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A New E-plane Bend for SIW Circuits and Antennas Using Gapwave Technology

Jian Yang*, Ali Razavi Parizi† ,

*Dept. of Signals and Systems, Chalmers University of Technology, S-41296 Gothenburg, Sweden
Email: jian.yang@chalmers.se
†Dept. of electrical engineering, Ferdowsi University of Mashhad, Iran
Email: alirazavi_parizi@yahoo.com

***Abstract*—The SIW (substrate integrated waveguide) technology makes use of metal vias in a dielectric substrate, electrically connecting two parallel metal plates, to make a waveguide. The main advantages of SIW are simple geometry, low manufacture cost and integratability with MMIC (monolithic microwave integrated circuit) or other circuits. It is often required to have E-plane bend components in the whole SIW circuits or antenna systems for the integration, for example, in multilayer configurations. However, it is difficult to make an E-plane bend by using only SIW technology. We present a new solution to E-plane bend for SIW circuits and antennas by combining the SIW technology and the so-called gap waveguide (or gapwave) technology in the paper, with the latter also realized in PCB (printed circuit board) technology, and therefore keeping its above-mentioned advantages.**

***Index Terms*—SIW technology, gap waveguide technology, E-plane bend, PCB technology**

I. Introduction

SIW (substrate integrated waveguide) technology is a new transmission line technology at frequencies of mm-waves and sub mm-waves [1]–[3], as shown in Fig. 1. It makes use of metal vias in a dielectric substrate, electrically connecting two parallel metal plates, to make a waveguide. The main advantages of the SIW technology are simple geometry, low manufacture cost and integratability with MMIC (monolithic microwave integrated circuit) or other circuits.

Since the first introduction with the name of post-wall waveguide [1] and laminated waveguide [4], the SIW technology has been applied to many different microwave components, for examples, H-plane bends [5], filters [2], directional couplers [6], oscillators [6], power amplifiers [7], slot array and leaky antennas [8], and circulators [9].

However, from the technical literature, it seems that the E-plane bend with SIW technology does not exist. An E-plane bend associated with applications of SIW is often an important component, especially in multilayer configurations, like the SWE antenna in [10]. In the present paper, we propose a solution to E-plane bend suitable for use in SIW circuit and antenna systems, by employing the gapwave technology.

II. Gapwave Technology

Fig. 2 (the cross section of a long parallel-plate waveguide) shows the principle of gapwave technology [11]–[13]: no wave can propagate between a PEC (perfect electric conductor) plate and a PMC (perfect magnetic conductor) plate when the distance h between the two plates is smaller than a quarter wavelength, and thus waves can propagate only along the waveguide formed by the two parallel PEC plates, i.e. the range of the blue E-fielld vectors drawn in Fig. 2. Note that there is no leakage into the PEC/PMC stop region even if there are no side metal walls physically. We can refer to this stop range as an invisible EM (electromagnetic) wall.

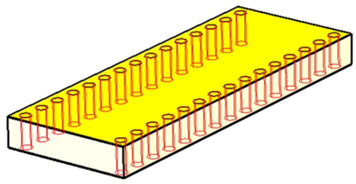


Fig. 1. Geometry of SIW (substrate integrated waveguide)

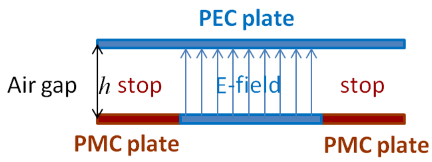


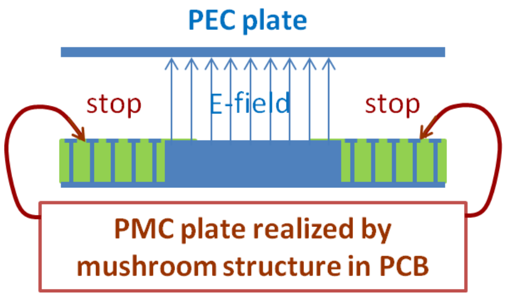
Fig. 2. Principle of Gapwave technology

Good metals, such as copper, are very close to PEC, and PMC (not existing in nature) can be realized by a mushroom structure in PCB (printed circuit board) or metal posts on a metal plate, easily with an octave (2:1) bandwidth; see Fig. 3.

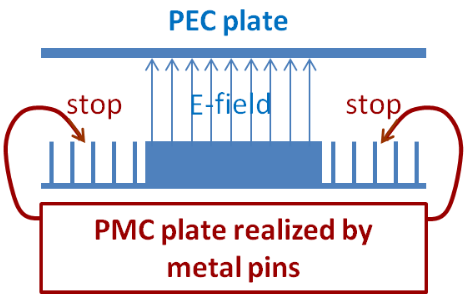
Gapwave technology has been also applied to make different microwave components for mm-waves and sub-mm-waves, such as filters [14], power divider [15], hybrid ring coupler [16], [17], packaging [18], [19], etc.

III. SIW E-plane Bend using Gapwave Technology

The proposed SIW E-plane bend and its geometrical parameters are illustrated in Fig. 4. In this structure, two substrate integrated waveguides (29×0.787 mm^2, where the width of 29 mm is the same as that of WG15 waveguide and the thickness of 0.787 mm is a standard thickness of Rogers substrate) are



(a)



(b)

Fig. 3. Realization of gapwave technology by (a) mushroom structure in PCB (printed circuit board) and (b)metal posts.

