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Design of a Novel Structure SIW 90° Coupler

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Abstract: This paper focuses on the analysis of passive devices using a recent emerging technology named Substrate Integrated Waveguide (SIW). This technology has been used in the conception of planar compact components for the microwave and millimeter wave's applications. Through using Ansoft HFSS and CST code a substrate integrated waveguide coupler has conceived and optimized in this study. The SIW 90° coupler design simulations show good performances with low return loss, high isolation better than -20 and -40 dB, respectively and broad operational bandwidth.

Keywords: Substrate Integrated Waveguide, HFSS, CST, 90° Coupler

Introduction

The extensive use of the rectangular waveguide components in millimeter-wave and microwave communication systems, radar and other equipments are due to their significant features such as their high Quality factor (Q-factor), high power capability and low insertion loss (Labay and Rao, 2011; Labay and Bornemann, 2008; Ahmad *et al*., 2013). However, they are difficult to be integrated in modern microwave and millimeter-wave integrated circuits because of their big size, nonplanar structure and strict requirement of manufacturing precision (Hao *et al*., 2006).

A new novel planar circuit named Substrate Integrated Waveguide (SIW) is facing recently a growing interest as it has common advantages with printed circuits such as low cost, small size (Labay and Rao, 2011; Ahmad *et al*., 2013) and which is known as the most popular and developed technology until now. Moreover, the SIW components are characterized with low insertion loss, low radiation loss and insensitive to outside interference since its components are covered by metal surfaces on both sides of the substrate (Hao *et al*., 2006; Abdel-Wahab *et al*., 2011; Rahali *et al*., 2014; Xinyu *et al*., 2005; Zhigang *et al*., 2011).

In this present paper, the design platform of the new SIW 90° coupler is presented and discussed. Besides, this letter presents 90° coupler prototypes which are optimized and simulated, in addition to the results which are presented and compared with two electromagnetic (3D) software.

Design of SIW 90° Coupler

SIW technology defines as a type of rectangular dielectric-filled waveguide which includes a planar substrate with arrays of metallic vias to realize bilateral edge walls and on the same substrate its transitions with planar structures for instance microstrip and Coplanar Waveguide (CPW) are designed and integrated (Murai *et al*., 2011; Patrovsky *et al*., 2008; Rahali and Fahem, 2013). Within the same planar platform the planar and nonplanar structures can be integrated, which leads in this case to the design and development of low-cost millimeter-wave Integrated Circuits (ICs) and systems (Ali *et al*., 2008; 2009; Rahali and Feham, 2014).

A 90° coupler with low cost and low loss Substrate Integrated Waveguide (SIW) has been designed for low profile and compact mm-wave applications.

Design of SIW

The SIW consists of two linear metallic connected via dielectric substrate with a height of b. The electromagnetic fields within the SIW are confined by these metallic via arrays (Ali *et al*., 2008). The width of the SIW is a, the diameter of the metallic vias is D while the space between the adjacent vias is s. The geometric parameters are primarily determined by the relationship between the conventional rectangular waveguide and the SIW (Guo *et al*., 2008; Djerafi and Wu, 2007; 2012; Djerafi *et al*., 2010; 2011).

In Fig. 1, port 1 is the input port, port 2 is considered as the through port, while port 3 stands for the coupling port and finally port 4 is used as an isolation port.

In order to achieve a wide-band performance the coupler parameters are finely tuned using three-Dimensional (3D) Electromagnetic (EM) simulation with HFSS and CST software.

Figure 2 presents the design parameters for the microstrip-to-SIW coupler. The designs use SIW parameters of low loss dielectric material, Rogers RO 4003 with $\varepsilon_r = 2.2$ and loss tangent of 0.009, substrate height $b = 0.5$ mm and the vias holes are $D = 0.4$ mm and their distances $s = 0.7$ mm.

