ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 2, February 2018

Design and Simulation of Coupled-line Couplers

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ABSTRACT: In this paper, two coupled-line couplers are designed and simulated using stripline technology. The coupled-line couplers (A and B) are designed with different values of coupling coefficient 6dB and 10dB respectively. Both of circuits have a coupled output port, a through output port and an isolated output port. In addition, even and odd modes techniques employed to analyse and synthesize the designed couplers.Furthermore, both circuits are tuned to function around 2.45 GHz. The design results are presented by simulation results obtained using Advanced Design System (ADS) software.

KEYWORDS:directional coupler, coupled-line coupler, stripline, ADS.

I.INTRODUCTION

Directional couplers are one of the microwave passive components that are used in array antennas, modulators, filters and power amplifiers for propose of dividing or combining the power[1-9]. A coupled-line coupler (CLC) is one of the configuration directional coupler. As, shown in Fig. 1, CLC is a four-port network constituted by the combination of two unshielded transmission lines (TLs) in close proximity to each other.The four ports are input, direct (through), coupled and isolated[1-5]. Due to this proximity, the electromagnetic fields of each line interact with each other, which cause to power trade between the two lines, or coupling [5].

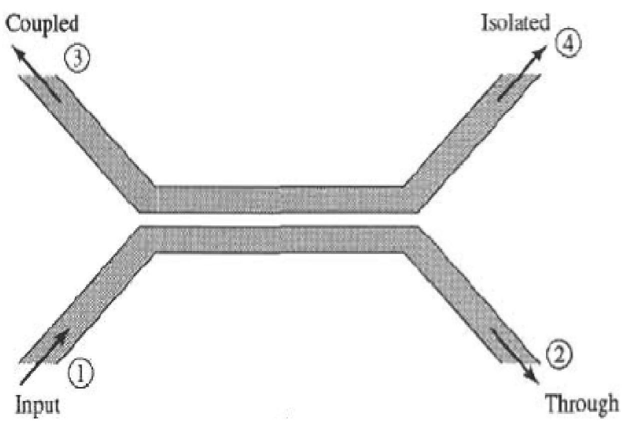

Fig.1. Typical structure of a coupled-line coupler

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Basically, there are tow types of CLC, backward wave and forward wave couplers.When the output coupling port is in the vicinity of the input port, the CLC is named backward as shown in Fig.1, otherwise it is forward [5].According to the current flow in an electromagnetic situation, there are two modes for thecoupled line. In the first mode, current flows down on conductor with a contra-flow current back up the other conductor caused by displacement current coupling between the two conductors. This is termed the odd mode current, and it has associated odd mode characteristic impedance, styledZ_{0o}. In the other mode, current flow by displacement current between each center conductor carrying the same polarity, and the ground that is common between them. Hence this is called the even mode current, and it has an associated even mode characteristic impedance, styled Z_{0e} [1-4]. Fig. 2 shows the polarity of the lines of each mode.

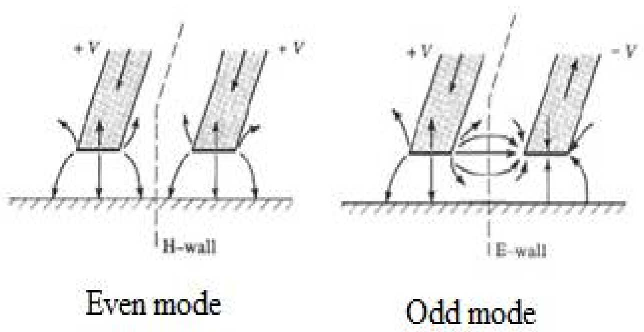

Fig.2. Even and odd modes excitations for a coupled line

For a single section coupler the even and odd modecharacteristic impedancesare defined as [10], [11] :

$$Z_{0e} = Z_O\sqrt{\frac{1+C}{1-C}} \quad (1)$$

$$Z_{0o} = Z_O\sqrt{\frac{1-C}{1+C}} \quad (2)$$

Where$Z_O$is the characteristic impedance andC is the voltage coupling factor of the coupler which can be calculated by [10], [11]:

$$C = 10^{\frac{-\text{couplingcoefficient}}{20}} \quad (3)$$

In general, the performance of the coupler is mainly depended on coupling factor, directivity and terminating impedance. The isolated port is usually terminated by a matched load.To increase the bandwidth, multi-section designs are normally used. Furthermore, features such as low insertion loss and high directivity are desired in the coupler [3].

