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Multi Section Coupled Line Directional Couplers Design

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ABSTRACT: Directional coupler is a passive device used for sampling incident and reflected microwave power conveniently and accurately for various applications in microwave systems. Directional coupler can be realized in strip, micro strip, coax and waveguide lines. Multi section coupled line couplers provide increased bandwidth. Theory of multi section coupled line directional couplers in strip line structures is the study for project work and to implement its design in microstrip lines. The operating frequency is 1.8 GHz.

KEYWORDS: micro strip; multi section coupled line coupler; characteristic impedance; coupling coefficient

I. INTRODUCTION

Strip line is considered as extended version of microstrip line. It looks like a sand witch structure. Here ground planes exits on both sides of the substrate while metal strip of design lies at the middle. Coplanar waveguide is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave-frequency signals[1]. On a smaller scale, coplanar waveguide transmission lines are also built into monolithic microwave integrated circuits.

Conventional coplanar waveguide (CPW) consists of a single conducting track printed onto a dielectric substrate, together with a pair of return conductors, one to either side of the track. All three conductors are on the same side of the substrate, and hence are coplanar [2]. The return conductors are separated from the central track by a small gap, which has an unvarying width along the length of the line. Conductor-backed coplanar waveguide (CBCPW) is a common variant which has a ground plane covering the entire back-face of the substrate [3].

The ground-plane serves as a third return conductor. The electromagnetic wave carried by a coplanar waveguide exists partly in the dielectric substrate, and partly in the air above it. In general, the dielectric constant of the substrate will be different (and greater) than that of the air, so that the wave is travelling in an inhomogeneous medium. In consequence CPW will not support a true TEM wave; at non-zero frequencies, both the E and H fields will have longitudinal components. Coupled lines can be of any form, depending on the application and generally consists of two transmission lines, but may contain more than two[4].

The lines can be symmetrical or asymmetrical and the separation between the lines may be either constant or variable. Both lines are placed in close to each other so that the electromagnetic fields can be interacting. The closer the lines are placed together, the stronger the interaction that takes place. When one port is excited with a known signal, a part of this signal appears at other ports [5]. This interaction effect known as desirable coupling is used to advantage in realizing several important microwave circuit functions, such as directional couplers and filters with the coupled line length usually being approximately a quarter-wave long.

II. SCHEMATIC OF PRESENTED COUPLER

A generic schematic of the presented coupler composed of two coupled line sections and one uncoupled line section is shown in Fig1. The coupled line sections are connected with use of uncoupled section. The presented structure is described by Z_0 characteristic impedance; k_i the coupling coefficient of the ith coupled line, θ_i is the electrical length of the ith coupled line and θ_{TL} is the electrical length of uncoupled transmission line.

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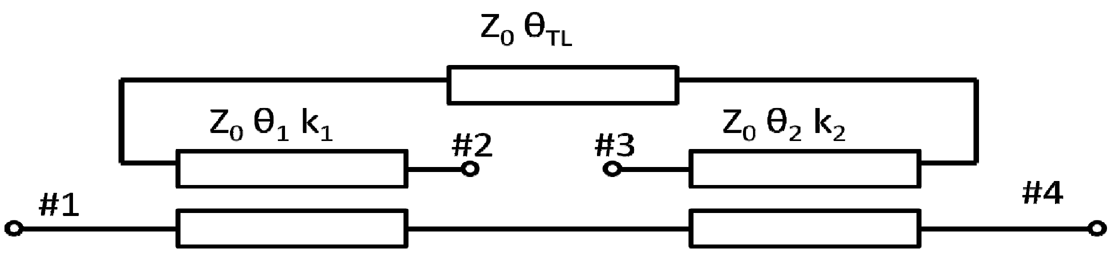

Fig 1. Generic schematic of a proposed directional coupler consisting of two coupled-line sections connected with the use of an uncoupled transmission line.

