

# Development of a Compact H-Plane SIW Horn Antenna with High Directivity

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**Abstract**— In this paper a new low profile, substrate integrated waveguide H-plane horn antenna with high directivity is introduced. In order to suppress parasitic radiation and to reduce conductor loss of the feeding structure, a coaxial probe is used to excite the antenna. The proposed SIW horn antenna is numerically studied using High Frequency Structure Simulator (HFSS) software. Radiation performance of the proposed antenna including reflection coefficient, radiation patterns and directivity are reported and compared with those for a conventional SIW horn. Results illustrate that the new structure provide directivity of 8.8 dBi, which is 1.9 dBi more than the directivity of the conventional H-plane SIW horn, while its size is only 60% of the conventional SIW horn at the centre frequency of 27 GHz.

**Keywords:** *Antenna, Substrate Integrated Waveguide (SIW), Horn Antenna.*

## I. INTRODUCTION

Horn antennas have been widely used at microwave frequencies as feeder of the reflector antenna systems. Unlike the bulky geometry of conventional horns using metallic waveguides, low profile horn structures designed in planar form are very suitable in practical communication systems subject to available space. The planar horn antennas are compatible with microwave and millimeter-wave circuits and provide convenient way in array applications.

Recently, substrate integrated waveguide (SIW) technology has been proposed to make planar rectangular waveguides [1-5]. The SIW structures provide a few important features such as low profile, light weight, easy integration with planar circuits especially in a production line.

Most of the previous published researches on the horn antennas are based on SIW technology. An integrated H-plane horn is proposed using [6]. A dielectric loaded SIW H-plane horn antenna is presented in order to obtain high gain and narrower beamwidths in both E- and H-planes[7]. In [8] a broadside horn antenna is implemented by SIW technology.

In this paper, a new types of an H-plane horn SIW is designed and studied at 27 GHz. The proposed antenna is the modification of the SIW horn structure introduced in [9]. The introduce SIW horn is numerically investigated using High Frequency Structure Simulator (HFSS). It is shown that directivity of the proposed antenna is improved, whereas its size is lower than the size of the conventional horn. The numerical results of the proposed horn is presented and compared with those obtained for the conventional SIW horn.

## II. ANTENNA STRUCTURES

The geometry of the conventional H-plane SIW horn antenna is illustrated in Fig 1. In this antenna, the sectoral horn is integrated to a rectangular waveguide by the substrate of SIW structure. They are fed by a 50  $\Omega$  coaxial line with inner radius of  $R_1$  and outer radius of  $R_2$ . The antenna is made on a single layer Rogers TMM4 substrate with  $\epsilon_r = 4.5$ , tangent loss of 0.002 and height of  $h$ . The distance between two adjacent Vias  $W$  and the radius of each one  $R$ . The design rules for rectangular and sectoral portions of the horn follow the similar principles as for the metallic conventional horns and, therefore, the same techniques can be used to improve the radiation performance of the antenna.

The geometry of the new structure H-plane horn antenna, named structure I, is illustrated in Fig. 2-a. A rectangular portion with width of  $a/2$  and length of  $L_3$  is etched at the top and bottom of the SIW ground. Compared with the conventional horn, it consists of two radiation apertures 1 and 2 with the size of  $a/2$  and  $D_2/2$  respectively. Total radiation aperture length of the proposed structure is equal to 60% of the length of conventional horn aperture. To obtain field distribution with same phase on two radiation apertures,  $L_3$  is equal to integer values of guided wavelength.

To improve radiation performance of the proposed antenna, structure II is introduced by adding a reflector plate around the radiation aperture 2 of the structure I, which is shown in Fig 2-b. Both structures are made on a single substrate using TMM4 and are fed by a coaxial probe same as the feeding structure of the conventional horn. The geometrical parameters of

proposed antennas including conventional horn are listed in Table I.