In this paper, two backward coupled-line coupler will be designed and simulated using stripline technology with different values of coupling coefficient. The corresponding simulation results are also presented in this paper together with some discussions.Sections of this paper are organized as following; section II is design procedure of coupled-line couplers. In section III,simulation results are shown. In section IV, results discussion and compression between the designed coupled-line couplers are illustrated. Finally, a brief conclusion is presented in section V.

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II.DESING METHODOLOGY

The design parameters specification for coupled-line couplers are listed in the tables 1 and 2. These specifications are required to calculate the dimensions of the couplers. Fig. 3 shows the circuit structure of the coupled line-coupler that will be designed.

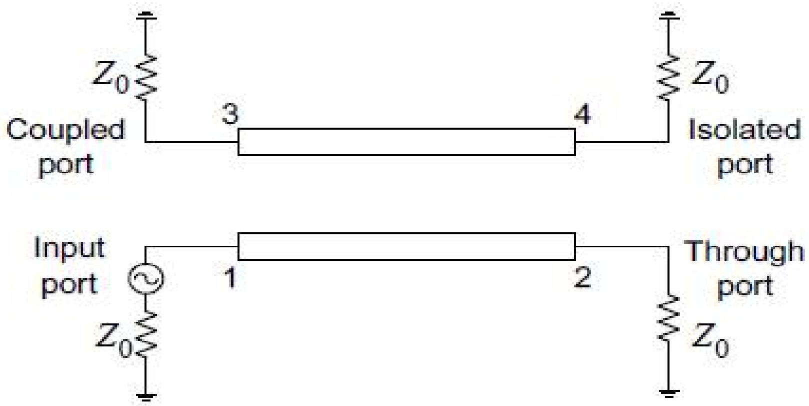

Fig. 3.Coupled-line coupler circuit

Table 1. Coupler-line Coupling coefficient specification

Coupler	Coupling coefficient C (dB)
Coupled-Line Coupler A	6
Coupled-Line Coupler B	10

Table 2. Design parameters specification

Parameter	Specification
Characteristic impedance, Zo (Ω)	50
Centre frequency / center frequency (GHz)	2.45
Substrate dielectric constant (εr)	4.5
Substrate thickness, h (mm)	0.508
Loss tangent (tan δ)	0.0027
Metallization / copper cladding (um)	35
Planar technology	Stripline
ADS Transmission Line	SCLin

1- Coupled-line coupler A

The steps of design basicallybegin by calculate the characteristics impedance for both modes. The value of the characteristic impedance for even mod (Z0e), and odd mode (Z0o)can be gettingthrough using the equations (1) and (2) respectively. In the questions,Z0 is characteristic impedance of the transmission line and it is equal to 50 Ω, while C is

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the coupling factor can be obtained using equation (3). For coupled-line coupler A, value of coupling factor is 6dB. Therefore, the coupling factor is calculated as following:

$$C = 10^{\frac{-6}{20}} = 0.5012$$

Thus:
Z0e = 86.74 ohm
Z0o = 28.82 ohm

By considering the specification design of the coupled line coupler in table 2 and by using the ADS LineCalc tools, the dimensions of thestripline quarter wave transmission line (SCLIN) are calculated. Table 3 showscalculation dimension results.

Table 3. Coupler-lineCoupler A dimension

Coupler	Parameter	Value (mil)
Coupled-Line Coupler A	Width (W)	3.983228
	Length (L)	568.185039
	Space (S)	0.919067

The equivalent simulated circuit schematic and layout of coupled-line coupler A that obtained by using ADS software are shown in Fig. 4 and Fig. 5respectively.

