A Broad-band Uniplanar Slotline Hybrid Ring Coupler with Over One Octave Bandwidth

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ABSTRACT

This paper presents a new uniplanar hybrid ring coupler using coplanar waveguide (CPW) and slotline. The coupler provides substantially improved amplitude and phase characteristics over a broad bandwidth compared to the conventional microstrip hybrid ring couplers. Experimental results show that the new coupler has a bandwidth of one octave from 2 GHz to 4 GHz with ± 0.25 *dB power dividing balance and* $\pm 1^o$ *phase balance.*

INTRODUCTION

The microstrip rat-race hybrid ring coupler is the power divider used in many printed microwave integrated circuit. The 20% to 25% bandwidth of this coupler limits its applications to narrow band circuits. Several designs have been developed to extend that bandwidth. One technique used a $\lambda_g/4$ coupled microstrip line section to replace the $3/4\lambda_g$ section of the conventional $3/2\lambda_g$ microstrip ring coupler [1]. Although the bandwidth was increased to approximately an octave, the difficulty of constructing the coupled microstrip line section, which required short circuits at the ends, limited its use to lower frequencies. Another modified version of the microstrip rat-race hybrid ring substituted a quarter-wavelength slotline section etched on the other side of substrate for the phase delay section [2]. Although a bandwidth of two octaves was realized, the two-sided substrate required a more complicated photolithographic process and limited the coupler to lower frequencies. Two other approaches used hypothetical ports with matching circuits [3,4]. This technique achieved a 50 percent bandwidth, however, the matching circuits required very wide microstrip lines and a large number of different impedances, and the broad-band design technique was useful in the sum mode of operation only. Both matching techniques also demanded intensive optimization to obtain good performance. To extend the bandwidth with a simple design and uniplanar structure, this paper presents a new uniplanar hybrid ring coupler consisting of a slotline ring with one slotline feed and three CPW feeds. The design technique substitutes one reverse-phase slotline-T junction for the conventional rat-race phase delay section. Since the phase reverse of the slotline-T junction is frequency independent, the resulting slotline ring coupler has a broad bandwidth.

This paper first discusses the broad-band transition circuits from coplanar waveguides to slotlines. A broad-band slotline hybrid ring coupler which uses the uniplanar MIC structure is then designed for use at 2-4 GHz. Experimental results presented in this paper verify the concept and show a usable bandwidth of more than one octave.

BROAD-BAND DESIGNS OF CPW/SLOTLINE TRANSITIONS

CPW and slotline are the fundamental transmission lines in uniplanar MIC. The transition between these two transmission structures was first proposed by Ogawa and Minagawa [5]. They used rectangular hollow patches to create slotline open circuits and match CPW to slotline. However, the insertion loss of this transition was larger than 1 dB and the usable bandwidth was less than 2:1. Ho and Hart [6] substituted the circular hollow patches for the rectangular hollow patches to extend the bandwidth. Since the slotline circular hollow patches are broad-band open circuits, the resulting CPW/slotline transition has a broad bandwidth. Although a bandwidth of more than 4:1 was reported, the slotline bending on one arm of the coplanar waveguide is inconvenient for the circuit layout and may cause high insertion loss.

Figure 1 shows a new CPW-slotline transition using slotline radial stubs for broad-band open circuit conditions. One important feature of this type of transition is that the CPW and slotline are connected without bending the transmission structures. Also, the circuit layout is easier than using the circular hollow patches, and the bandwidth is even wider. To design the transition the characteristic impedances Z_{CPW} and Z_S are both chosen as 50 ohms and the angle of the slotline radial stub is 90°. Figure 2 shows the frequency response of insertion loss for the CPW/slotline transition of Figure 1. The bandwidth of less than 1 dB insertion loss for two transitions and a slotline section is more than 5:1 which is better than the transition reported in [6].

BROAD-BAND UNIPLANAR SLOTLINE HYBRID RING COUPLERS

Figure 3 shows the physical configuration of the uniplanar slotline hybrid ring coupler. The E-arm of the uniplanar slotline ring is fed through a CPW line connected to a broad-band CPW-to-slotline transition. The slotline T-junction shown in Figure 3 is used as a phase inverter. The impedance of the slotline ring is given by

$$Z_s = \sqrt{2} \cdot Z_{CPW} \tag{1}$$

where Z_{CPW} is the impedance of the CPW feeds. The radius of the slotline ring is designed by [7]

$$2\pi r_s = \lambda_s \tag{2}$$

where λ_s is the guide wavelength of the slotline ring. Based on equations (1) and (2), a truly uniplanar slotline hybrid ring was built on a RT/Duroid 6010.8 substrate with the following dimensions:

substrate thickness:	h=1.27 mm
CPW gap width:	G=0.25 mm
CPW conductor width:	S=0.51
slotline line width:	W_{S1}=0.1 mm
slotline ring line width:	W_{S2}=0.43 mm
slotline ring radius:	r_S=7.77 mm
slotline radial stub radius:	d_S=6 mm.

