ULTRA WIDE BAND SLOTLINE HYBRID RING COUPLERS

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Abstract

The design procedure and results of two newly developed hybrid ring couplers using microstrip-coupled slotline ring are presented in this paper. The couplers have a wider bandwidth with an excellent power dividing balance and a fairly good isolation than the conventional microstrip hybrid ring coupler. The slotline cross-over hybrid ring coupler exhibits greater than 35 dB isolation and good power dividing balance of ±0.2 dB over an 80% bandwidth from 1.8 to 4.2 GHz. The experimental results agree very well with the theoretical prediction. With the advantage of allowing easy series or shunt insertion of devices, these couplers are useful in many applications for MICs and MMICs.

INTRODUCTION

The microstrip hybrid ring coupler has been widely used as a building component of power dividers and combiners in many microwave systems [1,2]. However, the inconvenience of adding tuning elements on microstrip and narrow bandwidth limit the application of the microstrip hybrid ring coupler structure. This paper presents two novel types of slotline hybrid ring couplers which have wider bandwidth as compared with the microstrip hybrid ring coupler as well as the advantages of installing shunt devices.

The first type of slotline hybrid ring coupler as shown in Figure 1(a) uses four external microstrip feedlines and a slotline ring to obtain a 0.6 dB insertion loss and ±0.3 dB power dividing balance over a 26% bandwidth centered at 3 GHz. The second type of slotline hybrid ring coupler as shown in Figure 1(b) uses a cross-over configuration to achieve an 80% bandwidth from 1.8 to 4.2 GHz, fairly good isolation and power dividing balance of ±0.2 dB. The circuit design was based on simple transmission line models. The insertion loss of the microstrip and slotline was included in the modeling. Although the effects of slotline ring discontinuity and curvature were not included, the analysis did predict the performance of the coupler very well. These couplers are amenable to monolithic implementation and should have many applications in microwave and millimeter-wave hybrid and monolithic integrated circuits.

SLOTLINE HYBRID RING COUPLER

The use of slotline ring for coupler was easily implemented by interfacing with microstrip. The microstrip transmission line, which acts as the feedline, is on opposite side of the substrate as shown in Figure 1(a). The equivalent circuit of this slotline hybrid ring coupler is shown in Figure 2. The impedance and the mean radius of the slotline hybrid ring coupler are the two most important design parameters. The impedances of the coupler and microstrip feedlines shown in Figure 2 are obtained by iterations to meet the following equation [3]:

$$\frac{Z_{os}^{\ 2}}{Z_{om}^{\ 2}} = 2\cdot N^2 \qquad (1)$$

where N is the turn ratio of the equivalent transformer, Z_{os} and Z_{om} are the slotline and microstrip characteristic impedance, respectively. The mean radius r of the slotline hybrid ring is determined by

$$2\cdot\pi\cdot r = 1.5\cdot\lambda_{gs} \qquad (2)$$

where λ_{gs} is the guided wavelength of the slotline ring. Based on this design, an experimental circuit was built on a 1.27 mm-thick RT/Duroid 6010.8 substrate with the following dimensions: (i) microstrip line width: 1.09 mm, (ii) slotline line width: 0.85 mm, (iii) hybrid ring mean radius: 12.78 mm.

Figures 3(a) and (b) show the experimental and calculated results of the slotline hybrid ring coupler, respectively. As shown in Figure 3(a), a 0.6 dB insertion loss, ±0.3 dB power dividing balance, and over 20 dB isolation has been achieved over 800 MHz bandwidth centered at 3GHz. The extra 0.6 dB loss is due to the SMA connectors, microstrip to slotline ring transitions, and slotline hybrid ring. Besides the additional losses, the experimental and calculated results shown in Figures 3(a) and (b) agree very well. Compared with the microstrip type of hybrid ring coupler with a typical bandwidth of 20% [4], the slotline hybrid ring coupler has a bandwidth of more than 26%.

SLOTLINE CROSS-OVER HYBRID RING COUPLER

To further improve the bandwidth, a new type of slotline hybrid ring coupler using a cross-over circuit was developed. This coupler simply consists of a slotline T-junction and microstrip to slotline ring transitions as shown in Figure 1(b). The slotline T-junction is used as a phase inverter to achieve the phase change of the cross-over branch line. The electrical field distribution around the slotline T-junction shown in Figure 4(a) functions as a phase inverter. The equivalent circuit of the slotline cross-over hybrid ring coupler can be represented in Figure 4(b). The equivalent circuit of the slotline T-junction is represented as a junction between regular transmission line and twisted transmission line.

