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Design of Substrate Integrated Waveguide

Ms. Sneha Talari ,
Assistant. Professor,
ECE Department, NNRG

Abstract: This paper presents the design of substrate Integrated waveguide (SIW) technology. A Dielectric filled rectangular waveguide is converted into SIW with periodic arrangement of metallized holes on both sides of the rectangular waveguide and is operated in L,S and X band. SIW exhibit high pass response of conventional waveguide and band stop features of periodic design. So filters are designed using this SIW exhibit less loss, less cost, less weight, high quality factor and high power handling capability.
Keywords — Filters, resonator filters, substrate integrated waveguide (SIW), dielectric materials, vias.

1. INTRODUCTION

The frequency range from 30 to 300 GHz is generally defined as millimetre waves or extremely high frequency waves. Wavelengths over this frequency band are ranged from 10 to 1 mm, thus naming it the millimetre-wave band or simply millimetre-wave (MMW or mmw). Compared to lower frequency bands, electromagnetic waves in this band are subject to high atmospheric attenuations and they are absorbed by atmospheric gases. Beyond this millimetre-wave range, electromagnetic radiation is referred to as terahertz (THz) radiation. Millimetre-wave bands offer exciting opportunities for various bandwidth demanding and spectrum-sensitive applications such as short-range communications in the 60 GHz band. In commercial system developments, low-cost, mass-producible, high-performance and high-yield microwave, and millimetre-wave technologies are critical for developing successful and sustainable commercial broadband systems, in particular, front end and antenna modules.

Antennas in standard technology or in SIW can be classified as either resonant or non-resonant types Resonant antennas, such as microstrip patches and dipoles, resonate at discrete frequencies. Non-resonant antennas or travelling-wave antennas do not resonate but rather leak energy out along their wave propagating path, thereby producing more efficient broadband structures. The resonant structures do not provide an easy-to-accept performance in the millimetre-wave range. This is because of very high conductor losses arising from immense current densities (singularities) at the strip edges, especially in the feeding network. The substrate becomes electrically thicker at higher frequency and more surface wave modes (parasitic modes) may exist. This can be deleterious for standard microstrip antennas with radiation efficiency reduction and radiation pattern perturbations, which result from the diffraction of surface waves at the edges of the antenna structure in an uncontrolled manner.

2. SUBSTRATE INTEGRATED WAVEGUIDE

A new generation of high-frequency integrated circuits called “substrate integrated circuits – SICs” was proposed and demonstrated many years ago.

This disruptive concept has unified the hybrid and monolithic integrations of various planar and non planar circuits that are made in single substrate and/or multilayer platforms. Basically, any non planar structures can be made or synthesized in planar form, which presents the foundation of SICs. Being synthesized on a planar substrate, the substrate integrated guide, for example, can be combined in a hybrid way with the SIW and the Substrate Integrated Nonradioactive Dielectric guide (SINRD) on the same substrate, operating with different modes and/or different frequency ranges. These guides can also be combined with standard waveguide, microstrip, Coplanar waveguide (CPW) or slot line, leading to attractive hybrid schemes of planar and non planar structures.

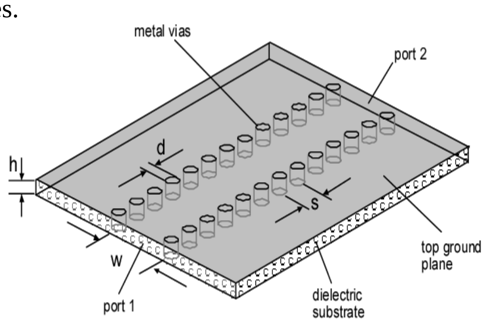


Fig. 1. Geometry of a substrate integrated waveguide.

Since the transmission line technology is instrumental for developing high-frequency electromagnetic hardware, the choice of an appropriate waveguide or line structure is critical for millimetre-wave developments and applications. The transmission lines of choice should allow high-density integration and mass-production scheme at low cost. Rectangular waveguides have widely been used in the development of microwave- and millimetre-wave components and systems with their salient features such as low insertion loss, high quality factor (Q-factor) and high power capability, etc.

Therefore, it is impossible to design and develop microwave and millimetre-wave integrated circuits with this technological platform. Benefiting from the properties of low profile, easy fabrication, and low cost, microstrip-like circuits including coplanar waveguides (CPW) and strip lines are presently the principal choices of integration for the development of microwave and millimetre wave circuits.

3. SIW TECHNIQUES AND DESIGN BASICS

The SIW (also known as post wall waveguide or a laminated waveguide) is a rectangular waveguide-like structure in an integrated planar form, which can be synthesized and fabricated by using two rows of conducting cylinders, vias or slots embedded in a dielectric substrate that is electrically sandwiched by two parallel metal plates.

The operating frequency range is delimited by the monomode propagation of quasi-TE10 wave as its cut-off frequency is only related to equivalent width aeq of the synthesized waveguide as long as the substrate thickness or waveguide height is smaller than this width.

4. VIA CONFIGURATIONS

Round metalized via holes are used to create the electric sidewalls or fences of SIW through two parallel via arrays. The discontinued current flow along the via- or slot-synthesized metalized sidewalls does not allow the propagation of TM modes. In addition, a large width-to-height ratio of SIW supports the propagation of TEm0 modes. Since these techniques are amenable to arbitrarily shaped perforations, the limitation of circular via shapes is no longer mandatory. Rectangular slot trenches were found to be advantageous for lower leakage and better definition of the SIW sidewalls. This is important for some designs such as those iris and window coupling geometries found in the filter design.

