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DESIGN OF SIW HORN ANTENNA WITH METAMATERIAL

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Abstract— *In this paper, a mushroom type metamaterial (rectangular patch with via) is place in front SIW horn antenna. Here the horn antenna is placed in front of metamaterial with and without in order to analyze the* $|S_{11}|$*. By the metamaterial, radiation pattern is observed. For the SIW horn antenna, the operating frequency is 15GHz with the substrate FR-4. When the metamaterial is loaded at the horn antenna, the bandwidth is improved. This improvement is due to the metamaterial as it is acting as an impedance transformer. The directivity of the gain is achieved in both with and without mushroom type metamaterial.*

Keywords: *Substrate integrated waveguide, Mushroom type metamaterial (rectangular patch with via), and horn antenna*

I. INTRODUCTION:

Substrate integrated waveguide (SIW) is a new concept for planar waveguide structure, which exhibits the low profile, low insertion loss, simple manufacturing, easy integration with other planar circuits. In particular, the feeding of surface-wave or leaky-wave antennas, the SIW H-plane horn antenna. The conventional horn antenna, the SIW horn antenna has a distinct shortcoming: The inside horn antenna contains a dielectric material, and some electromagnetic waves will be reflected at the boundary of the antenna aperture due to the permittivity difference [1]. The horn antenna is probably and widely used microwave antenna that provides a transition between waves propagating in a transmission line and waves radiating in the free space. However, their bulky geometry sometimes limits their application in the compact forms. The substrate integrated waveguide (SIW) technology has employment of the planar horn antennas to be integrated into the microwave and millimeter-wave circuits. The H-plane sectoral horn, which is formed by flaring the rectangular waveguide in the plane normal to the electric field, can be accomplished by SIW technology. Since then, have been reported on the substrate integrated H-plane horn antenna [2]. Substrate integrated waveguide (SIW) technology allows the implementation of rectangular waveguide functionalities into compact planar structures.The size reduction can be obtained with folded, half-mode, and quarter-mode SIWs. Therefore it was a quite obvious step to use SIW for the development of planar horn antennas, showing low profile and weight and able to fabricate in a single dielectric substrate. Similar to classic all-metal horn antennas, the phase distribution of the electric field in the aperture of a planar SIW-based horn is not uniform. This may results a sizeable reduction of the aperture efficiency and hence in a low antenna gain. The phase distribution and to enhance the gain. Some dielectric slabs and lenses are used as terminating loads in the horn aperture, to serve both as a guiding structure and a phase corrector. The metal-via arrays are embedded inside the horn to emulate a perfect electric conductor
(PEC) boundary condition. This can be used to change the propagation constant of the mode, thus correcting the aperture phase and improving the gain. [3].These new circuits combine the classical non planar technologies (waveguide or coaxial transmission lines) such as high quality factors, and the benefits of planar circuits such as low cost and easy compact. In this, substrate integrated waveguide (SIW) allows to construct types of commonly used antennas. However, different limitations are used for the substrate that appear for implementation of certain types of antennas, i.e. low efficiency as frequency is increased due to dielectric loss, strong mismatch as a consequence of the use of thin substrate layers, and high reflection at the end of the aperture caused by the impedance difference between the dielectric and air [4]. Due to its planar structure, simple fabrication, easy integration, the substrate integrated waveguide (SIW) horn antenna has many applications. It is known that due to the mismatch between the substrate inside the horn antenna and the free space at the horn aperture, the planar SIW horn antenna works in a narrow band. Solution based on loading extended substrate provides a straightforward method to reduce the mismatch [5]. The substrate integrated waveguide (SIW) technology is a very especially for systems operating in the millimeter-wave region. The most significant SIW is the possibility to integrate all the components on the same substrate, including passive components (filters, couplers, etc.), active elements (oscillators, amplifiers, etc.) as well as antennas. This allows the possibility to create substrate integrated circuits (SICs) [6].

II. ANTENNA DESIGN:

A. METAMATERIAL:

Metamaterials are recently developed artificial materials .It's the only material in the world having negative permittivity, negative permeability and negative refractive index simultaneously. Due to having these three permeability it exhibits unusual properties compared to readily available materials.

In Greek word Meta means beyond, Materials are named so these as exhibit properties beyond the properties of naturally available materials. Metamaterials is not a special type of material, if an array of structure of any metal will be able to change the electric and magnetic property of the wave passing through it and leads to negative permittivity and refractive index simultaneously, that metallic structure can be called as metamaterials.

B. UNIT CELL DESIGN:

In this a unit cell metamaterial is designed in order to measure the characterization of the unit cell. In this rectangular patch the port has been placed at the two sides. The work is done in HFSS software. The diameter d of the via is 1.6mm and the rectangular patch with a=5mm and b=8mm.

