Coplanar-Waveguide Tandem Couplers With Backside Conductor

Tien-Yu Chang, Chun-Lin Liao, and Chun Hsiung Chen

***Abstract*—Novel tight coplanar-waveguide (CPW) directional couplers are developed by connecting two loose couplers in tandem configuration. In this study, the CPW tandem couplers without and with backside conductor are implemented on the FR4 substrate. These tandem couplers are carefully examined theoretically and experimentally, and good match between simulated and measured results is observed. The proposed tandem couplers have the merits of tight coupling under relaxed fabrication requirements.**

***Index Terms*—Backside conductor, coplanar waveguide, tandem coupler.**

I. INTRODUCTION

DIRECTIONAL couplers are useful in developing various microwave circuit components such as power dividers, balanced amplifiers, and balanced mixers. Recently, coplanar waveguide (CPW) receives widespread attention due to the merits of easy integration with solid-state devices and passive components.

To develop the CPW-based directional couplers, various related coupled CPW structures were proposed and examined. In 1970, Wen [1] implemented the first edge-coupled CPW directional coupler, however, it is difficult to enhance the coupling effect to a level such as 3 dB due to the limitation in fabrication process. In order to implement tight couplers, both broadside coupled CPW [2] and conductor-backed edge-coupled CPW [3] structures were proposed, but in these structures the conductors should be placed on the different sides of the substrate. Based on the concept proposed by Lange [4], Chua *et al.* [5] developed the tight Lange couplers in CPW configuration.

The tightness level of a CPW directional coupler is usually limited by its strip and slot widths. This thin-width restriction may be relaxed by using the tandem scheme, which properly connects two loose couplers to form a tight coupler. Up to now, the researches about tandem couplers were mostly limited to the microstrip-line based structures [6]. Recently, the tandem scheme was employed to develop a tight uniplanar coupler [7] that composes of two loose CPW directional couplers without backside conductor. In this tandem scheme, the two individual CPW couplers can be close to each other without introducing severe cross-coupling interference between two couplers, thus the size of the resultant uniplanar tandem coupler may be made smaller. This is an advantage over the microstrip-based tandem configuration.

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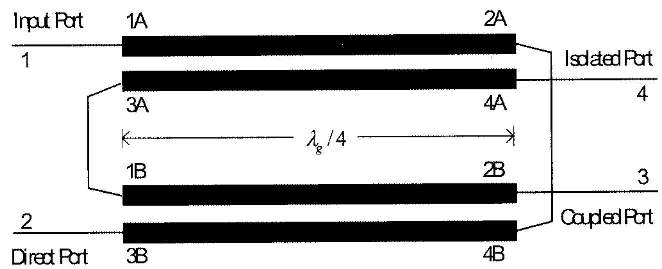

Fig. 1. Schematic diagram of tandem coupler.

In practice, CPW circuits are usually implemented with a backside conductor so as to improve the mechanical strength and to simplify the measurement procedures. Unfortunately, addition of the backside conductor usually lowers the coupling coefficient of the CPW directional coupler because of the decrease in the even-mode impedance. In this study, the tandem scheme is adopted to design a tight CPW directional coupler with backside conductor, and the effect of backside conductor will be discussed. Specifically, a CPW tandem coupler with backside conductor is implemented, which has a maximum coupling of 2.6 dB at the center frequency (1 GHz), the 2 dB bandwidth of 91%, and the return loss and isolation both better than 18 dB.

II. CPW TANDEM COUPLERS

A tandem coupler is realized by connecting two individual couplers as shown in Fig. 1. Here, port 2A of coupler A is connected to port 4B of coupler B, and port 3A of coupler A is connected to port 1B of coupler B. As a result, port 3B and port 2B of coupler B are the direct port 2 and the coupled port 3, while port 1A and port 4A of coupler A are the input port 1 and the isolated port 4 of the resultant tandem coupler. It is very easy to design a tandem coupler whose coupling coefficient is larger than 3 dB. With higher coupling coefficient, the bandwidth could be made larger.

Fig. 2 shows the layout and cross-section view of the proposed CPW tandem coupler with backside conductor that is composed of two loosely coupled CPW directional couplers. The crossovers of the coupled lines are introduced to make the coupler symmetric, and air bridges should be connected to each ground plane so as to suppress the unwanted coupled-slotline mode. Note that the width d of the common ground strip has little effect on the coupler's performance, thus it can be made smaller to make the coupler compact.

