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NOVEL SUSPENDED-LINE MICROSTRIP COUPLER USING BCB AS SUPPORTING LAYER

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ABSTRACT: *In this letter a novel λ/4 micromachined directional coupler is presented with a 10 μm benzocyclobutene (BCB) layer used to suspend one transmission line over another one in order to achieve a 3-dB coupling. The coupler is centered at a frequency of 24 GHz.* © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 1813–1814, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22574

Key words: *directional coupler; BCB; coupled lines; millimeter wave couplers*

1. INTRODUCTION

Directional couplers are essential components in every millimeter wave transceiver system. One of the main advantages of coupled-line couplers over branch-line couplers is their wider bandwidth response of about 50% for a 0.4-dB coupling unbalance, compared with 15% for the branch-line couplers [1].

One of the main disadvantages of coupled-lines is the difficulty of achieving tight couplings such as 3 dB. For this reason it has been suggested to use couplers in tandem [2]. In [3] two 8.3-dB couplers centered at 60 GHz are connected in tandem to achieve a 3-dB coupling. Nevertheless, this configuration is larger than a single coupler as more than one coupler is needed.

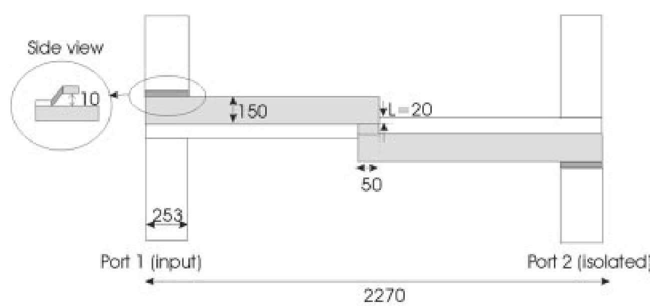
In [4] a CPW suspended air-bridge coupler is presented at a center frequency of 30 GHz. However, if large microstrips are suspended over an air bridge, residual stress will limit the size of the structure. In this letter we propose a microstrip-suspended line coupler where benzocyclobutene (BCB) is used to support the top coupled-line, giving good mechanical strength. The main advantages of using BCB as the supportive structure are that relatively thick layers can be manufactured [5], it has low loss tangent (0.008), and it requires simple manufacturing process [6].

2. DESIGN

The coupler was designed on a 125-mm-thick quartz substrate with a permitivity er = 3.8. The loss tangent is about tan δ = 0.00033. The top layer was suspended over a 10-μm-thick BCB layer (er = 2.6) as shown in Figure 1. To achieve the correct coupling the top line overlaps L = 20 μm the bottom line as shown in Figure 1 (larger overlappings correspond to tighter couplings). At the center of the structure the top line is crossed to the opposite side to realize a codirectional coupler. The meandered transmission lines were optimized to 56% miter for best performance (see Fig. 2).

3. FABRICATION

First a Cr/Au seed layer is thermally evaporated on a 125-μm-thick quartz substrate. A photoresistive mold is then formed over the seed layer to pattern the coupler bottom layer which is formed by electroplating techniques. Then the mold and seed layer is removed and a 10-μm BCB layer formed by UV lithography at a curing temperature of 150°C. The top layer of the coupler is formed by the same process starting with the seed layers, mold, and electroplating described at the beginning of this paragraph. All metal layers are 3-μm thick. Finally, the coupler is placed inside a test housing, where the coupler is fixed to the gold-coated brass



(a)

(b)

Figure 1 (a) Top view of proposed suspended line directional coupler. (b) Side view showing the quartz substrate, the gold top, and bottom transmission lines and the BCB supportive layer. All dimensions are in micrometers

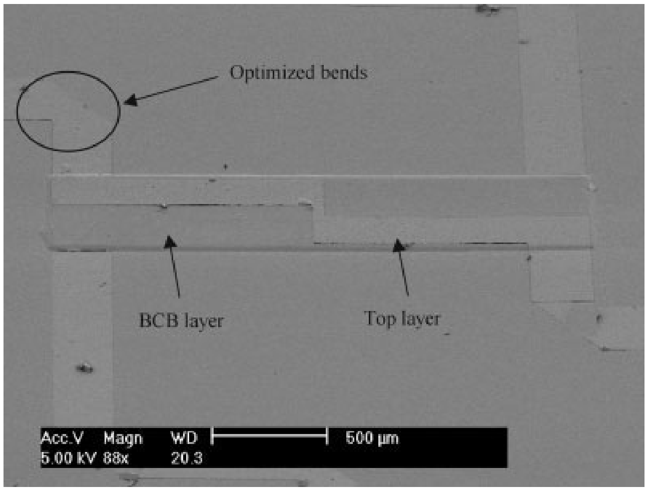


Figure 2 SEM image of whole suspended line coupler

housing using silver paste. K connectors are used to interface the circuit with the measurement equipment.