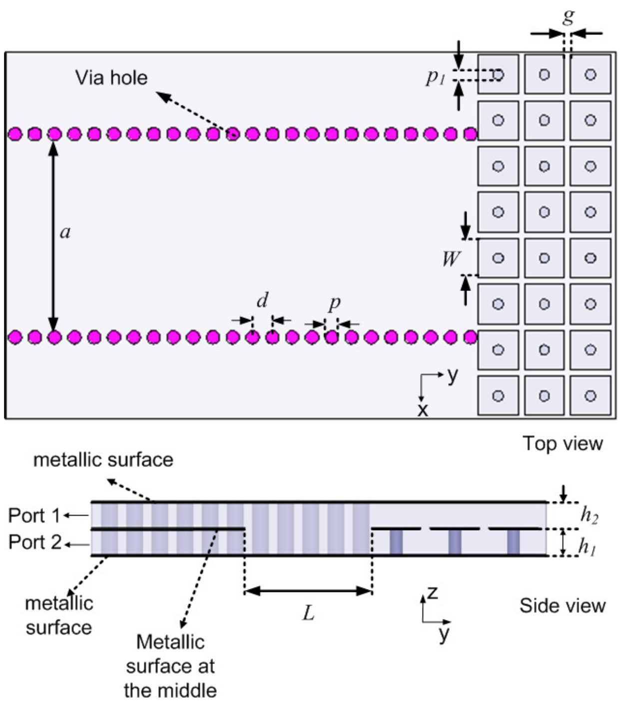


Fig. 4. Configuration of the proposed SIW E-plane bend with mushroom structure of gapwave technology.

connected to each other and loaded with a E-plane bend by a mushroom structure in PCB and an gap filled with the same dielectric (Rogers 5880) above the mushrooms.

In a certain frequency range, the mushroom structure, together with the top smooth plate with a small gap, creates a

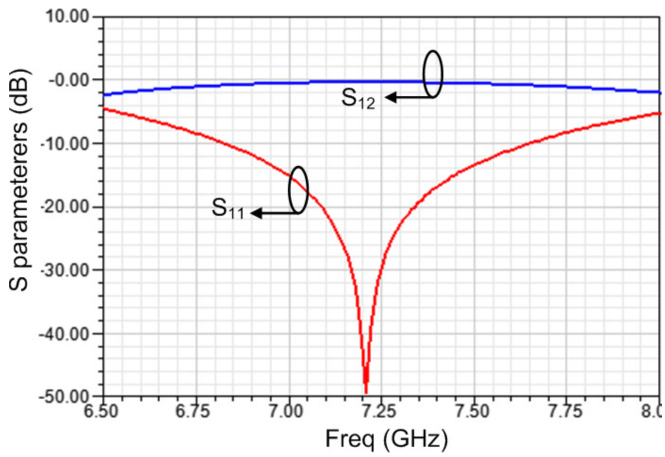


Fig. 5. Simulated S-parameters of the E-plane bend.

stopband, at which the existing mode in SIW is not able to propagate through the gap. As a result, the propagating mode in SIW tends to reflect back and continue its way through the E-plane bend. By proper choice of L, the minimum reflection and the maximum transmission through the E-plane bend can be achieved.

The dimensions of the mushroom structure are obtained from the one in [20], with a stopband of 5.3–11.3 GHz. Moreover, the values of a, p and d are determined according to the design rules coming from [8] and [21]. The number of mushroom columns should be both large enough in order to stop the propagation of SIW mode in the substrate gap and compact in size. As shown in Fig. 4, a structure of 3 columns is used in this preliminary study. The spacing between vias in SIW should be small enough so that the leakage through the SIW side walls become negligible and the width a of SIW is chosen to have the same width of WG15 standard waveguide with an operating frequency range of 7–10 GHz.

Based on the above discussion, the structure has been designed with the dimensions listed in Table I, where their definitions are illustrated in Fig. 4. The Rogers 5880 with relative permittivity of $\varepsilon_r = 2.2$ and tangent loss of $tan\delta = 0.0009$ is used as the substrate for both the SIW part and the mushroom gapwave part. The designed structure is simulated using HFSS and the simulation results are illustrated in Fig. 5, where the reflection coefficient and the insertion loss of the designed structure are depicted. It is observed that over the frequency range of 6.8–7.6 GHz (11.7%), the reflection coefficient is below -10 dB and the insertion loss is between 0.2–0.7 dB.

TABLE I
DIMENSIONS IN MILLIMETER OF THE DESIGNED STRUCTURE DEPICTED IN FIG. 4

Parameter	Value	Parameter	Value
a	29 mm	W	6 mm
p	3 mm	p_1	1.5 mm
d	2 mm	g	1.0 mm
h_1	0.787 mm	L	15 mm
h_2	0.787 mm		

At the moment, we are optimizing the structure of the E-plane bend, aiming to a wider bandwidth and a lower reflection coefficient. Manufacture and measurement verification will be also carried out after the optimization.

IV. Conclusions

A preliminary study on a new solution to E-plane bend for SIW circuit and antenna systems has been presented. Combining the SIW technolgy with the gapwave technology, the SIW E-plane bend has retained the advantages of simple geometry, low manufacture cost and integratability with other circuits.

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