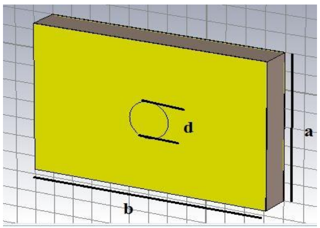

Fig 1(a) Via unit cell design

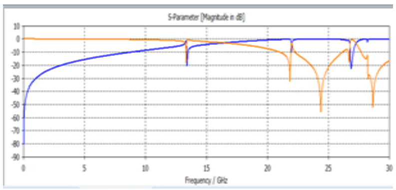

Fig 1(b) Characterization of unit cell

C. SIW HORN ANTENNA WITH METAMATERIAL:

The SIW horn antenna and the mushroom-type metamaterial (rectangular patch with via). The SIW horn antenna with 1.6mm-thickness FR-4 substrate. The metalized vias with radius 0.5mm. Arrays of metallized vias terminated with rectangular metallic patches is placed in front of the horn antenna. The metamaterial structure is determined by the via diameter *d*, gap *g*.

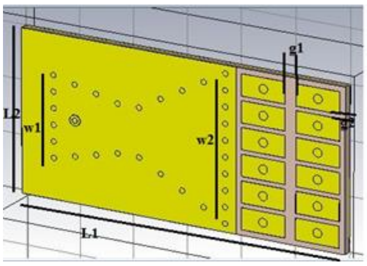

Fig 2(a) Perspective view

The L1=60mm, L2=30mm, d=1mm, g=10mm, g2=4.8mm and w2=40mmis given and the coaxial feeding with the diameter 1.5mm. The horn shape via has distance between them is 3 and 10mm .

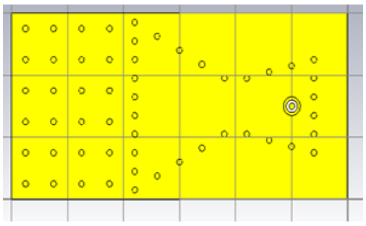

Fig 2(b) Back view

The feeding probe with diameter is inserted to avoid radiation loss. The feeding is given at the bottom to top of the layer. The port is assumed at the bottom of the coaxial feeding.

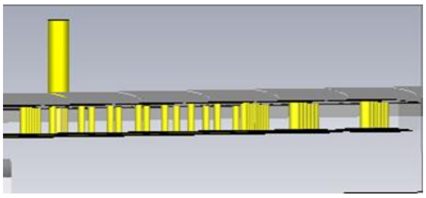

Fig 2(c) Bottom view

The SIW horn antenna is full of vias with copper is inserted between the substrate FR-4 and the mushroom type metamaterial placed in front of the horn antenna is shown in Fig 2(a) .Coaxial feeding is assumed to avoid the radiation loss and port has been assumed at the bottom of the feeding is shown in Fig 2(b). The vias arrangements are shown in Fig 2(c). The vias and patches are filled with copper and the above the substrate and ground are also copper is placed.

D. SIW HORN ANTENNA WITHOUT METAMATERIAL:

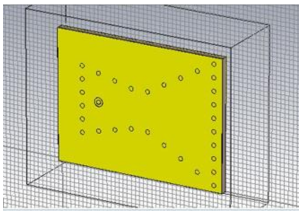

Fig 3(a) Perspective view

Here the vias are inserted between the substrate in horn shape and above the substrate a copperplate is placed is shown in Fig 3(a) and the vias arrangement of the horn shape is shown in Fig 3(b).

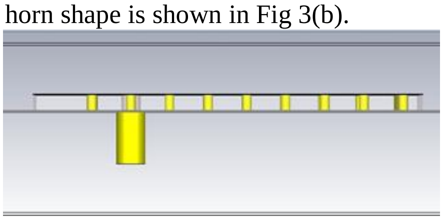

Fig 3(b) Bottom view

PARAMETERS USED:

Table 1: Parameters used

Parameters	**Materials Used**
Substrate	FR-4
Vias	Copper
Patch	Copper
Ground	Copper

III. RESULT AND DISCUSSION:

The result that analyzed between SIW horn antenna with metamaterial and SIW horn antenna without metamaterial.

A. RESULT OF SIW HORN ANTENNA WITH METAMATERIAL:

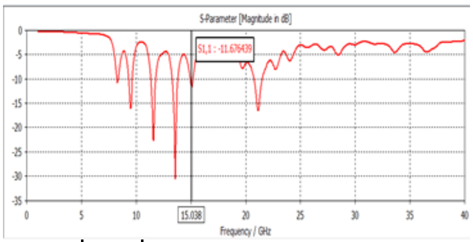

Fig 4(a) │S11│ of SIW horn with metamaterial

When placing the mushroom type metamaterial in front of the SIW horn antenna the │S_{11}│is achieved below -10dB Fig 4(a) is shown above and the frequency range achieved 15GHz.

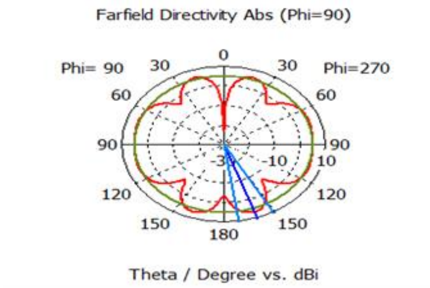

Fig 4(b) Polar plot

The polar plot is shown in Fig 4(b) for the 15GHz and the directivity gain has been achieved 6.43dBi and bandwidth is improved. The far field radiation pattern is shown in Fig 4(c).