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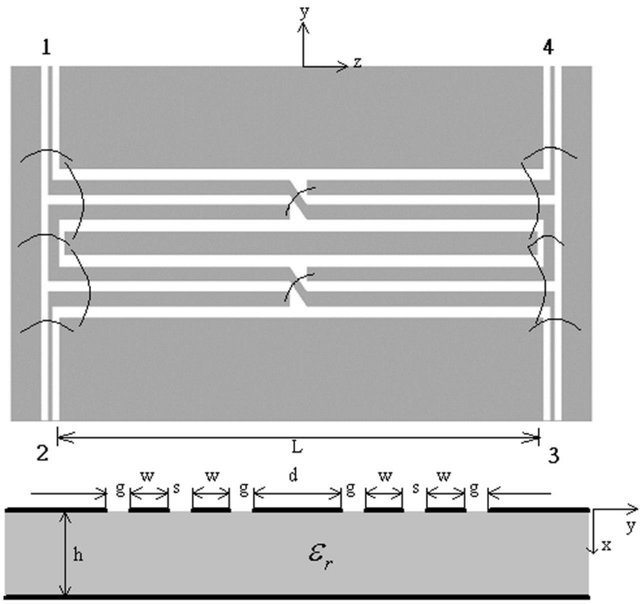

Fig. 2. Layout and cross-section view of CPW tandem coupler with backside conductor.

TABLE I
PARAMETERS OF CPW TANDEM COUPLERS

	Fig. 3	Fig. 4
Backside Conductor	No	Yes
ε_r	4.35	
h	1.45 mm	
Loss tangent	0.022	
Metal thickness	0.07 mm	
L	47mm	48mm
w	1.3mm	0.7mm
g	1.7mm	2.5mm
s	0.85mm	0.3mm
d	2.7mm	1.5mm

In this study, the CPW tandem couplers without and with backside conductor are implemented on the FR4 substrate, with the center frequency designed at 1 GHz. The parameters of the fabricated tandem couplers, obtained from the software LineCal of ADS, are listed in Table I. The characteristic impedance of the whole system is chosen as 100 Ω because the strip widths for the 50 Ω system would be so large that the associated discontinuity effect may not be neglected.

The fabricated tandem couplers are measured by the HP8722C automatic network analyzer. Here, the TRL calibration technique is used to eliminate the unwanted effects of the feeding lines. These couplers are also simulated by the commercial software (Ensemble). The measured and simulated results for the implemented tandem couplers are shown in Figs. 3 and 4, and good agreement between them is observed.

III. RESULTS

Depicted in Fig. 3 are the results for the CPW tandem coupler without backside conductor for which the coupled port has

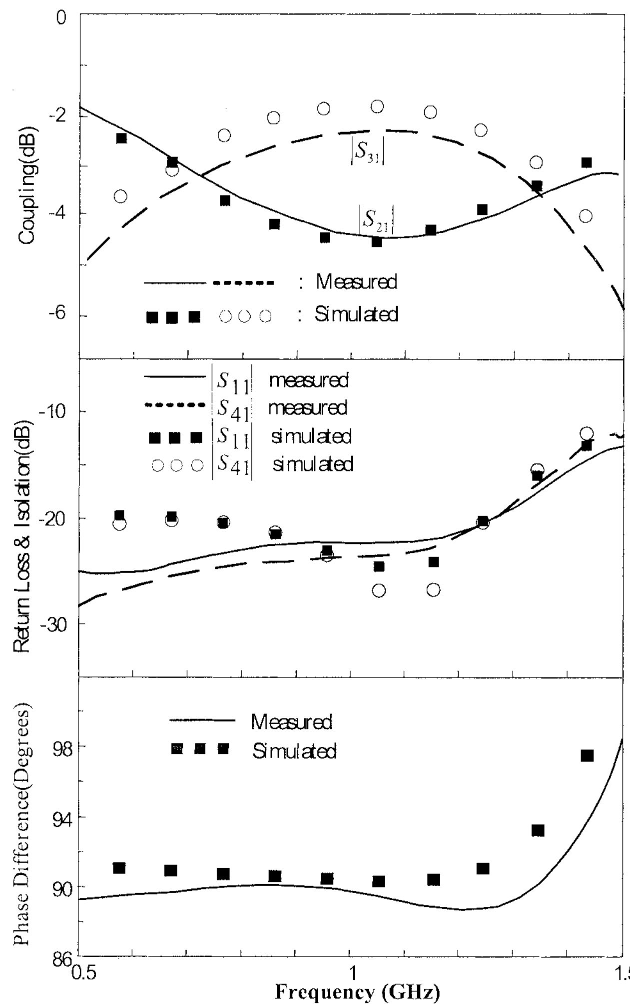

Fig. 3. Measured and simulated results for CPW tandem coupler without backside conductor.

