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NOVEL ANTENNA

SUBSTRATE INTEGRATED WAVEGUIDE (HORN)

[1]Bhima Chavhan, [2]Durgesh Gaikwad, [3]Zeeshan Khan

[1]Student, [2]Student, [3]Student

[1 2 3] Electronics & Telecommunication Pune Institute of Computer Technology, Pune, India

ABSTRACT:

With the demand for communication systems such as satellite, mobile, space, and military systems increasing, antennas' function in transmitting or receiving signals is dramatically expanding. Gain, bandwidth, and radiation patterns are separate requirements for each of these systems. Apart from their electrical properties, antennas are subject to limitations regarding their size, volume, weight, manufacturing ease, and price. The antennas that have been created and constructed are Substrate Integrated Waveguide (SIW) H-plane horn antennas, in which the waveguide and horn are both made utilizing a straightforward fabrication process on the same substrate. The return loss and bandwidth of two antennas, short length dielectric loaded and short aperture dielectric loaded SIW H- planar horn antennas, were tested. In order to make up for the loss in gain brought on by the antennas being shrunk, a dielectric slab was put in front of the aperture of both horns. Both antennas have a small construction and are reasonably priced because to the Substrate Integrated Waveguide (SIW) technology that is employed.

Index Terms – Component, Substrate Integrated Waveguide (SIW).

I. Introduction

Antennas are an essential part of communication systems. An antenna is a metallic object that can be used to transmit or receive radio waves, acting as a bridge between free space and a guiding device. A waveguide can be used as the guiding device or transmission line to convey electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver. Because they do not emit electromagnetic radiation, waveguides have the best transmission properties of any transmission line.

The horn antenna is one of the most basic and extensively used microwave antennas. The horn is a hollow pipe with various cross-sections that is flared to a bigger opening and can assume many forms. The type, direction, and amount of flare can all have a significant impact on the element's overall performance as a radiator.

A horn and a waveguide are shown in as can be seen from the figure, both are nonplanar structures. Such nonplanar structures can be transformed into planar form by using a technology known as the Substrate Integrated Circuits (SICs). SICs allow the integration of various planar and nonplanar circuits in a single substrate and/or multilayer platforms. The SICs can be used to synthesize almost all kinds of dielectric filled waveguide using the Substrate Integrated Waveguides (SIWs) scheme which is one of the members of the SIC family.

SIWs were developed to provide high performance microwave and millimetre-wave waveguide components which are fabricated using low-cost technologies like the common printed circuit board (PCB) fabrication method. The SIWs are rectangular waveguides formed by two solid conductor planes, separated by a dielectric substrate, with conductor sidewalls emulated by rows of metalized through plated vias.The SIW can be used for the integration of H-plane sectoral horn antenna.

II. Substrate Integrated Waveguide an overview

Substrate Integrated Circuits (SICs) are high frequency integrated circuits, the concept of which is to synthesize non-planar structure with a dielectric substrate and make it in planar form, which is completely compatible with other planar structures. This can usually be achieved by creating artificial waveguiding channels. In this case, alternated dielectric constant profiles of substrate using air holes or composite dielectric media and/or synthesized metallic walls using metallized vias are generally used. The resulting structure on the substrate will be a planar waveguide, which has much better loss characteristics than planar counterparts, allowing for the design of millimeter wave systems using a low-cost fabrication technique. Furthermore, the synthesis of a non-planar waveguide in substrate permits the realization of efficient wideband transitions or baluns between the synthesized nonplanar waveguide and planar circuits such as microstrip and coplanar waveguide (CPW) integrated circuits. With these baluns and/or transitions, the complexity and cost of interconnection between non-planar high-Q circuits and planar circuits are reduced to a minimum. Thus, a complete millimeter wave front-end circuit for radio and radar applications could be designed and built on one dielectric substrate with only simple fabrication process.