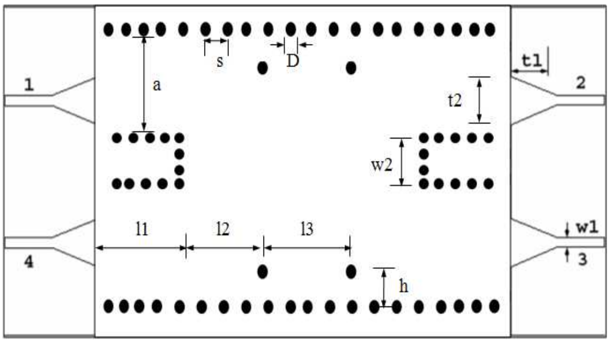

Fig. 1. Configuration for the proposed SIW couplers with geometric parameters

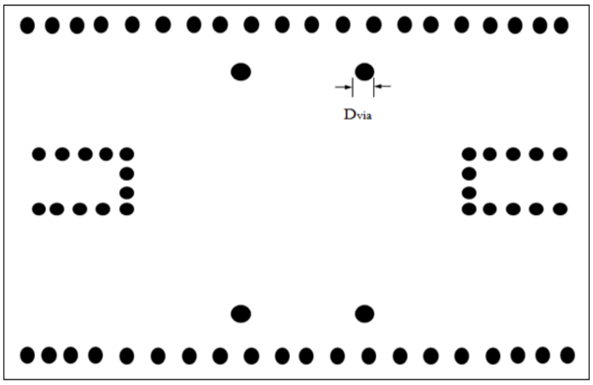

Fig. 2. Configuration for the proposed SIW couplers with different Dvia

Table 1. Dimension of the structure

a	h	t1	t2
12.25 mm	2.2 mm	20.5 mm	7.2 mm
w2	l1	l2	l3
3.7 mm	4.1 mm	10.4 mm	10.4 mm

For the microstrip line which has the same substrate and metallization thickness as the SIW is selected and which leads to a 50 Ω line width of w1 = 1.3 mm. These parameters are identical for all microstrip-to-SIW couplers highlighted in this study and the remaining design-specific dimensions are presented in Table 1.

Parameter Studies for SIW 90° Coupler

As an example, SIW 90° coupler is designed and the extra metallic via Dvia is optimized with different diameters. This variation shows a good improvement in the return loss and isolation. The design of the SIW coupler with different parameters Dvia is optimized to improve the return loss and isolation of -17 to -23 dB and, -27 to -44 dB, respectively. These results are shown in Fig. 3 and 4.

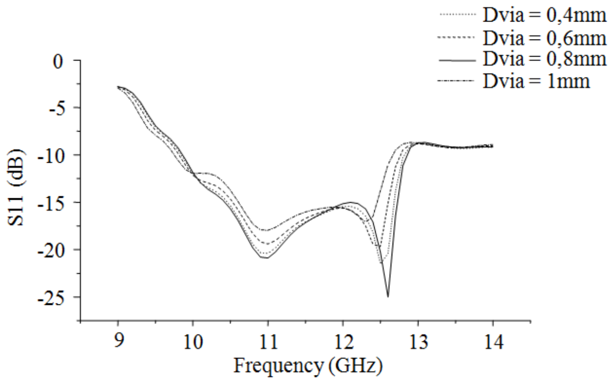

Fig. 3. Simulated S11 with different Dvia

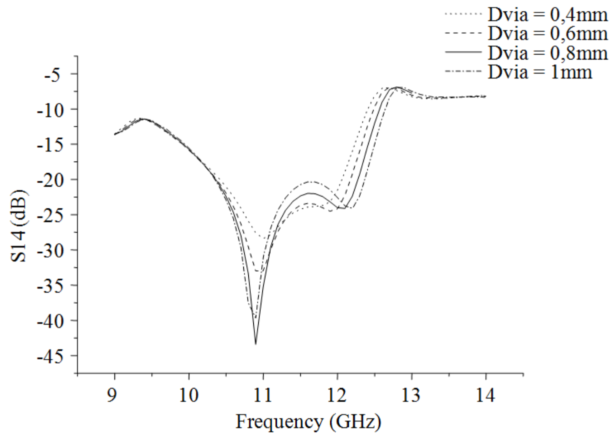

Fig. 4. Simulated S14 with different Dvia

Simulation Results

The electric field distribution of the *TE*10 mode (Abdel-Wahab *et al*., 2012), the reflection coefficients *S*11, the transmission coefficients *S*21, the coupling coefficient *S*31 as well as the isolation coefficient *S*41 are presented in Fig. 5 and 6, respectively. It is noticeable through the results of this analysis that the 90° coupler character in the band is [9.5-12.5] GHz, in which the levels of reflection and isolation are below -15dB in more than 24% of the bandwidth and the insertion loss S 21 and coupling S31 are between -3 and -6 dB.

The simulation phase difference between two outputs ports is shown in Fig. 7. It is obvious that the phase difference is distributed in the range 89~93° in which the frequency band fluctuates between 9.5 and 12.5 GHz.

So, it is clear that these simulation results demonstrate the good performance of this integrated structure.

