Modified Substrate Integrated Wave Guide (SIW) Horn Antenna

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***Abstract*—A modified substrate integrated waveguide (SIW) horn antenna is proposed in this paper. A probe is used as the feed line of the antenna in order to avoid parasitic radiation and high conductor loss. The proposed antenna is numerically investigated using HFSS software package. Radiation properties of the antenna including reflection coefficient, gain and radiation patterns are reported and compared with those of a conventional SIW horn antenna of the same sized aperture. Results show that wider impedance bandwidth and higher gain can be obtained by the proposed antenna.**

***Index Terms*— Horn antennas, half mode substrate integrated wave guide (HMSIW), coaxial line.**

I. INTRODUCTION

Recently the substrate integrated waveguide (SIW) technology has widely used in implementation of microwave devices and antennas [1-9]. Horn antenna is one of the antennas implemented by this technology. There are few published researches on SIW horn antennas. In [10] an integrated H-plane horn antenna is proposed. In [11] a dielectric slab is added to the SIW H-plane horn antenna in order to have narrow beam widths both in E-plane and H-plane. In [12] a broadside horn antenna is implemented by SIW technology. In [13-14] half mode substrate integrated wave guide (HMSIW) technique is used to provide a minimized horn antenna.

In this paper, a modified SIW horn antenna is introduced. The proposed structure can be interpreted as a 1×2 array of HMSIW horn antenna presented in [14]. The proposed antenna is numerically investigated using HFSS software and its radiation properties are investigated. The results are also compared with those obtained for a conventional SIW horn antenna of the same sized aperture. It was observed that wider impedance bandwidth and higher gain can be obtained by the proposed antenna.

II. ANTENNA DESIGN AND CONFIGURATION

The proposed antenna with its geometrical parameters is depicted in Fig. 1. As illustrated, the proposed structure is constructed by the 1×2 array of HMSIW horn antenna presented in [14]. In this scheme, the sectoral horn is integrated to a rectangular waveguide by a single substrate using SIW technology and fed by a 50 ohm coaxial line with the inner radius of R_1 and outer radius of R_2. Using probe for feeding is to eliminate the drawbacks caused by microstrip feed line. Microstrip line feeding of SIW horn antenna suffers from parasitic radiation, which may degrade E-plane radiation pattern of the horn antenna. Moreover, high conductor loss at high frequencies, reduce radiation efficiency of the antenna. Conversely, using a probe as the antenna feed, the above mentioned imperfections are avoided.

The width a_1, the substrate thickness b, the working frequency f and the dielectric constant ε_r are chosen in such a way that, the single mode TE_{10} can propagate in SIW waveguide. Metallic grooves are used to construct the side walls of SIW. The gaps between grooves are so small that the power is caged inside the structure and the leakage from the side walls of SIW is negligible.

As mentioned before, the proposed antenna is constructed by the 1×2 array of HMSIW horn antenna presented in [14] so the design process of proposed antenna is based on the design process of antenna introduced in [14].

The geometrical parameters of the proposed antenna and their values are listed in Table I. Rogers TMM4 with ε_r of 4.5, thickness b of 2.5mm and loss tangent of 0.002 is used as the substrate. Parameter h, the height of the probe feed, affects the insertion loss at the operating frequency. By the full wave optimization, the value of 1.8 mm is determined for h to obtain minimum insertion loss at the vicinity of 28 GHz. The proposed SIW horn antenna shown in Fig. 1 is simulated and its results are presented in the next part.

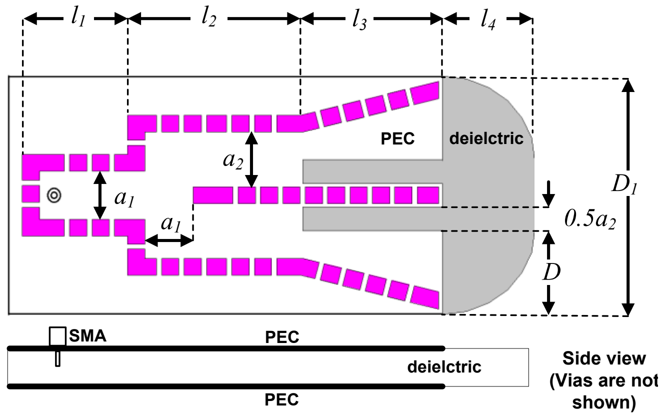

Fig. 1. Topology of modified SIW horn antenna.

