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A FULLY PLANAR MICROSTRIP COUPLED-LINE COUPLER WITH A HIGH COUPLING LEVEL

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ABSTRACT: *A fully planar microstrip coupler with a high coupling level up to 4 dB is fabricated on PCB. Based on the conventional coupled-line structure, a gap size of coupled lines about 14 μm is realized by low cost IC process. It has a single stage and requires no bond wire. In measurement, a bandwidth more than 50% and isolation and return loss better than −20 dB are achieved. The measured responses have good agreement with EM simulation data.* © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 46: 170–172, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20934

Key words: *directional coupler; microstrip circuit*

1. INTRODUCTION

Directional couplers are important elements in microwave integrated circuits (MICs) [1]. They can be used in design of baluns, power dividers/combiners, filters, attenuators, and instrumentation systems. A hybrid coupler, that is, a coupler with 3-dB coupling, is useful for building power-distributed amplifiers [2], balanced mixers [3], and so forth. A fully planar conventional microstrip coupler has a coupling of less than 10 dB due to the lower realizable limit of the slot width in microstrip technology. This has lead to the development of many methods. For the vertically installed planar (VIP) circuit [4], coupled lines were constructed perpendicularly to the main microstrip circuit board. In [5, 6], a semi-reentrant microstrip section was used to realize tight coupling. In [7], couplers were designed in a multilayer structure with two- and three-strip couplings. These approaches rely on broadside coupling through a dielectric layer between the microstrip lines.

It is also possible to use an original or unfolded Lange coupler [1, 3] for 3-dB coupling. This design concept is based on using multifold constructive edge couplings to enhance the coupling between the two main lines in multiple coupled microstrip. It is found that bond wires are inevitably required in circuit realization, since nonadjacent lines are assumed to have identical potentials.

In this paper, our aim is to make a conventional single-stage microstrip coupler with a coupling level that is as high as possible. This high-level coupling is achieved by fabricating a narrow gap between the coupled microstripe using a low-cost IC process. The design is based on the structure of a 3-dB coupler. The measurement shows that the fabricated coupler has a 4-dB coupling. The good measurement results are due to the small coupling gap used in our previous RF passive devices [8, 9]. Note that the entire circuit is fully planar, requires no bond wire, and retrieves the simplicity of the original circuit design.

2. DESIGN AND FABRICATION

For a coupler with coupling C, the even- and odd-mode impedances are required to be [1]:

$$Z_{oe} = z_0 \sqrt{\frac{1 + C}{1 - C}}, \tag{1}$$

$$Z_{00} = Z_o \sqrt{\frac{1 - C}{1 + C}}. \tag{2}$$

The Z_0 values are chosen to be 50Ω and 42.3Ω for devices 1 and 2, respectively, where additional λ/4 converter impedance (Z_t) of 46.0Ω is used for device 2 to match the 50Ω. The smaller Z_0 and Z_t in Device 2 is for smaller conductor loss in transmission lines at the design frequency 5 GHz. RT/Duroid 6010 substrate with $\varepsilon_r = 10.2$ and thickness = 1.27 mm is chosen to realize the

