Implementation of Three-Way Power Divider Based on Substrate Integrated Waveguide

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***Abstract*—This paper presents the design, fabrication, and measurement results of an X-band 1×3 substrate integrated waveguide (SIW) power divider. The 1×3 SIW power divider provides equal amplitude with uniform phase distribution at each output port. These features are demonstrated by measurements experimentally. The amounts of measured power at the output ports are quite close to ideal power equality factor (4.77 dB) for three-way power division. Operating bandwidth of the fabricated divider is nearly 17.5% and reflection coefficient is better than –18.75 dB at the design frequency of 10 GHz as shown in both simulation and measurement results.**

Keywords— Substrate Integrated Waveguide, power divider.

I. INTRODUCTION

Substrate Integrated Waveguide (SIW) is one of the most popular wave guiding structure due to its low cost, compact size, ease of integration, and relatively low loss [1], [2]. SIW structures can be fabricated as a printed circuit board (PCB) assembly. SIW based feeding structures have low transition loss since they can be monolithically integrated with planar components. In order to benefit from these advantages, the basic waveguide power divider types in literature are applied using SIW technology in [3]. Thanks to these fundamental SIW power divider types, various multi-way power dividers can be obtained by concatenating them successively. Many SIW power divider studies using this technique with different even numbered output ports are available in the literature [4], [5]. However, successive addition technique only allows “1 × 2^n” (n=1, 2, 3…) type power dividers. To meet the odd numbered output ports requirement by using the successive addition technique, the input power has to be divided more than required output port number and unnecessary ports should be terminated causing additional insertion and reflection losses. Furthermore, RF termination increases the cost and space required for the implementation.

In this study, a 1×3 SIW power divider has been fabricated and measured based on the design that we have presented before [6]. In order to be able to integrate SMA ports, a microstrip to SIW transition is also designed and inserted to the power divider structure. The maximum magnitude difference between each output ports are measured about 0.5 dB in the 8.93–10.68 GHz frequency range.

II. DESIGN OF THE MICROSTRIP TO SIW TRANSITION

A single layer transition from microstrip line to a SIW with a tapered microstrip line section has been proposed in [7] and the analytical design equations for a low reflection tapered transition section have been reported by in [8]. To characterize the transition, two microstrip to SIW transition designed to utilize in the operating frequency band of the designed power divider are connected back to back as in Fig. 1 and simulated with the help of CST MICROWAVE STUDIO [9].

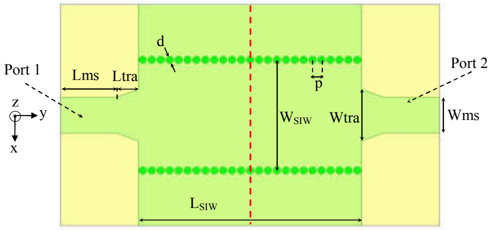

Fig. 1. Microstrip to SIW Transition

The structure in Fig. 1 has a mirror-image symmetry with respect to the red dashed-line. The width of tapered section gradually increased from w_{ms} to w_{tra} in order to minimize the reflection coefficient and insertion loss. The transition is designed on 1.575 mm-thick Rogers 5880 ($\varepsilon_r = 2.2$, $\tan\delta = 0.0009$ at 10 GHz). The vias in the design are identical and uniformly spaced. Table I summarizes the physical parameters of the optimized transition. The microstrip to SIW transition is manufactured by using the in-house facilities at the rapid prototyping tool. Fig. 2 (a) shows the implemented transition structure where the SMA connectors are also integrated. Fig. 2 (c) illustrates the measured and simulated S-parameters of the transition structure.

TABLE I. DESIGN PARAMETERS OF THE TRANSITION (mm)

W_{SIW}	p	d	L_{SIW}	L_{tra}	L_{ms}	W_{tra}	W_{ms}
15	1.2	1	30	3	7.5	7	4.85

There is a good agreement between the simulations and the measurement results. The discrepancies may be attributed to the fabrication imperfections and the influence of the connectors which are not included in the simulations.

