Dielectric Resonator loaded Substrate Integrated Waveguide Cavity Backed Slot Antenna for Bandwidth Enhancement

Abhishek Sharma[1], Soumava Mukherjee[2], Animesh Biswas[3]
Dept. of Electrical Engineering
Indian Institute of Technology Kanpur
Kanpur-208016, Uttar Pradesh, INDIA
E-Mail: [1]sharma@iitk.ac.in, [2]soumavam@gmail.com, [3]abiswas@iitk.ac.in

***Abstract*—In this paper, a substrate integrated waveguide cavity backed slot antenna with dielectric resonator loading in X-Band is presented. With loading, enhanced impedance bandwidth ($S_{11} < -10$ dB) of about 11.74% is obtained without much affecting its gain and radiation pattern. The peak gain of proposed antenna is about 5.6 dBi with maximum cross polarized radiation level of -30 dB. The simulation of proposed antenna is carried out in Ansys HFSS.**

I. Introduction

Planar slot antennas are in great demand for wireless communication due to their numerous advantages such as low profile with good radiation performance, conformability, easy integration with planar microwave circuits. But it suffers from bi-directional radiation characteristics and narrow bandwidth. The bi-directional radiation nature can be eliminate by using a metallic cavity beneath the antenna. The use of metallic cavity also improves the gain but at the cost of increased weight due to the non planar nature of metallic cavity [1]-[2]. The development of substrate integrated waveguide (SIW) [3] technology helps to implement the waveguide like structures in planar form.

Lou *et. al.* [4] has proposed the planar slot antenna backed by SIW cavity to make the design low profile and fully planar. The proposed antenna is center-fed by using grounded co-planar waveguide (GCPW) constructed on the same substrate. An impedance bandwidth of about 1.7%, with 5.4 dBi gain and -19 dB maximum cross polarized radiation level has been obtained. An effort has been made by Mukherjee *et.al.* [5] to further improve the bandwidth of cavity backed slot antenna using offset feeding instead of center feeding. An impedance bandwidth of about 4.2% has been achieved, with 5.6 dBi gain and -30 dB maximum cross polarized level.

The loading of dielectic resonator (DR) on the antenna has proven a useful technique to improve the impedance bandwidth [6]-[8]. In this paper, an effort is made to further improve the bandwidth of SIW cavity backed slot antenna (SCBSA) by DR loading. The dimensions of slot, DR and feed position are further optimized to get the wide bandwidth performance in X-Band. The rest of the paper is organized as follows. Section II discusses the antenna design. Simulation results are provided in Section III. Finally, the paper is concluded in Section IV.

II. Antenna Design

The top view of the cavity backed slot antenna without and with DR is shown in Fig. 1(a) and 1(b), respectively. The proposed antenna is designed with RT Duroid 5880

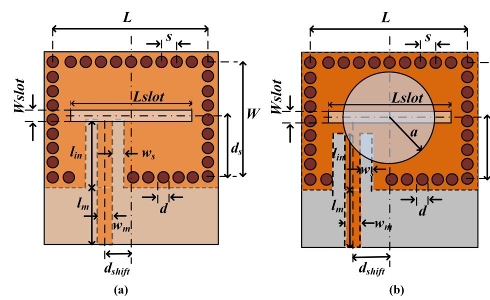

Fig. 1. Top View of proposed antenna. (a) **SCBSA:** L=16.72mm, W=15mm, d=1mm, s=1.6mm, w_m=2.42mm, w_s=1.22mm, l_{in}=8.2mm, l_m=5mm, d_{shift}=2mm, L_{slot}=12mm, W_{slot}=*1mm*, d_s=8.2mm (b) **SCBSA with DR:** l_{in}=7mm, d_{shift}=3.7mm, L_{slot}=13.2mm, a=6.7mm

substrate whose height is 0.787mm. The dielectric constant and loss tangent of substrate is 2.2 and 0.0009, respectively. The slot is etched on the upper metallic plate of the SIW cavity whose side walls are formed using the metallic vias. The diameter d, and pitch s of the vias are designed to satisfy the minimum leakage design criteria i.e. $\frac{d}{s} > 0.5$ and $\frac{d}{\lambda_0} < 0.1$ [3]. The antenna is fed using 50Ω GCPW line constructed on the bottom plate of SIW cavity. An offset feeding is used to enhance the impedance bandwidth. The offset feeding technique was first proposed by Cassivi *et. al.* [9] which helps to excite all the possible modes in the resonating cavity. Later in [5], it has been shown that the input impedance seen by the feeding port of SIW cavity backed slot antenna can be modified by shifting the feeding line from the center line of the cavity as shown in Fig. 1(a) and helps to improve the impedance matching of the antenna. In [5], the placement of the slot is optimized by Ansys HFSS such that the slot antenna disturbs the current path of TE_{120} mode of the SIW cavity which is excited by the proper choice of inset and offset of the feedline.

