International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

Design And Analysis of Hybrid Coupler

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***Abstract*— The proposed work is to design the 90˚ hybrid coupler that can operate with an arbitrary frequency 1.5GHZ to 3GHZ. The paper describes the two different design of hybrid coupler : firstly by using lumped element and secondly by using microstrip line. The system is designed for constant parameters like centre frequency 1.9GHZ, uses FR4 substrate with dielectric constant 4.6 and h is 1.6mm. All the results have been observed by using ADS (Advance Design System) software. The results of hybrid coupler are well satisfied by using above two elements. The size of the hybrid coupler is reduced; due to these it can be used in applications such as MMIC where size is important criteria. Measured result shows 18.2% bandwidth for given frequency. The measured results are in well agreement with simulation and demonstration of its performance.**

Keywords— Lumped element, Microstrip line, ADS software

I. Introduction

Power divider and power couplers are used for power combination or power combining which are passive microwave components. Have a fixed division ratio, used to divide signals for a given phase difference and division ratio [1][2] . Hybrid coupler is 4 port passive circuits, which splits the incident power signal into 2 output ports with 3db attenuation i.e. 50%of i.e. power get lost. They are electrically and mechanically symmetrical. Ideal couplers are perfectly matched with all ports .a common application[3] for hybrid coupler is for splitting the signal at the input ,equally with two output signals .Depending on the signal spilt ratio of a hybrid ,most applications needs equal splitting of the input signals between two same circuits.in addition with this it also use for combining signals. The quadrature (90 degree) is a special case of directional coupler, with coupling factor 3dB and phase difference between output is either 90 degree i.e. quadrature hybrid 180 degree i.e., magic T or rat race hybrid.

In this paper hybrid coupler design is based on lumped element i.e. R, L, C and transmission line. (CPW, stripling, microstrip) design given is by using microstrip line, with centre frequency of 1.9 GHZ. Lumped component design is promising because it provides low insertion loss, wider bandwidth and smaller size circuit, which is very better fit for monolithic microwave integrated circuit MMIC.

Advance Design System (ADS) by Agilent technologies is used as simulation tool in this paper [4][10].

There are so many advantages for choosing microstrip line because of low cost, its suitable for manufacturing in large quantities they are outstanding with its volume and weight as compare to waveguide.it containing whole circuit ion a substrate, suitable for insertion of MIC. Couplers having different applications [8][9] like microwave phase shifter, driver circuit protection and in phase/quadrature modulation/demodulation. Hybrid used to combine two power amplifiers.as shown in figure 2, it's used for combining the output from two lower power amplifier to achieve greater output power. From the combination that is possible from either of the individual power amplifier.

Characteristics of the coupler

Substrate dielectric constant Er.=4.6
Centre frequency =1.9GHZ
Bandwidth=18.6%
Height of substrate=1.6mm
tanD=0.0019