When port 1 is excited with input power then the port 3 is coupled port and port 4 is isolated port. The coupling characteristic of the presented schematic is written by observing the circuit i.e. there are two paths to couple the power into port 3. The sum of the power coming from the two paths is appearing at the port 3. It is as follows,

$$S_{31} = T_1 C_2 + T_2 C_1 E \qquad (1)$$

where the coefficients C_i, T_i $(i = 1,2)$ are S—parameters of a coupled-line section, given by the well-known formulas

$$C_i = \frac{j k_i \sin(\theta_i f)}{\sqrt{1-k_i^2}\cos(\theta_i f) + j\sin(\theta_i f)} \qquad (2a)$$

$$T_i = \frac{\sqrt{1-k_i^2}}{\sqrt{1-k_i^2}\cos(\theta_i f) + j\sin(\theta_i f)} \qquad (2b)$$

where the remaining factor E is the transmission coefficient of an uncoupled transmission line connecting the coupled-line sections

$$E = \cos(\theta_{TL} f) - j\sin(\theta_{TL} f)$$

and f is the normalized frequency. The magnitude of the coupling characteristic can be expressed as follows [4]

$$|S_{31}| = \sqrt{\frac{N}{D}} \qquad (3)$$

Where

$$N = k_1^2(1-k_2^2)sin^2(\theta_1 f) + k_2^2(1-k_1^2)sin^2(\theta_2 f) + 2k_1k_2\sqrt{1-k_1^2}\sqrt{1-k_2^2}\sin(\theta_1 f)\sin(\theta_2 f)\cos(\theta_{TL} f)$$

$$D = [1-k_1^2cos^2(\theta_1 f)][1-k_2^2cos^2(\theta_2 f)]$$

Electrical lengths θ_1, θ_2 and θ_{TL} are chooses as which allow achieving the frequency response of the presented coupler, being even with respect to the normalized frequency f_0. The chosen electrical lengths are gathered in Table1 those are calculated by using trigonometric identities, for which $\theta_1 + \theta_2 + \theta_{TL} = 360^o$

Coupler	θ_1(deg)	θ_2(deg)	θ_{TL}(deg)
A	90	90	180
B	90	180	90
C	90	270	0

Table1: Electrical Lengths of Three Chosen Directional Couplers

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By taking these electrical lengths and finding suitable coupling coefficients k_1 and k_2 by using numerical procedure based on the minimization of the following form,

$$D = \max\{X\} - \min\{X\} \quad (4)$$

Where vector X is defined as follows:

$$X = \left\{\sqrt{1-|S_{31}(f_1)|^2}, |S_{31}(f_0)|, \frac{1}{\sqrt{2}}\, 10^{\frac{\delta_c}{20}}\right\} \quad (5)$$

And f_1 is the frequency at which the coupling characteristic has its maximum, and δ_c is the coupling imbalance expressed in decibels.

III. NUMERICAL PROCEDURE

For solving the given equation (4), it is necessary to find out maximum and minimum of vector X. Firstly take electrical lengths of coupler A and starting values of coupling coefficients $k_1(0.1)$ and $k_2(0.1)$ and observe the vector X and increasing one of the coefficients and again check the vector values then do the same procedure to getting minimum D. Whenever we are getting minimum D value, at that point note down the coupling coefficient values those are the values can provide equal-ripple frequency characteristics.

