Directional Couplers and Filter Research Based on the Asymmetrical Coplanar Waveguide

H. M. Liu, S. J. Fang

***Abstract*—Through the project and on the basis of the support of the MTT-S Scholarship program, some achievements have been achieved including weak coupling trans-directional coupler with capacitor-shunted ground-defected coupled CPWs and inductor-loaded ACPWs, and trans-directional coupler with DGS and conductor-backed asymmetric coplanar waveguides for good performance. Papers based on the above outcomes have been published recently. And they will be introduced shortly in the report. Then, next career plans will be described briefly, and the impact of the MTT-S scholarship program will be indicated in the last section of the report.**

***Index Terms*—Directional couplers, Asymmetrical coplanar waveguide**

I. Achievements

THE project "directional couplers and filter research based on the asymmetrical coplanar waveguide" has been researched for more than one year. During the period with the support of the MTT-S scholarship program, dramatic breakthroughs have been obtained, and some achievements have been published[1,2]. First, the weak coupling trans – directional (TRD) coupler with capacitor-shunted ground -defected coupled CPWs and inductor-loaded ACPWs is introduced.

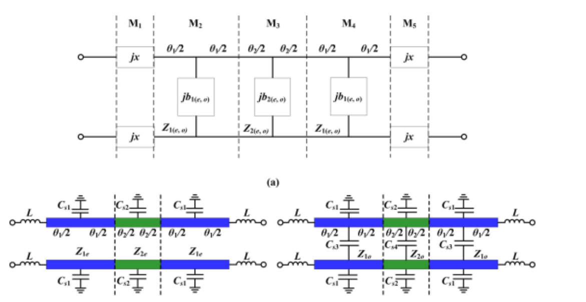

Fig. 1. Equivalent circuits of the proposed trans-directional coupler. (a) Schematic equivalent circuit. (b) Even-mode equivalent circuit. (c) Odd-mode equivalent circuit.

The schematic equivalent circuit of the TRD coupler is shown in Fig. 1(a). The coupled CPWs consist of three parts with electrical length of θ_1 or θ_2, which are loaded with unequal shunt susceptance $b_{1(e,o)}$ or $b_{2(e,o)}$ on the middle of each part. Let x be the series reactance. $Z_{1(e,o)}$ and $Z_{2(e,o)}$ represent the even- and odd-mode characteristic impedance of each segment. If the series reactance x is realized by inductor L, and the even- and odd-mode shunt susceptances b_{1e}, b_{2e}, b_{1o}, and b_{2o} are implemented by capacitors C_{s1}, C_{s2}, C_{s3} and C_{s4}, the even- and odd-mode equivalent circuits of the proposed coupler are given in Figs. 2(b) and 2(c).

According to the formulae proposed, two TRD couplers with coupling factor of 10 dB and 20dB are designed and fabricated. Choose the 10-dB TRD coupler as an example. The layout is shown in Fig. 2. A DGS is etched under the middle part of the coupled CPWs with the width of w_g and the length of l_2 to

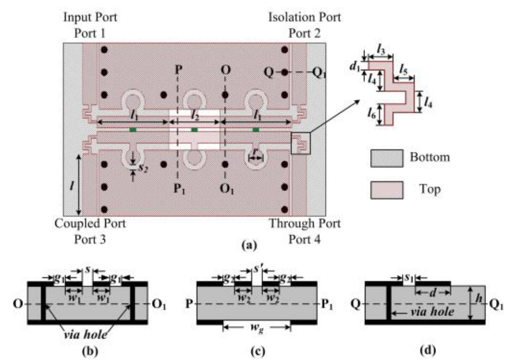

Fig. 2. (a) Layout of the proposed 10-dB trans-directional coupler. (b) Cross-sectional view of coupled CPWs. (c) Cross-sectional view of the coupled CPWs with GDS. (c) Cross-sectional view of ACPW.

realize high impedance coupled lines. The top side of the coupled CPWs is divided into three sections. w_1, g_1, s and l_1 represent the dimensions of right/left coupled CPWs, and w_2, g_2, s' and l_2 express the middle coupled CPWs. Then six circular open stubs with diameter of r are connected to the coupled CPWs instead of the capacitors C_{s1} and C_{s2}, while four meander lines are used to realize the inductor L. Taking account of the effect of the ground for coupled CPWs, ACPW is employed as input and output with strip width of d and slot width of s_1. The ground planes are connected to each other using via holes in order to avoid the generation of undesired waveguide modes. The photograph of the fabricated prototype is shown in Fig. 3.

