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Compact Right-Angled Coplanar Waveguide Using Central Short-Circuited Slotline

Chieh-Yu Liao and Chun-Long Wang
Electronics Engineering, National Taiwan University of Science and Technology
106 Keelung Rd., Sec. 4, No. 43, Taipei, Taiwan
M10102214@mail.ntust.edu.tw; clw@mail.ntust.edu.tw

Abstract- In this paper, a compact right-angled CPW using the central short-circuited slotline is proposed. The short-circuited slotline is fabricated on the central strip of the CPW so that it will not consume any additional area. As compared with the right-angled CPW using the short-circuited slotline [14], the reflection coefficient is maintained at a low value around -10 dB while the transmission coefficient is increased from -4.49 dB to -3.28 dB. Besides, the power loss is substantially reduced from 0.55 to 0.37.

***Keywords*:** Compact, right-angled, coplanar waveguide, central short-circuited slotline, power loss.

1. Introduction

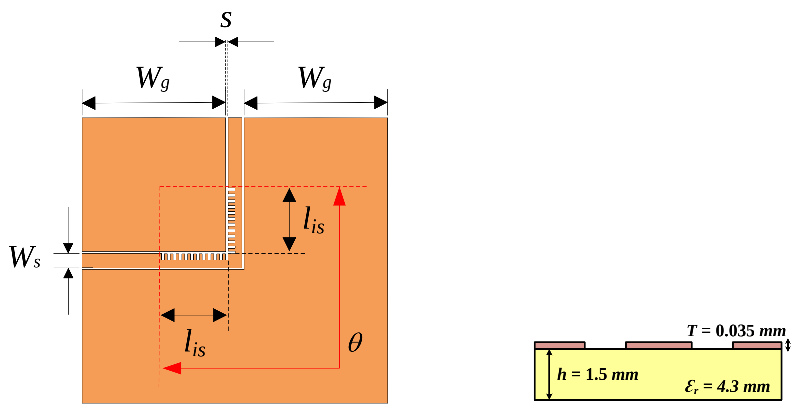
In 1969, the coplanar waveguide (CPW), which consists of the central strip and two ground planes running parallel to the central strip, is presented by C.-P. Wen [1]-[2]. Since the central strip and ground planes of the CPW are on top of the same surface, it is convenient for the CPW to shunt circuits on the PCB [3]. Besides, the CPW has various advantages such as low dispersion, small crosstalk, and less radiation loss, which make it being commonly used in the microwave circuit designs.

The CPW has two modes, namely the CPW-mode and coupled slotline-mode (CSL-mode) while the CPW-mode is used to conduct the signal and the CSL-mode is undesirable. When the CPW makes a right-angled bend, the CSL-mode will be induced [4]. The induced CSL-mode will in turn increase the radiation loss and therefore decrease the efficiency of the microwave circuits [5]. To eliminate the CSL-mode, bondwires are placed near the CPW right-angled bend in order to equalize the potentials of the inner and outer routes [6]-[7]. However, the inclusion of the bondwires will increase the cost and bondwires themselves would bring forth parasite capacitance, limiting the operating bandwidth of the microwave circuits [8]. To enhance the performance of the bondwires, the CPW right-angled bend is chamfered, step-compensated, or dielectric-overlaid [9]-[11]. Although the performance of the bondwires may be improved through these methods, the fabrication complexities such as repeated photolithography or micromachining are increased [12]. In order to reduce the fabrication complexities, a balanced coplanar waveguide using the U-shaped slot, which does not need bondwires, is proposed [13]. However, the circuit size of the U-shaped slot is large and the radiation loss of the U-shaped slot is severe. In order to reduce the circuit size and the radiation loss, the right-angled coplanar waveguide using the short-circuited slotline is proposed [14]. In this paper, in order to further reduce the circuit size and the radiation loss, the right-angled coplanar waveguide using the central short-circuited slotline is proposed.

2. Reflection and Transmission Coefficients

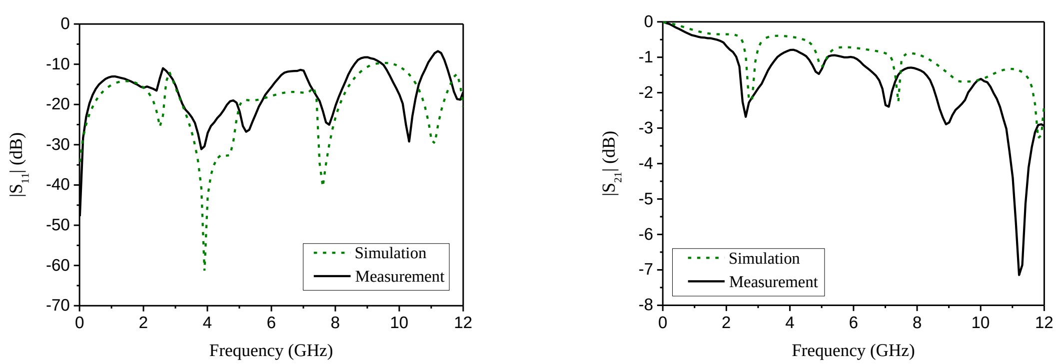
The schematic view of the right-angled coplanar waveguide (CPW) using the central short-circuited slotline is shown in Fig. 1 where the short-circuited slotline is implemented on the central strip of the CPW. The central short-circuited slotline is used to increase the electrical length of the inner slot of the CPW so that the electrical lengths of the inner and outer slots will be equal. As compared with the right-angled CPW using the short-circuited slotline (Fig. 24, [14]), there is no additional area copied by the short-circuited slotline since the short-circuited slotline is implemented on the central strip of the CPW. In order to acquire the frequency responses of the reflection and transmission coefficients, the right-angled CPW using the central short-circuited slotline shown in Fig. 1 is simulated by using the commercial software Advanced Design System