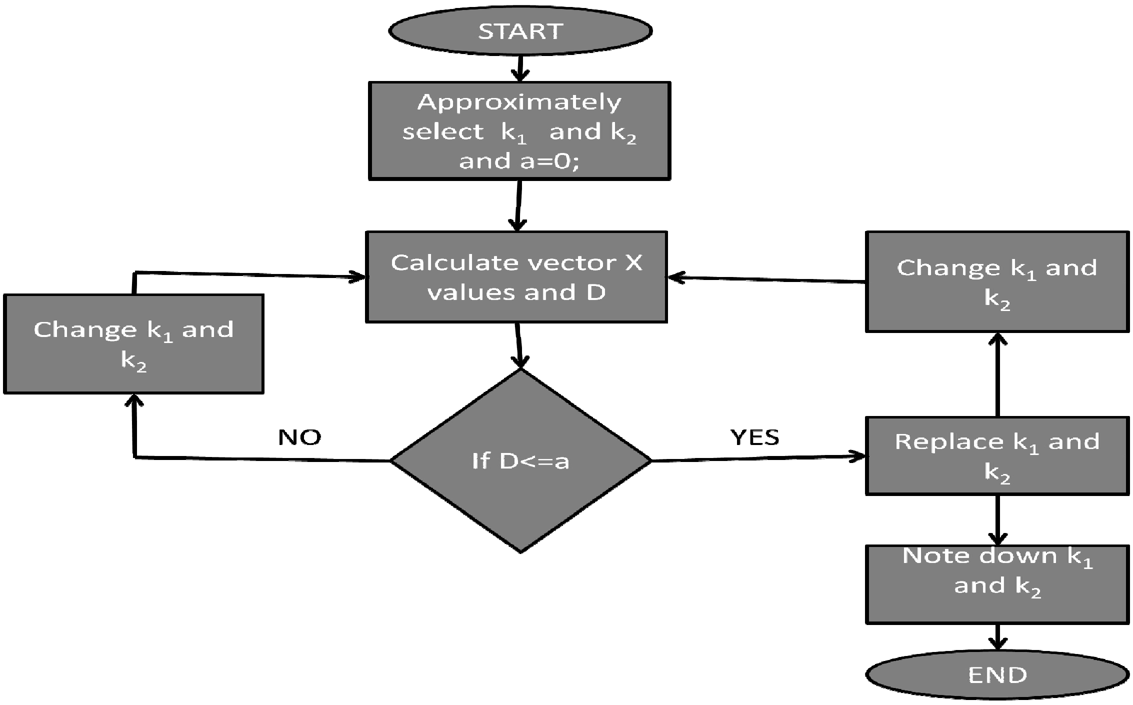

Fig 2: Flow chart for numerical procedure

Same procedure is applied for both coupler B and coupler C and note down the coupling coefficients k_1 and k_2. The coupling coefficient values with corresponding bandwidth for the three types of couplers A, B and C found for a set of typical coupling imbalance values are listed in Table 2-4, respectively.

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Coupling imbalance δ_c(dB)	k_1	k_2	Bandwidth f_u/f_l
0.1	0.800	0.148	2.5
0.2	0.813	0.178	3.0
0.3	0.828	0.218	3.5
0.4	0.836	0.242	3.8
0.5	0.847	0.277	4.4
0.6	0.853	0.297	4.7
0.7	0.862	0.329	5.0
0.8	0.870	0.359	5.6
0.9	0.880	0.400	6.1
1	0.885	0.419	6.4

Table 2: Coupling Coefficients and Corresponding Bandwidth of the 3-dB Directional Coupler A

Coupling imbalance δ_c(dB)	k_1	k_2	Bandwidth f_u/f_l
0.1	0.698	0.215	2.7
0.2	0.690	0.257	3.0
0.3	0.681	0.295	3.4
0.4	0.672	0.329	3.7
0.5	0.663	0.360	4.0
0.6	0.652	0.395	4.2
0.7	0.641	0.427	4.5
0.8	0.632	0.452	4.7
0.9	0.621	0.480	5.0
1	0.609	0.509	5.2

Table 3: Coupling Coefficients and Corresponding Bandwidth of the 3-dB Directional Coupler B

Coupling imbalance δ_c((dB)	k_1	k_2	Bandwidth f_u/f_l
0.1	0.766	0.108	2.8
0.2	0.769	0.113	3.08
0.3	0.772	0.127	3.3
0.4	0.775	0.142	3.6
0.5	0.778	0.160	4.0
0.6	0.780	0.174	4.2
0.7	0.783	0.197	4.7
0.8	0.784	0.207	4.8
0.9	0.786	0.227	5.0
1	0.787	0.240	5.4

Table 4: Coupling Coefficients and Corresponding Bandwidth of the 3-dB Directional Coupler

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IV.MATLAB RESULTS

The frequency characteristics are calculated using the equation (3), the results are as follows;

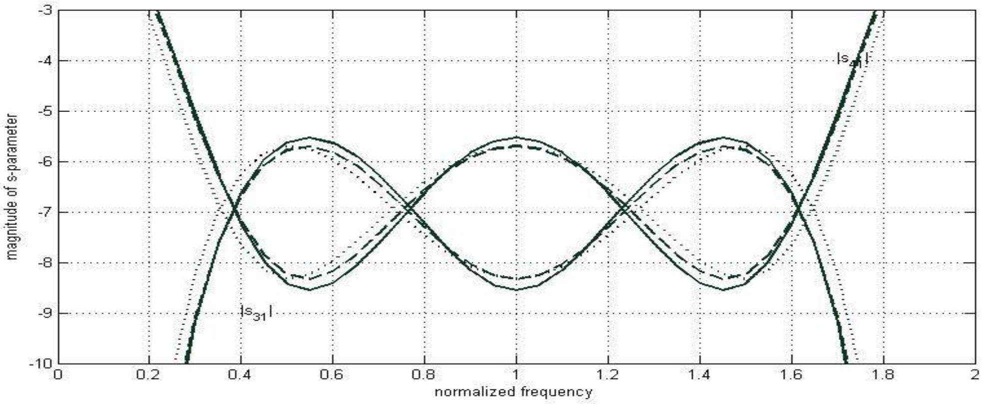

Fig 3: frequency characteristics of the presented couplers: coupler A—dotted lines, coupler B—solid lines, Coupler C—dashed lines