a maximum coupling of 2.1 dB at the center frequency (1 GHz). (Here, the individual coupler is designed to have 6.91 dB coupling.) The average value of the couplings for the direct port and the coupled port is 3.3 dB. This coupler has a bandwidth of 90%, for which the power difference between the direct port and the coupled port is within 2 dB. The return loss and isolation are better than 15 dB and 14 dB within the band. The performances of return loss and isolation at higher frequencies are worse due to the various junction discontinuity effects that are more significant at higher frequencies. The phase difference between the direct and coupled ports is approximately 90° with an error within ±4° in the entire band.

Note that addition of a backside conductor in the tandem coupler would result in a severe reduction in the coupling coefficient. By adding a backside conductor to the CPW tandem coupler in Fig. 3, its simulated coupling coefficient is found to decrease to the level of 7.4 dB, a degrade in coupling by more than 5 dB. For other kinds of directional couplers such as CPW Lange coupler, the best solution to increase the coupling is to increase the distance g (Fig. 2) between the signal line and ground plane [7]. For the CPW tandem couplers proposed in this study,

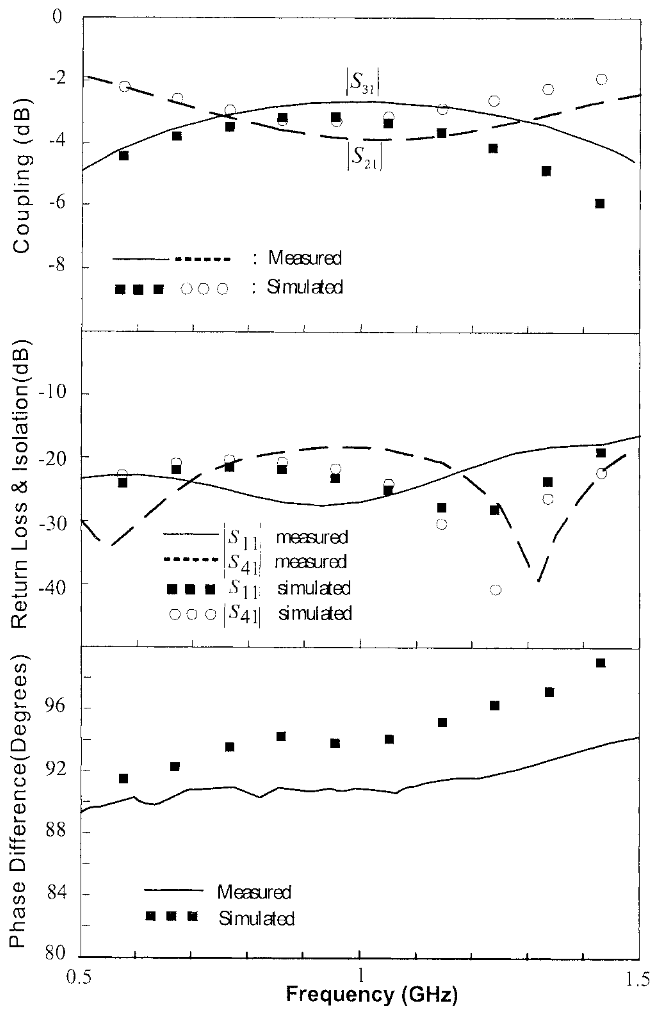

Fig. 4. Measured and simulated results for CPW tandem coupler with backside conductor.

it has only to slightly adjust the parameters of the coupler so as to obtain the same tight coupling.

Fig. 4 shows the measured and simulated results for the redesigned CPW tandem coupler with backside conductor for which the coupled port has a maximum coupling of 2.6 dB at the center frequency (1 GHz), and the average coupling over the entire band is about 3.2 dB. (The individual coupler has 7.58 dB coupling.) The 2 dB bandwidth of this tandem coupler is 91%. The return loss and isolation are both better than 18 dB in the entire band. The phase difference between the direct and coupled ports is approximately 90° with an error within ±5°.

IV. Conclusion

The CPW tandem couplers without and with backside conductor have been implemented and carefully examined. These CPW couplers have the desired properties of tight coupling under relaxed fabrication requirements, and are well suitable for use in a standard MMIC process.

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