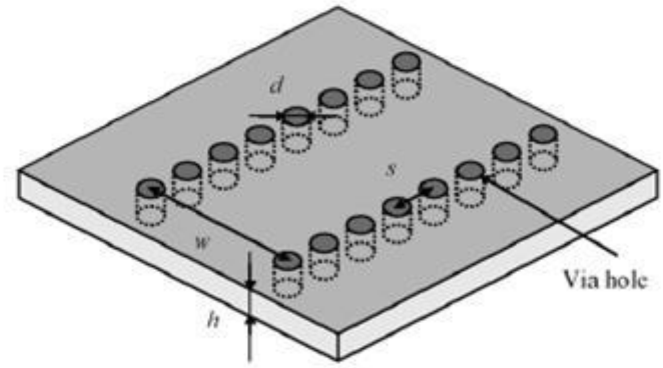
This reduces considerably the packaging, interconnect and assembly problems that are found in current millimeter wave radio equipments.The different members belonging to this family of SICs are:

- Substrate Integrated Waveguide (SIW).
- Substrate Integrated Slab Waveguide (SISW).
- Substrate Integrated Non-Radiating Dielectric (SINRD) circuits.

Amongst these, the SIW technology is the most popular and also the most developed platform as it is quite easy to ”transplant” the existing and matured modeling and design techniques of the rectangular waveguide components into the SIW that is simply a synthesized rectangular waveguide.

III. Modes in the SIW structure

When a mode is established in some guided wave structure, the surface currents are then established. The SIW structure can be regarded as a special rectangular waveguide with a series of slots on the bilateral narrow walls. According to the design principle of waveguide slot antenna, if the slots cut the currents, a large amount of radiation may appear. However, if the slots are cut along the direction of current flowing there is very less radiation.



Where,

d= diameter of Via

h= height of substrate

s = center to center distance

w= dielectric field metallic waveguide

IV. SYSTEM DESIGN

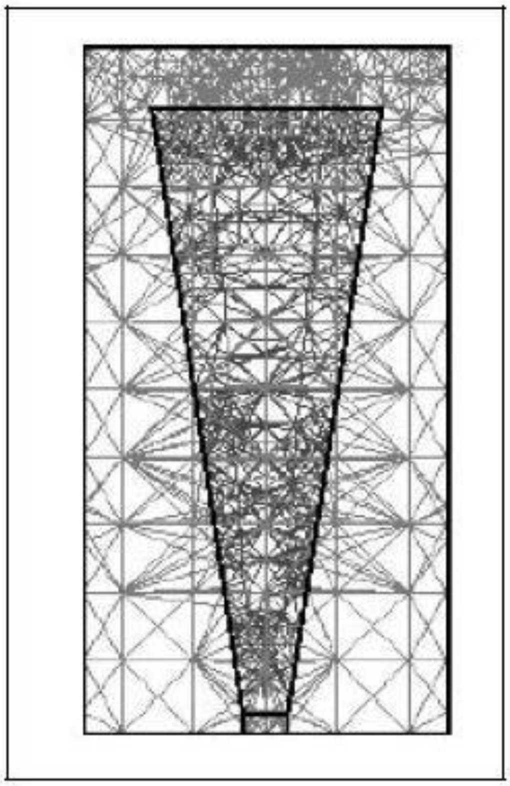
The design of the SIW Horn antenna has to be carried out using the software ANSOFT High Frequency Structure Simulator (HFSS). High Frequency Structure Simulator is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modelling that takes advantage of the familiar Microsoft Windows Graphical User Interface. It integrates simulation, visualization, solid modelling and automation in an easy to learn environment where solutions to 3D EM problems are quickly and accurately obtained. HFSS can be used to calculate parameters such as S-Parameters, antenna parameters like gain, directivity etc.and radiation patterns. In order to calculate the full three-dimensional electromagnetic field inside a structure and the corresponding S-parameters, HFSS employs the finite element method (FEM). The basic approach of this method is to divide a complex structure into a large number of tetrahedral elements. Each tetrahedron is composed of four equilateral triangles and this collection of tetrahedra is known as the finite element mesh. shows the finite element mesh for a sample horn antenna. This figure was taken from [7]. At each vertex of the tetrahedron, components of the field tangential to the three edges meeting at that vertex are stored. The other stored component is the vector field at the midpoint of selected edges, which is also tangential to a face and normal to the edge. Using these stored values, the vector field quantity such as the H-field or the E- field inside each tetrahedron is estimated. A first-order tangential element basis function is used for performing the interpolation. Maxwell’s equations are then formulated from the field quantities and are later transformed into matrix equations that can be solved using traditional numerical techniques.

