Substrate-Integrated Waveguide Transitions To Planar Transmission-Line Technologies

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Abstract — **For the purpose of integrating active, nonlinear and surface-mount components in substrate-integrated waveguide (SIW) technology, this paper presents a variety of new and modified transitions from SIW to other planar transmission lines. Typical performances are shown involving connections to microstrip, coplanar waveguide (both conductor-backed and regular), coplanar strip line and slot line technologies. Both modified and new transition examples in the 18 – 27 GHz range demonstrate the feasibility of such interfaces for bandwidths in the order of 40 percent. Measurements and full-wave simulations validate the proposed designs.**

Index Terms — **Substrate-integrated waveguide, microstrip, coplanar waveguide, coplanar strip line, slot line, interfaces, transitions.**

I. INTRODUCTION

Substrate-Integrated Waveguide (SIW) components have emerged as a viable alternative to all-metal waveguide and microstrip or coplanar waveguide (CPW) circuitries, e.g. [1]. This fact is demonstrated in many recent publications on SIW filters, power dividers, couplers and antennas. For applications in state-of–the-art microwave systems, however, SIW will have to interface with other planar transmission-line media for the purpose of integrating active, nonlinear and surface-mount components.

Several transitions to microstrip and CPW technology have been proposed. They can be roughly divided into single-substrate or multilayered substrate applications. Multilayered connections can be typically used in circuits involving a multilayered fabrication process such as LTCC [2]. Dual-layered SIW transitions to microstrip [3] or CPW technology [4] have been successfully proposed, but multilayered SIW circuit implementations often suffer from alignment problems.

Thus the vast majority of recently published transitions from SIW to other transmission-line media have been proposed as single-layered circuits [5] – [11] and include connections to microstrip [5], [6], grounded CPW [7], [8], regular CPW [9], and coplanar stripline (CPS) [10]. A transition involving a slotline has been presented within a SIW magic-T structure for mixer applications [11].

This paper presents modified and new transitions between SIW and microstrip, CPW, CPS and slotline. It is demonstrated that such transitions are feasible on a single substrate and that wideband interfaces with more than 40 percent bandwidth can be realized.

II. RESULTS AND DISCUSSION

Typical to all transitions involving SIWs is the requirement that the TE$_{10}$-mode-like field in the SIW be adapted to the fundamental mode of the transmission line it is interfaced with. Due to the similarity between the fundamental waveguide and microstrip modes, the SIW-to-microstrip transition was the first one proposed [5], and design guidelines are well understood [6].

Fig. 1 shows a photograph and performance of a back-to-back microstrip-to-SIW transition on RT/Duroid 5880 substrate with ε_r=2.2, tanδ=0.0009, substrate height h=0.508mm, metallization thickness t=17.5µm, and conductivity σ=5.8x10^{7}S/m. The microstrip taper section, which has been fine-optimized for extended bandwidth, is clearly visible in the inset of Fig. 1. Simulations with HFSS and measurements are in good agreement over the entire 16 to 30 GHz bandwidth. The maximum insertion loss of the back-to-back transition is better than one dB over most of the frequency range, except between 16.25 GHz and 16.95 GHz where it rises to up to 1.26 dB. The measured return loss is better than 15 dB between 17.5 and 30 GHz (>50 percent).

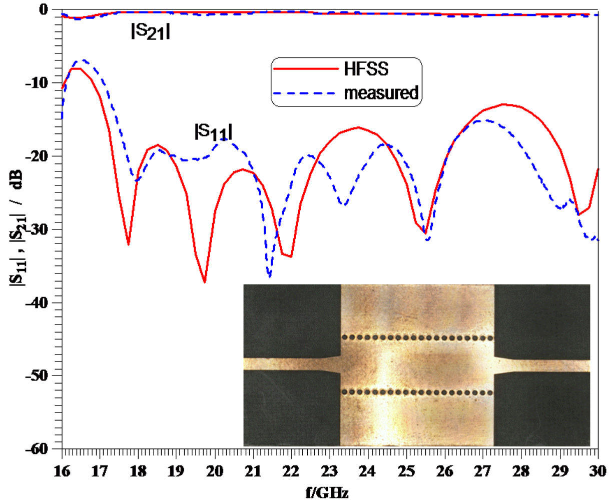

Fig. 1. Photograph and simulated and measured responses of a back-to-back microstrip-to-SIW transition.

