

## Impact of Coupling Coefficient on Coupled Line Coupler

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**Abstract-** The coupled line coupler is a type of directional coupler which finds practical utility. It is mainly used for sampling the microwave power. In this paper, 3 couplers A,B & C are designed with different values of coupling coefficient 6dB,10dB & 18dB respectively at a frequency of 2.5GHz using ADS tool. The return loss, isolation loss & transmission loss are determined. The design & simulation is done using microstrip line technology.

**Keywords-** Advanced Design System(ADS); directional coupler; return loss; isolation loss; transmission loss; microstrip line.

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### I. INTRODUCTION

The coupled line coupler is of 4-port microwave passive, bidirectional device. It is also called as parallel coupled directional coupler. It is a section of parallel coupled transmission line of length one quarter wavelength in the propagating medium. The electrical length of the coupled line section is  $\theta$ . The width of the strip conductors in the coupled section is  $w$  & spacing between them is  $s$ . The four ports of the coupled line are decoupled at the ends to form four strip lines. Fig.1 shows the typical structure of a coupled line coupler.

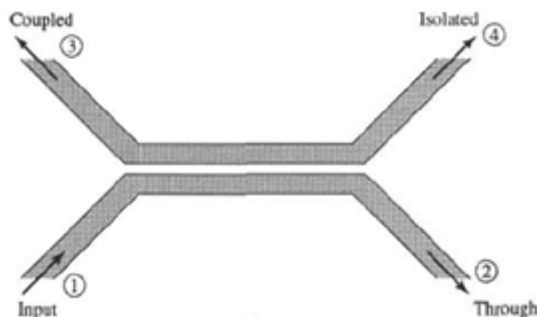


Fig.1. Typical structure of a coupled-line coupler

If one of the ports is excited, then due to the electric & magnetic field interaction, the signal gets coupled to the auxiliary line and the coupled signal travels in the opposite direction to that of the input signal. Since the coupling action takes place in the backward direction, the parallel line coupler is also called as backward wave coupler.

Any one of the four ports can be chosen as the input port. With the port designations as marked, consider port1 as the input port. The coupled signal travels backwards in the auxiliary line and appears at port 3. The remaining power comes out of port2. Port 4 is the isolated port. The amount of coupling depends on the spacing between the parallel coupled conductors.

The voltage signals appearing at ports 2 and 3 differ in phase by  $90^\circ$ . Further, the voltage at the coupled port 3

attains a maximum value when the electrical length  $\theta=\pi/2$  or the physical length  $L=\lambda_g/4$  where  $\lambda_g$  is the guide wavelength in microstrip.

### II. ANALYSIS

There are two modes of current flow in an electromagnetic situation for a coupled line. The first is one current flowing down one 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, styled  $Z_{o_o}$ . The other mode is one current flow by displacement current between each Centre 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  $Z_{o_e}$ . Fig. 2 shows the polarity of the lines of each mode.

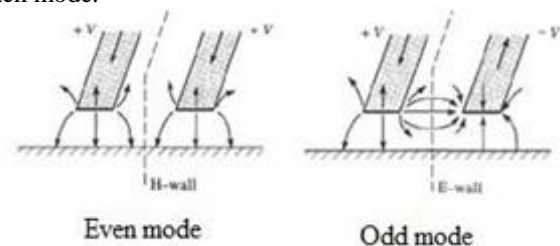


Fig.2. Even and odd modes excitations for a coupled line

At the design frequency ( $f=f_0$ ), the electrical length  $\theta=\theta_0=\pi/2$  and the voltage coupling coefficient of the coupler attains a maximum value.

For a single section coupler the even and odd mode characteristic impedances are defined as:

$$Z_{o_e} = Z_o \sqrt{\frac{1+C_o}{1-C_o}} \quad (1)$$

$$Z_{o_o} = Z_o \sqrt{\frac{1-C_o}{1+C_o}} \quad (2)$$

Co is the mean coupling coefficient at the design frequency. The port impedance is Zo. The equations (1) & (2) form the design equations for this coupler. In the design of the coupler, the coupling coefficient and port impedance are specified. The values of Zoe & Zoo are calculated which in turn are used to determine the dimensions of the coupler.