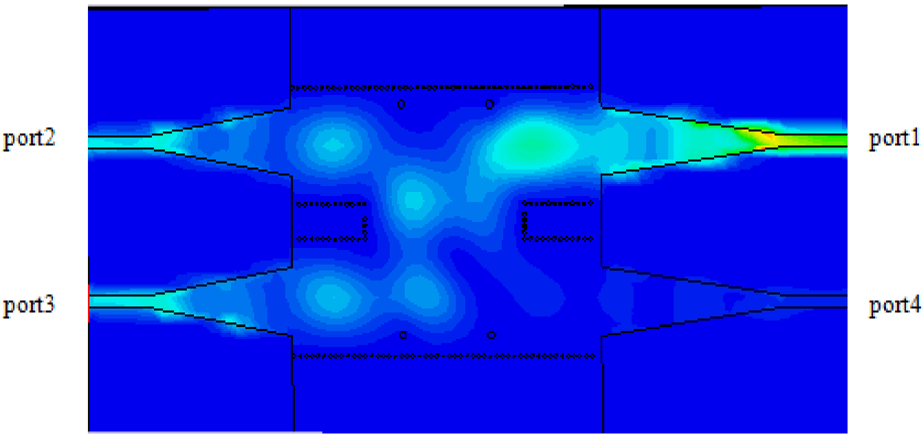

Fig. 5. Electric field distribution of TE10 mode for SIW coupler at f = 11 GHz

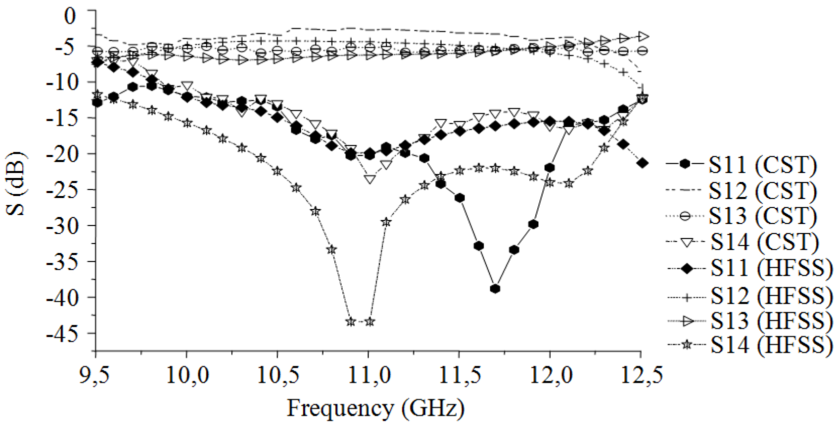

Fig. 6. Performance comparison between HFSS and CST with Dvia = 0.8mm

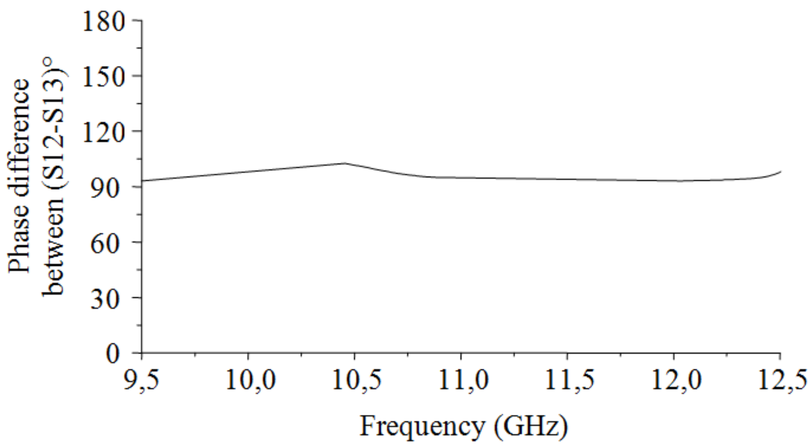

Fig. 7. Simulated phase difference

Conclusion

This paper focuses on the analysis of 90° coupler using a recent emerging technology named Substrate Integrated Waveguide (SIW). Prototypes of these 90° couplers with different via diameters are designed and simulated by the HFSS and CST code. Therefore, the paper presents results of this modeling which are discussed and allow as well integrating these devices in planar circuits.

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Author's Contributions

Abdelkhalek Nasri: Author makes considerable contributions to conception and design, Analysis and interpretation of data.

Hassen Zairi: Author contributes in reviewing the article it critically for significant intellectual content.

Ali Gharsallah: Author give final approval of the version to be submitted.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of other authors have read and approved the manuscript and no ethical issues involved.

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