Using the cross-over junction shown in Figure 4(b), a conventional hybrid ring coupler shown in Figure 1(a) is now modified as a compact and symmetric cross-over hybrid ring coupler. As mentioned in the previous section, the impedance and the mean radius of the slotline ring should be determined in the first step of design procedure. The impedances of the ring and microstrip line are designed by the same way as described earlier. However, the radius of the slotline cross-over hybrid ring is determined by [5]

$$2 \cdot \pi \cdot r = \lambda_{gs} \tag{3}$$

where λ_{gs} is the guided wavelength of the slotline ring. The test circuit was built on a 1.27 mm RT/Duroid 6010.8 substrate with the following dimensions: (i) microstrip line width: 1.09 mm, (ii) slotline ring line width: 0.85 mm, (iii) slotline ring mean radius: 8.42 mm, and (iv) slotline feed line width: 0.22 mm. The experimental and calculated results of the slotline cross-over hybrid ring coupler are shown in Figures 5(a) and (b) for comparison. The calculated isolation is greater than 50 dB, which cannot be illustrated in Figure 5(b).

As shown in Figure 5(a), greater than 35 dB isolation and good power dividing balance of ±0.2 dB was achieved over an 80% bandwidth from 1.8 to 4.2 GHz. The transmission from port 1 to port 3 is almost identical to that from port 1 to port 4. The two curves (P_3/P_1 and P_4/P_1) overlap each other as shown in Figure 5(a). The extra 1.3 dB insertion loss for the experimental results is due to the transitions of coaxial to microstrip and microstrip to slotline, and the slotline T-junction. The slotline T-junction can be optimized to reduce this extra insertion loss. Except the extra insertion loss, the measured and calculated results shown in Figures 5(a) and (b) agree very well.

CONCLUSIONS

Two new circuits of the slotline hybrid ring coupler have been developed with a wide bandwidth, an excellent power dividing balance, and a fairly good isolation. The circuit analyses were based on simple transmission line circuit models. The experimental and calculated results agree very well. The slotline hybrid ring coupler and the cross-over hybrid ring coupler exhibit a 26% and 80% bandwidth centered at 3GHz, respectively. The compact, symmetric configuration of the slotline cross-over hybrid ring coupler should have many applications in hybrid and monolithic integrated circuits.

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REFERENCES

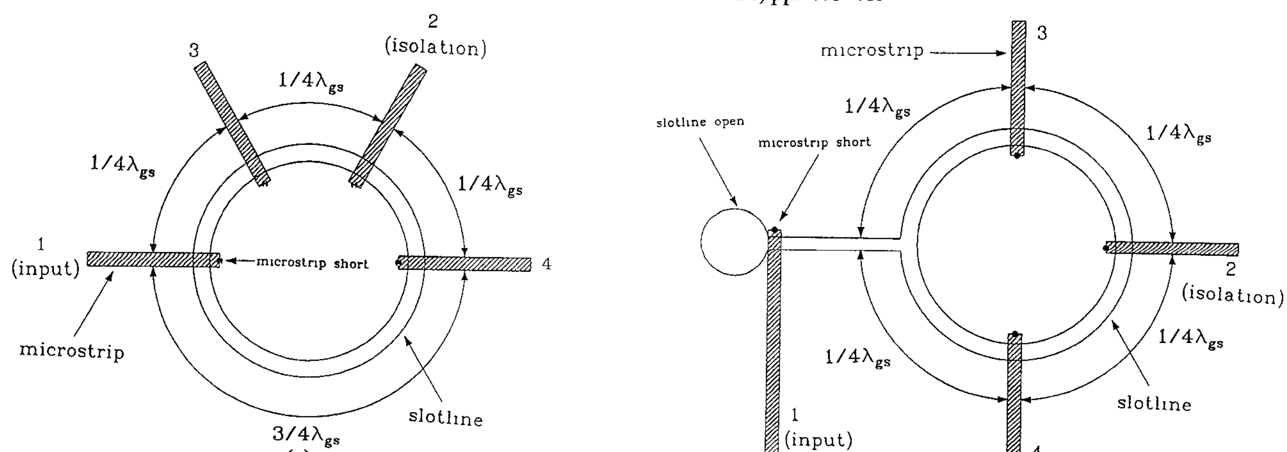
[1] T. C. Edwards, *Foundations for Microstrip Circuit Design*, John Wiley & Sons, New York, 1981, Chapter 8.