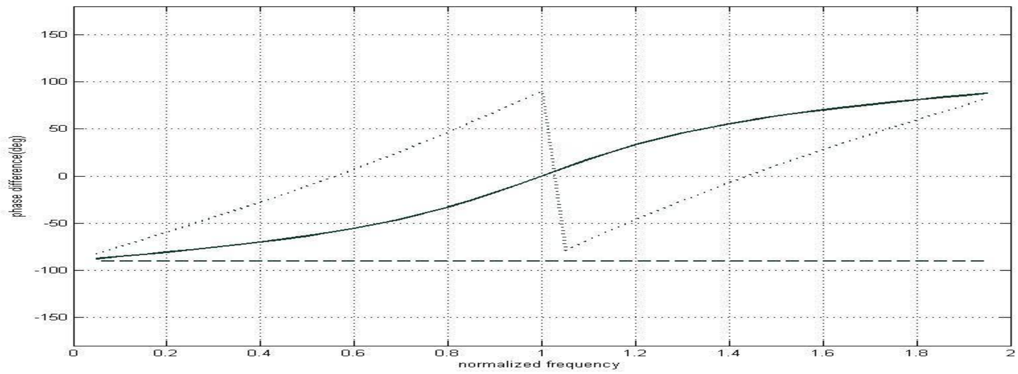

Fig 4: Phase difference of presented couplers: coupler A—dotted lines, coupler B—solid lines, Coupler C--dashed lines

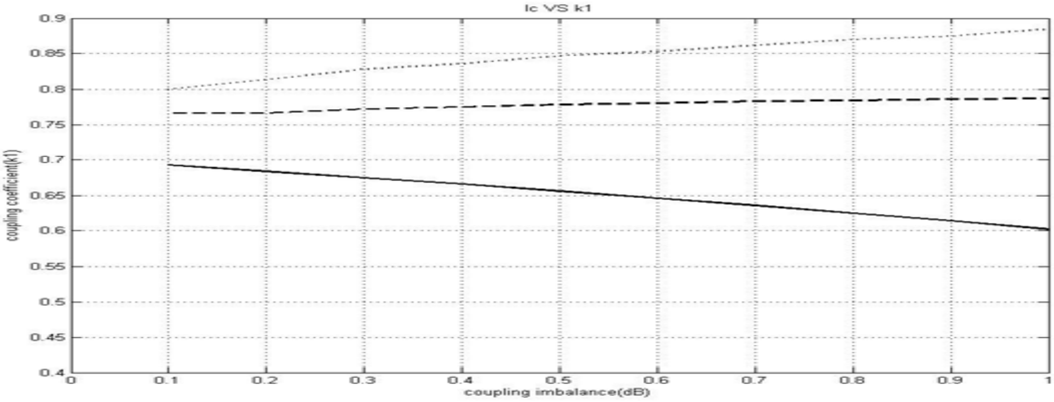

Fig5: Bandwidth of the three presented types of 3-dB directional coupler versus coupling imbalance in dB Coupling imbalance versus Bandwidth.

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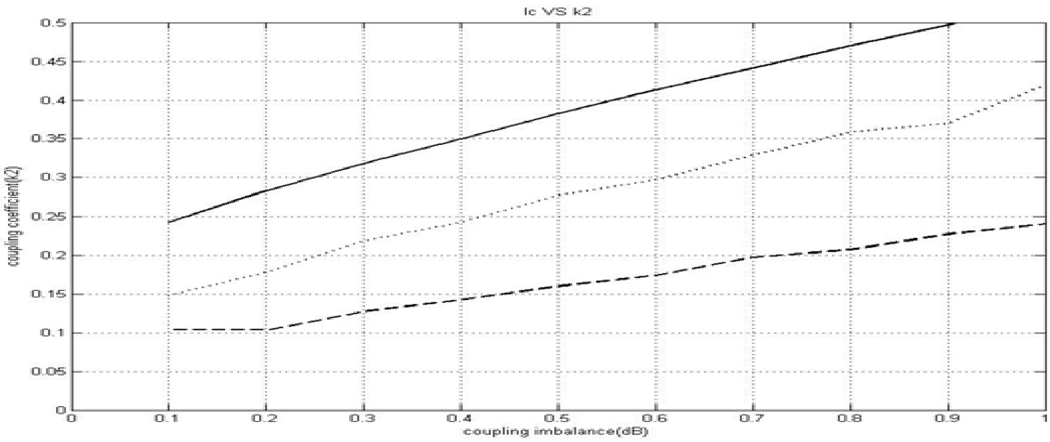

Fig 6: Comparison of the coupling coefficient k_2 ensuring equal-ripple frequency characteristics for three presented of 3-dB directional coupler. Coupler A- solid line, coupler B-dash dot line, coupler C-dashed line.