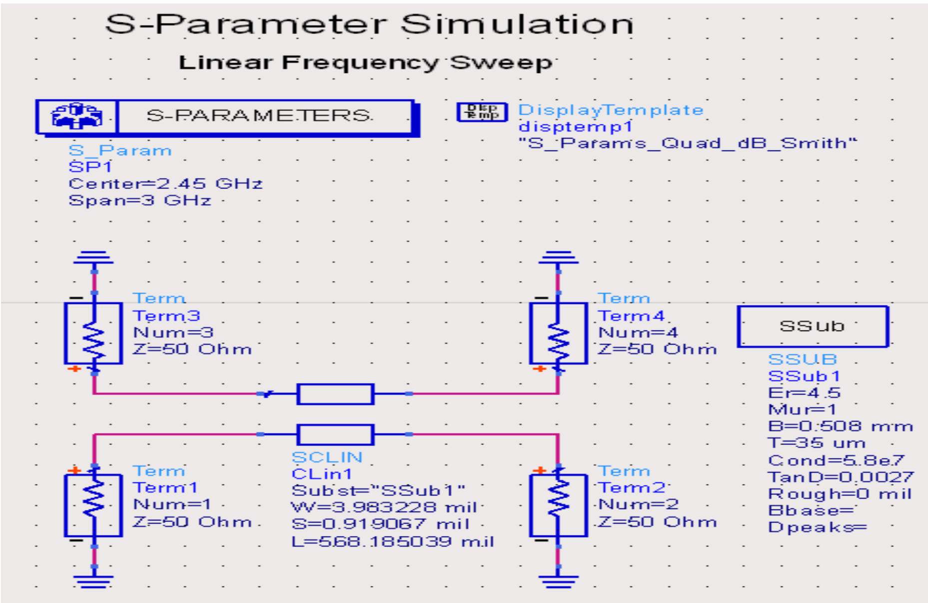

Fig. 4. Circuit schematic of coupled-line coupler A

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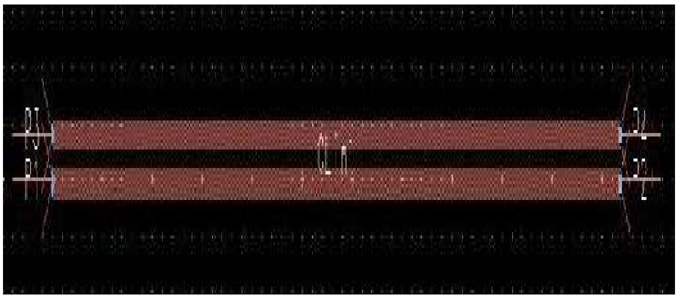

Fig. 5. Layout of coupled-line coupler A

2- Coupled-line coupler B

For coupled-line couple B, the same design steps are followed in which firstly calculation of the even mode characteristic impedance (Z0e) and the oddmode characteristic impedance (Z0o) using the equation (1) and (2), but this coupler has 10 dB coupling coefficient.Therefore,coupling factor is calculated as following:

$$C = 10^{\frac{-10}{20}} = 0.31623$$

Thus:
Z0e = 69.37 ohm
Z0o = 36.038 ohm

By considering the specification design of the coupled line coupler in table 2 and by using the ADS LineCalc tools, the dimensions of the stripline quarter wave transmission line (SCLIN) are calculated. Table 4 shows calculation dimension results.

Table 4. Coupler-line Coupler B dimension

Coupler	Parameter	Value (mil)
Coupled-Line Coupler B	Width (W)	5.430197
	Length (L)	568.185039
	Space (S)	2.848760

The layout andequivalent simulated circuit schematic of coupled-line coupler B that obtained by using ADS software are shown in Fig. 6 and Fig. 7respectively.

