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Design, Fabrication and Test of a Broadband High Directivity Directional Coupler

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***Abstract*— Presented is an ultra-broadband stripline directional coupler with significant improvement in its directivity parameter which is of interest in many measurement applications. The main focus of this paper is on the influence of using shunt stubs as capacitance compensators to improve specifications of wideband directional couplers. This improvement is performed on a two-layer non-uniform line directional coupler working in 2-18 GHz band. Experimental results, for various classes of wideband stripline couplers loaded with these stubs, exhibit remarkable improvement in the directivity parameter.**

Keywords*— broadband directional coupler; high directivity directional coupler; stripline structures.

I. INTRODUCTION

Directional couplers are widely applied in various microwave applications for sampling from a signal sometimes both incident and reflected waves (this application is called a reflectometer, which forms the heart of a vector or scalar network analyzer) to measure its power or to inject it into other parts of the system. When a coupler is used as a reflectometer or after a transmitter to check the integrity of its antenna connection, the sensitivity and accuracy of measurement are limited to the directivity parameter of the employed coupler. Accordingly directivity parameter of a directional coupler is of great importance in case of power measurement.

Directional couplers can be implemented in the context of different transmission line structures such as waveguides, microstrips, striplines and etc. However as there is a need of an integrated structure to cover a wide bandwidth for many measurement applications, the only solution for implementation of couplers in this case is to use stripline coupled line circuits. The first idea that comes to mind in order to increase the bandwidth of a microwave structure is to use multi-section configurations. The main problem of multi-section directional coupler is the abrupt change occurs at the start and end of each section which leads to poor match, coupling flatness and directivity of the coupler. To avoid intrinsic discontinuity of multi-section configuration, a continuous variation in transverse dimension of the coupler can be implemented which is known as non-uniform line directional coupler [1].

Non-uniform line directional couplers, which was first designed in a modular procedure by Tresselt in 1966 [2], have been widely employed in various microwave systems. The deficiency of a coupler designed using this technique is mainly its directivity parameter which arises from the undesirable termination lines in the coupler structure. Being more detailed, a coupler designed using [2], is depicted in Fig. 1. As demonstrated in Figure 1, it is almost impossible to connect SMA connectors to the structure and therefore for practical applications these terminating lines should be modified. However, this modification is inevitable and, as it is expected, it disturbs the coupler functionality.

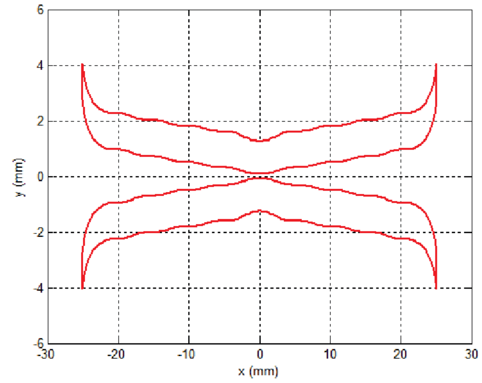

Fig. 1. Coupler primary scheme without any modification in end lines

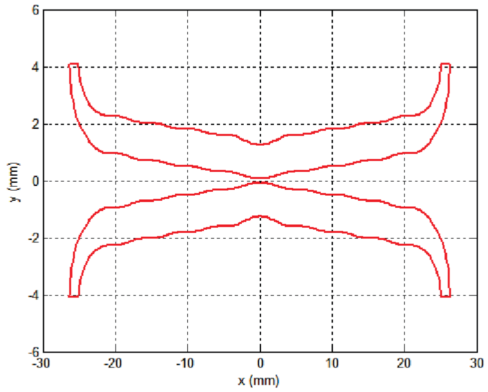

Fig. 2. Coupler scheme with modification in end lines

This amendment is usually performed manually and the Modified scheme of the coupler is shown in Fig. 2. Furthermore, we have to employ Shelton’s technique [3] to attain the coupler structure from previously calculated coupling diagram. However inaccuracies in [3], which mainly arise from neglecting copper thickness and also lack of clear criterion for high and low coupling levels, are other phenomena that lead to aggravation in coupler characteristics.

In this Letter, stubs have been employed to improve directivity parameter of the previously designed non-uniform line directional coupler. This technique was firstly introduced in [4] for narrowband or moderately wide bandwidth structure, however in this paper we develop it for ultra-broadband configurations. In this regard, two modified version of 2-18 GHz directional coupler with coupling coefficient equal to 20dB are investigated and experimental results are demonstrated.

II. MODIFIED COUPLER CONFIGURATION

The aim of this paper is to improve the directivity parameter of a 2-18 GHz stripline coupler with 20dB coupling coefficient and a ripple equal to 0.2 dB. The dielectric used is a 31mil RT/Duroid 5880 laminate layer on which traces of coupler are printed.

The configurations of the proposed couplers using compensating stubs are shown in Fig. 3 and Fig. 4. The structural parameters for couplers with two and ten compensating stubs have been found in a process of optimization and listed in Table I. As it is expected these stubs are symmetric with respect to x and y axes.

