Proceedings of Asia-Pacific Microwave Conference 2006

A Micromachined Wide-band Suspended-line Coupler at 24GHz for Vehicle Radar Applications

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***Abstract* — Directional couplers have extensive applications in microwave circuits such as beamforming networks. Recently there has been growing scientific and commercial interest in microwave components for anti-crash and pre-crash systems in cars centered at 24GHz. In this paper a novel suspended transmission-line 3dB coupler at 24GHz is presented. This circuit has been micromachined on a glass-quartz substrate and BCB layers have been used to suspend the transmission lines of the coupler. In this paper simulated and experimental results are presented and the fabrication method described.**

***Index Terms* — Transmission line couplers, multiple layer coupling structures, BCB, surface micromachining.**

I. Introduction

The 24GHz band is being widely used for short range anti collision vehicle radars. In [1] a system consisting of 4 short-range sensors and two computers integrated in the test car is proposed. In [2] a switching system is described to build a pulsed-radar for vehicles at 24GHz. And in [3] a radar mixer is described for the same application.

A key component of radar applications are beamforming networks, such as Butler matrices, Blass matrices or Nolen matrices [4]. All these networks are composed of an array of hybrid couplers and phase shifters. Conventional branch-line couplers have the disadvantage of having narrow bandwidths (of about 10%). However, if wider bandwidths are required, other configurations should be used. Transmission line couplers have the advantage of wider bandwidths (>20%), nevertheless it is difficult to achieve tight couplings, (i.e. 3dB) since the coupling gap gets impractically narrow.

In this paper, we present a novel type of suspended transmission- line couplers [5,6] at a center frequency of 24 GHz. This device is micromachined on a glass-quartz substrate with a permittivity of ε_r=3.8 and thickness of h=125µm. BCB is used to suspend the transmission lines of the directional couplers.

II. Circuit Design

In this paper a novel type of suspended transmission-line couplers is presented. These couplers have a wide frequency bandwidth of about 50% with a coupling un-balance of +/-0.3dB, while the conventional Branch line couplers have a bandwidth of approximately 15% for the same coupling unbalance. Transmission-line couplers consist of two parallel λ/4-coupled lines. One of the main limitations of these directional couplers is the difficulty of manufacturing very close gaps for tight couplings (such as 3dB). In this paper we suggest a new type in which one of the lines is suspended over the other one with a BCB layer gap of 10µm as shown in Fig.1 hence achieving very tight couplings. The total length of the coupler is 2270µm. The couplers were designed using Ansoft HFSS simulator.

All the bends of the transmission lines were also optimized for best performance to a miter of 56%. Fig. 1 shows a sketch of the final layout of the coupler. Fig. 2 shows a SEM image of the fabricated coupler.

III. Fabrication

The coupler was fabricated on a 125µm thick quartz substrate. A Cr/Au layer is thermally evaporated on the quartz substrate. The mold for the gold electroplating is formed with photo resist using UV photolithography. A 3µm thick gold layer is electroplated to form the signal lines. After that, the mold and seed layers are removed and a 10µm layer of BCB is patterned using UV photolithography and cured at 150°C. To form the suspended transmission lines, a seed layer is evaporated and a 3µm thick gold layer is electroplated on the quartz substrate and BCB layers after forming a photo resistive cast.

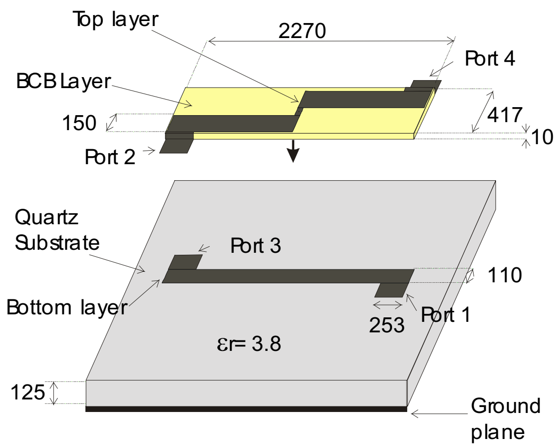

Fig. 1. Schematic of suspended transmission-line coupler on a quartz substrate showing the top conductor, the BCB layer and the bottom layer (dimensions in micrometers).

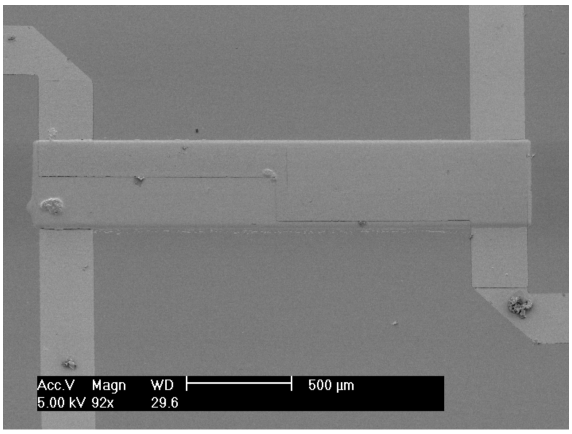

Fig. 2. SEM image of the micromachined suspended line coupler.

At last, the photoresistive cast is removed using acetone and the seed layer is removed by a wet etchant.

The coupler was then bonded with silver epoxy to a brass packaging box with a gold coating, shown in Fig 3. The transmission lines of the coupler were connected to K connectors using silver paste.