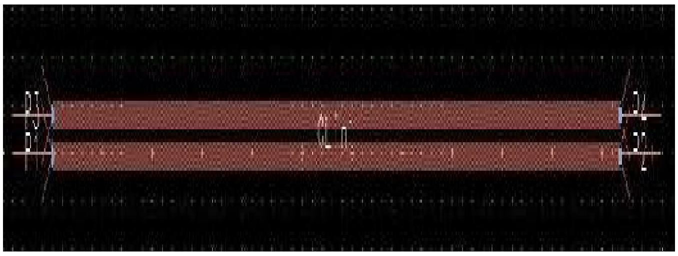

Fig. 6. Layout of coupled-line coupler B

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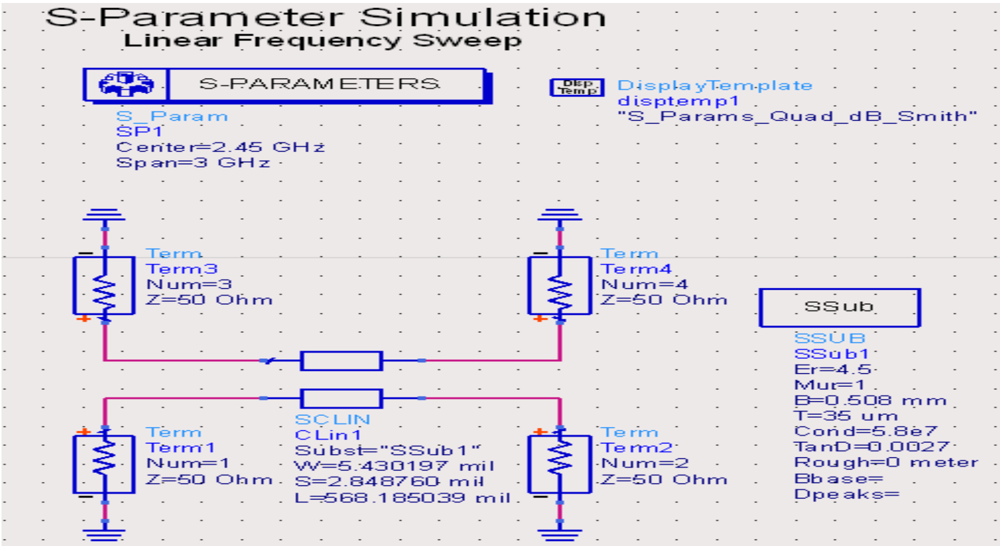

Fig. 7. Circuit schematic of coupled-line coupler B

III.SIMULATION RESULTES

The simulation obtained results are mainly indicated to the S parameters of the coupled –line coupler circuit that have been plotted as shown in Fig. 4 and Fig. 7 .Both of circuits are four ports network. However, the values of scattering parameters of the ports are obtained from reflection coefficient graphs. Fig. 8 shows the simulation results of the power output at the four ports (in Sparameters) versus frequency for coupled-line coupler A, while Fig. 9 illustrates the simulation results for coupled-line coupler B.