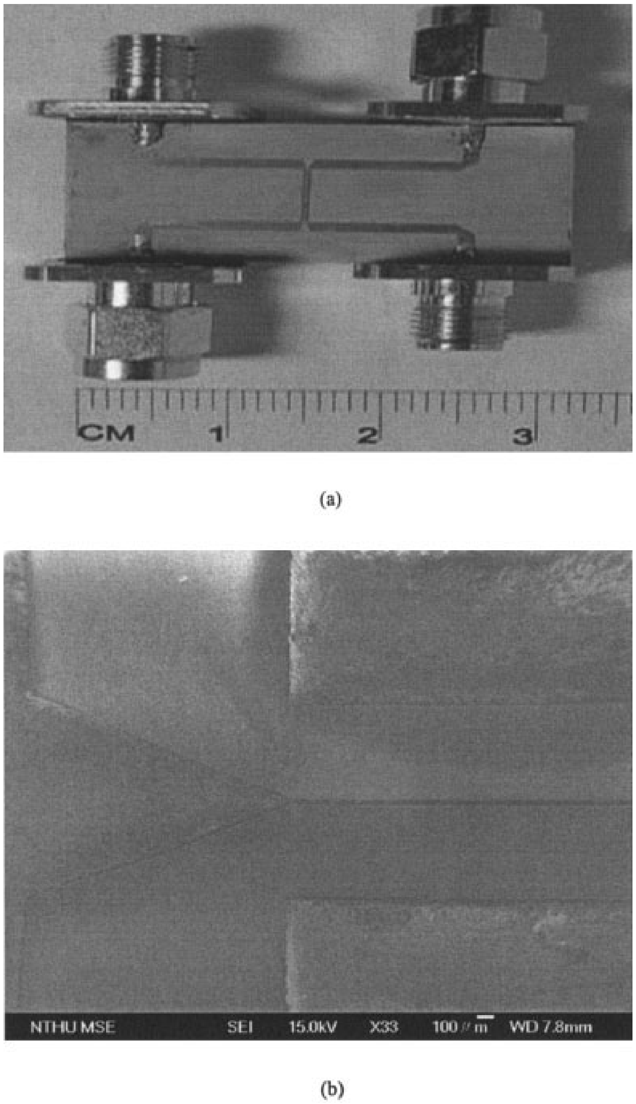
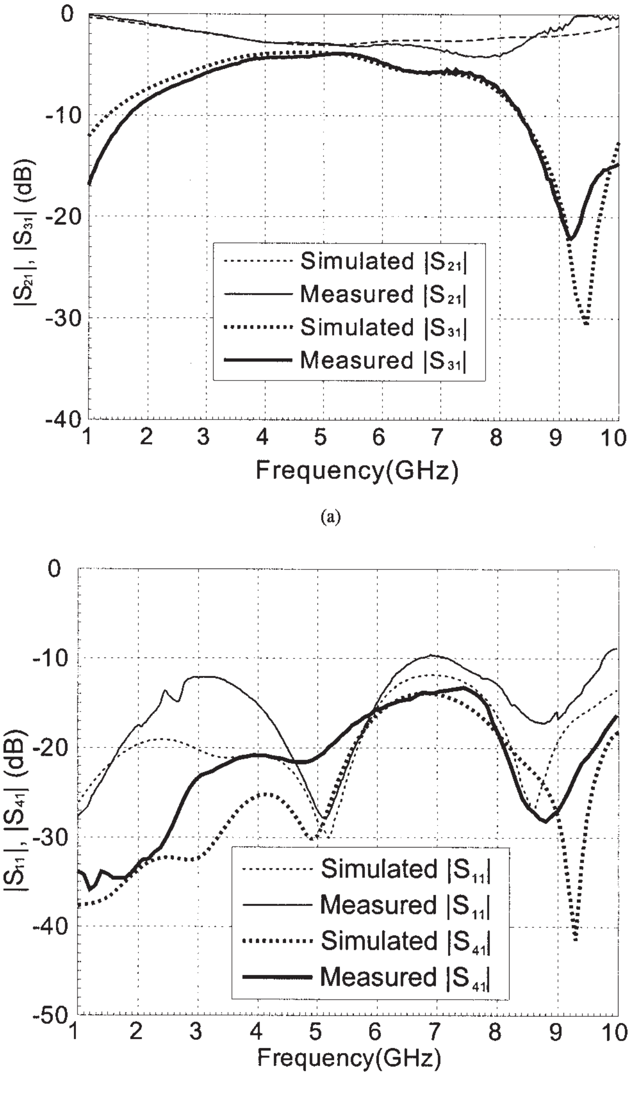


Figure 1 The fabricated coupler: (a) photograph of the entire circuit; (b) enlarged picture of the coupled lines



(a)

(b)