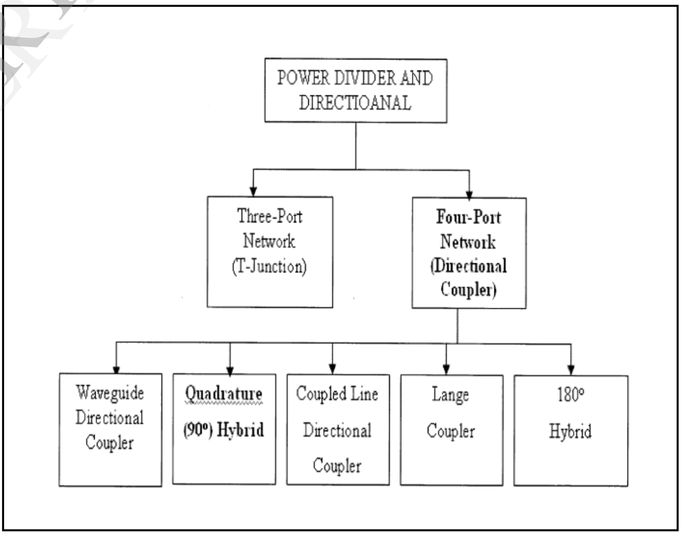


Figure1 Types of power divider and directional

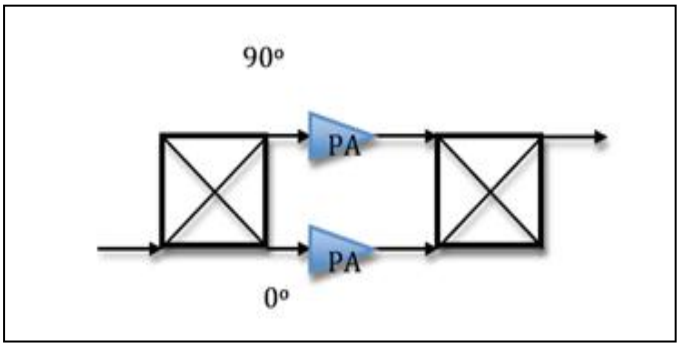


Figure2 Hybrid used to combine two power amplifier

II. DESIGN APPROACH

Given coupler consist of two pairs of transmission lines with characteristic impedances of 50Ω and 35.5 Ω. at low frequency its physical size is large which can be reduce as proposed in [6][7].

A. *Using Lumped Element*

The one technology for 90 degree coupler is using lumped components. It's useful because connecting wires are assumed to be ideal and each element is considered to be independent. The initial step in the design is to synthesize the nominal values of inductor I and capacitor C based on design. Lumped element design is as shown in figure 3

The equations used for synthesizing the element value based on 1.9GHZ frequency and characteristic impedance 50 Ω and 50/√2 Ω.

$$L = Z_0/(2\pi f)\ nH$$
$$C = 1/(Z_0 2\pi f)\ pF$$

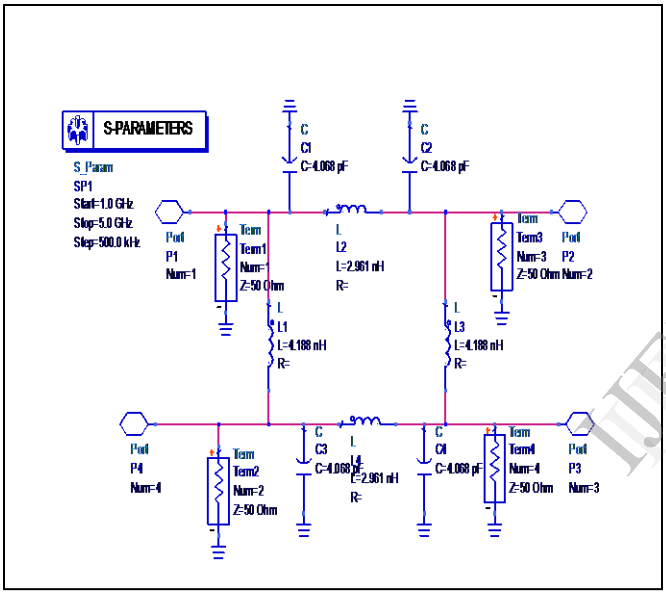


Figure 3 Lumped equivalent circuit for hybrid coupler

B. *Microstrip Line*

Each transmission line is designed by using the principle of lambda quarter transformer for perfect matching between the ports. Lines are designed with 2 characteristics impedance Z_0 50 Ω & 35.5 Ω For extracting even and odd impedance even and odd analysis is used, which is based on two principles: symmetry of circuit and superposition

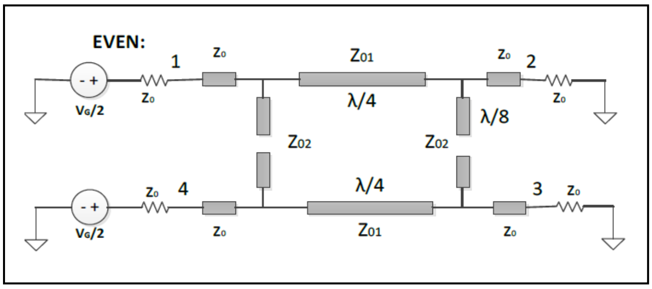


Figure 4.a. Even mode symmetry

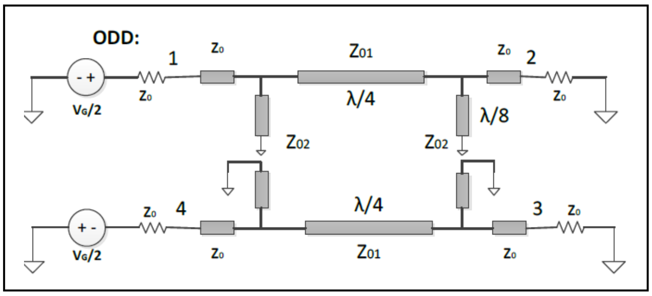


Figure 4.b. Odd mode symmetry

III. ANALYTICAL MODEL

The designs of microstrip line for determine its length, width, height by assuming an infinitesimal TL thickness.