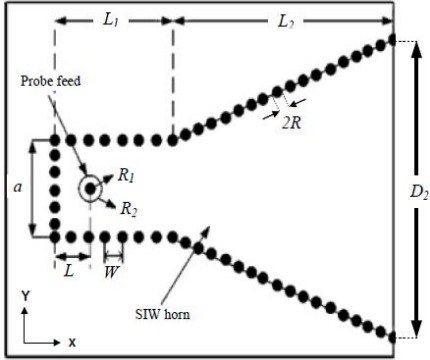


Fig. 1: Geometry of the conventional SIW H-plane horn antenna.

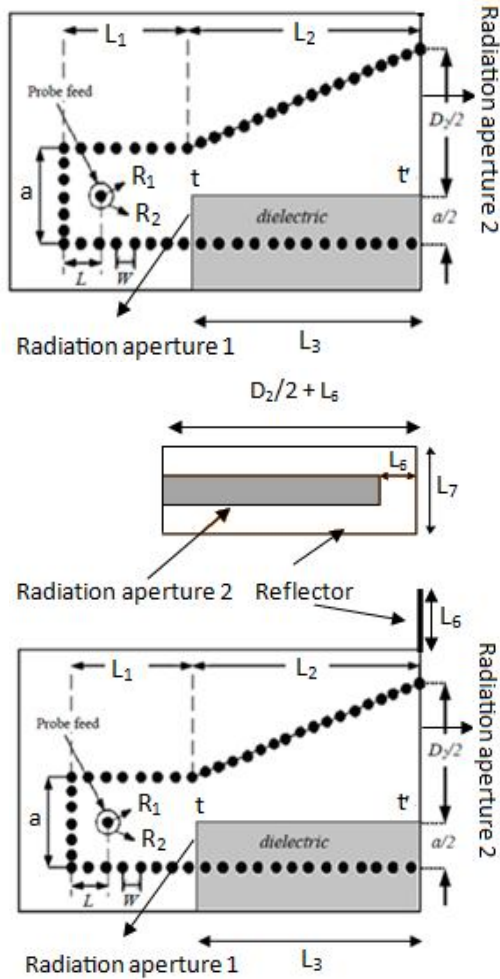


Fig. 2: Geometry of the antennas proposed, a) structure I, b) structure II.

### I. RESULTS AND DISCUSSION

Reflection coefficient of the two new structures including to that of the conventional SIW horn antennas are plotted in Fig. 3 versus frequency. It can be seen that they nearly provide same frequency response with the centre frequency of around

27 GHz. They are well matched with nearly same impedance bandwidth.

Table 1: Geometrical parameters of different horn antennas (all dimensions in mm)

Parameter	conventional horn	Modified horn	Modified horn with reflector
$D_2$	14	14	14
$L_1$	7	7	7
$L_2$	10	10	10
$L_3$	-	10.6	10.6
$L$	1.8	1.2	1.2
$a$	5	5	5
$h$	2.5	2.5	2.5
$W$	1	1	1
$R_1$	0.5	0.5	0.5
$R_2$	0.2175	0.2175	0.2175
$R$	0.4	0.4	0.4
$L_6$	-	-	0.8
$L_7$	-	-	5

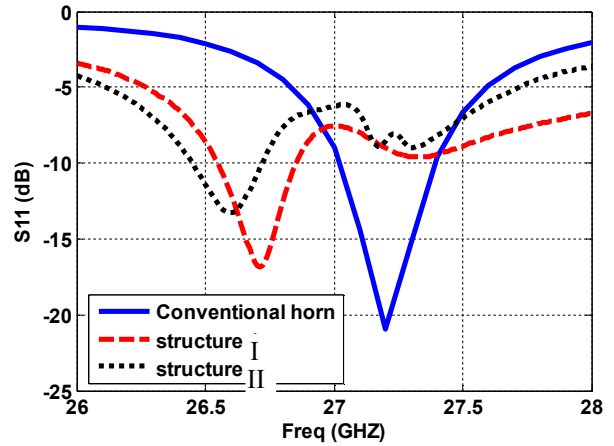


Fig. 3: Simulated  $S_{11}$  of different horn antennas.