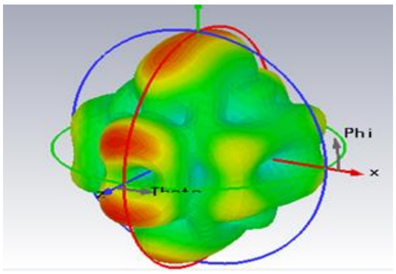

Fig 4(c) radiation pattern

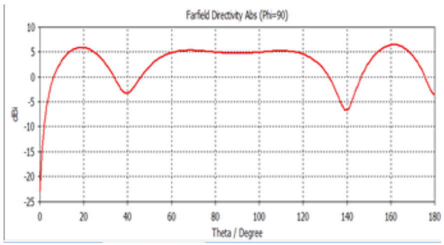

Fig 4(d) Directivity of SIW horn with metamaterial

The directivity of the gain is achieved to 6.43dBi s shown in Fig 4(d) and the gain of the mushroom type metamaterial is shown in Fig 4(e).

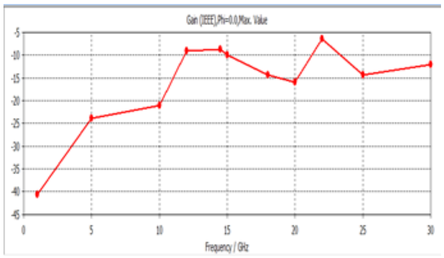

Fig 4(e) Gain of SIW horn with metamaterial

B. SIW HORN ANTENNA WITHOUT METAMATERIAL:

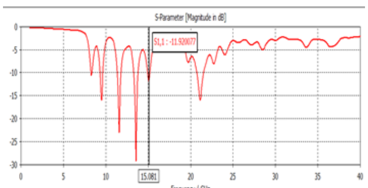

Fig 5(a) $|S_{11}|$ of SIW horn without metamaterial

The $|S_{11}|$ of the SIW horn antenna is shown in Fig 5(a) and the frequency range achieved on 15GHz.

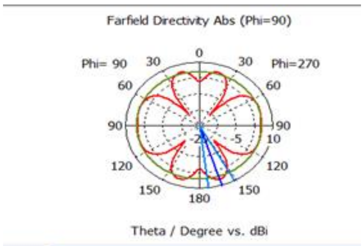

Fig 5(b) Polar plot

The polar plot is shown in Fig 5(b) for the 15GHz and the directivity gain has been achieved 6.57dBi and bandwidth is improved. The far field radiation pattern is shown in Fig 5(c).

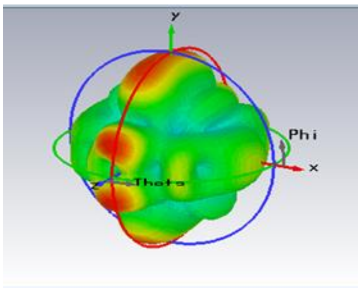

Fig 5(c) radiation pattern

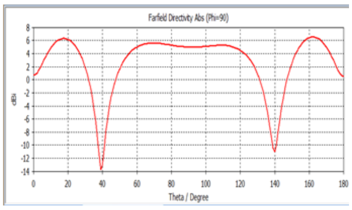

Fig 5(d) Directivity of SIW horn without metamaterial

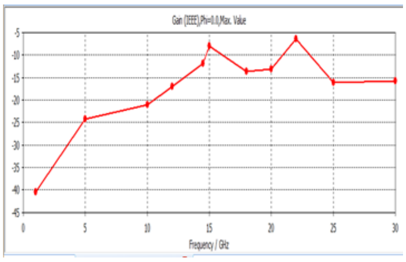

Fig 5(e) Gain of SIW horn without metamaterial

C. COMPARSION BETWEEN SIW HORN ANTENNA WITH AND WITHOUT METAMATERIAL

Table 2: SIW horn antenna with and without metamaterial

	SIW HORN WITH METAMATERIAL	SIW HORN WITHOUT ETAMATERIAL
Frequency	15GHz	15GHz
$\lvert S_{11} \rvert$	< -10dB	-10dB
Directivity	6. 43dBi	57dBi

IV. CONCLUSION:

In this paper, a SIW horn antenna loaded with mushroom-type metamaterial (rectangular patch with via) is done. The metamaterial acts as a good impedance transformer for SIW horn antenna. Through loading metamaterial, bandwidths of the SIW horn antenna are improved. Due to the metamaterial, radiation performance is observed for SIW horn antenna. In both cases the $|S11|$ is < -10dB and the frequency is achieved in15GHz. Both with and without metamaterial most commonly used for the satellite communication. The directivity of the gain for the SIW horn without metamaterial is much better when compared with the SIW horn with metamaterial.

V. REFERENCES

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