[2] K. Chang, et al, "W-Band (75-110 GHz) Microstrip Components," *IEEE Trans. Microwave Theory and Tech.*, vol. MTT-33, pp. 1375-1382, December 1985.

[3] E. A. Mariani and J. P. Agrios, "Slotline filters and couplers," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-18, pp. 1089-1095, Dec. 1970

[4] K. C. Gupta, Ramesh Garg, and I. J. Bahl, *Microstrip lines and slotlines*, Artech House, Inc., Dedham, Massachusetts, 1979, pp. 234-236

[5] R. G. Manton, "Hybrid networks and their uses in radio-frequency circuits," *Radio Electron. Eng.*, 1984, 54, pp. 473-489



(a) (b)

Figure 1 (a) Slotline hybrid ring coupler. (b) Slotline cross-over hybrid ring coupler

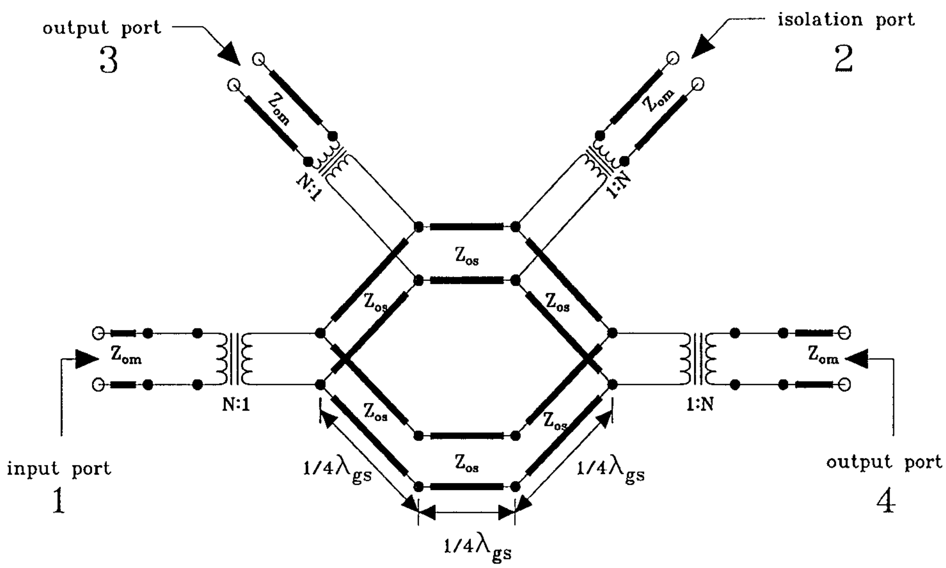


Figure 2 Equivalent circuit of the slotline hybrid ring coupler.