TABLE I. GEOMETRICAL PARAMETERS OF THE DESIGNED ANTENNA

Para	Value (mm)	Para	Value (mm)
a_1	3.7	l_1	8
a_2	4.2	l_2	13.3
D	6.39	l_3	10.628
D_1	18.29	l_4	9
R_1	0.2175	b	2.5
R_2	0.5		

III. RESULTS AND DISCUSSION

The proposed antenna is simulated and its performance is compared with the conventional SIW horn antenna of the same size. For comparison, a conventional dielectric loaded SIW horn with the same dimensions is designed and simulated. For the designed conventional SIW horn the length of horn sector, the width of aperture and the length of dielectric slab are chosen 21.62mm ($\approx l_2+l_3$), D_1 and l_4 relatively. The designed conventional SIW horn is also fed by a probe fed SIW with the length of l_1 and width of a_1.

The field distribution of the designed antenna at 28GHz is illustrated in Fig. 2. It can be observed that the electric field across the antenna aperture is the combination of two electric fields related to the two dielectric loaded HMSIW horn antennas which means that the proposed antenna acts as a 1×2 array of HMSIW horn antennas. In this figure, a quite uniform phase front at the aperture of antenna can be observed which reveals that the quadratic phase error has been removed in the proposed horn antenna.

The reflection coefficients of proposed horn antenna and conventional SIW horn antenna are shown in Fig. 3. It is observed that the impedance bandwidth is improved for the proposed horn antenna. The fractional impedance bandwidth for conventional SIW horn and the proposed horn is 1.8% (27~27.5GHz) and 5.6% (26.64~28.14GHz) respectively.

In Fig. 4 the variation of gain over impedance bandwidth is investigated for both conventional SIW horn and the proposed horn antennas. It can be observed that higher gain can be obtained by the proposed antenna. The maximum gain of 10.3dB is obtained for conventional SIW horn however for the proposed horn antenna the maximum gain of 11dB is achieved. For the proposed antenna, the variation of side lobe level (SLL) in both E-plane (X-Z plane) and H-plane (X-Y plane) over the antenna impedance bandwidth is investigated. Results are shown in Fig. 5 in which it is revealed that the reduction of gain at the vicinity of 27.6 GHz is due to SLL enhancement.

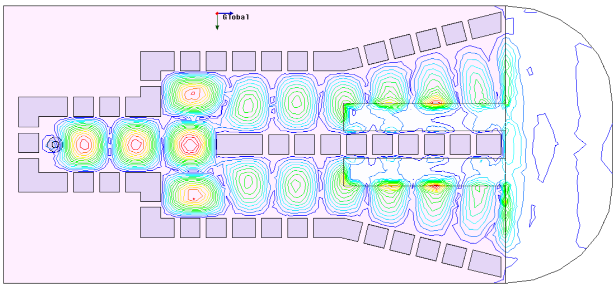

Fig. 2. Field distribution in the designed modified SIW horn antenna @ 28GHz.

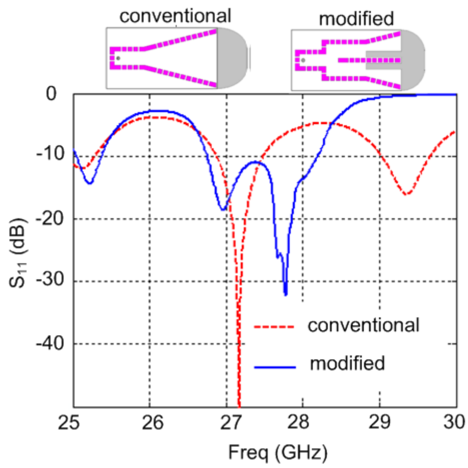

Fig. 3. Reflection coefficient for proposed modified SIW horn and conventional SIW horn antenna.