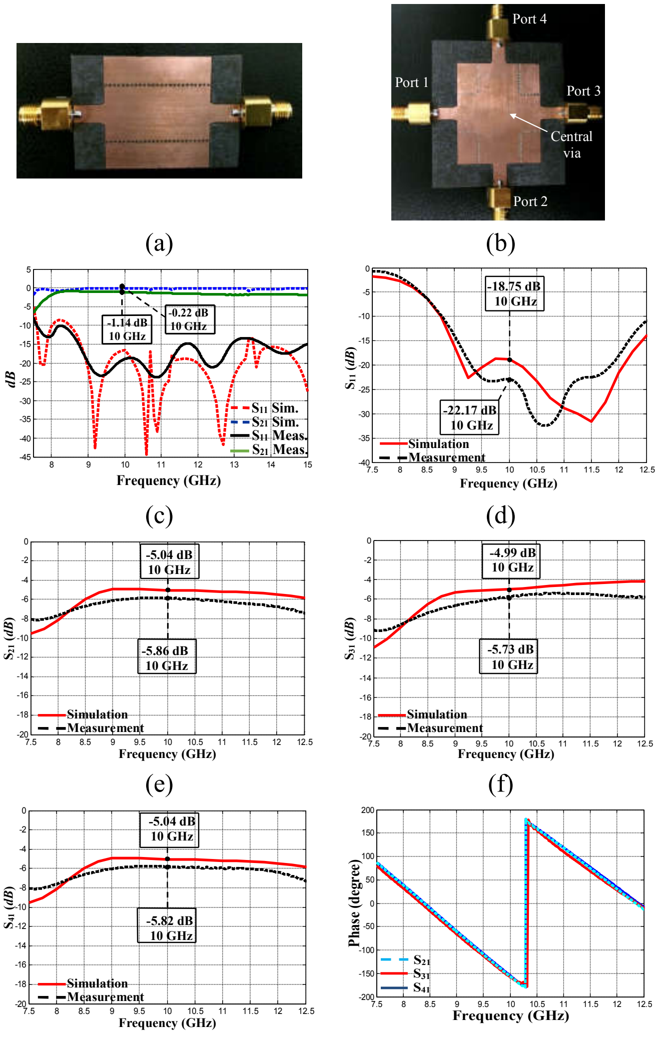

Fig. 2. (a) Fabricated microstrip to SIW transition, (b) Fabricated SIW power divider, (c) Measured and simulated S-parameters results for the microstrip to SIW transition. Comparisons between measurement and simulation results of SIW power divider (d) S_{11}, (e) S_{21}, (f) S_{31}, (g) S_{41}, and (h) Measured Phases at output ports

III. FABRICATION OF THE 1×3 POWER DIVIDER

The proposed 1×3 SIW power divider in [6] provides uniform feeding to antenna and microwave systems requiring same phase and power levels at the input ports of systems. The central via shown in Fig. 2 (b) has been utilized to adjust the magnitude and phase values of the divided power. The designed microstrip to SIW transition structure is employed at the ports of the power divider. The modified power divider is simulated and manufactured on the same substrate (Rogers 5880) as shown in Fig. 2 (b). The simulation and measurement results are compared in terms of magnitude of the S-parameters. It should be noted here that the measurements are performed by terminating all the output ports by a matched load except the port under test. When the power divider is excited from Port 1, the input power is divided into three at the output ports with nearly the same phases and magnitudes. Fig. 2 (d) shows that the reflection coefficient (S_{11}) of the power divider is better than −18.75 dB for both the simulation and the measurement results. The power levels that are measured at the output ports of the divider between 8.93 GHz and 10.68 GHz are nearly equal as shown in Fig. 2 (e), Fig. 2 (f) and Fig. 2 (g). The maximum magnitude difference between each output ports is measured as ± *0.5* dB at the operating frequency band. Furthermore, the amounts of measured power at the output ports are quite close to ideal power equality factor (*4.77 dB*) for three-way power division operation considering loss characteristic of fabricated microstrip to SIW transition results.

The measured phase results, i.e., $\angle S_{21}$, $\angle S_{31}$, and $\angle S_{41}$, are very close to each other as shown in Fig. 2 (h). Since the Port 2 and Port 4 are mirror-image with respect to the input Port (Port 1), the phases with respect to Port 1 are nearly equal as expected. The phase of Port 3 with respect to Port 1 is designed to have the same phase by tuning the physical parameters of the structure.

IV. CONCLUSION

A three-way X-band SIW power divider production is presented for antenna feeding and microwave applications at the 8.93–10.68 GHz range. This power divider has demonstrated the advantages of a low-profile, design simplicity, and low insertion losses at each output ports. In spite of some fabrication imperfections, it is shown that measured and simulated results agree well indicating the viability of the power divider for applications requiring odd numbered output ports.

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