Figure 4 shows the measured insertion loss for the power dividing balance of the E-arm and the mutual isolation between the E-arm and H-arm. The power dividing balance of the E-arm is less than ±0.25 dB from 2 to 4 GHz. The insertion loss at the center frequency of 3 GHz is less than 0.6 dB. The isolation between the E-arm and H-arm is greater than 36 dB. Figure 5 illustrates the measured insertion loss for the H-arm's power dividing balance and the mutual isolation between the two balanced arms. The H-arm's power dividing balance is less than ±0.2 dB, and the mutual isolation between two balanced arms is greater than 12 dB. The insertion loss of the H-arm's power dividing is less than 0.5 dB at the center frequency.

CONCLUSIONS

A new uniplanar slotline ring coupler was developed and the design procedures were discussed. The experimental results of a truly uniplanar slotline ring coupler illustrated superior performances over a broad bandwidth compared to the microstrip rat-race and all other modified hybrid ring couplers. With its advantages of broad-band operation, simple design procedure, uniplanar structure, and ease of integration with solid state devices, this new uniplanar slotline ring coupler should have many applications in hybrid and monolithic integrated circuits.

ACKNOWLEDGMENTS

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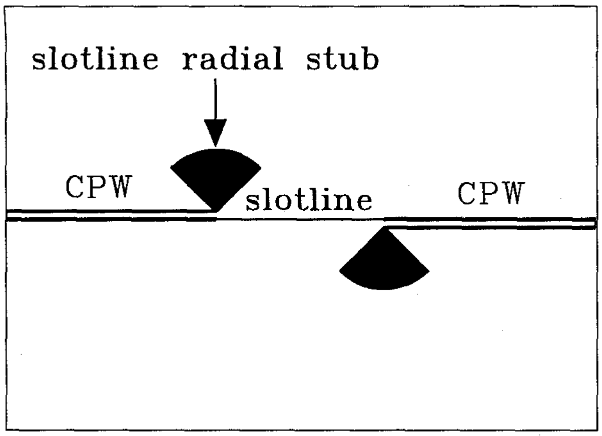

Figure 1 Geometry of CPW to slotline transition.

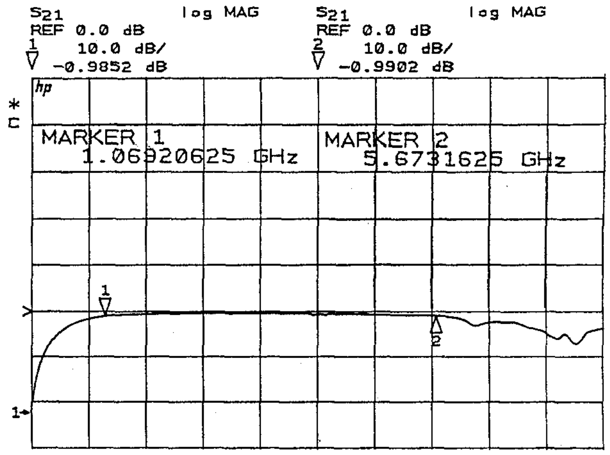

Figure 2 Measured insertion loss of CPW-slotline transition.