(ADS). The simulated reflection and transmission coefficients are shown in Fig. 2. In order to verify the simulation results, the right-angled CPW using the central short-circuited slotline shown in Fig. 1 is fabricated as shown in Fig. 3. The substrate used in the fabrication is FR4, which has a relative dielectric constant ε_r = 4.3, height h =1.5mm, loss tangent = 0.02, and thickness T = 0.035mm. The fabricated circuit shown in Fig. 3 is then measured through using the VNA Agilent E5071C after the VNA is calibrated with the Agilent N4431B 4-port RF Electronic Calibration (ECal) Module. The measured frequency responses of the reflection and transmission coefficients are also shown in the Fig. 2. As can be seen from Fig. 2, the simulation and measurement results agree well from DC to 12 GHz except for some small discrepancies, which may be caused by the parasitic effects of the connectors shown in Fig. 3. Besides, the simulated and measured reflection coefficients are smaller than -9.67 dB and -6.74 dB, respectively, while the simulated and measured transmission coefficients are larger than -3.28 dB and -7.14 dB, respectively. As compared with the reflection coefficient of the right-angled CPW using the short-circuited slotline (Fig. 29, [14]), the reflection coefficient remains at a low value around -10 dB. As compared with the transmission coefficient of the right-angled CPW using the short-circuited slotline (Fig. 30, [14]), the transmission coefficient is increased from -4.49 dB to -3.28 dB.



(a) (b)

Fig. 1 Schematic view of the right-angled coplanar waveguide using the central short-circuited slotline. (a) Top view. (b) Cross-sectional view.



(a) (b)

Fig. 2 Comparison between the simulated and measured frequency responses for the right-angled CPW using the central short-circuited slotline. (a) Reflection coefficient. (b) Transmission coefficient.

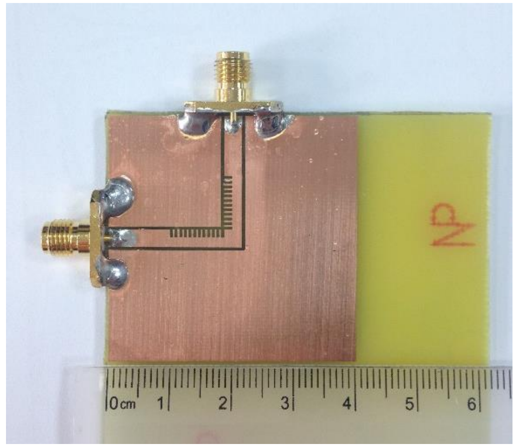


Fig. 3 The fabricated circuit for the right-angled CPW using the central short-circuited slotline.

3. Power Loss

In order to investigate the power loss (1-$|S_{11}|^2$-$|S_{21}|^2$) of the right-angled CPW using the central short-circuited slotline, Fig. 1 is simulated by using the commercial software Advanced Design System (ADS) and the power loss is plotted in Fig. 4. As seen from Fig. 4, the peak value of the power loss is less than 0.37 from DC to 12 GHz. As compared with the power loss for the right-angled CPW using the short-circuited slotline (Fig. 32, [14]), the power loss is greatly decreased from 0.55 to 0.37.

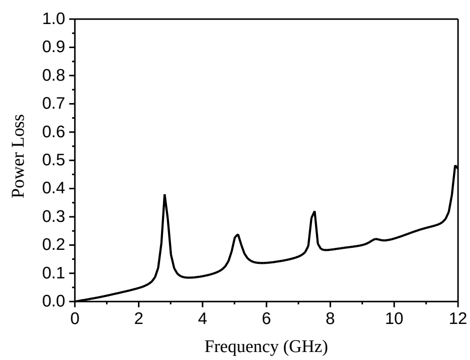


Fig. 4 Power loss for the right-angled CPW using the central short-circuited slotline.