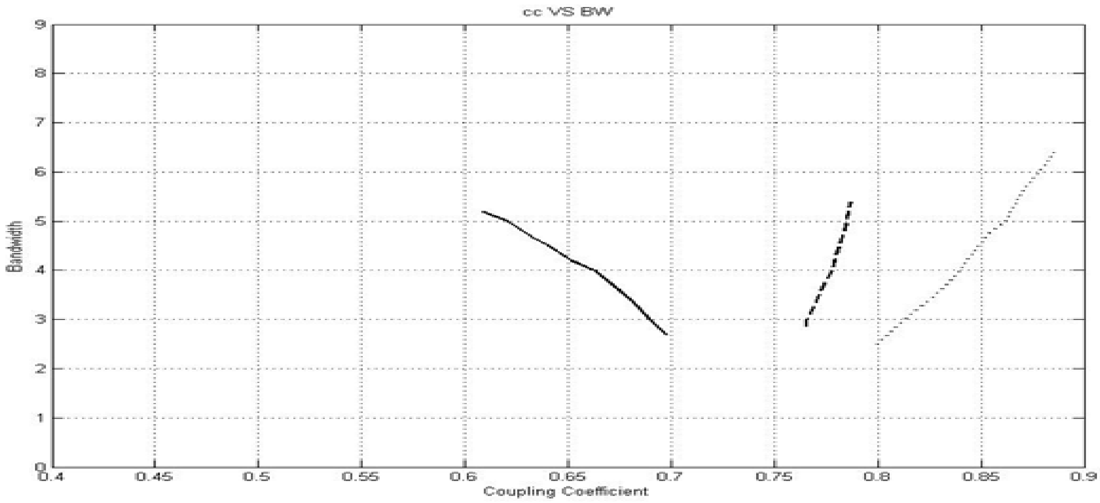

Fig 7: Bandwidth of the three presented types of 3-dB directional coupler versus the coupling of most tight coupled section

The results which are presented in chapter 5 are belongs to three types of coupled line directional couplers A, B and C. based on these results one can may estimate that which coupler is proffered one among three types. Fig 6 reflects that the coupling characteristics of three types of couplers, the graph is between normalized frequency and magnitude of S-Parameters (S_{31} and S_{41}). Those are equal ripple frequency characteristics.

The phase difference of three types of presented directional couplers are showed in Fig 4, by observing that it is clear that the coupler A and coupler B are not having constant phase difference, but the coupler C has constant phase difference among the frequency.

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V. CONCLUSION AND FUTURE SCOPE

A new type of broadband directional coupler has been presented, being a connection of two coupled-line sections having unequal electrical lengths and a transmission-line section. It has been shown that the frequency response of such a coupler is equal-ripple frequency characteristics. Three different configurations of such couplers have been discussed and it has been shown that the presented coupler C is suitable compared to the other couplers A and B for more applications which are having lesser bandwidth. Coupler C also having constant phase characteristics. Therefore, the presented concept of multisection directional couplers constitutes an attractive alternative to the classic solutions.

REFERENCES

[1]. David M. Pozar " Microwave Engineering 4th Edition" Wiley john & sons, Inc. ISBN 978-0-470-63155-3.2011

[2]. R. K. Mongia, I. J. Bahl, P. Bhartia, J. Hong "RF and Microwave Coupled-Line Circuits Second Edition" arctech house, Boston, LondonISBN-13: 978-1-59693-156-5, 2007.

[3]. Robert E. Collin. A classic reissue "Foundations for Microwave Engineering second edition" IEEE Press Series On Electromagnetic Wave Theory, ISBN D-7flD3-bD31-l,2001

[4]. RAINEE N. SIMONS *NASA Glenn Research Center Cleveland, Ohio* "Coplanar Waveguide, Circuits, Components and systems" Wiley-interscience, ISBN 0-471-16121-7., 2001

[5]. Kamil Staszek, Krysztof Wincza, *Member, IEEE*, and Slawomir Grusczynski, *Member, IEEE*, " MULTISECTION COUPLERS WITH COUPLED-LINE SECTIONS HAVING UNEQUAL LENGTH" *IEEE Trans. MTT, Vol. 62, No.7, July 2014*

BIOGRAPHY

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