Rounded corners increase the overall mechanical stability, allowing for a better metallization, which often cannot be avoided in the fabrication process due to the finite diameter in micromachining process.

5. RECENT SIW MINIATURIZATION TECHNIQUES

In past few years, researchers worldwide have used various techniques towards miniaturization of SIW. Most broadly the techniques can be categorized as follows:

A. Slotted SIW (SSIW)

The SSIW has a small longitudinal opening alongside one of the metallic surfaces. It enables fundamental propagating mode away from conventional full SIW model into a half-mode. It also eases incorporation of lumped elements or active components and allows the waveguide to be loaded with impedances. The slots worked as a series capacitor in addition to radiator. Since its operational frequency was below the waveguide cut-off frequency, it led to a substantial compactness of structure.

B. Folded SIW (FSIW)

FSIW technique is mainly suitable for the waveguide whose height is much smaller than its width. A transversely folded waveguide can be categorized into two types, depending on the way they are folded.

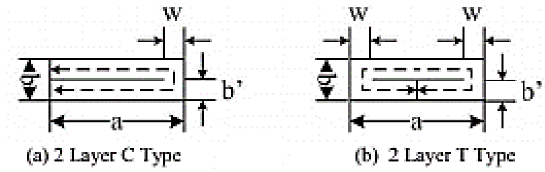


Fig.2. Folded SIW.

SIW with a folded front-end of C-type has front end part to second layer enabled SIW antenna length reduction by the size of one-quarter guided wavelength. It also used two slots each half-length long at different broad-wall plane to realize wide-band end-fire radiation.

C. Half Mode(HMSIW)/Quarter Mode SIW (QMSIW)

The model of the half-mode substrate integrated waveguide (HMSIW) for miniaturization was demonstrated in from its structure as depicted in figure, it can be observed that surface area of the metallic sheets and waveguide width are reduced by nearly half while propagation characteristics have been proven slightly better than conventional one. This technique has been effectively employed for devising compact antennas, filters, 3-dB couplers, and power dividers.

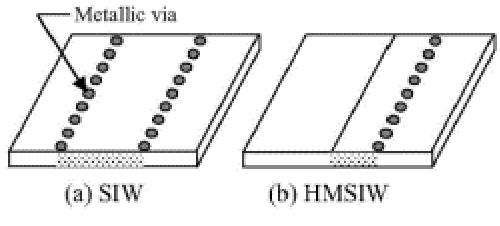
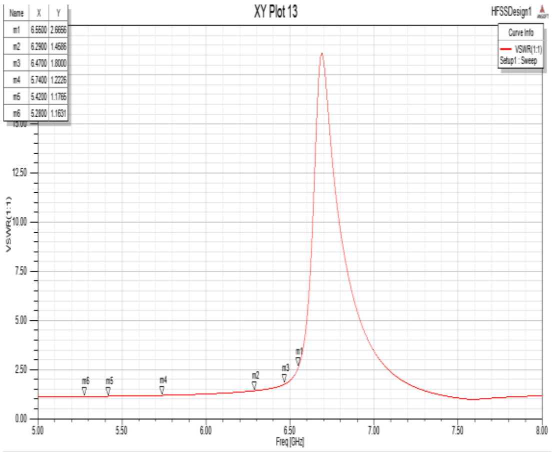


Fig.3. Half Mode SIW.

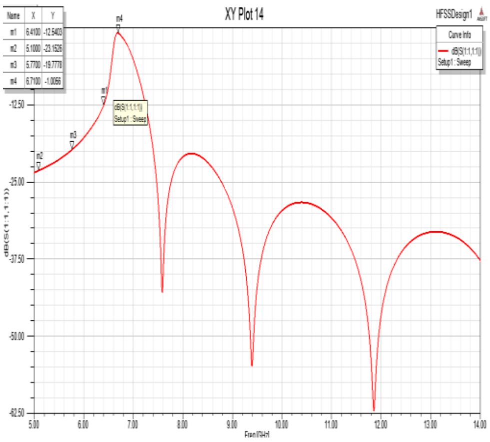
6. RESULTS

a. VSWR



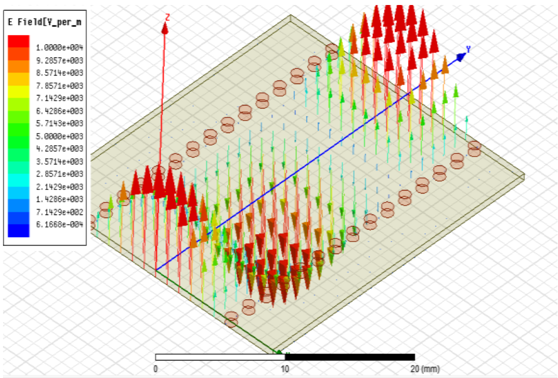
At 5.2GHz, the VSWR of substrate integrated waveguide is 1.16.

b. S Parameters



At 5.2 GHz the reflection loss is -23.15dB.

c. E Field



The dominant mode of TE wave is TE_{10} mode. since the vias are placed at the sidewalls of siw only TE wave propagates.

7. CONCLUSIONS

SIW is the most promising technology in area of millimetre wave and RF communication but has limitation of having large size. To reduce the size and make it more compact, several miniaturization techniques are used. This paper shows the VSWR,E field and Return loss obtained in SIW which operates in L,S,X band and are used for reducing the size of SIW based components. Out of all techniques specified above in this paper, combination of Folded and Half/Quarter mode are most preferred techniques to miniaturize the SIW based components.

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