Transition Design for Active SIW Components

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***Abstract*—This report presents a multi-function transition design for active substrate integrated waveguide (SIW) components. With the current semiconductor technology, transistor and diode are mounted on microstrip circuit, to reach the goal of DC basing, impedance matching and fundamental requirements. Besides, various SIW passive circuits with performance enhancement are proposed. We integrate the two concepts into a single platform. Unlike the conventional SIW-to-microstrip line design, the proposed transition achieves the functions of DC de-coupled, low loss, wideband, compact, impedance transformation and mode matching. We aim at introducing the proposed design as a leading system-on-substrate technology for the implementation of cost-effective and high performance millimeter-wave and terahertz circuits and systems.**

***Index Terms*—Microstrip line, series stub, substrate integrated waveguide and transition**

I. Introduction

TWO fundamental functions of transmission lines are to transmit signals over a long distance and to build distributed circuit elements. Substrate integrated waveguide (SIW) is one of the transmission lines and it has been a compelling development on millimeter-wave and terahertz distributed circuit elements. The features, such as low loss, self-package, low cost fabrication, high design flexibility, and high power handling, makes the SIW passive component suitable for high performance wireless communication systems. Apart from passive components, active circuits are also fundamentally important; however, existing transistors or diodes are designed to be mounted on microstrip line, rather than SIW. For this reason, SIW-to-microstrip line transition is an indispensable structure.

First of all, for SIW-to-microstrip line transition design, it converts quasi-TE10 mode in SIW to quasi-TEM mode in microstrip line and vice versa. Secondly, the frequency responses of the characteristic impedances of the SIW and microstrip line are different, so it should achieve impedance matching over a certain bandwidth. Fortunately, SIW and microstrip line can be fabricated on the same substrate, so it makes the transition possible to be compact and planar. In [1], the tapered line transition is the most frequently-used technique of bridging SIW and microstrip line because of its sample structure and wideband performance. Several variations of this transition are reported in [2]-[4].

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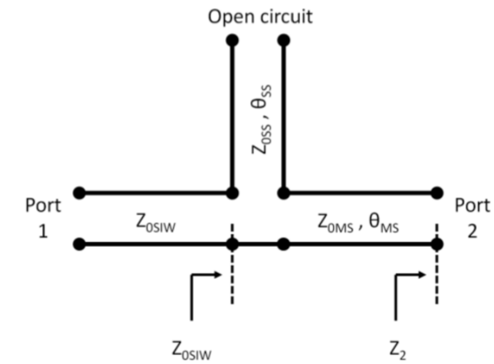

Fig. 1 Circuit diagram of the SIW-to-microstrip line transition using series stub concept.

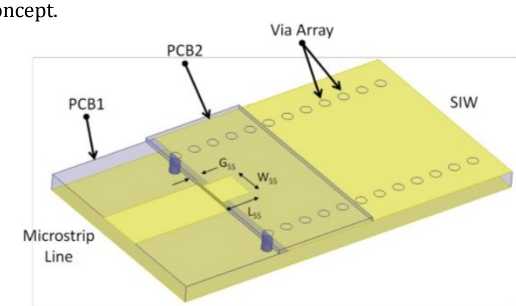

Fig. 2 3D structure of the first transition with two pieces of printed circuit boards, PCB1 and PCB2, and tuning parameters, GSS, WSS, and LSS.

DC biasing is essential for the active circuits while SIW is always DC grounded. Therefore, DC isolation is required in SIW-to-microstrip line transition design. Lumped DC-blocking capacitor is commonly used; whereas it generates the high loss at millimeter-wave and terahertz frequency ranges. Coupled-line structure is also a universal method; whereas it limits the relative bandwidth and introduces an additional 90° electrical length into the circuit. On the other hand, impedance transformation is not realized in these mentioned methods. DC-decoupled SIW-to-microstrip line transition with impedance transformation is proposed in this report. Two different techniques of the transitions are utilized, namely series stub concept and inserted microstrip line concept. Unlike the conversional tapered line transition, the proposed designs fulfill DC de-coupling, low loss, wideband, compact, impedance transformation, and mode matching.

II. First Transition Design

Fig. 1 indicates the circuit diagram of the first proposed transition with series stub concept. The series stub is made by microstrip line, including three sections of transmission lines. The DC potential of the SIW is always zero due to the waveguide structure, while the DC potential of the microstrip line is freely chosen. Port 2 is a microstrip port that can be loaded by the active device. In case, a reactive load impedance Z_2 is loaded at port 2. With different electrical lengths of θ_{MS} and θ_{SS}, the impedance is transformed to match Z_{0SIW} by the concept of two elements ell matching network.

