Two-Section Flexible Branch-Line Coupler using PDMS as Dielectric Substrate and Superstrate

M.A. Sobri, S. K. A. Rahim, M.I. Sabran

***Abstract*—This report presents the design of flexible two-section branch-line coupler (BLC) that operated at 6 GHz. The BLC are designed and fabricated on Polydimethylsiloxane (PDMS) material with 2.65-2.72 dielectric constant as substrate and superstrate and using copper foil sheet as a conductive element. The PDMS has several unique properties such as good chemical stability and low dielectric constant. By using PDMS as a structure for the substrate, it will increase the flexibility of the coupler and make it easier to be installed on the curve surface of the applications. This bandwidth of proposed two-section BLC is increased about 31.39% compared to the conventional BLC is limited to 10%-20% due to quarter-wave length requirement. The proposed BLC was simulated, measured and the S-parameter was analyzed to determine the characteristics of BLC. The simulation results show the similar performance in terms of the reflection coefficient and other S-parameter compared to the conventional BLC.**

Index Terms— branch-line coupler (BLC), Polydimethylsiloxane (PDMS), electromagnetic interference (EMI).

I. Introduction

BRANCH line couplers (BLC) are fundamental components in RF and Microwave for power division. The BLC has four port network, port 1 is the input, port 2 is the output of the transmission, and port 3 is the output of coupled while port 4 is isolated. The basic operation of the BLC is the power input at port 1 is shared equally between port 2 and port 3 with a 90^{o} phase difference between these outputs while port 4 is isolated which mean no power into this port [1].

Normally, the BLC it was fabricated using the substrate that cannot be bending such as FR4 or RT/duroid board. The advantages for these substrates are high performance, easy to fabricate and low cost. However, these substrate not reliable when to install them in the curve surface or flexible applications. Based on the conventional branch line coupler design techniques, the size of the coupler is very small in order to operate in high frequency and the bandwidth of branch line coupler is limited to 10%-20% due to the quarter-wave length requirement [1]. The effect when the coupler is too small is difficult to install the connector in each port of the coupler. However, the size and bandwidth of branch line coupler can be increased to more by using multiple sections in cascade.

A lot of research have been done by using different materials as flexible substrates. In these research, a variety of the polymer materials such as Liquid-crystal polymers (LCP), Polyether Imide (PEI), and Polyethylene terephthalate (PET) have been chosen as the substrate for the flexible electronic applications due to the attractive RF characteristics of low relative dielectric constants, capability of being laminated, and low dissipation factors [2]. Besides, a polymer like Polydimethylsiloxane (PDMS) also has been widely used in RF and Microwave field. Furthermore, the low of Young's modulus of this material made the PDMS become more durable [3]. Moreover, the PDMS have a good structural strength and electromagnetic interference (EMI) shielding properties [4]. By using PDMS as a substrate of branch line coupler, it can increase the flexibility and durability of the coupler.

In this paper, flexible two-section BLC using the PDMS material as a substrate is presented. It offers bandwidth enhancement about 45% compared to the conventional BLC. To increase the flexibility of the bending proposed, one layer of PDMS is introduced as a superstrate. The proposed design is fabricated and measured. All the results were compared and discussed effectively.

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II. DESIGN CONCEPTS

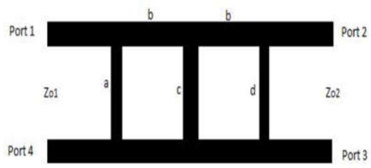

Fig. 1. Two-section branch line coupler

Figure 1 shows the basic configuration of two-section BLC. Zo1 and Zo2 are input impedance and output impedance while parameter a, b, c, and d are characteristic impedance of the branches.The bandwidth can be improved by optimizing the impedances, which gives the values of optimized impedances of a = d = 120.8 ohm and b = c = 35.4 ohm. The proposed BLC is built on a PDMS substrate with thickness h = 1.3 mm, a dielectric constant Ɛr = 2.9, and loss tangent δ = 0.02. The PDMS also have a tensile strength of 7.1 MPa. The width and length of each transmission lines have been calculated by using method microstrip transmission line. All the geometries are shown in Figure.2 and Table 1.

Table 1. Parameter of the proposed BLC

Parameter	Value (mm)	Parameter	Value (mm)
L1	13.6	W1	4.9
L2	4.9	W2	6.8
L3	0.509	W3	8.572
L4	4.028	W4	3.332
Thickness of substrate	1.3	Thickness upper superstrate	0.8
Thickness of copper	0.035	Thickness below superstrate	1

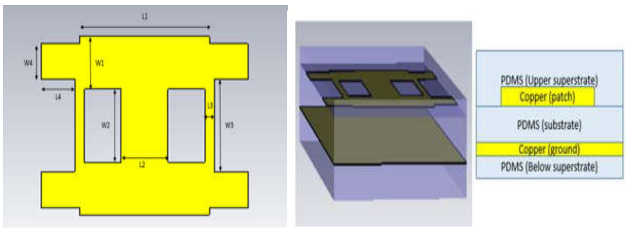

Fig. 2. Geometries of the proposed BLC (a) front view (b) dimensions.