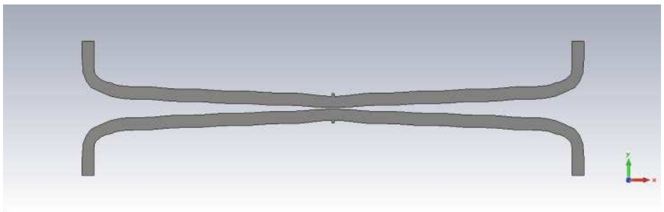

Fig. 3. Layout of coupler with two compensating stubs

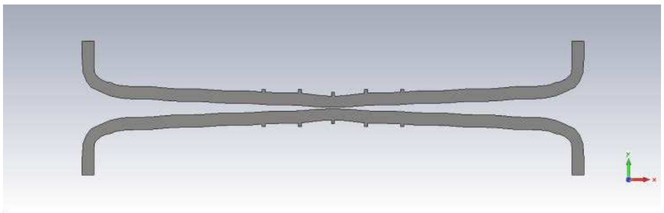

Fig. 4. Layout of coupler with ten compensating stubs

To verify the simulation results and observe the effect of using stubs to improve directivity parameter, 3 prototype of this coupler including classic coupler and the couplers shown in Fig. 3 and Fig. 4 are implemented and tested. In this way, a view of the coupler with two stubs is shown in Fig. 5.

TABLE I. STRUCTURAL PARAMETERS OF COMPENSATING STUBS IN IMPLEMENTED COUPLER STRUCTURES

	Stub 1			Stub 2			Stub 3		
	W1 (mm)	L1 (mm)	x1 (mm)	W2 (mm)	L2 (mm)	x2 (mm)	W3 (mm)	L3 (mm)	x3 (mm)
Ver.1	×	×	×	×	×	×	×	×	×
Ver.2	0.25	0.27	0	×	×	×	×	×	×
Ver.3	0.35	0.38	0	0.37	0.39	3.2	0.35	0.3	7

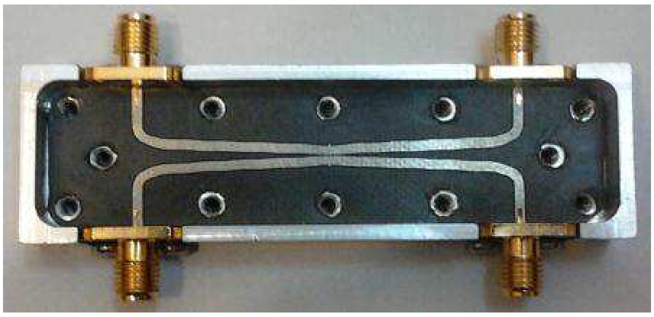

Fig. 5. Prototype of the fabricated coupler with two stubs (the upper substrate is removed)

III. RESULTS

The directivity parameter of these coupler prototypes is measured and is shown in Fig. 6. As depicted in this figure, by adding more compensating stubs to the coupler structure the performance of coupler has been improved such that by employing ten stubs, directivity of better than 15dB in the whole of bandwidth is achieved. It should be noted that overall directivity improvement in whole of the bandwidth is significant in comparison with the classic structure.

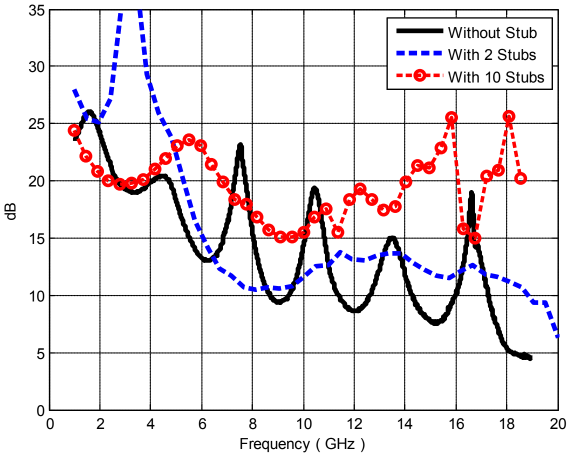

Fig. 6. Comparison between measurement results of couplers directivity

Coupling coefficient and return loss of the coupler with ten compensating stubs is shown in Fig. 7. As depicted in this figure, measured coupling coefficient lies between -20 dB and -21 dB values and return loss is better than -15dB in the desired frequency bandwidth.

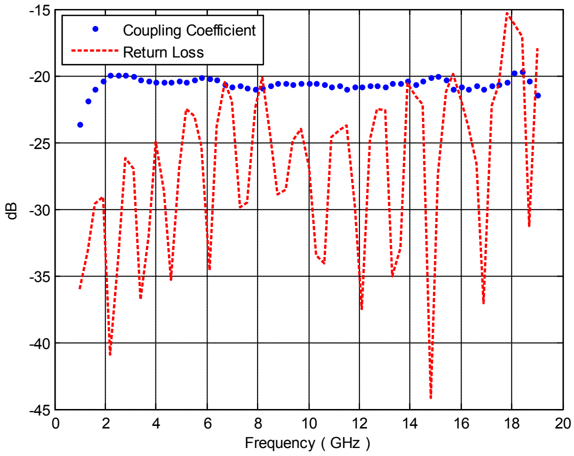

Fig. 7. Measurement results of coupling coefficient and return loss of the coupler using ten compensating stubs.

IV. CONCLUSION

The efficacy of using parasitic stubs in non-uniform ultra-broadband directional coupler has been studied for the first time. In this regard, a 2-18 GHz directional coupler with the aim of improvement in directivity parameter is proposed. Experimental results show noticeable improvement in coupler directivity performance without impairing other coupler parameters such as insertion loss and coupling flatness.

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