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A REVIEW ON DIRECTIONAL COUPLERS WITH INTRODUCTION OF TRANSMISSION LINES IN BETWEEN COUPLED LINE SECTIONS

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ABSTRACT

This paper reviews latest trends in high directivity parallel coupled line directional couplers. These developments are characterized with the improvements in directivity with the use of uncoupled transmission lines between the coupled sections. This paper reviews the designs of microstrip/stripline based designs, single section/two section couplers and coupled/uncoupled transmission lines introduced in between the coupled line sections. The designs are reviewed for coupler properties such as coupling, directivity, isolation and bandwidth.

Keywords: Coupled Line Couplers, Directional Coupler, Directivity, Coupling, Uncoupled Transmission Lines.

I. INTRODUCTION

Directional couplers are passive microwave devices. They form the most basic circuits in microwave applications. Ideally directional couplers should be matched and lossless so that we can achieve coupling as desired for specific application, directivity and isolation as high as possible, low insertion losses and wide bandwidth.

Broad applications of directional couplers includes sampling of signals (which can be further used in the measurement of power, measurement of frequency, signal leveling and reflection coefficient measurements), measurement of the stationary wave, combination of the microwave signals etc. Typically coupled-line couplers consist of single or multiple quarter-wavelength coupled-line sections that allow for broadening of the operational bandwidth [1].

In recent years a new design technique is being developed where coupled-line sections are connected together with transmission line. It has been presented that transmission line sections can be introduced in between coupled-line sections to improve the directivity because these delay lines are responsible for the phase velocities to become equal. The introduction of these design changes not only improves directivity but also allows for reduced length of coupler and increased flexibility in the design of directional couplers [1]. This is at the expense of minor bandwidth reduction, slightly poorer directivity and unequal phase velocities in even and odd mode mainly because of the inhomogeneous medium of a microstrip transmission line [2]. As a solution to this problem, Epsilon Negative Transmission Line, lumped-element compensation, an inductor loaded microstrip directional coupler, Coupler multilayer microstrip configuration are different methods proposed for improving directivity and coupling factor of a coupled line coupler [2]. Other methods such as Lange type couplers, modified Lange type couplers combining the coplanar waveguide (CPW) and the microstrip techniques, broadside-coupled CPW couplers, tandem-connected couplers, single-layer structures with a patterned ground plane were successful in increasing directivity but possessed disadvantages on the fronts of bonding between the microstrip lines, area occupied and complicated design and manufacturing process [3].

II. REVIEW OF LATEST TRENDS IN DESIGN OF DIRECTIONAL COUPLERS

This section reviews the different papers published for improvements in the design of directional couplers. The designs reviewed are all based on introduction of transmission lines of various types in between the coupled line sections.

2.1. High-directivity coupled-line coupler with tight coupling

In traditional microstrip directional couplers we get coupling of 8-40 dB range and the directivity is generally 20dB [4]. The presented design deals with two practical problems faced in the traditional microstrip coupled line couplers, refer top view of the design layout is shown in Fig. 1. Firstly, there is a problem of narrow separation between the coupled transmission lines. This is generally greater than 0.1 mm in the PCB fabrication process [3]. Secondly, there is a difference in even and odd mode velocities in the coupled lines which also cause less directivity. In this design, two coupled-line sections are combined, which are different from the other designs which employ non-coupled connecting delay lines [3].

The performance of this design is evident with tight coupling coefficient and high-directivity performance which can be replicated in a PCB microstrip structure. This could be achieved due to flexible parameters and the ability of coupled sections to compensate the difference in velocities in odd and even phases. At near optimum dimensions, this design of coupled microstrip line coupler could achieve tight coupling (3dB) and more than 60 dB of directivity on practical implementation, refer Fig. 2 [3].

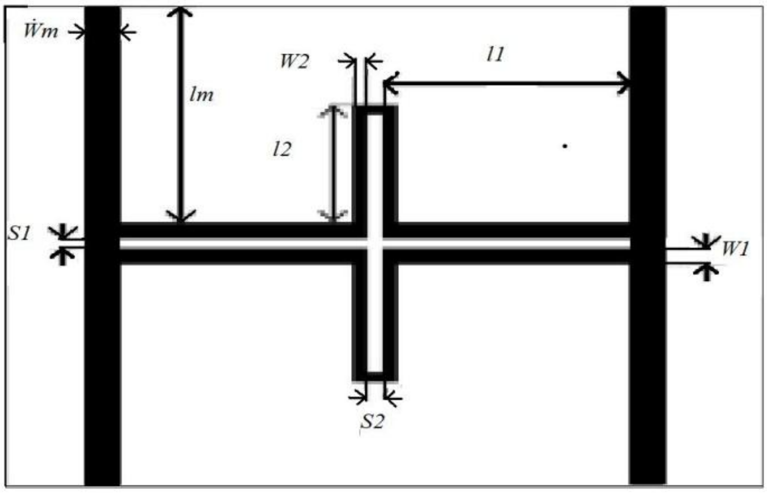

Fig. 1: Top view of the design layout of high directivity coupler introducing coupled transmission delay lines [3].