4. Electric Field Distribution

In order to investigate the electric field distribution of the right-angled CPW using the central short-circuited slotline, Fig. 1 is simulated by using the commercial software Advanced Design System (ADS) and the electric field distribution at 6 GHz is plotted in Fig. 5. As can be seen from Fig. 5, the electric field distribution on the inner and outer slots are in phase since the inner and outer slots are designed to have equal electrical lengths. As a result, the CPW-mode to CSL-mode conversion will be inhibited, which in turn increases the transmission coefficient of the CPW-mode. Besides, the power loss caused by the CSL-mode will also be reduced, which in turn results in a low power loss value.

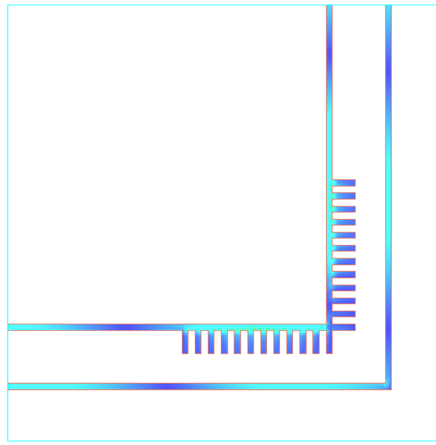


Fig. 5 The electric field distribution at 6 GHz for the right-angled CPW using the central short-circuited slotline.

5. Conclusion

In this paper, a right-angled CPW using the central short-circuited slotline is proposed. Since the short-circuited slotline is implemented on the central strip of the CPW, no additional area will be consumed. As compared with the right-angled CPW using the short-circuited slotline [14], the value of the reflection coefficient is maintained at a low value around -10 dB while the value of the transmission coefficient is increased from -4.49 dB to -3.28 dB. Besides, the value of the power loss is substantially reduced from 0.55 to 0.37. The electric field distribution demonstrates that the inner and outer slots are in phase since the electrical lengths of the inner and outer slots are made equal through the central short-circuited slotline.

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References

[1] C. P. Wen, “Coplanar waveguide: a surface strip transmission line suitable for nonreciprocal gyromagnetic device applications,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 17, no. 12, pp. 1087–1090, Dec. 1969.

[2] D. M. Pozar, *Microwave Engineering. 3th ed.*, John Wiley & Sons Inc., pp. 174–178, 2005.

[3] R. N. Simons, Coplanar Waveguide circuits, Components, and Systems, John Wiley & Sons Inc., 2001.

[4] M.-D. Wu, S.-M. Deng, R.-B. Wu, and P. Hsu, “Full-wave characterization of the mode conversion in a coplanar waveguide right-angled bend,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 43, pp. 2532–2538, Nov. 1995.

[5] T. Hirota, Y. Tarusawa, and H. Ogawa, “Uniplanar MMIC hybrids–A proposed new MMIC structure,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 35, no. 6, pp. 576–581, Jun. 1987.

[6] D. Jaisson, “Coplanar waveguide bend with radial compensation,” in *Proc. Inst. Elect. Eng.– Microwaves, Antennas, and Propagation*, vol. 143, no. 5, pp. 447–450, Oct. 1996.

[7] H. Kim, and R. Franklin-Drayton, “Wire-bond free technique for right angle coplanar waveguide bend structures,” *IEEE Trans. Microw. Theory Tech.*, vol. 57, no. 2, pp. 442–448, 2009.

[8] N. H. L. Koster, S. Koblowski, R. Bertenburg, S. Heinen, and I. Wolff, “Investigations on air bridges used for MMICs in CPW technique,” in *Proc. 19th European Microwave Conference*, pp. 666–671, 1989.

[9] R. N. Simons and G. E. Ponchak, “Modeling of some coplanar waveguide discontinuities,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 36, no. 12, pp. 1796–1803, Dec. 1988.

[10] P. M. Watson and K. C. Gupta, “Design and optimization of CPW circuits using EM-ANN models for CPW components,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 45, no. 12, pp. 2515–2523, Dec. 1997.

[11] T. M. Weller, R. M. Henderson, K. J. Herrick, S. V. Robertson, R. T. Kihm, and L. P. B. Katehi, “Three-dimensional high-frequency distribution networks. I. Optimization of CPW discontinuities,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 48, no. 10, pp. 1635–1642, Oct. 2000.

[12] J. Y. Park, J. H. Sim, J. K. Shin, and J. H. Lee, “Fabrication of thick silicon dioxide air-bridge for RF application using micromachining technology,” in *Int. Microprocesses and Nanotechnology Conference*, 2001, pp. 202–203.

[13] C.-Y. Lin, Y.-C. Lee, C.-Y. Liao, and C.-L. Wang, “Reflection noise elimination using bondwire-free balanced CPW,” *Asia-Pacific Radio Science Conference 2013*, E1b-1.

[14] C.-Y. Liao, J.-D. Cai, J.-C. Guo, and C.-L. Wang, “Right-angled coplanar waveguide using short-circuited slotline,” *IEEE Trans. Electromagnetic Compatibility*, vol. 63, no. 1, pp. 215–228, Feb. 2021.