A Broad-Band Uniplanar Branch-Line Coupler Using a Coupled Rectangular Slotline Ring

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***Abstract*—A new uniplanar branch-line coupler has been developed that provides substantially improved broad-band amplitude and phase characteristics when compared to conventional microstrip branch-line couplers. Experimental results show that the new coupler has over 20-dB isolation over a bandwidth of more than 40% centered at 3 GHz with ±1-dB power dividing balance.**

I. Introduction

THE MICROSTRIP branch-line coupler is a basic component in applications such as power dividers, balanced mixers, frequency discriminators, and phase shifters. The 10–20% bandwidth of a two-branch coupler limits its applications to narrow-band circuits. Additional coupler sections can overcome this disadvantage [1], but the practical design of couplers with more than four sections is difficult in microstrip [2]. The line widths required by the very high- and low-impedance branch arms may also create undesirable aspect ratios and junction effects. Several computer optimization techniques have been developed to obtain realizable impedance ranges [3] and predict junction effects [4]; however, realizing even two-branch and three-branch couplers in the millimeter-wave region is still difficult.

Coplanar waveguide (CPW) and slotline are alternative transmission lines that are truly uniplanar. They easily allow the mounting of series and shunt solid-state devices. MMIC application such as the series T-junction and signal phase reversals are possible with CPW and slotline. These merits make CPW and slotline very suitable for the designs of balanced circuits in microwave and millimeter-wave MMIC's.

This letter presents a new simple and broad-band uniplanar branch-line coupler consisting of a rectangular slotline ring coupled with two parallel slotline feeds. The design technique uses two slotlines as shunt branch arms and substitutes two CPW's for the series arms. Since the CPW-slotline T-junction is less sensitive to frequency, the resulting slotline ring coupler has a better phase and amplitude performances. Experimental results presented in this paper verify the concept and show a usable bandwidth of more than 40% with a power balance of ±1 dB.

II. Circuit Design and Measurement

Fig. 1(a) shows the conventional microstrip two-branch coupler. When a signal is applied to port 1, outputs appear at ports 2 and 3 that are equal in amplitude and differ in phase by 90°. Port 4 represents the isolation arm. Fig. 1(b) shows the physical configuration of the new uniplanar branch-line coupler. The series arms of the coupler are fed through two parallel slotlines coupled by a rectangular slotline ring on two sides. The other two sides of the rectangular slotline ring are shunt branch arms. Bond wires are soldered at the discontinuities between the series and shunt arms to enforce the even mode propagation in the coupled slotlines (CPW's). The corresponding line characteristic impedances of CPW and slotline branch arms for 3-dB coupling, in terms of the termination impedance Z_0, can be expressed as

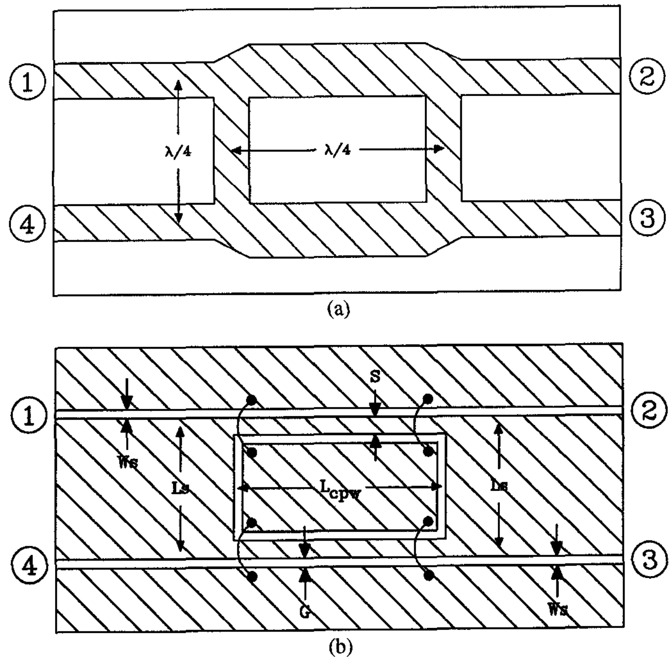

Fig. 1. (a) Conventional microstrip branch-line coupler. (b) Configuration of the uniplanar branch-line coupler.

$$Z_{\mathrm{CPW}} = \frac{Z_0}{\sqrt{2}} \quad (1)$$

$$Z_S = Z_0, \quad (2)$$

where Z_{CPW} is the impedance of the CPW series arms, and Z_S is the impedance of the slotline shunt branch arms. According to these equations, a truly uniplanar branch-line coupler was built on a RT/Duroid 6010.8 ($\varepsilon_r = 10.8$) substrate with the following dimensions: a) substrate thickness: $h = 1.27$ mm, b) CPW center strip width: $S = 0.71$ mm, c) CPW gap width:

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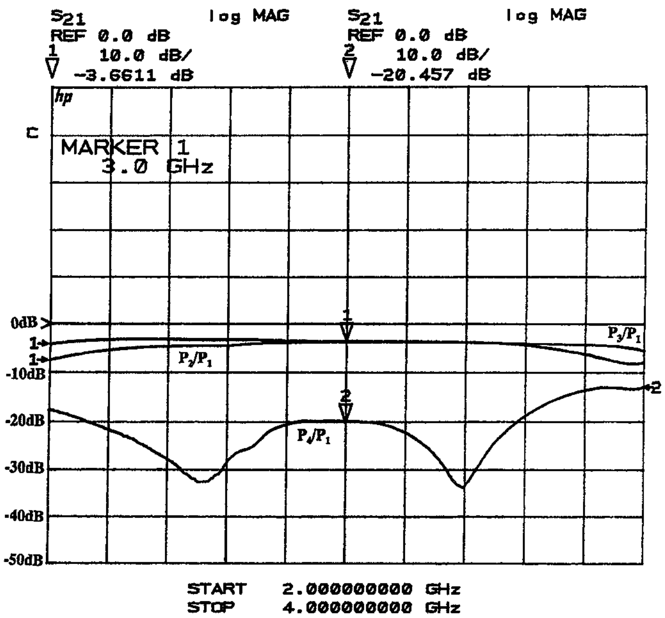

Fig. 2. Measured frequency responses of insertion loss for the through, coupling, and isolation ports of a uniplanar branch-line coupler.