III. RESULTS AND DISCUSSION

The result S-parameter from simulation and measurement for two-section BLC with PDMS are shown in Fig. 3. The S11 and S14 for simulation are -35.5 dB and -38.48 dB. Meanwhile, the measured S11 and S14 are -8.86 dB and -31.90 dB. The simulation value for S12 and S13 are -3.54 dB and - 3.70 dB. As for measuring, the value for S12 and S13 are -5.05 dB and -4.32 dB. The phase different for simulation and measured two-section BLC with PDMS are shown in Fig. 4. The phase different for simulation are 89.17° and for measured are 50°. Details comparison between simulated and measured is shown in Table II

The comparison results from simulation and measured are a slight difference due to unspecific ratio on the curing agent and the difference thickness of PDMS substrate. During fabrication of coupler, to get the actual thickness of PDMS substrate is very difficult. The process fabrication of PDMS need to be very accurate and monitored because of the permittivity constant and dielectric constant on PDMS is easily changing. If the thickness of PDMS substrate is not accurate then the resonance frequency on BLC will be change. The effect when the PDMS superstrate of difference thickness was loaded on proposed BLC is changing the resonant frequency to the higher side of the frequency band.

Table 2. Comparison between simulated and measured of two-section BLC

Performance	Simulation	Measurement
S11	-35.5	-8.86
S12	-3.54	-5.05
S13	-3.70	-4.32
S14	-38.48	-31.90
Phase Different	89.17	50

IV. CONCLUSION

A flexible branch-line coupler using two-section technique operating at 6 GHz has been designed for this project. The proposed flexible BLC design using a PDMS as a substrate and superstrate are to make sure great benefits in term of flexibility without degrading the performance of BLC. The simulation results show the similar performance in terms of the reflection coefficient and other S-parameter compared to the conventional BLC. However, the bandwidth performance for proposed BLC is better than the conventional BLC. Although we can use the PDMS as a shielding layer and substrate for BLC, the process fabrication of PDMS need to be very accurate and monitor because of the permittivity constant and dielectric constant on PDMS is easily changing due to unspecific ratio on the curing agent and the different thickness of the dielectric layer.

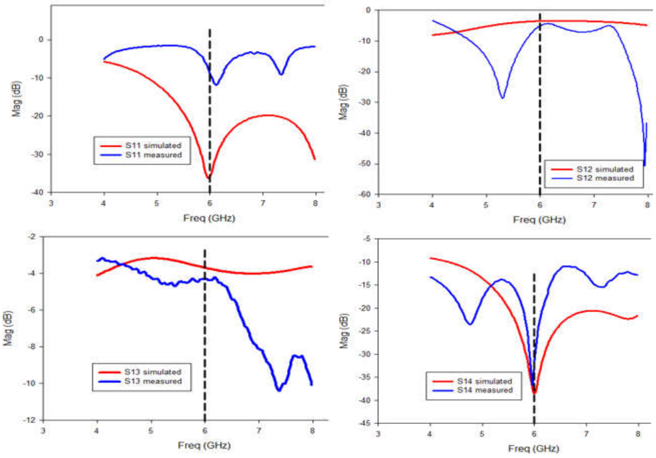

Fig. 3. S-Parameter performance, simulated vs measured.

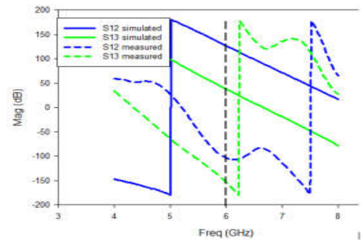

Fig. 4. Phase different performance, simulated vs measured

V. CAREER PLAN AND FELLOWSHIP IMPACT

I would like to thank the MTT-S Education Committee for granting me MTT-S Undergraduate/Pre-graduate Scholarship for Fall 2016. It was a great honor to receive the MTT-S Undergraduate award and give me a great motivation for my scientific research. The financial support I received helped me to focus more of my efforts on my research rather than worry about personal finances. As for my future plans, I would like to gain experience in the RF industry for a couple of years and will continue education in the Ph.D. program in the RF/microwave field.

REFERENCES

[1] D. M. Pozar. Microwave Engineering. Fourth edition. University of Massachussets at Atmherst. 2012.

[2] A. C. Durgun and C. A. Balanis, “Design, Simulation, Fabrication, and Testing of Flexible Bow-Tie Antennas”, IEEE Transactions on Antennas and Propagation, vol. 54, no. 12, December 2011.

[3] G. DeJean, R. Bairavasubramanian, D. Thompson, G. E. Ponchak, M. M. Tentzeris, and J. Papapolymerou, “Liquid crystal polymer (LCP): A new organic material for the development of multilayer dual-frequency/ dual-polarization flexible antenna arrays,” IEEE Antennas Wireless Propag. Lett. vol. 4, pp. 22–26, 2005.

[4] M. Chen, L. Zhang, S. Duan, S. Jing, H. Jiang, M. Luo and C. Li, “Highly conductive and flexible polymer composites with improved mechanical and electromagnetic interference shielding performances”, The Royal Society of Chemistry, vol. 6, no.3796-3803, 2014.

[5] Shen Jun-Yu, Liu Qiang, Wu Yong-Le, Liu Yuan-An, Li Shu-Lan, Yu Cui-Ping, and Lin Gan1, “ High-Directivity Single- and Dual-Band Directional Couplers Based on Substrate Integrated Coaxial Line Technology” Microwave Symposium Digest (IMS), 2013 IEEE MTT-S International. pp.1, 4. 2013.