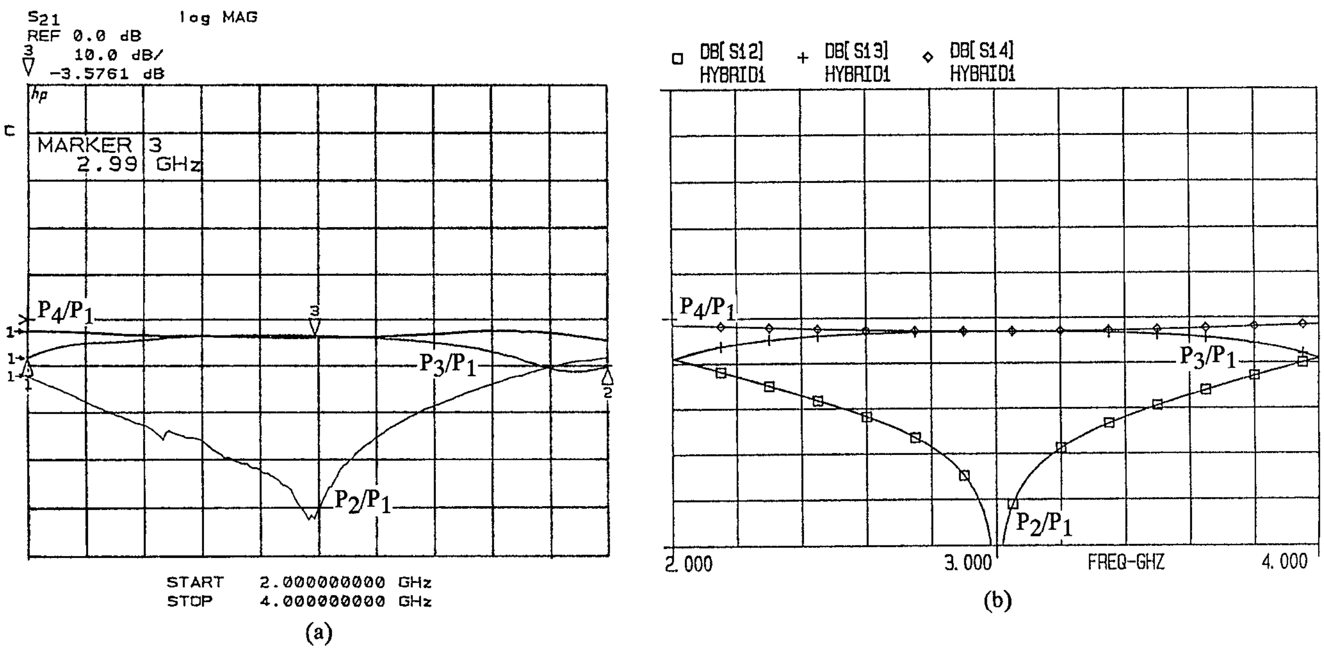


Figure 3 Insertion loss of a slotline hybrid ring coupler: (a) measured results. (b) calculated results

