Multilayer MMIC Broad-Side Coupler with a Symmetric Structure

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***Abstract*— A multilayer monolithic microwave integrated circuit (MMIC) broad-side coupler that has a symmetric structure has been fabricated and demonstrated. To enable the coupler area to be reduced, the width of the coupled lines in the fabricated coupler is made as narrow as 15 μm by using a meander-like configuration. The coupled lines are 2.28-mm long and effectively laid out in a small area of 0.9 mm $\times$ 0.12 mm. The device works well and has good performance at frequencies between 10–17.5 GHz, with coupling loss of 4.2 $\pm$ 0.4 dB and return loss of better than 20 dB. This newly developed coupler offers advantages of simple symmetric design and small circuit area.**

***Index Terms*—Broad-side coupler, multilayer MMIC, symmetric structure.**

I. Introduction

POWER combining and dividing with a phase shift is a useful technique for eliminating undesired signals, such as nth-order distortions, inter-modulations, images, etc. In microwave circuits, quadrature hybrids or distributed-line couplers are commonly used for this purpose. Nowadays, there is a demand for highly integrated monolithic microwave integrated circuits (MMIC's), and therefore some of them are required to include quadrature hybrids or distributed-line couplers. Generally, however, hybrids and couplers occupy a large area in MMIC's because they are essentially composed of quarter-wavelength transmission lines. Large chip size means high cost, and thus a number of approaches to overcome the size problem have been proposed [1], [2]. The size of quadrature branch-line hybrids can be reduced by the quasi-lumped elements method, but their operation bandwidth is very narrow, i.e., 20% or less of the center frequency [1]. Distributed-line couplers, however, are able to work in wider frequency bands. Heretofore, distributed-line couplers have been fabricated on a planer structures by edge-coupling strip lines. The strip lines are usually interdigitated to accommodate coupling factors of 3 dB [3], though, so shortening or bending of such lines is difficult. A broad-side coupler with a tight coupling factor of 3 dB has been obtained through the use of the multilayer MMIC process [2]. It is constructed with two strip lines on different layers and ground metal below the strips. Its size can be reduced by using a meander-like layout. However, its structure is inconveniently asymmetric. In this letter, a newly proposed multilayer broad-side coupler with a symmetric structure is described. The fabricated symmetric coupler shows good performance in the frequency range between 10–17.5 GHz.

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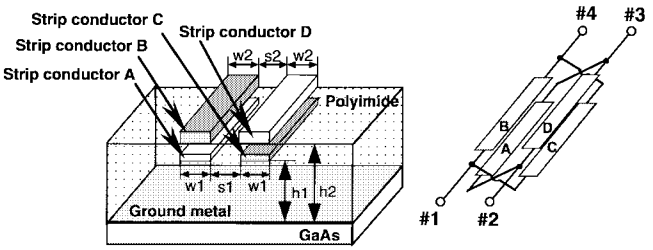

Fig. 1. Structure of the multilayer symmetric broad-side coupler.

II. Structure

The structure of the proposed multilayer symmetric broad-side coupler is shown in Fig. 1. The coupler is composed of four parallel strip conductors and 1-μm-thick ground metal on the GaAs wafer surface. A multilayer polyimide film is coated on the ground. Its top surface is flat, and its thickness, h2, is 9 μm on the ground metal. There are two strip conductors B and D located on the top surface of the polyimide above the ground metal, as shown in Fig. 1. Both conductors have a width (w2) of 5 μm, and the gap between them (s2) is also 5 μm. There are two more strip conductors A and C on an intermediate layer in the polyimide film, located just below conductors B and D, respectively. The height of the layer housing conductors A and C (h1) is 6.5 μm from the ground metal. Both conductors A and C have a width (w1) of 3 μm, and the gap between them (s1) is 5 μm. When strip conductors A and D are connected to each other as shown in Fig. 1, the two strips behave like a single line. Strip conductors B and D are also connected to each other, and therefore, the four strips work as a broad-side symmetrical coupler. The width of the entire coupled line structure is only 15 μm, allowing us to give it a meander-like configuration and, as a result, obtain a major reduction in the circuit area.