III. DESIGN

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 can be. Fig. 3 shows the circuit configuration of the coupled line-coupler that will be designed.

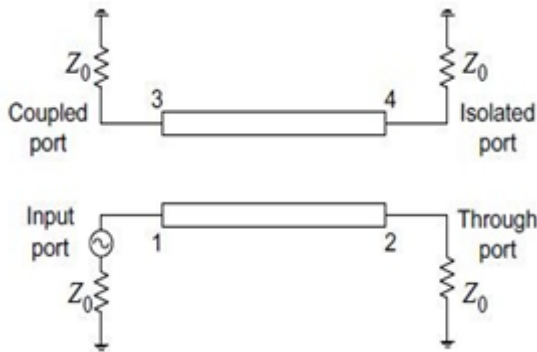


Fig.3. Coupled-line coupler circuit.

The three couplers are designed for different values of coupling coefficient as shown in Table1.

Table1.Coupler-line Coupling coefficient specification

Parallel line coupler	Coupling coefficient C in dB
Coupler-A	6
Coupler-B	10
Coupler-C	18

The specifications for the design of couplers are shown in Table2.

Table 2. Design parameters specification.

Parameters	Specifications
Characteristic impedance(in Ω)	50
Centre frequency (in GHz)	2.5
Substrate dielectric constant	4.5
Substrate thickness (in mm)	0.508
Loss tangent	0.0027
Metallisation/ Copper cladding (in um)	35
Planar Technology	Microstrip line

The design steps include determining the characteristic impedance for even mode and odd mode using the equations (1) and (2) respectively. The physical dimensions of the coupler are determined from Linecalc using ADS (Advanced Design System) tool.

1.Coupled-line coupler-A

The dimensions & impedance values of coupler-A is shown in Table3.

Table3: Dimensions of Coupler -A

Coupler-A	Parameter s	Values
Dimensions in mm	Width (W)	0.136067
	Length(L)	14.14350
	Spacing(S)	0.014231
Characteristic Impedance in Ω	Zoe	86.74
	Zoo	28.82

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

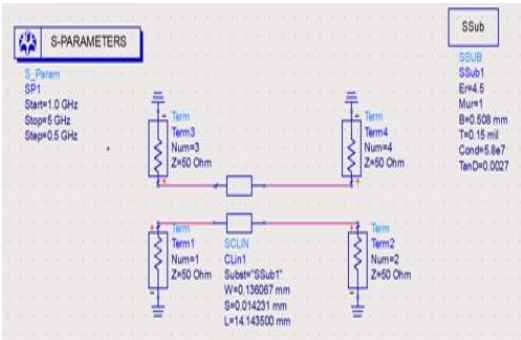


Fig.4: Circuit schematic of Coupler-A

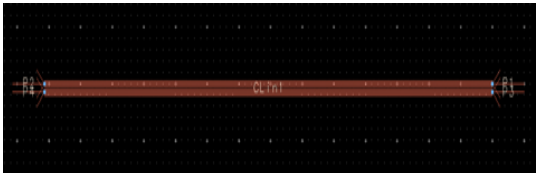


Fig.5: Layout of Coupler-A

2.Coupled-line coupler-B

The dimensions & impedance values of coupler-B is shown in Table4.

Table4: Dimensions of Coupler -B

Coupler-B	Parameters	Values
Dimensions in mm	Width (W)	0.182452
	Length(L)	14.14350
	Spacing(S)	0.054063
Characteristic Impedance in Ω	Zoe	69.37
	Zoo	36.038

The equivalent simulated circuit schematic and layout of coupled-line coupler B that obtained by using ADS tool are shown in fig.6 and fig.7.