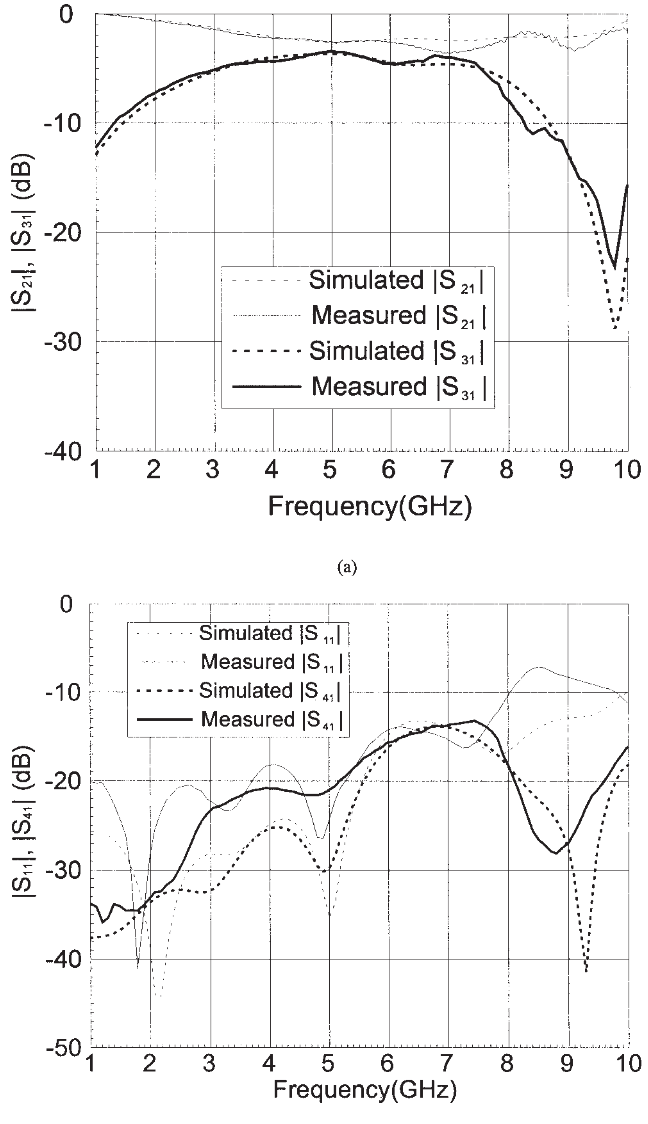
Figure 2 Measured and simulated responses of the fabricated device 1: (a) $|S_{21}|$ (through) and $|S_{21}|$ (coupling); (b) $|S_{31}|$ (return loss) and $|S_{41}|$ (isolation)

circuit. An EM simulator IE3D [10] is used to validate the circuit design before the circuit is fabricated. The required line width and interline spacing are 309 and 4 μm, and 560 and 4 μm for devices 1 and 2, respectively. The circuit is fabricated using a conventional low-cost IC process with a >1-μm resolution and standard FeCl etching. An infrared red aligner is used for pattern exposure and HFD5 solution for circuit development. The solution is heated up to 50° to 60°C in order to obtain a better etching in the valley of the central gap. The circuit measurements are performed by an Agilent/HP 8720C vector network analyzer.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The photo of the fabricated coupler is shown in Figure 1(a), and an enlarged pattern of a part of the coupled lines is in Figure 1(b). Transmission-line sections with 50Ω characteristic impedance are used to extend the circuit ports in order to save enough spaces of the SMA connectors for measurement. Since the chemical-solution etching is isotropic, the fabricated circuit inevitably has a V-shape coupling gap. As shown in the enlarged circuit picture in Figure 1(b), the upper opening of the V-shape gap can be estimated to be 24 μm, since total distance between the outer edges of the strips is 620 μm. The performance of the coupler is simulated by using 90° metal edges of 14-μm gap size, which is the average of the upper opening and the 4-μm width at the valley. Figure 2 compares the simulated and measured responses of device 1. In Figure 2(a), the measured $|S_{21}|$ (through) and $|S_{31}|$ (coupling) responses have very good agreement over the frequency range 3–9 GHz. In Figure 2(b), the isolation- and return-loss responses of the fabricated coupler are better than 20 dB.