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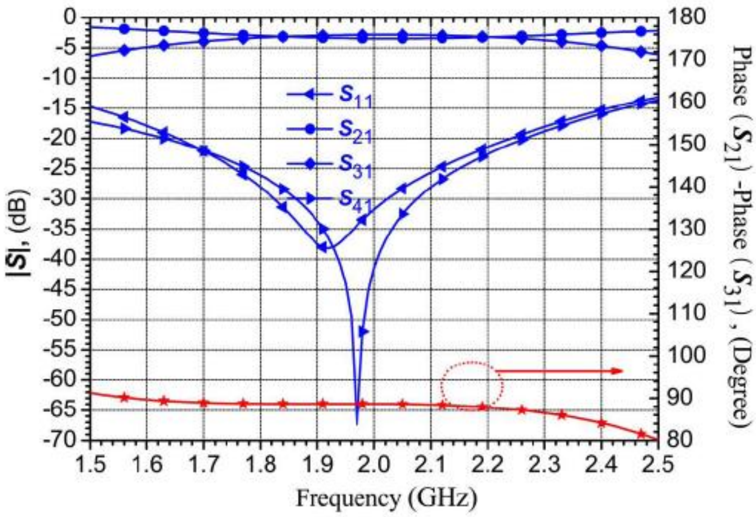

Fig. 2: The scattering parameters of high directivity coupler introducing coupled transmission delay lines [3].

2.2. Reduced length two section directional coupler

This design of directional coupler aimed to improve the bandwidth. It uses two coupled line sections in between which an uncoupled transmission line is introduced [1]. This is better than the traditional two section coupled line coupler in three ways. Firstly, it is showing equi-rippling coupling characteristics just like the classical coupler. Secondly, it has reduced coupling requirement and less electrical length. Thirdly, it has wider bandwidth. The basic stripline design is shown in Fig. 3. For coupling of 3dB, this design could achieve a wide bandwidth from ranging from 0.72 to 2.75 GHz, refer Fig. 4 [1]. This type of design can be useful in applications requiring wide bandwidth and average directivity.

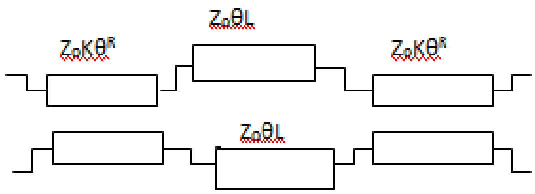

Fig.3: Basic design of a reduced length two section directional coupler [1].

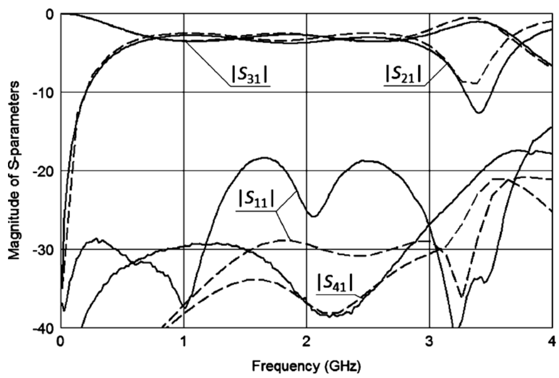

Fig. 4: Amplitude characteristics of the 3dB design of reduced length two section directional coupler. The solid lines are measured values and the dashed lines are the calculated values [1].

2.3. Directional couplers design based on the connection of coupled-line sections with left-handed transmission lines introduced in between

In this design of directional coupler, two sections of uncoupled Left Handed Transmission Lines (LHTLs) are introduced in between two sections of coupled lines. It used two symmetrically placed two sections of uncoupled LHTLs to achieve tight coupling, refer Fig. 5. Both the respective sections, coupled-line and LHTL, are matched to the impedance (Z_0). This design coupler also provides for broadband operation [5].