V. DESIGNING STEPS

The different steps involved in the designing are as follows:

Drawing:

The three dimensional geometric model of SIW Horn antenna structure to be drawn is a collection of two dimensional objects like polyline, circle, ellipse and three dimensional objects like box and cylinder. These objects can be directly drawn in HFSS using menu commands. The circle has been used as a port to identify where energy can enter or exit a structure. In some cases, it is difficult to create a satisfactory three- dimensional model by just using the simple 2D and 3D objects. For this reason the drawing interface in HFSS provides a few more options such as Subtract, Unite and Intersect.



Assigning Material:

While solving any structure for its electromagnetic properties, HFSS creates a finite element mesh for each object, which is based on the material that is assigned to the corresponding object. Thus, accurate assignment of materials is extremely essential. An object in HFSS can be assigned materials such as a air, copper, Teflon etc. Permittivity, permeability, electric loss tangent and magnetic loss tangent are the properties associated with dielectrics and if required, can be modified by the user.

Assigning Boundaries:

A boundary can be assigned to any two-dimensional area such as a plane, a face of an object or an interface between two objects. *Port* is the only boundary condition which is used to define a surface that permits energy flow into and out of a structure.*Perfect E* is a perfect electric boundary or a perfect conductor and aligns the electric field (E-field) perpendicular to the defined surface. For simulation these radiated waves would need to be absorbed, and so, the *Radiation* boundary is used. i.e. the waves are absorbed by an object that is assigned a *Radiation* boundary.

Setting up the Solution:

Choosing the mesh parameters and selecting the frequencies at which the structure will be solved are the two most important parameters of setting up the solution.The frequencies are selected using the *Frequencies* tab. Either Fast Frequency Sweep (FFS) or Discrete Frequencies or both can be chosen. FFS is a quick method of solving for a frequency sweep. This is so, because it takes a minimal number of frequency samples and then compares them to a rational fitting model. In other words, it performs interpolation on the data based on a small number of frequency values and wherever data variations are higher, it takes more samples. When the data at the sampled points fits the model, the frequency sweep is complete.

VI. CONCLUSION

The designed dielectric loaded Substrate Integrated Waveguide (SIW) H-plane horn antenna provides an optimized design for H-plane horn antennas. The Substrate Integrated Waveguide technology allows the fabrication of the antennas to be done on a substrate by making Plated through Holes (PTH) at the specified locations. This made the fabrication of antennas very easy and thus, resulted in low cost. Also, the SIW antennas being planar, the size of the fabricated antennas are very compact. In case of a conventional antenna, with the reduction of size, the gain also reduces. But, a Substrate Integrated Waveguide (SIW) antenna helped in reducing the size of the antenna without compensating for the gain. This was done by placing a dielectric slab of proper length in front of the aperture of the horn. Through proper choosing of the structure and the parameters, the software used, High Frequency Structure Simulator (HFSS) helped in finding out the maximum gain for a given size. The two antennas, Short length Substrate Integrated Waveguide H-plane horn antenna and the Short aperture Substrate Integrated Waveguide H-plane horn antenna were fabricated and tested for the return loss and the bandwidth. The measured results are in good agreement with the simulated results.

VII. REFERENCES

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