Figures 3(a) and 3(b) show the measured coupling response and return loss/isolation of device 2, respectively. Good coupler characteristics such as high coupling of 3.8 dB, small insertion loss of −3.9 dB, and very wide bandwidth (1 dB) of 52% are achieved that are comparable to or better than the reported very-wide-bandwidth data. The slightly inferior return loss of −24.3 dB and directivity of −21.0 dB may be due to the small power reflection in a nonideal impedance transformer. The good agreement between the measured and modeled coupler characteristics is due to the sharp and accurate etching profile close to the EM simulation,



(a)

(b)

Figure 3 Measured and simulated responses of the fabricated device 2: (a) $|S_{21}|$ (through) and $|S_{31}|$ (coupling); (b) $|S_{11}|$ (return loss) and $|S_{41}|$ (isolation)

TABLE 1 Performance of the Fabricated Coupler at Design Frequency F_O = 5 GHz

Device 1	Simulated	Measured
S_{11} [dB]	−28.2	−26.9
S_{21} [dB]	−3.07	−2.91
S_{31} [dB]	−3.82	−4.02
S_{41} [dB]	−30.0	−21.0
1-dB BW	3.1–6.0	3.4–6.0
[GHz]	58%	52%
Device 2	**Simulated**	**Measured**
S_{11} [dB]	−35.4	−24.3
S_{21} [dB]	−2.90	−2.90
S_{31} [dB]	−3.90	−3.80
S_{41} [dB]	−29.8	−21.0
1-dB BW	3.3–6.2	3.7–6.3
[GHz]	58%	52%

as shown in the inset of Figure 1. However, since the used IC technology is nearly two decades old with only line definition of >1 μm, this process may provide a simple and low-cost solution for fabricating high-performance couplers and other RF devices.

Table 1 summarizes the measured and simulated data of the couplers at 5 GHz. Device 1 has a coupling level ($|S_{31}|$) of 3.8 dB for the simulation and 4.0 dB for the measurement. The measured isolation and return-loss data of the fabricated coupler are better than 20 dB, and the 1-dB bandwidth of the circuit is more than 50%. Device 2 also has a coupling level ($|S_{31}|$) of 3.8 dB for the simulation and 3.9 dB for the measurement. The simultaneously measured high coupling, high directivity, and broad bandwidth are simply due to the smaller coupling gap from the fundamental theory analysis that was justified by the close match of the measurements to the EM simulations.

4. CONCLUSION

A microstrip coupler with a 4-dB coupling level has been fabricated on PCB by etching a 14-μm gap. The entire circuit is fully planar and no bond wire is required. This simple technology will have applications to high-performance RF passive devices on PCB.

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LOW-LOSS SPLICE IN A MICROSTRUCTURED FIBRE USING A CONVENTIONAL FUSION SPLICER

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ABSTRACT: *A simple splice technique to fuse a SMF-28™ and a microstructured fibre using a conventional electric-arc splicer is presented. The technique consists in applying the electric arc in the SMF-28™ region. The fusion-loss dependence with arc duration for constant fusion power is also investigated. A splice loss of 0.25 dB is obtained with high reproducibility.* © 2005 Wiley Periodicals, Inc. Microwave Opt Technol Lett 46: 172–174, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20935

Key words: *microstructured optical fibre; SMF-28™; fusion splicer; loss*

INTRODUCTION

Photonic-crystal fibre (PCF) technology has recently attracted much interest among researchers because of its special properties and potential applications in novel fibre devices. The optical properties of these microstructured optical fibres (MOF) may vary in a dramatic manner, depending on its geometry, inter-hole spacing, hole size, and hole-lattice arrangement. Those structures can provide an effective nonlinearity much higher than that of conventional single mode fibres. As a result, several nonlinear effects have been demonstrated, such as four-wave mixing (FWM) [1], cross-phase modulation (XPM) [2], and stimulated and spontaneous Brillouin scattering effect [3]. Another nonlinear effect that can be explored using PCFs is the generation of stimulated and spontaneous Raman effects [4]. Soliton self-frequency shift [5], wavelength conversion [1], and dispersion-compensation [6] are other examples of important applications of this kind of fibre in optical communications. An important issue in the practical applications of microstructured fibres is its connection with single-mode fibres (SMF) with low loss. Good splicing of microstructured fibres to standard SMF is extremely vital in order to enhance its potential use in communication systems. Furthermore, splicing of fibres with different glass materials is difficult due to the