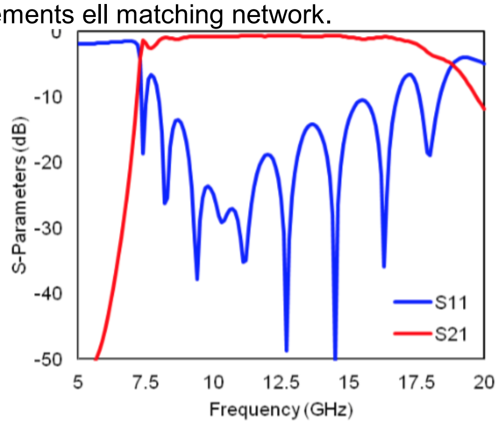

Fig. 3 Simulated S-parameters of the back-to-back transition using series stub concept.

A 3D electromagnetic model is built in Anosft HFSS as illuminated in Fig. 2. By adjusting the stub width Wss, stub length Lss, and the gap between microstrip line and SIW Gss of the transition, arbitrary reactive impedance can be matched to SIW. It is chosen that the characteristic impedances of both microstrip line and SIW are 50Ω at 10 GHz and the length of the open circuit series stub is 90° at 10 GHz. For the series stub, the signal line is connected to the signal line of the microstrip line and the ground line is connected to the signal line of the SIW. The top surface of the SIW is shared as a ground of the series stub. Based on the simulated S-parameters of the back-to-back transition shown in Fig. 3, not more than 1.1 dB insertion loss and not less than 10 dB return loss are observed over the frequency range of 8.0 GHz - 16.7 GHz.

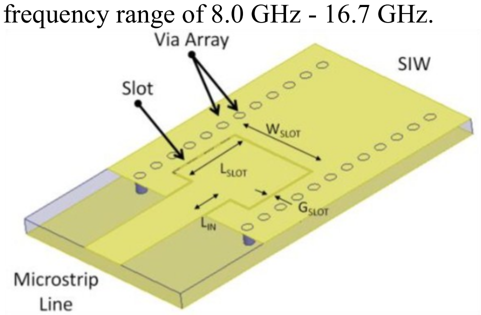

Fig. 4 3D structure of the second transition with tuning parameters L_{IN}, L_{SLOT}, W_{SLOT}, and G_{SLOT}.

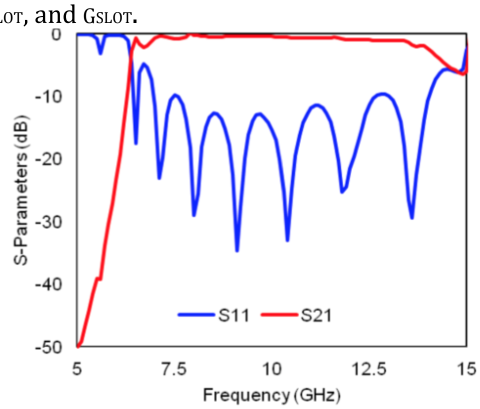

Fig. 5 Simulated S-parameters of the back-to-back transition using inserted microstrip line concept.

III. Second Transition Design

Fig. 4 indicates the conceptual diagram of the second proposed transition with inserted microstrip line concept. Part of the microstrip line with open circuit end and various structures are inserted into the SIW section, causing strong edge coupling. Compared with the first design, a single-layer design is realized. However, the shape of the inserted part is significant to impedance transformation.

A 3D electromagnetic model is drawn in Fig. 4. In this design, the characteristic impedances chosen of both microstrip line and SIW are 50Ω at 10GHz. And rectangular shape is selected with gap width (G_{SLOT}) of 0.03mm. By adjusting the width W_{SLOT}, length L_{SLOT} and inserted line L_{IN} of the transition, arbitrary reactive impedance can be matched to that of SIW. Based on the simulated S-parameters of the back-to-back transition shown in Fig. 5, not more than 1.0 dB insertion loss and not less than 10dB return loss are observed over the frequency range of 7.6 GHz - 12.6 GHz.

IV. Conclusion

Two transition designs utilizing series stub concept and inserted microstrip line are presented in this report. The proposed transitions are applied to bridge the active microstrip circuit and passive SIW component at X-band. The DC-decoupling nature of these transitions saves DC-blocking capacitor at the designed frequency range. The similar concept will be optimal to various transmission lines at millimeter-wave and Terahertz frequency ranges.

V. Near career Plan

The MTT-S scholarship supported my research and motivated my interest in microwave circuits. This is the dominant reason for me to continue pursuing a PhD degree in the University of California, San Diego (UCSD) upon my graduation from City University of Hong Kong. I am also currently researching on microwave circuits. I appreciate this scholarship to lighten my previous research and provided me with the motivation for future study.

VI. Refferences

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