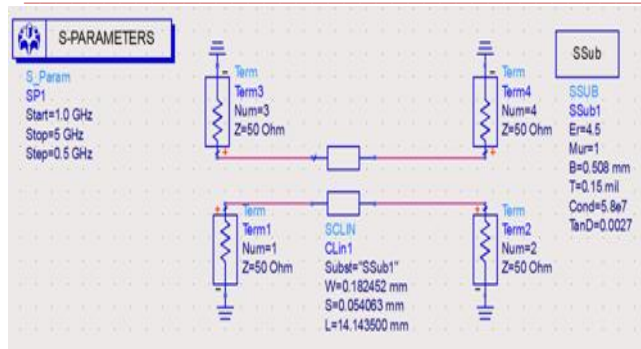


Fig.6: Circuit schematic of Coupler-B

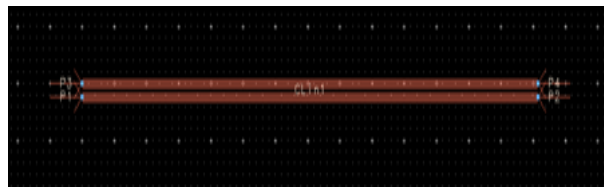


Fig.7: Layout of Coupler-B

3.Coupled-line coupler-C

The dimensions & impedance values of coupler-C is shown in Table5.

Table5: Dimensions of Coupler –C

Coupler-C	Parameters	Values
Dimensions in mm	Width (W)	0.211943
	Length(L)	14.14350
	Spacing(S)	0.179522
Characteristic Impedance in $\Omega$	$Z_{0e}$	56.75
	$Z_{0o}$	44.05

The equivalent simulated circuit schematic and layout of coupled-line coupler C that obtained by using ADS tool are shown in fig.8 and fig.9.

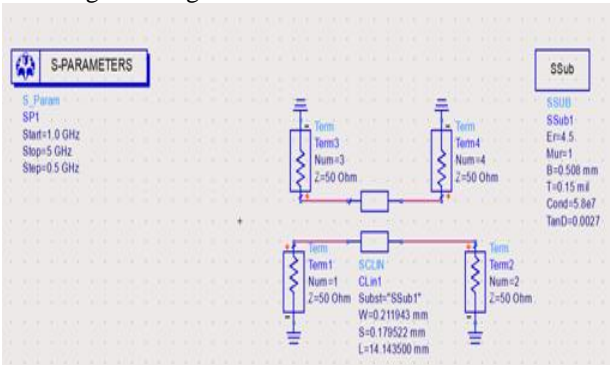


Fig.8: Circuit schematic of Coupler-C

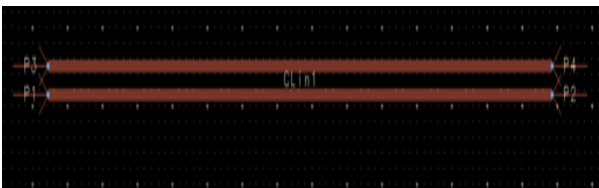


Fig.9: Layout of Coupler-C

IV. RESULTS

There are different types of losses that occur in couplers which are defined in terms of scattering parameters namely

- 1.Return loss(dB) =  $-20\log|S_{11}|$
- 2.Transmission loss(dB) =  $-20\log|S_{21}|$
- 3.Isolation loss(dB) =  $-20\log|S_{41}|$

The variation of scattering parameters as a function of frequency is shown for different couplers A, B & C in Fig.10, Fig.11 & Fig.12 respectively.