The S-parameters of the fabricated 10-dB coupler were measured using an Agilent N5230A network analyzer. The measured isolation is better than 20 dB from 1.427 to 1.520 GHz (6.3%) with a best isolation of about 40 dB at 1.474 GHz. In the bandwidth of $|S_{21}| < -20$ dB, the insertion loss for the through port is 0.68±0.02 dB and the value of the coupling is

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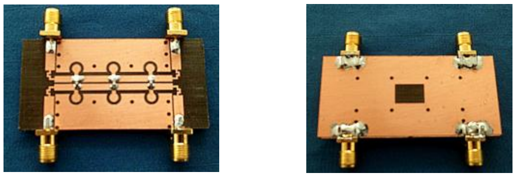
about 10.8±0.4 dB. Furthermore, the measured impedance bandwidth ($|S_{11}|$ < -20 dB) is 13.6%, from 1.414 to 1.620 GHz. The measured best directivity is about 30 dB at 1.474 GHz, and the measured output port phase difference is 90°±5° in the frequency range of 1.410-1.591 GHz. Detail results are listed in the published paper [1].



(a) Top view (b) Bottom view

Fig. 3. Photograph of the proposed 10-dB trans-directional coupler.

Then the TRD coupler with DGS and conductor-backed asymmetric coplanar waveguides is introduced, and the paper on the basis of it is published in [2].

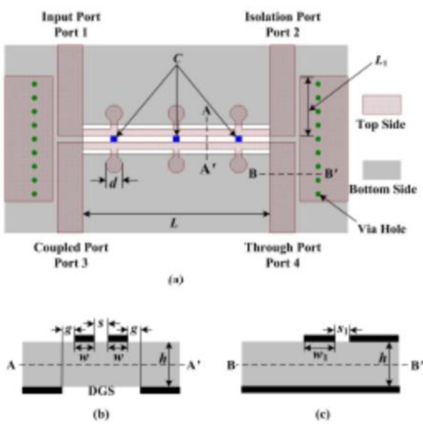
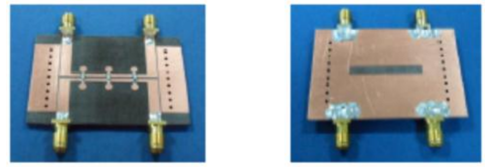


Fig. 4. The layout of the TRD coupler with DGS and CBACPW. (a) Top view of the coupler; (b) Cross-sectional view of the coupled microstrip lines with DGS; (c) Cross-sectional view of CBACPW with one lateral ground plane.

The layout of this TRD coupler is shown in Fig. 4. To operate at TRD mode, coupled lines are loaded by periodical shunt capacitors. However, even- and odd-mode phase velocities of coupled microstrip lines are different and capacitances of commercial lumped capacitors usually don't match with theoretical values, which lead to more than 10% drift of operating frequency with maximum coupling level and poor isolation. To solve this problem, DGS is etched under coupled microstrip lines to adjust even- and odd-mode phase velocities, and CBACPW is inserted into each port of the coupler to improve isolation. Fig. 5 shows the photograph of the fabricated TRD coupler.

The proposed TRD coupler exhibits a return loss of better than 20 dB, isolation of better than 20 dB, balanced output power distribution (3.25±0.35 dB) and consistent 90° (±2°) output signals phase difference over a fractional bandwidth of 15.4% (1.501-1.752 GHz) with a maximum isolation of about 53 dB at 1.635 GHz.

II. Career Plans



(a) Top view (b) Bottom view

Fig. 5. Photograph of the fabricated TRD coupler.

During the Chinese national natural fund project "Directional couplers and filter research based on the asymmetrical coplanar waveguide", I have learned more about the directional coupler and asymmetrical coplanar waveguide. After accomplish the project, I find that I am interested in the RF and microwave field, so I prepare to accomplish the PhD degree in the Antenna and Microwave Institute, Dalian Maritime University, Liaoning, China in the next step.

During the research of "Directional couplers and filter research based on the asymmetrical coplanar waveguide", I discover that the trans-directional coupler has so many advantages such as tight coupling, small volume, and DC blocking, and less research has been done on it, so I devote myself to the research of the trans-directional coupler during the PhD study.

Besides the research of the trans-directional coupler, I will also extend my study to antenna, Butler matrix, active circuit and so on. I think I will learn more and study more to improve my competence, and publish high quality papers during my PhD study.

III. Impacts Of The MTT-S Scholarship Program

The MTT-S scholarship program has strong impact on the decision of my career. With the support of the scholarship and during the research process, I have improved my ability and interests, which influence me on the choice of whether I should get job or do further study. Finally, I find that I am so interested in the RF and microwave circuit field, thus I decided to accomplish the PhD degree to explore and further increase my knowledge. So I must thank the MTT-S scholarship program and I feel that the program is significant for us students.

References

[1] H. M. Liu, Z. B. Wang, S. J. Fang, "Trans-directional coupler with capacitor-shunted ground-defected coupled CPWs and inductor-loaded ACPWs for weak coupling applications," *Journal of Electromagnetic Waves and Applications*, vol. 27, no. 1, pp. 104-116, 2013.

[2] Z. B. Wang, H. M. Liu, S. J. Fang, Q. Wang, "A Novel 3-dB Trans-directional Coupler with DGS and Conductor-backed Asymmetric Coplanar Waveguides," *Frequenz*, vol. 67, no. 3-4, pp. 67-72, 2013.