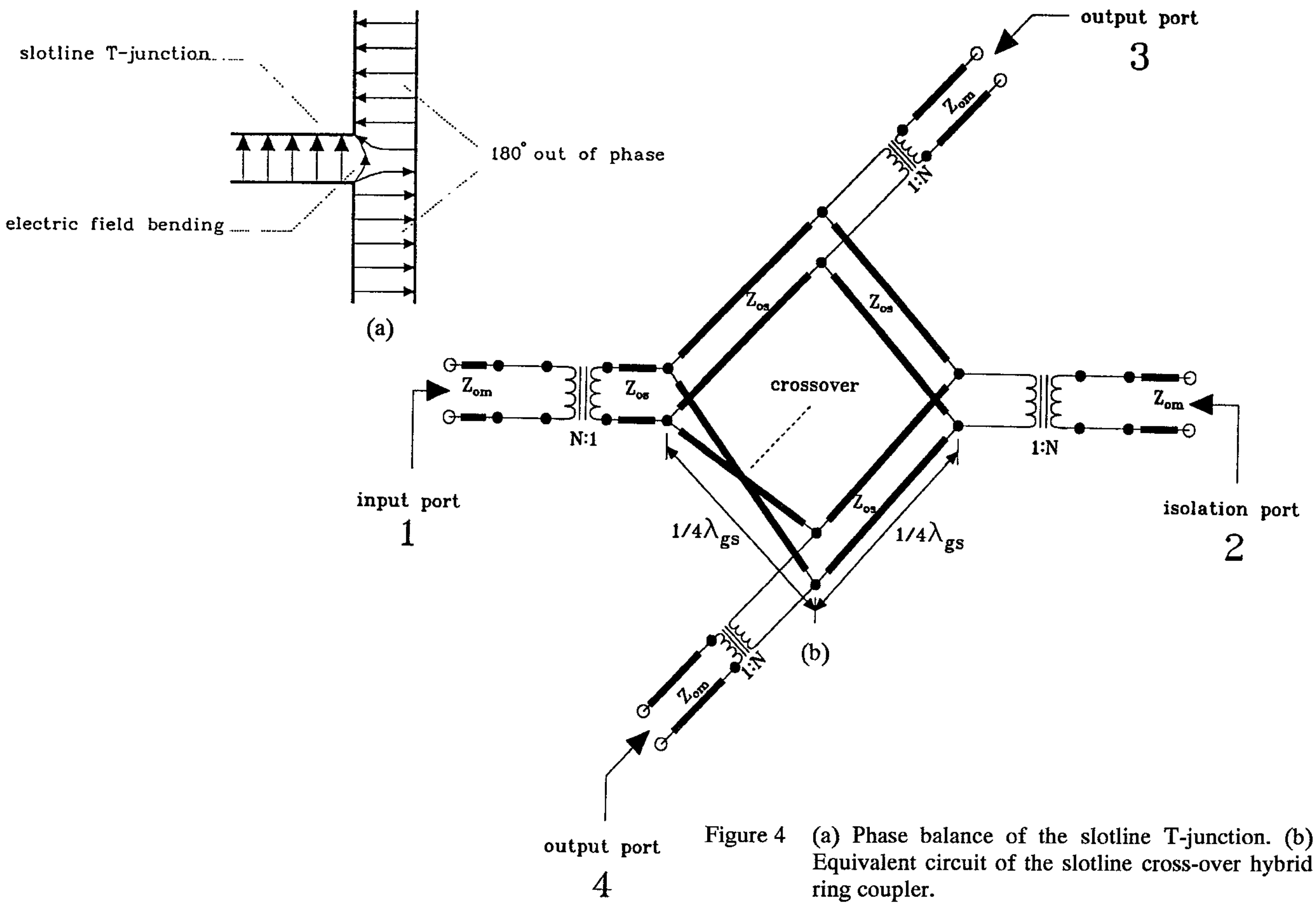


Figure 4 (a) Phase balance of the slotline T-junction. (b) Equivalent circuit of the slotline cross-over hybrid ring coupler.

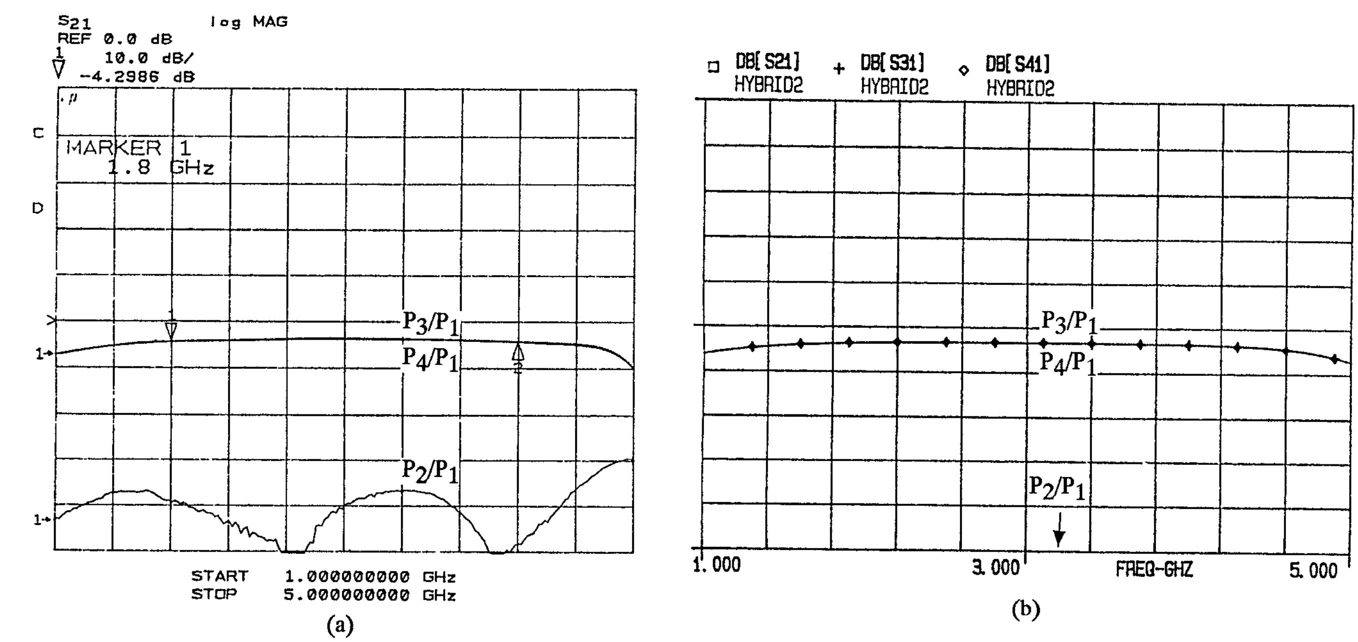


Figure 5 Insertion loss of a cross-over hybrid ring coupler: (a) measured results. (b) calculated results.