Numerical results for field distribution at the radiating aperture for conventional horn and structure 1 are plotted in Fig. 4. It can be seen that field distribution for the modified horn is more uniform than that of the conventional horn.

Fig. 5-a and Fig. 5-b show radiation patterns of all horn antennas. It can be seen that the beamwidth of H-plane all horns are nearly the same, while for the new structures E-plane patterns provide narrower beamwidth than that of the conventional horn. This is due to that dielectric portion of the structure in front of aperture 1 with a length of  $L_3$ , operates as a dielectric lens [7] and hence, antenna directivity is highly improved. Also, for the second new structure Side Lobe Level (SLL) is lower than the SLL of the structure I at both E- and H-plane.

It can be concluded that in spite of reducing the length of radiation aperture of structure I compared to that of the

conventional horn, H-plane beamwidth remain unchanged. This is due to uniform field distribution along the radiation aperture of the new structure.

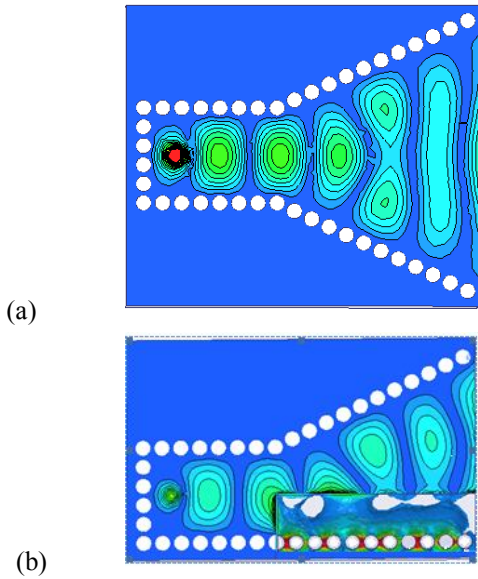


Fig. 4: Simulated E-field distribution along radiation aperture, a) conventional horn, b) structure I.

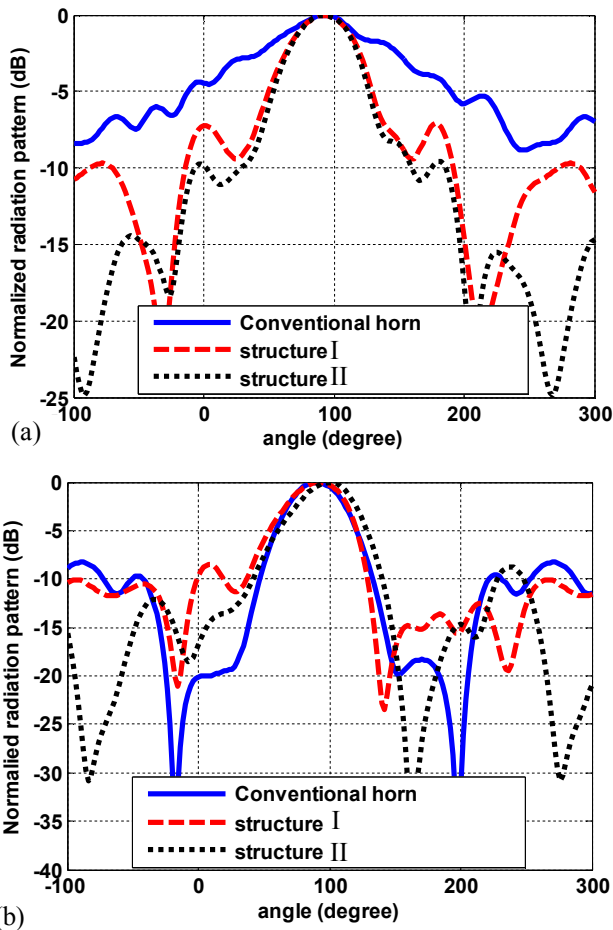


Fig. 5: Simulated radiation patterns of all horn antennas: a) E-plane, b) H-plane.