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A transition on the same substrate between SIW and a grounded CPW with via holes is shown in Fig. 2. Both HFSS and CST predict the reflection coefficient to be better than 20 dB between 18 and 27 GHz (40 percent bandwidth) and the insertion loss at 0.3dB. The differences between CST and HFSS results are attributed to the proximity between the slots and the via holes and the different meshing associated with it. Upon investigating a back-to-back transition (not shown here for lack of space), it was found that the length between the two transitions influences the performance. This explains the different results obtained for such a transition in [7] and [8]. Also note that the next quasi-waveguide mode in the channelized, grounded CPW (GCPW) depends on the vicinity of the via holes to the GCPW slots. Since this distance is limited due to manufacturing requirements, the fundamental-mode bandwidth of this transition is limited.

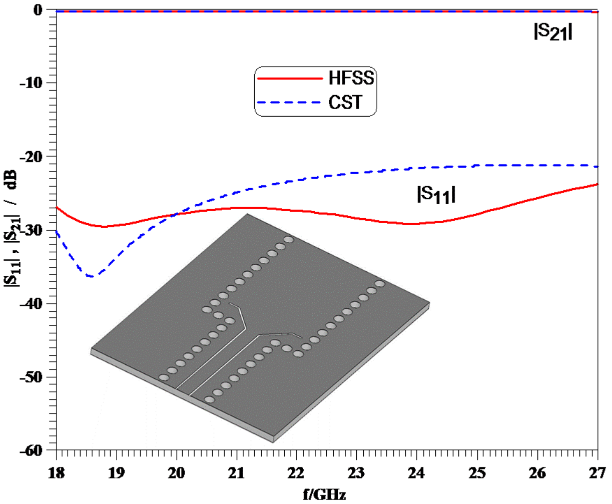

Fig. 2. 3-D view and response of a transition between SIW and grounded CPW.

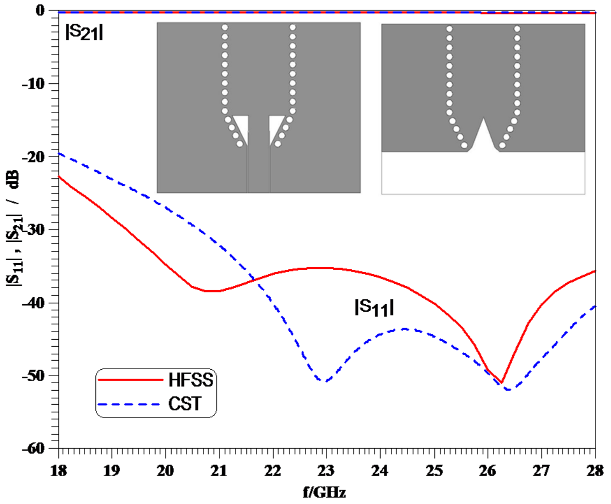

Fig. 3. Top/bottom metallization and performance of a transition between SIW and regular CPW.

This is not the case for a connection to a regular CPW [9]. Fig. 3 shows a SIW-to-regular-CPW connection on RT/Duroid 5880. It is a modified version of the one presented in [9] in the sense that the lateral vias shown in [9] have been removed, thus leading to a narrower and more compact design. Note that the agreement of results obtained with HFSS and CST is fairly good. While the return loss in HFSS is better than 20 dB over the entire frequency range of 18 to 28 GHz (43 percent bandwidth), CST predicts the worst return loss of this transition to be 19.5 dB at 18 GHz. The maximum insertion loss is 0.35 dB with all dielectric and conductor losses included.

An interface between SIW and CPS was proposed in [10] and applied to a narrowband SIW feed of a printed two-element Yagi-Uda antenna. The transition isolates a part of the top metallization and connects it to ground using additional via holes. Thus the slot mode between the two conducting strips of the CPS can propagate.