The SCBSA proposed in [5] is loaded with DR (Fig. 1(b)) which is placed symmetrically with respect to the slot to further enhance the bandwidth. The dielectric constant of DR is 2.2 with loss tangent 0.0009. The height of DR is 6.7mm and is designed to resonate at 9.9 GHz. After loading the antenna with DR, the slot length and feed position are further optimized so that the resonance of both slot and DR are in close proximity to get the wide band performance.

III. Simulation Results

The simulation is carried out using Ansys HFSS which is based on Finite Element Method (FEM). The simulated response of the proposed antenna is shown in Fig. 2. The antenna resonates at 8.69 GHz which corresponds to the slot antenna resonance and at 9.34 GHz which corresponds to the resonance of DR. The impedance bandwidth ($S_{11} < -10$ dB) of SCBSA is 430 MHz (4.2%) which is increased to 1.05 GHz (11.74 %) after loading the antenna with DR. The mode responsible for radiation in SCBSA is TE_{120}. The surface current distribution in the cavity at 8.69 GHz and 9.34 GHz is shown in Fig. 3(a) and 3(b), respectively. The current is out of phase at the opposite side of the slot at 8.69 GHz which helps it to radiate into free space. The field concentration inside the DR at 9.34 GHz is more than at 8.69 GHz as shown in Fig. 3(c) and 3(d). This confirms that the DR is radiating at 9.34 GHz with $HE_{11\delta}$ mode while at 8.69 GHz it is acting as a medium for radiation from slot antenna. The normalized radiation pattern of the proposed antenna is shown in Fig. 4. The radiation pattern is stable throughout the matching band. The cross polarized radiation level is below -30 dB in the direction of maximum radiation. The antenna shows a peak gain of 5.6 dBi and is almost constant throughout the bandwidth as depicted in Fig. 2.

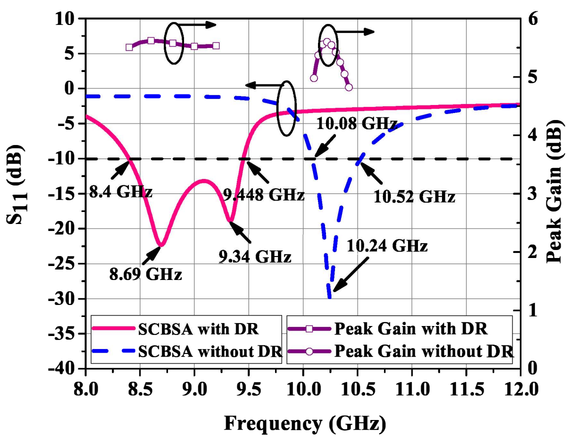

Fig. 2. Simulated S_{11} (dB) and peak gain (dB) of the proposed antenna

IV. Conclusion

The impedance bandwidth of SIW cavity backed slot antenna has been increased approximately three times using DR loading. The gain and the radiation pattern is not much affected by DR loading. The peak gain of 5.6 dBi has been achieved with consistent radiation pattern and low cross-polarization level throughout the impedance bandwidth.

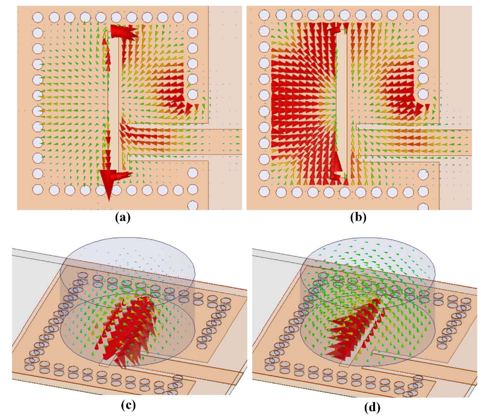

Fig. 3. Surface current distribution in cavity (a) at 8.69 GHz (b) at 9.34 GHz and Electric field distribution in DR (c) at 8.69 GHz (d) at 9.34 GHz

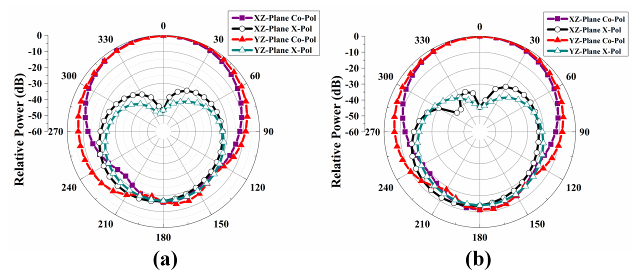

Fig. 4. Normalized radiation pattern of the proposed antenna: (a) 8.69 GHz (b) 9.34 GHz

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