4. SIMULATION AND EXPERIMENTAL RESULTS

The simulation results using a full wave simulator (Ansoft HFSS v. 9) are shown in Figure 3(a). A coupling of 3 dB $\pm$ 0.4 dB is achieved for 50% bandwidth for the ideal coupler. The phase response shows 90 ° $\pm$ 0.7 ° for the 50% bandwidth. The return loss and isolation are better than -25 dB all over the band.

The experimental response is shown in Figure 3(b). An overcoupling of about 0.6 dB is observed at the center frequency. For a coupling unbalance of $\pm$0.8 dB the bandwidth is about 25%. For this bandwidth, the phase difference was 90 ° $\pm$ 4°. The power losses are close to 1 dB. The return loss and isolated responses are lower than -15 dB throughout the band.

To understand the effect of the differences between the experimental and previously simulated results [7] the structure was measured using a profiler. It was found that the top and bottom transmission lines were 1-μm thicker than expected. Also, the BCB layer was found to be about 9.2 μm. With these new measured values a full wave simulation was carried out giving a coupling unbalance of $\pm$0.8 dB, very similar to the measured response. The results of the overcoupling are shown in Figure 3(a). This results are summarized in Table 1.

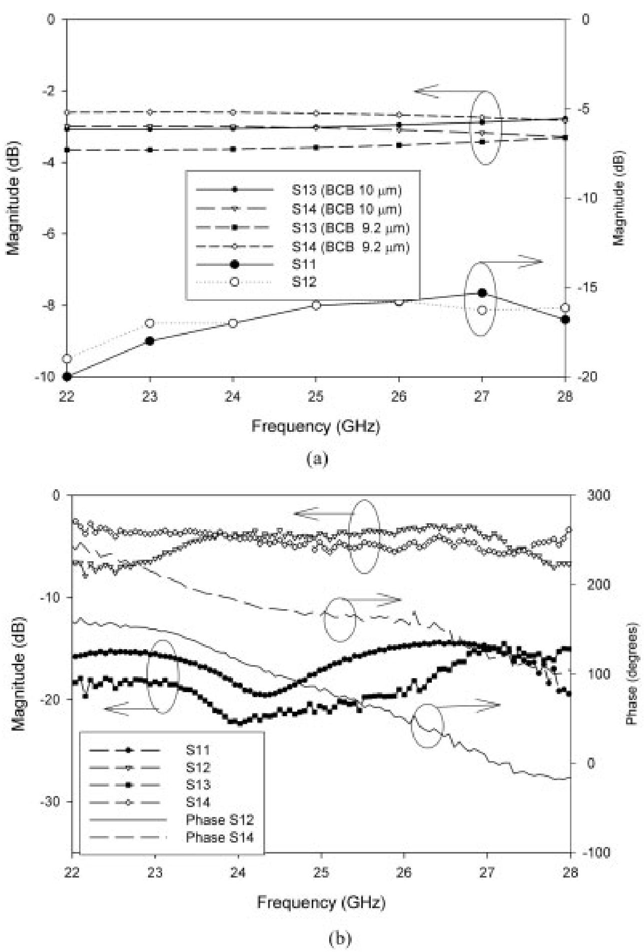


Figure 3 (a) Simulated magnitude response of coupled line coupler. (b) Measured phase and magnitude response of coupled line coupler

TABLE 1 Overcoupling of Simulated and Experimental Structures at Center Frequency

Structure	Overcoupling at Center Frequency
Simulated with original dimensions	$\pm$0 dB
Simulated with measured dimensions	$\pm$0.7 dB
Experimental	$\pm$0.6 dB

The first simulation assumes the original dimensions, whereas the second one assumes the measured transmission lines plus BCB dimensions.

5. CONCLUSION

In this letter a novel type of l/4 coupled line couplers was presented at a center frequency of 24 GHz. This novel structure consists of a bottom transmission line patterned on quartz substrate coupled to a line suspended on a BCB supportive layer. The BCB allows thick structures with low losses. Experimental and simulated results were presented.

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