CORRUGATED SUBSTRATE INTEGRATED WAVEGUIDE HORN ANTENNA IN C BAND

1SUSHMA PANDEY, 2ROHINI DESHPANDE, 3SULABHA RANADE

1Student of Department of E&TC, K J Somaiya College of Engineering, Mumbai University, Mumbai, India 2,3SAMEER, IIT Campus, Mumbai, India
E-mail: sushmaaarjaria31@gmail.com

Abstract- In this paper we proposed Corrugated Substrate Integrated Waveguide Horn Antenna in C band. CSIW is a new technology which is used to convert non planner devices in to planner form. In CSIW upper and bottom conducting plane are completely isolated by substrate, here the material is used for substrate with dielectric constant of 3.6.CSIW horn antenna designed and fabricated. Simulation is done in HFSS. Losses like radiation leakage, dielectric loss and dispersion are taken care while designing. The simulation results are verified with measurement. The objective of this paper is to provide broad perspective of CSIW horn antenna. CSIW horn antenna provides wide bandwidth.

Keywords- CSIW, Dielectric Loss , Horn Antenna.

I. INTRODUCTION

Waveguide and transmission lines are used for transmission of electromagnetic energy from source to destination. As the electromagnetic waves are completely contained in the metallic boundary of the waveguide, the radiation losses are less. But these metallic waveguides are bulky and non-planar in nature. Here comes the need of CSIW technology, which does not require conducting vias to achieve TE_{10} type boundary conditions. Here vias are replaced by quarter wavelength microstrip stubs arranged in a corrugated pattern on the edges of the waveguide.

II. CSIW TECHNOLOGY

A. SIW

A new generation of high frequency circuits is called Substrate Integrated Circuits (SICs). Different member of its family are Substrate Integrated Waveguide (SIW), Substrate Integrated Slab Waveguide (SISW). Substrate Integrated waveguide is composed of two parallel rows of metallic posts inserted in a plated substrate. If the distance between the posts and their diameter are chosen properly, the energy leaking between consecutive posts is negligible, as demonstrated in.

B. CSIW

Corrugated Substrate Integrated Waveguides is a new SIW structure which does not require conducting vias to achieve TE_{10} type boundary conditions at the side walls. In CSIW Open-circuit quarter-wave-length microstrip stubs can be used in place of vias to form the sidewalls. CSIW are planar structures fabricated using two periodic rows of Open-circuit quarter-wave-length microstrip stubs at the upper plane which is completely isolated with lower conducting plane. CSIW technology is used in many applications like antenna, interconnect and System on Substrate. Planner antenna has undesired surface currents on the outlines lead to near field radiation and reduced gain as well as high side lobe levels. For antenna pattern improvement, the concept of corrugation structures has been studied. Corrugations have been proven successful in tapered slot antenna structures for front to back ratio. The advantage of corrugated SIW is that, it can be integrate with active components without DC Isolation.

C. Transmission of Electromagnetic energy in CSIW

Wave propagation in waveguide is superposition of all modes. The field which is passing through device contains both propagating and attenuating modes. The top conductor of the CSIW comprises two distinct features: 1) host waveguide of width ‘a’ and 2) microstrip stubs connected to each side of the host waveguide. It is first assumed that the microstrip stubs behave as isolated open-circuit transmission lines with input admittance ‘y’. This admittance is a function of the stub length, and the microstrip stub characteristic impedance. Fringing fields at the open end may be accounted for by a length extension. The second assumption is that the host waveguide can be represented by a dielectric filled rectangular waveguide with perfect-magnetic-conductor (PMC) sidewalls and perfect-electric-conductor (PEC) top and bottom walls, as shown in Fig. 1.

![Fig 1 Transverse cross section of the equivalent host waveguide](image-url)
Perfect electric conductor (PEC) surface is the surface which fully reflects incident waves with reflection phase of 180 degree, while the perfect magnetic conductor (PMC) introduces a zero degree phase shift.

D. CSIW horn antenna

CSIW technology is implemented as horn antenna because horn antenna having the advantages like low VSWR, high gain, relatively wide bandwidth. Horn antenna can be designed using CSIW technology very successfully. The rectangular waveguide horn is one of the simplest and probably the most widely used microwave antenna. The application of SIW for the design of an integrated H-plane horn antenna was proposed in. This structure is easy to be integrated with the feed network and is a good candidate to feed the surface-wave antennas or the leaky-wave antennas. The flare of the horn provides gradual transition to match impedance of the tube (RSIW) to the impedance of the free space. If flare has not been there, i.e. if horn is not there, then sudden end of the conductive wall would have caused abrupt change in the impedance from the wave impedance in the waveguide to the wave impedance in the free space. The feed of the horn is rectangular CSIW and the design procedure is same as that of an RSIW. The other end of the RSIW is flared as per design which makes it a Horn antenna and directional. Here, we present a corrugated SIW horn antenna. This antenna is integrated by using a single substrate. It is easy to fabricate and the structure is compact. To eliminate the higher order modes in the waveguide, the thickness of the substrate is restricted. For a horn of maximum gain, the aperture phase distribution along the H-plane is nearly uniform.

HFSS 13 was used to obtain these results. The substrate thickness was 1.6 mm, and its relative permittivity was 3.6. The CSIW dimensions were a=12 mm, t=5.5 mm, u=0.4 mm, and p=1 mm, and the microstrips taper from 3 to 9 mm over a length of 8 mm, flared length 17 mm.