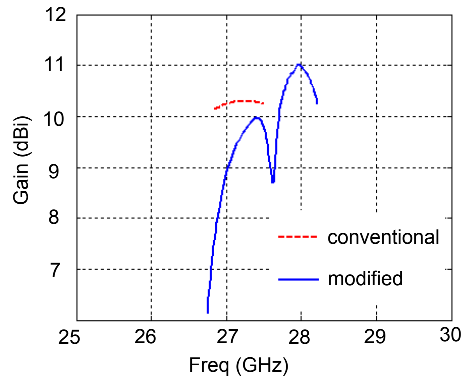

Fig. 4. Gain variation over antenna impedance bandwidth for both proposed modified horn and conventional SIW horn antenna.

In Fig. 6 the Radiation patterns of proposed antenna in E-plane (X-Z plane) and H-plane (X-Y plane) are illustrated. The radiation patterns are shown at 28GHz. Narrow beams in both E and H planes and cross polar level (CPL) of below -25 dB are observed. The beam width variation of the designed antenna in both E-& H-planes is also depicted in Fig. 7.

IV. CONCLUSION

In this paper a modified SIW horn antenna is presented and numerically investigated using HFSS. A coaxial line is used for feeding in order to eliminate spurious radiation due to the feed network. Also conductor loss is low by probe excitation of antenna which leads to high radiation efficiency, which is important in high frequency communication systems. Numerical results illustrate that by proper choosing of the geometrical parameters, the proposed antenna provides wider impedance bandwidth in compare with conventional SIW horn antenna of the same size.

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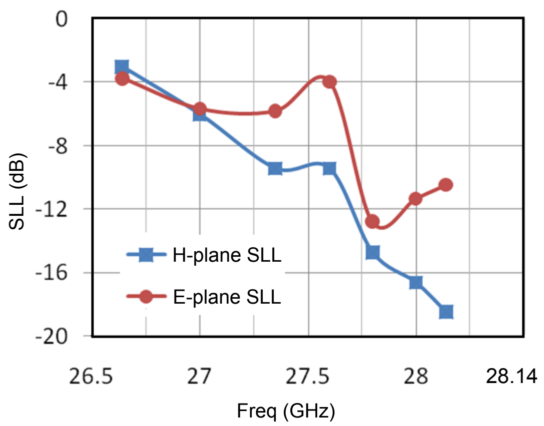

Fig. 5. Side lobe level (SLL) variation of the proposed antenna over its impedance bandwidth.

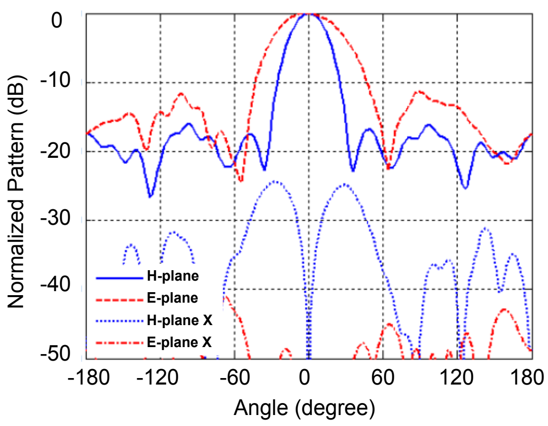

Fig. 6. Normalized radiation patterns of proposed antenna in E-& H planes @ 28 GHz.

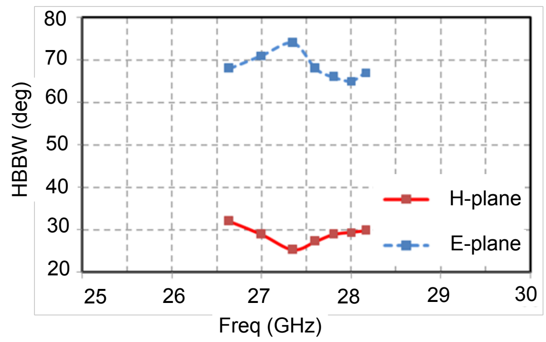

Fig. 7. Beam width variation of the designed antenna in both E-& H-planes over its impedance bandwidth.