In order to improve backward radiation of the proposed structure I, a reflector metallic plate is located around the radiating aperture 2. The 3-dimensional view of the structure, which is made by HFSS is shown in Fig. 6. Fig. 5-b shows that Front to Back Ratio (FTBR) is effectively enhanced for the structure II. Our study shows that extending the reflector plate around all radiation apertures would affect radiation patterns and antenna directivity is not improved.

To study the effect of reflector height on the radiation performance of the structure II, a parametric study is carried out. The variation of SLL and antenna directivity of the proposed structure II is shown in Fig. 5 versus  $L_7$  the length of reflector. It can be seen that with increasing  $L_7$  up to 5 mm directivity and SLL is improved. Further increasing  $L_7$  from 5 mm SLL and directivity is not changed.

Simulation results for the proposed antenna including radiation performance of conventional horn and with those of the structure presented in [9] are summarized in Table II.

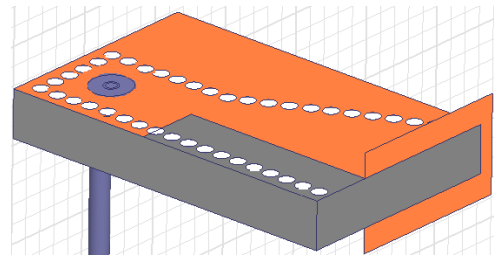


Fig. 6: The 3-dimensional view of the proposed structure with reflector in HFSS.

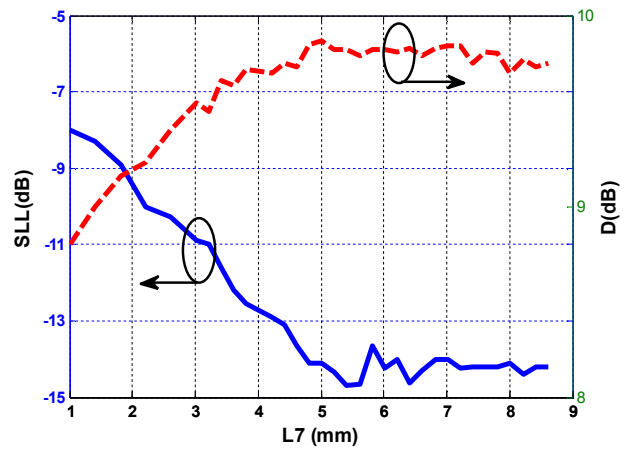


Fig. 7: Simulation results of directivity and  $SLL$  versus  $L_7$  for horn structure II.

#### IV. CONCLUSIONS

In this paper a new technique is proposed to improve directivity of the Substrate Integrated Waveguide (SIW) H-plane horn antennas. In the new structure, a rectangular portion with suitable width and length is etched at the top and bottom of the SIW ground of the conventional SIW horn. Compared with the conventional horn, antenna size is lowered while total radiation aperture length of the proposed structure

Table II: Radiation performance of the investigated SIW horn antennas

Parameter	Conventional horn	Structure I	Structure II	SIW horn in [9]
Centre frequency (GHz)	27.2	26.6	26.55	27.1
H-plane half power beam width	48°	48°	48°	57°
E-plane half power beam width	124°	62°	60°	140°
Directivity (dB)	6.9	8.8	9.8	6.4
Front to Back Ratio (dB)	6.7	8.7	16.5	6.4
Side Lobe Level (dB)	-18	-8	-15	-10
Antenna size (mm <sup>3</sup> )	18.5×15.8×2.5	18.5×11.56×2.5	18.5×11.86×5	18.5×11.86×2.5

is nearly halved, which lead to uniform field distribution along radiation aperture. Also, using dielectric lens in front of a portion of radiation aperture would decrease E-plane beamwidth and hence, antenna directivity is highly improved. The results show that proposed antenna with reflector plate provides 9.8 dB directivity, SLL of -15 dB and FTBR of 16.5 dB.

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