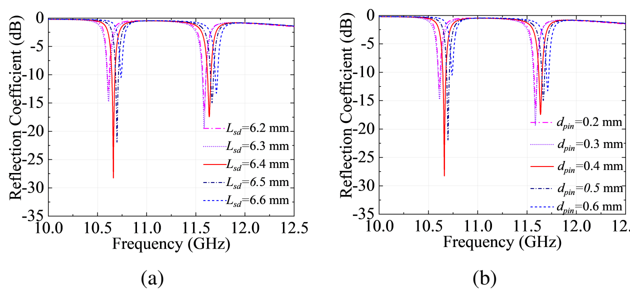

Fig. 2. Reflection coefficient dependence on: (a) L_{SD} (b) d_{pin}.

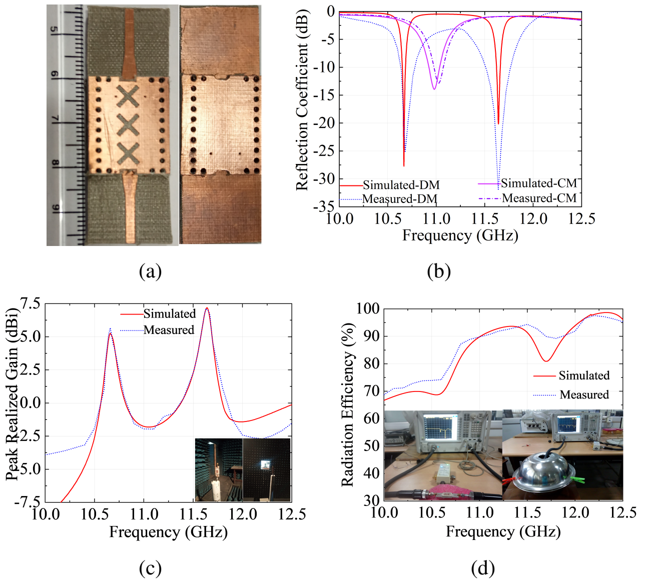

Fig. 3. Simulated and experimental results of proposed antenna: (a) Fabrication prototype, (b) Reflection coefficient, (c) Peak realized gain, and (d) Radiation efficiency.

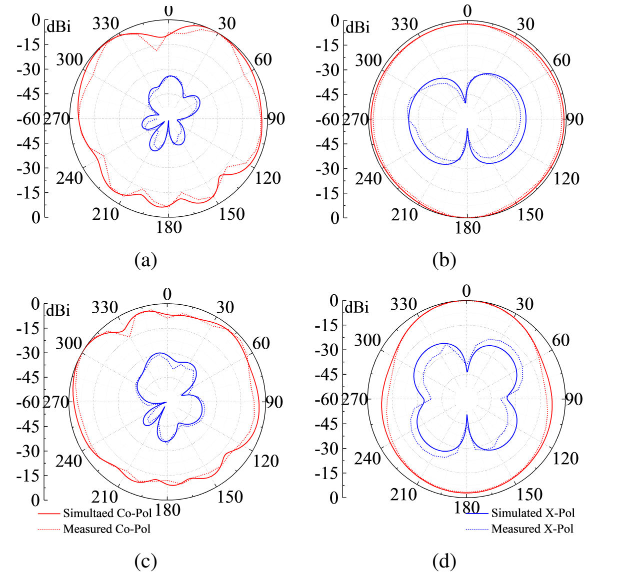

Fig. 4. Normalized radiation pattern: (a) E-plane, (b) H-plane at 10.66 GHz and (a) E-plane, (b) H-plane at 11.64 GHz.

solid slabs (volume: V) are inserted in layer-1 and layer-3 (A and B), as shown in Fig. 1 (top right corner). The solid slabs behave as a perfect electric conductors connected to the SIW cavity (excitation and ground). The structure dimensions are: $d_{via} = 1.4$, $P_{via} = 2.2$, $d_{pin} = 0.4$ $L_{SD} = 6.36$, $W_{slot} = 0.8$, $L_{slot} = 6$, $L_S = 19.28$, $W_C = 1$, $W_S = 18.2$, $L_C = 3.4$, $W_{SIW} = 14$, $V = 4.4 \times 1 \times 1.524$ mm^3, $W_{Equi} = 13.05$, $h_1 = h_2 = h_3 = 1.524$; unit: millimeters and $\theta_{max} = 45°$. Three cross-shaped slots and two shorting pins facilitate radiations and better impedance matching, respectively. The parametric study is carried out to optimize the distance (L_{SD}) between cross-shaped slots and diameter(d_{pin}) of shorting pins, as shown in Fig. 2. The best sizes are: L_{SD}=6.4 and d_{pin}=0.4 mm, respectively. The mode of propagation in the SIW cavity is TE_{120} at 10.66 and 11.64 GHz. The structure is designed using RO4232 substrate ($\varepsilon_r = 3.2$ and $\tan\delta = 0.0018$) and simulated with EM HFSS ver. 2020R2 software.

III. Experimental Validation

Fig. 3 (a) shows the top and bottom views of the laboratory prototype of the antenna and the simulated and measured results of return loss (RL), respectively. It shows the measured fractional bandwidth (FBW) 1.2 and 2.06% (simulate: 1 and 1.2%) respectively. Fig. 3 (c) depicts the measured values of peak gain at 5.67 and 6.99 dBi (simulated: 5.25 and 7.20 dBi). The radiation efficiencies are (Fig. 3 (d)) 79.75 and 92.78% (simulated: 76.02 and 86.25%) at resonating frequencies of 10.66 and 11.64 GHz, respectively. The measured and simulated results of the E-plane and H-plane radiation patterns (omni-directional in both planes) are shown in Fig. 4. The measured cross-polarization level (CPL) is below 37.94 dB for both bands. Thus, the experimental and simulated values of the antenna characteristic and parameters are in good agreement to each other. Table I presents a comparison of the present study with the previously reported results.

Table I
Comparison of Competitive Proposed Antenna

Ref.	f_L/f_H	FBW (%)	Peak gain (dBi)	RE (%)	CPL (dB)
[5]	5.14/5.8	2.7/2.6	4.91/5.12	NR	-35
[6]	4.1/4.9	3.2/3.9	4.36/4.83	≥ 80	-33
This work	10.66/11.64	1.2/2.06	5.67/6.99	79.75/92.78	-37.94

IV. Conclusion

In this work, a dual-band multilayer SIW cavity backed slot antenna is presented with a measured FBW of 1.2 and 2.06%, peak gain of 5.67 and 6.99 dBi, radiation efficiency of 79.75 and 92.78%, and cross polarization level more than 37.94 dB at the resonating frequencies of 10.66 and 11.64 GHz, respectively. The designed antenna proves its suitability for X-band application.

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