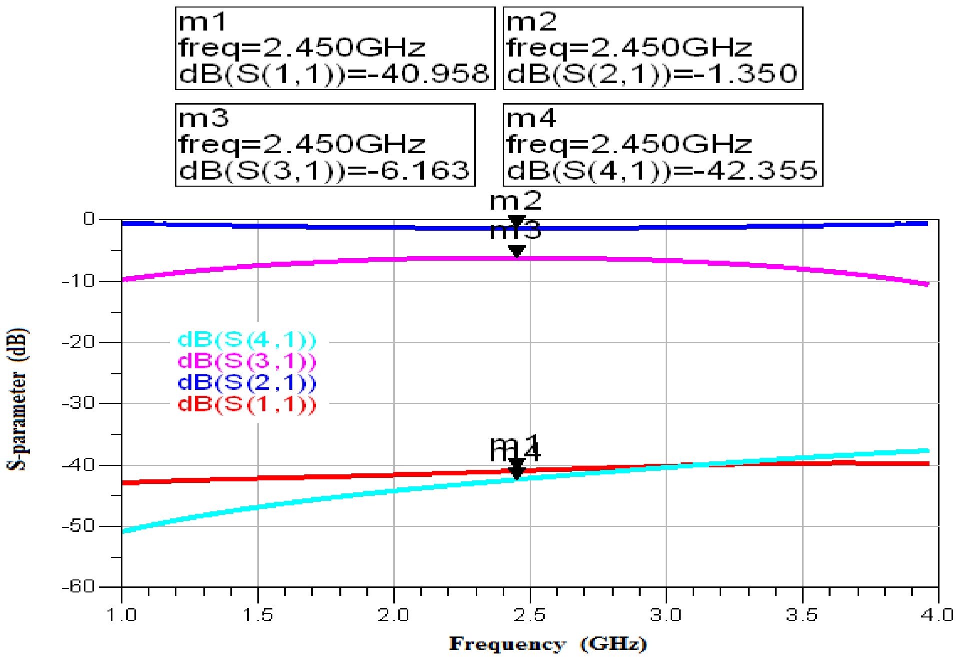

Fig. 8. S-parameter for the coupled line coupler A

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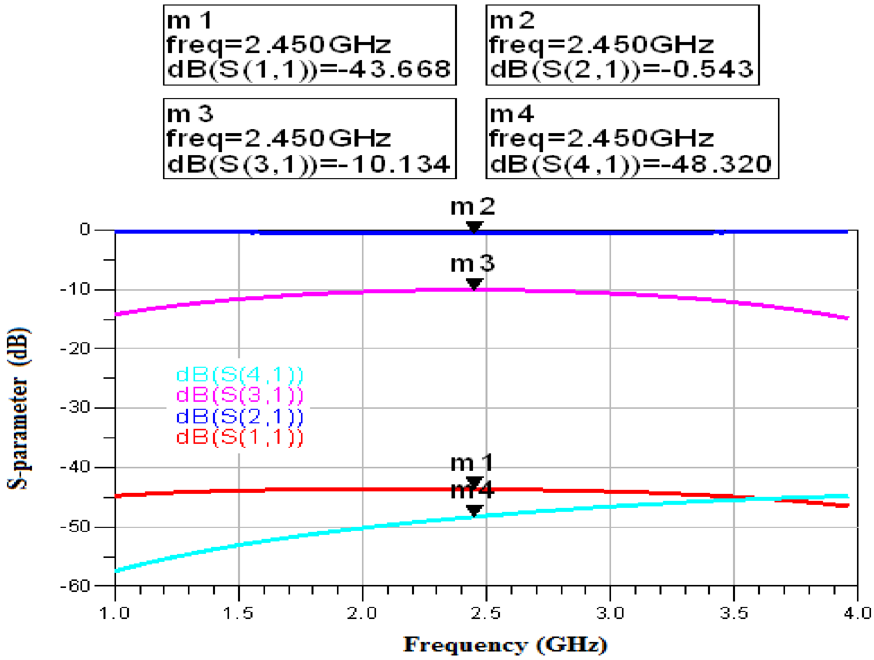

Fig.9. S-parameter for the coupled line coupler B

IV.RESULTS DISCUSION AND COMPRESSION

By analysing the simulated results, it can be observed that changing the coupling coefficient has an effect on the output power at ports at central frequency (2.45GHz). Moreover, the dimension of the coupler is also change as the coupled coefficient change. However, table 5 contains a comparison between both designed coupled-line couples.

Table 5. Simulation results comparison

		Circuit A	Circuit B
Coupling Coefficient (dB)		6	10
Dimension (mil)	Width (W)	3.983228	5.430197
	Length (L)	568.185039	568.185039
	Space (S)	0.919067	2.848760
[S]	S_{11}(dB)	-40.958	-43.668
	S_{21}(dB)	-1.350	-0.543
	S_{31}(dB)	-6.136	-10.134
	S_{41}(dB)	-42.355	-48.320

Form the table 5, it can be indicated that the advantage of circuit B in which it denotes coupled-line coupler B, has low reflection at port 1 and better isolation at port 4. On the other hand, Circuit A that refers to coupled-line coupler A, has small width and space compare to circuit B. The reflection at port 1 is a little greater than that of Circuit B but still fairly good. Therefore, the coupling coefficient is direct proportional to the space between the coupled transmission line and its width.

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V.CONCLUSION

In this paper, two coupled-line couplers have designed and simulated using ADS software.The designs were for specified given parameters using stripline technology. However, the simulation results that obtained are shown good matching and isolation performance for designed coupled-line couplers.

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