III. THEORICAL FORMULATION FOR CSIW HORN ANTENNA

For a CSIW, TE_{10} mode is dominant mode. It is possible to propagate several modes of electromagnetic waves within waveguide. There is a cut off frequency of each mode which can be determined with physical dimension of waveguide. Hence for CSIW the width and height are important consideration. Below Fig. 3 shows CSIW model and the parameters to be considered.

A CSIW is a waveguide having dielectric substrate sandwiched between two conducting plates with corrugated stubs at the upper one. The design technique of CSIW can be easily understood, if CSIW correlated with SIW. It is mentioned that , 'p' is the period between the stubs, ‘d’ is width of stubs, ‘b’ is the height of substrate, ‘a’ is distance between stubs of both the rows, substrate dielectric constant ‘ε_r’ and ‘a_equ’ is the width of dielectric filled metallic waveguide (equivalent to its vias SIW counterpart). If ‘a_con’ is the width of conventional wave guide and ‘ε_con’ is 1 (air) than its equivalent dielectric filled waveguide width is formulated as in equation (1):

$$ a_{equ} = a_{con} / \sqrt{\varepsilon_r} $$

Depending on ‘a_equ’, where ‘c’ is velocity of light, the cutoff frequency ‘f_c’ can be calculated by equation (2):

$$ f_c = c / (2.a_{equ}.\sqrt{\varepsilon_r}) $$

The width ‘d’ and the periodic distance ‘p’ of stubs must be selected such that there are no leakage radiations from them. The periodic length must be greater than the width of the stub so that the structure is physically realizable as in equation (3).

$$ p > d $$

Since CSIW is a periodic guided wave structure, the electromagnetic band-stop phenomenon will probably appear which should be avoided over the waveguide bandwidth of interest. Therefore the condition shown below (4) should be used to avoid any band-gap effects in the operating bandwidth.

$$ (p / \lambda_g) < 0.25 $$

The number of stubs should not exceed 20 per wavelength as in the given condition (5):

$$ (p/\lambda_g) > 0.05 $$

The distance between stubs of both the rows ‘a’ can be calculated using a simple formula given below (6) and

$$ a_{con} = a_{equ} / \sqrt{\varepsilon_r} $$

HFSS 13 was used to obtain these results. The substrate thickness was 1.6 mm, and its relative permittivity was 3.6. The CSIW dimensions were a=12 mm, t=5.5 mm, u=0.4 mm, and p=1 mm, and the microstrips taper from 3 to 9 mm over a length of 8 mm, flared length 17 mm.
in four other formulas are discussed to determine the value of ‘a’.

\[ a = a_{equ} + \frac{d_2}{0.95p} \] (6)

Using the above design techniques or rules a Corrugated Substrate Integrated waveguide can be designed from its conventional waveguide structure. The stub is the quarter wavelength in length, \( L_{stub} \).

\[ L_{stub} = \frac{\lambda_g}{4} \] (7)

A horn is a rectangular waveguide which is flared at one end. The flared portion can be square, rectangular or conical in shape. Horns provide low VSWR, High gain, relatively wide bandwidth and they are not difficult to fabricate. To design the rectangular CSIW feeder of horn antenna design technique is same as we discussed above. In H-Plane horn antenna the height ‘b’ remains same throughout.

The other parameters can be calculated from the relations given below.

\[ A = (3\lambda_g R_1)^{0.5} \] (8)

\[ l_H = R_1^2 + \left(\frac{A}{2}\right)^2 \] (9)

\[ \alpha_H = \tan^{-1}\left(\frac{A}{2R_1}\right) \] (10)

\[ R_H = (A-a_{equ}) \left[ \left(l_H/A\right)^2\cdot0.25 \right]^{0.5} \] (11)

IV. RESULT

A CSIW horn antenna is designed and fabricated. HFSS 13.0 tool is use as simulator. Simulation and VNA the results are taken for frequency range of 300 KHz to 8 GHz.

This antenna is presented in C band at center frequency of 7 GHz. Here tapered microstrip feed is given. Permittivity of material is taken 3.6 for simulation. Fig 4 shows the model created in HFSS. All the parameter have unit in millimeter.

Return loss is very important parameter of antenna. Fig 6 shows Measured result of return loss of CSIW Horn Antenna in VNA. Measured bandwidth is 1500 MHz The lowest frequency within bandwidth is located at 6.04 GHz and the highest frequency is located at 7.54 GHz. The first resonance is found around 6.3 GHz the second resonance around 6.8GHz.

VSWR value should be below than 2 for proper energy transmission. Following fig 7 shows VSWR value at the resonant frequencies 6.30 GHz and 6.86 respectively 1.2 and 1.12.
A radiation pattern defines the variation of the power radiated by an antenna.

It also gives the intensity of field radiated by antenna in all directions. The antenna radiation pattern is similar to that of a conventional horn antenna.

CONCLUSION

We can conclude from the above simulation and fabricated results the conventional waveguide structures are successfully converted and fabricated into planar form on planar circuits and are easily interconnected with microstrip lines with CSIW technology. CSIW horn antenna is designed at center frequency of 7 GHz.

Measured bandwidth of this antenna is 1500 MHz. By analysis of results we can say that the advantages of conventional horn antenna like large bandwidth is continue here with CSIW Horn Antenna. Radiation pattern graph is similar to the normal Horn Antenna radiation pattern.

ACKNOWLEDGMENT

I would like to thanks the K J Somaiya College of engineering and SAMEER to providing research opportunity in the field of Antenna.

REFERENCES


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