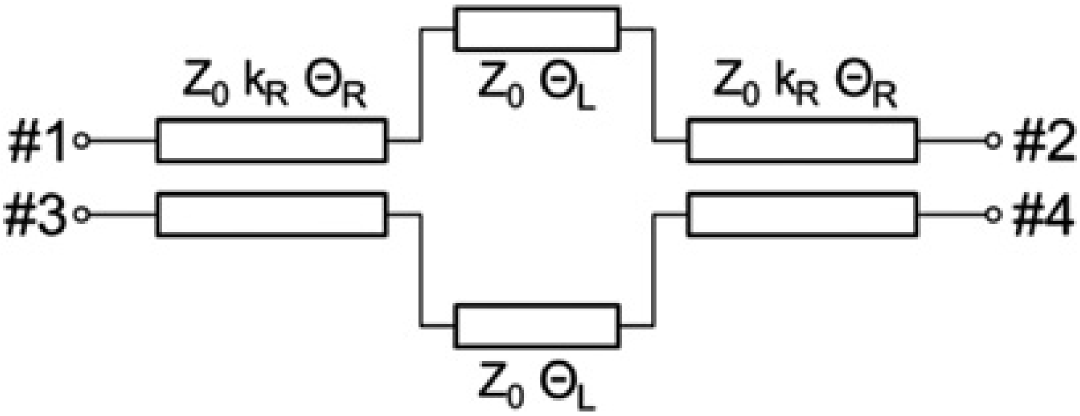

Fig. 5: Diagram of directional coupler utilizing two sections of coupled line and LHTLs introduced [5].

This design of coupled-line couplers allows broadband 3-dB directional couplers to be practical for a planar microstrip design. To verify the theoretical approach, two couplers were realized on a microstrip planar section using shunt TL sections using using lumped series capacitors and interdigital capacitors as shown in Fig. 6. The results are shown in Fig. 7 and Fig. 8 respectively.

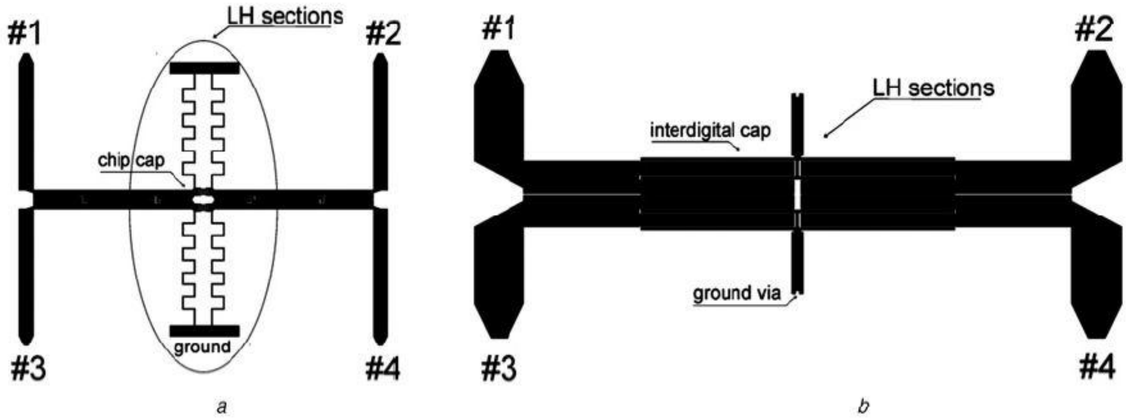

Fig. 6: Layout of the 3dB coupled line coupler designed using LHTLs; a) lumped series capacitors and shunt TL sections, b) Interdigital capacitors and shunt TL sections [5]

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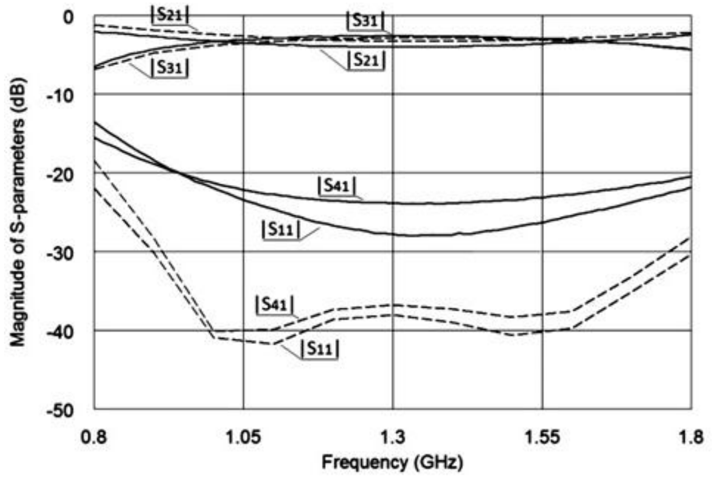

Fig. 7: Simulation results: Amplitude characteristics of 3dB coupled line coupler using lumped series capacitors and shunt TL sections [5].