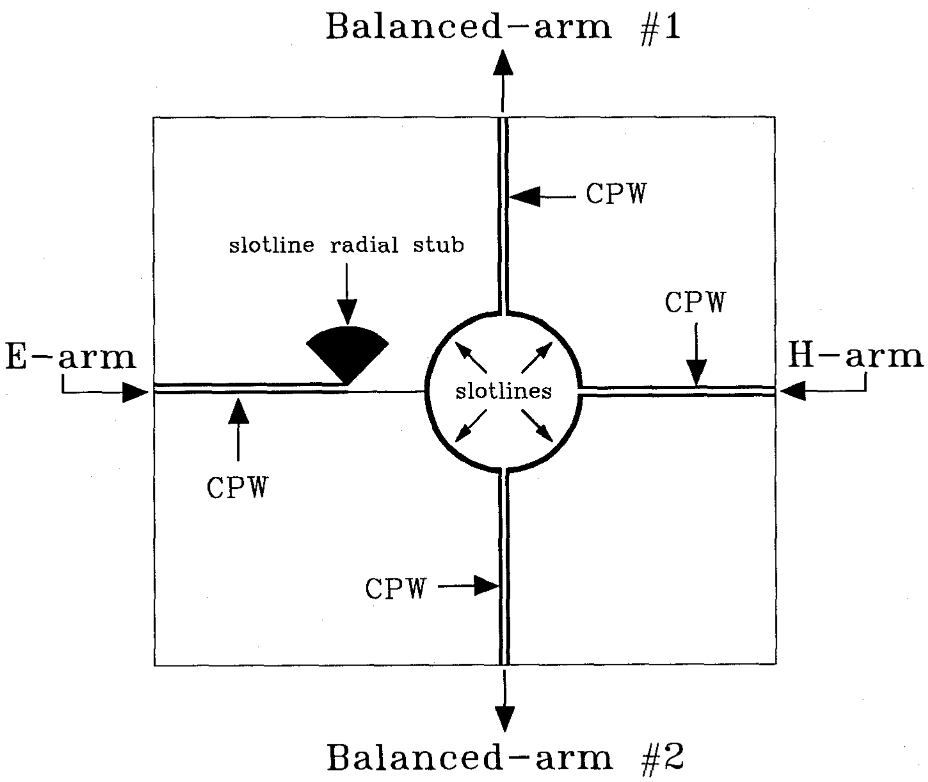

Figure 3 Physical configuration of the uniplanar slotline hybrid ring coupler.

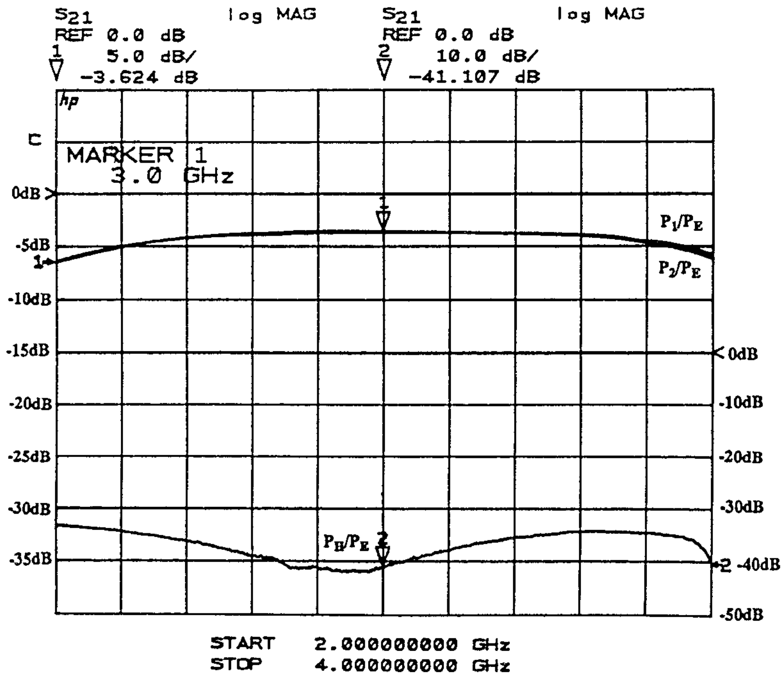

Figure 4 Measured insertion loss for the E-arm's power dividing balance and mutual isolation between E-arm and H-arm.

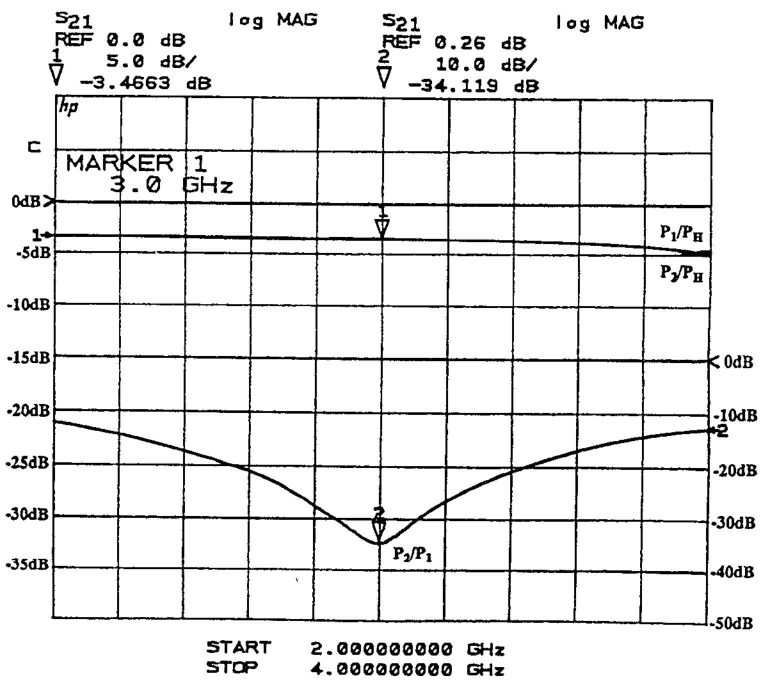

Figure 5 Measured insertion loss for the H-arm's power dividing balance and mutual isolation between two balanced arms.