IV. Simulated and Experimental Results

The coupler was simulated using Ansoft HFSS full wave electromagnetic software, using the structure in Fig 4. The packaging box and coaxial-mictrostrip transition (from the K connector to the coupler) was included in the simulation, see Fig. 4. The simulated and measured frequency response of the micromachined transmission line coupler are shown in Fig. 5, where the simulated magnitude response for the through and coupled ports of the coupler is 3.6 dB and –3.8dB respectively at the center frequency, which is read to be 25.5GHz. For a 50% bandwidth, the coupling is -3dB with a coupling unbalance of about +/-0.4dB. The phase difference between the coupled and through ports is about 90^{o} throughout the band. For the experimental measurements at 25.5 GHz the through port value is -3.5dB and the coupled port is -4.5dB. The experimental over-coupling of about 0.5dB is thought to be due to manufacturing tolerances on the thickness of the lines (about +1µm) and the thickness of the BCB layer. The return loss and isolation are better than -15dB throughout the band, very similar to the simulated response. The measured phase response shows an 86^{o} phase shift at around 25.5 GHz, shown in Fig. 6.

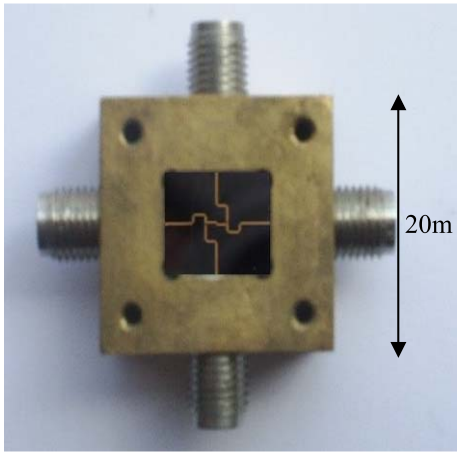

Fig. 3. Micromachined transmission line coupler inside the test housing.

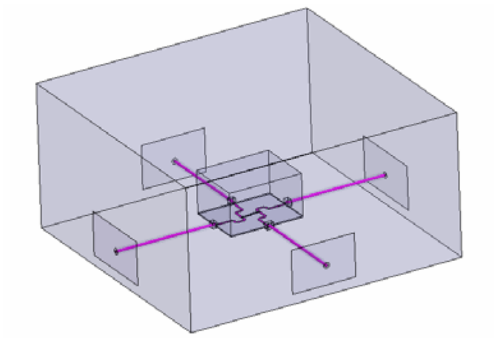

Fig.4. Ansoft HFSS simulation of the transmission line coupler inside the test housing.

V. Conclusions

In this paper a novel type of suspended transmission line couplers at 24GHz for vehicle front-end radars has been successfully built using micromachined techniques.

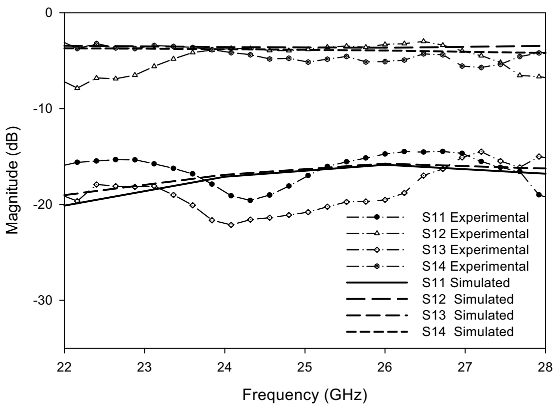

Fig. 5. Frequency response of the suspended transmission line coupler.

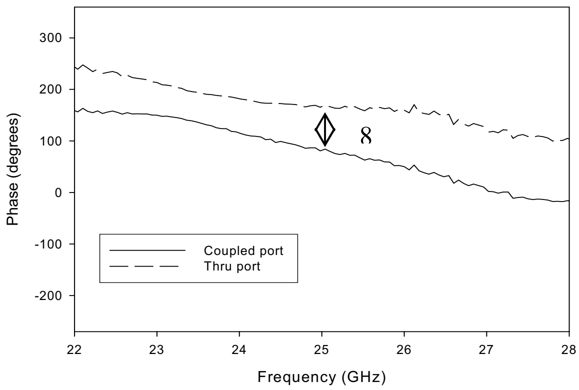

Fig. 6. Measured phase response of the suspended transmission line coupler.

Experimental and simulated results of the coupler were presented, showing good agreement between theory and experiment. The construction method has been fully described. This wideband transmission line coupler has potential application in beam former networks or mixers for automotive radar applications.

REFERENCES

[1] M. Skutek, et. al. "A precrash system based on radar for automotive applications", *IEEE Proceedings of Intelligent Vehicles Symposium*, pp:37 - 41, June 2003.

[2] I. Gresham, A Jenkins. "A fast switching, high isolation absorptive SPST SiGe switch for 24 GHz automotive applications" Presented on the *33rd European Microwave Conference*, vol. 3 , pp. 903-906, Oct. 2003.

[3] I. Gresham, A Jenkins. "A low-noise broadband SiGe mixer for 24GHz ultra-wideband automotive applications". Proceedings of *RAWCON '03*, pp:361-364, Aug. 2003.

[4] A. Corona. M.J. Lancaster. "A high-temperature superconducting Butler matrix". *IEEE Trans. on Applied Superconductivity*, vol. 13 , Issue. 4 , pp 3867-3872, Dec. 2003.

[5] G. Matthaei, L. Young and E.M Jones. "*Microwave filters, impedance matching networks, and coupling structures*". Artech House Inc. 1980.

[6] Hong-Teuk kim, et. al. "CPW MMIC coupler based in offset broadside air-gap coupling fabricated by standard air bridge processes". *Electronics Letters*. Vol. 37, No. 6, pp 358,359, March 2001.