III. Experimental Results

The coupler is designed to operate at a center frequency of 14 GHz and is required to have a length of 2.28 mm. Fig. 2 shows a photograph of the fabricated symmetric broad-side coupler. Each of the four strip conductors is connected to its partner at its end and are led to an input–output port through strip/coplanar waveguide (CPW) transitions. Since the length

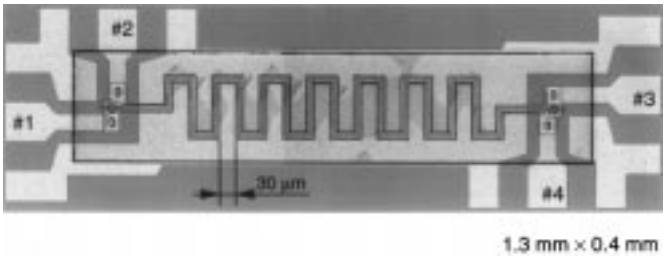

Fig. 2. Photograph of the MMIC symmetric broad-side coupler.

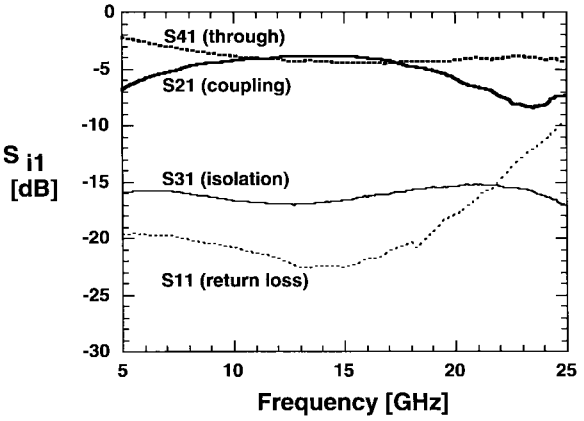

Fig. 3. Amplitude characteristics of the coupler.

of the connection line between strips is shorter than 60 μm, the effect of this nonideal connection is negligible. In the figure, if an RF signal is input from port 1, the coupler outputs the signals to port 2 (coupling) and port 4 (through). In this case, port 3 is isolated. A meander-like configuration effectively reduces the intrinsic area of the coupler to 0.9 mm $\times$ 0.12 mm as shown in Fig. 2. Fig. 3 shows the measured amplitude performance of the coupler. The phase characteristics of the coupled signals are shown in Fig. 4. In the frequency band of 10–17.5 GHz, coupling loss of 4.2 $\pm$ 0.4 dB was obtained. Return loss and isolation in the frequency band are better than 20 and 15 dB, respectively. In this band, the phase difference between through and coupled ports is 87°–96°.

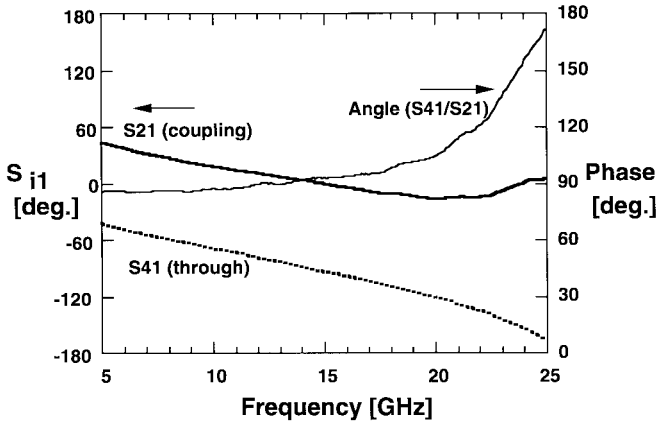

Fig. 4. Phase characteristics of the coupler.

IV. Conclusion

A symmetric type of multilayer MMIC broad-side coupler has been fabricated and demonstrated. The coupler shows good performance, even though its size is significantly reduced by the use of a meander-like configuration. This newly developed coupler has the advantages of simple symmetric design and small circuit area, making it especially suitable for highly integrated and size-restricted MMIC's.

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