Fig. 4 shows a modified version of the transition in [10] on RT/Duroid 6002 substrate with ε_r=2.94, tanδ=0.0012, substrate height h=0.508mm, metallization thickness t=17.5μm, and conductivity σ=5.8x10^{7}S/m. The insets show top and bottom metallization, both as being viewed from the top. In modifying the transition and using a row of via holes, which are located on the side of the conductor that is farther away from the slot, the bandwidth has been significantly increased. The return loss is better than 20 dB between 18 and 26.3 GHz (37 percent bandwidth), and the maximum insertion loss within this range is predicted as 0.9 dB. The good agreement between HFSS and CST results demonstrate that a SIW-to-CPS transition is feasible over fairly wide bandwidth.

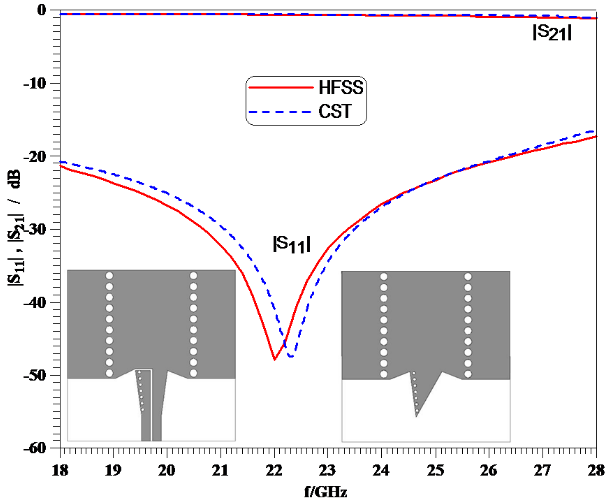

Fig. 4. Top/bottom metallization (as seen from the top) and response of a transition between SIW and CPS.

A SIW-to-slotline interface has only been attempted in [11] within the context of a four-port SIW network (magic T). Our new approach to realize a direct transition employs modifications of the CPS transition in Fig. 4, in which we widen the strips for the slotline to be formed.

Fig. 5 shows the top and bottom metallization as seen from the top and the overall performance of the transition on

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RT/Duroid 6002. Good agreement between HFSS and CST verifies the design. The return loss is better than 20 dB over the entire 18 to 28 GHz (43 percent) bandwidth. Insertion losses are slightly higher than those for the SIW-to-CPS transition and amount to a maximum of 1.6 dB towards the end of the band.

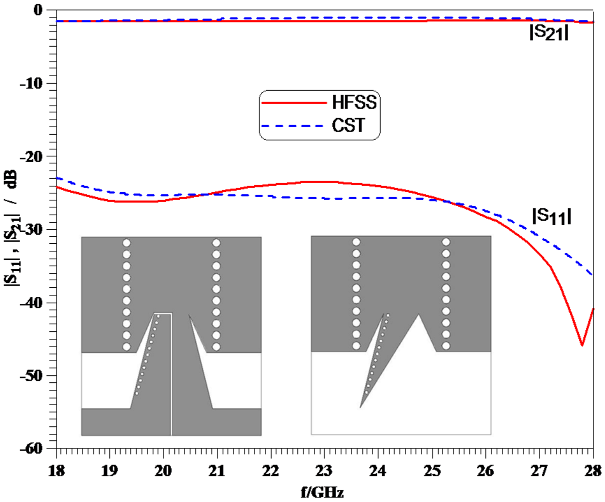

Fig. 5. Top/bottom metallization (as seen from the top) and response of a transition between SIW and slotline.

III. CONCLUSION

Modified and new transitions between substrate-integrated waveguide (SIW) technology and other transmission-line media are investigated. It is demonstrated that interfaces with bandwidths in the order of 40 percent can be established when connecting SIW to microstrip, regular coplanar waveguide (CPW), grounded CPW, coplanar stripline (CPS) and slot lines. The designs are verified by measurements and full-wave simulations of commercially available software packages. It is expected that the transitions presented here will contribute to integration capabilities of active, nonlinear and surface-mount components with SIW technology.

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