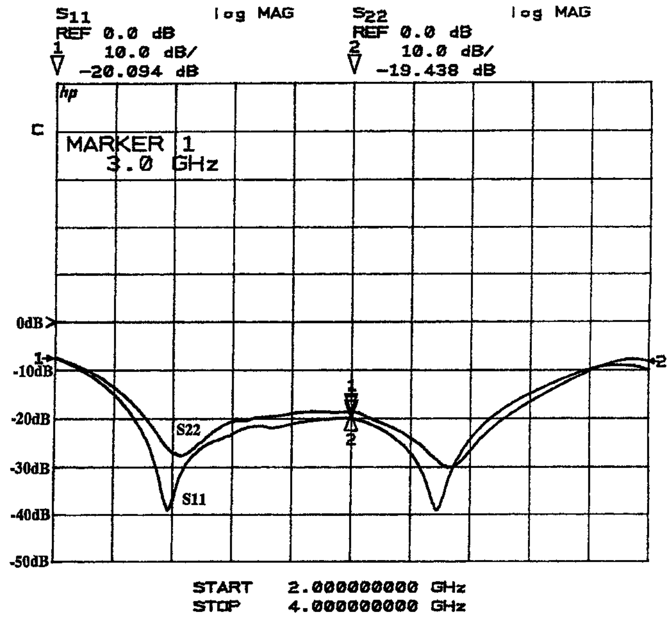

Fig. 3. Measured frequency responses of the input/output port return loss.

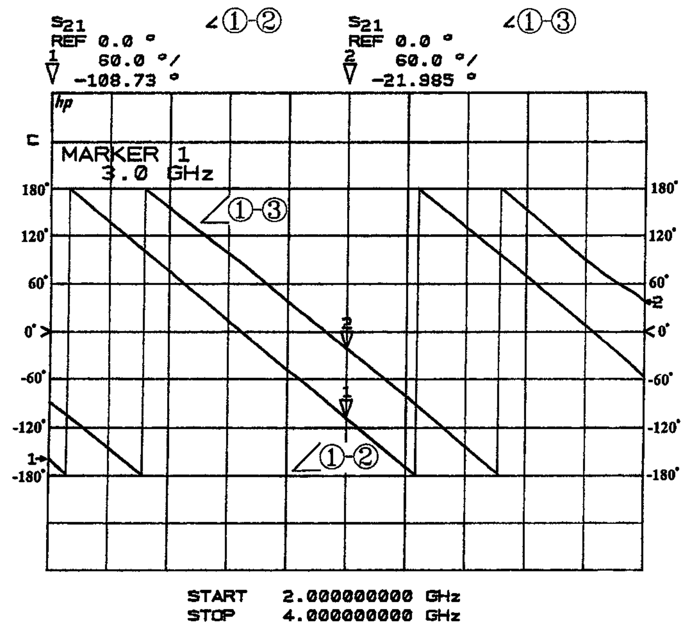

Fig. 4. Measured phase balance of the uniplanar branch-line coupler.

$G = 0.1$ mm, d) rectangular slotline ring line width: $W_S = 0.1$ mm, e) length of CPW series arm: $L_{\text{cpw}} = 10.385$ mm, and f) length of slotline shunt branch: $L_S = 7.77$ mm.

Figs. 2 and 3 show the measured performance of the fabricated uniplanar branch-line coupler. To test the uniplanar branch-line coupler, a wide-band CPW-to-slotline transition was used to connect to ports 1, 2, 3, and 4. The transition consisted of a CPW short and a slotline radial stub [5]. The measurements were made using standard SMA connectors and an HP-8510 network analyzer. The loss performances include two coaxial-to-CPW transitions and two CPW-to-slotline transitions. Fig. 2 shows the measured insertion loss for the output power dividing balance between ports 2 and 3. The power dividing balance is ±1 dB with bandwidth of more than 40% at the center frequency of 3 GHz. Fig. 2 shows that the measured isolation between ports 1 and 4 is greater than 20 dB. Over the same range, a good input and output match is shown in Fig. 3 with return losses of more than 20 and 19 dB, respectively. The second increase in return loss shown in Fig. 3 is due to the CPW-to-slotline transitions. Fig. 4 shows the phase balance between ports 2 and 3. Phase quadrature is maintained at $83° \pm 3°$ over a bandwidth of 45%. The 7° phase error is partly due to fabrication tolerances and misalignments of connectors.

III. Conclusion

A new uniplanar branch-line coupler has been developed and its design procedures have been discussed. The uniplanar branch-line coupler exhibits superior broad-band performance over conventional microstrip branch-line couplers. With its advantages of easy integration with solid-state devices, this new uniplanar branch-line coupler should have many applications in hybrid and monolithic integrated circuits.

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