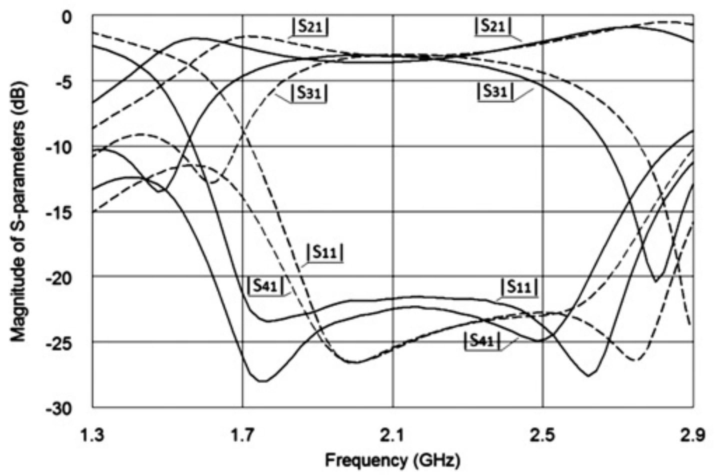

Fig. 8: Simulation results: Amplitude characteristics of 3dB coupled line coupler using lumped interdigital capacitors and shunt TL sections [5].

2.4. Directional Coupler Using Composite Right/Left-Handed (CRLH) Transmission Lines

This design of coupler provides tight coupling over a wide range of bandwidth. It used CRLH transmission lines and a much advanced conductor material YBCO thin film high temperature superconductor (HTS) in place of Copper [2]. The layout is shown in Fig. 9. The use of a superconducting material is responsible for achieving high directivity. In traditional coupled line couplers conducting material is Copper which is inhomogenous which leads to loss in directivity, the superconducting material ensures that directivity is not lost while CRLH transmission lines ensure a tight coupling is achieved over a wide range of frequencies [2].

CRLH unit cells helps in controlling characteristic impedance and dispersion relation in the lines while use of HTS ensure low conductor losses and high directivity. Both these improvements improved the performance of CRLH HTS based directional coupler. Refer Fig. 10 for s-parameters [2].

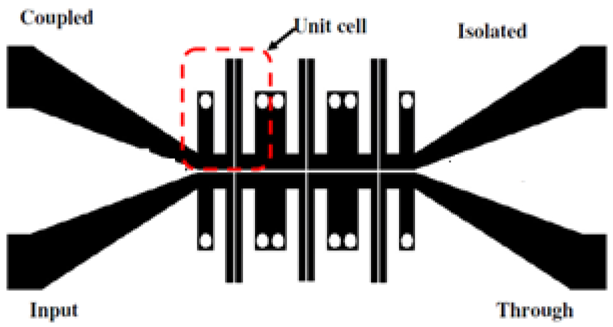

Fig. 9: The layout of CRLH based directional coupler [2].

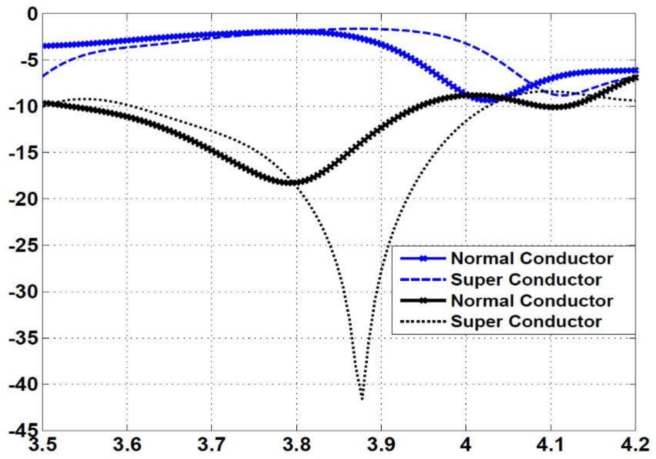

Fig. 10: S-parameters of the presented directional coupler [2]

III. CONCLUSION

We have reviewed the latest trends in the layout design of directional couplers. There are new materials being introduced in the design process which are improving the efficiency of the couplers. Meta-materials are being used to enhance coupling. High temperature superconductors are finding their applications in bringing about better directivity as compared to the presently used inhomogeneous conductor like Copper.

These improvements are guided primarily by the ease of manufacturing process and the range of applications. These improvements in coupling, directivity, bandwidth and control of losses will pave way towards more efficient power networks and wide range of applications.

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