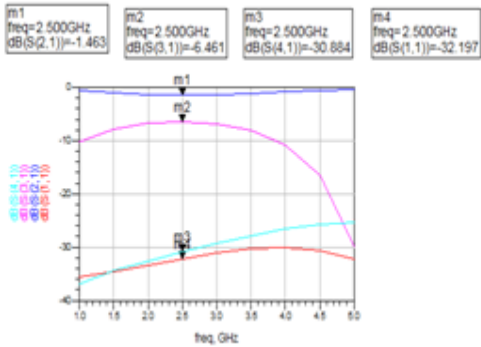


Fig.10: S-parameters variation as a function of frequency for coupler-A

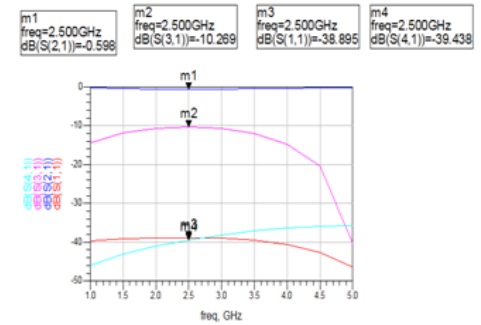


Fig.11: S-parameters variation as a function of frequency for coupler-B

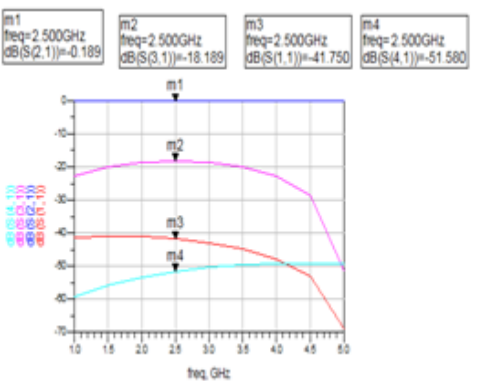


Fig.12: S-parameters variation as a function of frequency for coupler-C

Table.6 shows the comparison of scattering parameters for three couplers. Better return loss (reflection at port 1) & isolation loss (between the ports 1 & 4) are achieved as the coupling factor increases. The coupler- C has better return loss & isolation loss compared to couplers A & B.

**Table.6: Comparison of scattering parameters for three couplers.**

<b>S-Parameters in dB</b>	<b>Coupler-A (C=6dB)</b>	<b>Coupler-B (C=10dB)</b>	<b>Coupler-C (C=18dB)</b>
S11	-32.197	-38.895	-41.750
S21	-1.463	-0.598	-0.189
S31	-6.461	-10.269	-18.189
S41	-30.884	-39.438	-51.580

## V. CONCLUSION

In this paper, three coupled line couplers are designed and simulated using ADS tool using stripline planar technology. From the simulation results, it is observed that by varying the value of the coupling coefficient has an effect on the output power at ports at centre frequency 2.5GHz. The losses also varies with coupling factor. Also the dimensions of the coupler also changes with the coupling coefficient.

The coupled line coupler C has better return loss & isolation loss compared to couplers A & B, but at the same time, the width & spacing between the conductors increases. On the other hand, coupler A has smaller dimensions with tolerable losses.

## REFERENCES

- [1] K. H. Yusof, N. Seman and M. H. Jamaluddin “ Design and Analysis of Wideband 3 and 6 dB Coupled-Line Coupler with different Grounding Techniques ” 2013 IEEE International RF and Microwave Conference (RFM 2013) December 09-11,2013 –Penang Malaysia.
- [2] L. Chui, Q. Xue, “Investigation of a Wideband 90° Hybrid Coupler With an Arbitrary Coupling Level,” IEEE Trans. Microwave Theory & Tech., vol. 58, no. 4, pp. 1022 - 1029, April. 2010.
- [3] R. Mongia, I. Bahl, and P. Bhartia, RF and Microwave Coupled-Line Circuits. Boston, MA: Artech House, pp. 1–21,1999.
- [4] Yongle Wu, Weinong Sun, Sai-Wing Leung, Yinliang Diao, Kwok-Hung Chan, and Yun-Ming Siu, Single-Layer Microstrip High-Directivity Coupled-Line Coupler With Tight Coupling” IEEE Transactions On Microwave Theory And Techniques, Vol. 61, No. 2, February 2013.
- [5] David M. Pozar, “Microwave Engineering”, fourth edition, John Wiley & Sons. Inc, 1998.
- [6] Leo G. Maloratsky, “Passive RF Microwave Integrated Circuits”. Elsevier Inc, 2004.