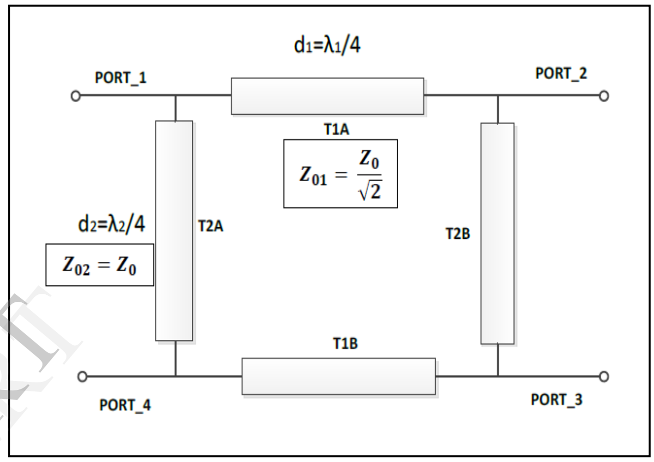


Figure5 new design approaches for hybrid coupler

A. *Impedance calculation*

For calculation of the impedance two formulas are given

a) for W/H < 2

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln\left(\frac{8H}{W} + \frac{W}{4H}\right) \Omega$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12\frac{H}{W}}} + 0.04\left(1 - \frac{W}{H}\right)^2\right]$$

b) for W/H > 2

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}\left[\frac{W}{H} + 1.393 + \frac{2}{3}\ln\left(\frac{W}{H} + 1.444\right)\right]}} \Omega$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 12\frac{H}{W}}}$$

B. Calcuation of W,H,D of Microstrip Line

$$\beta d = \frac{2\pi}{\lambda}\frac{\lambda_0}{4}$$

$$\lambda_0 = \lambda$$

$$\beta d = \frac{\pi}{2}$$

$$d_n = \frac{\lambda_n}{4}$$

$$d_1 = \frac{\lambda_1}{4} = \frac{c}{(\sqrt{\epsilon_{eff1}})f_0}$$

$$d_2 = \frac{\lambda_2}{4} = \frac{c}{(\sqrt{\epsilon_{eff2}})f_0}$$

Where βphase is constant and d is the distance.

$$\frac{w_2}{h_2} = \frac{8e^A}{e^{2A}-2}$$

$$A = 2\pi\frac{Z_0}{Z_f}\sqrt{\frac{\epsilon_r+1}{2}} + \frac{\epsilon_r-1}{\epsilon_r+1}\left(0.23 + \frac{0.11}{\epsilon_r}\right)$$

$$\frac{W_1}{h_1} = \frac{2}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\epsilon_r-1}{2\epsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\epsilon_r}\right]\right\}$$

$$B = \frac{\pi Z_f}{2Z_0\sqrt{\epsilon_r}}$$

C. S parameter calculation

For even and odd mode

$$\begin{bmatrix} A^e & B^e \\ C^e & D^e \end{bmatrix} = \begin{bmatrix} -B_e Z_{01} & jZ_{01} \\ -j(B_e)^2 Z_{01} + jY_{01} & -B_e Z_{01} \end{bmatrix}$$

$$\begin{bmatrix} A^0 & B^0 \\ C^0 & D^0 \end{bmatrix} = \begin{bmatrix} -B_0 Z_{01} & jZ_{01} \\ -j(B_0)^2 Z_{01} + jY_{01} & -B_0 Z_{01} \end{bmatrix}$$

$$S^e{}_{11} = \frac{-C^e(Z_0)^2 + (A^e - D^e)Z_0 + B^e}{C^e(Z_0)^2 + (A^e + B^e)Z_0 + B^e}$$

$$S^0{}_{11} = \frac{-C^0(Z_0)^2 + (A^0 - D^0)Z_0 + B^0}{C^0(Z_0)^2 + (A^0 + B^0)Z_0 + B^0}$$

$$S^e{}_{12} = \frac{2Z_0(A^eD^e - B^eC^e)}{C^e(Z_0)^2 + (A^e + B^e)Z_0 + B^e}$$

$$S^0{}_{12} = \frac{2Z_0(A^0D^0 - B^0C^0)}{C^0(Z_0)^2 + (A^0 + B^0)Z_0 + B^0}$$

$$S_{12} = \frac{S^e{}_{12}}{2} + \frac{S^0{}_{12}}{2} = S_{21}$$

$$S_{13} = \frac{S^e{}_{12}}{2} - \frac{S^0{}_{12}}{2} = S_{31}$$

Calculated:
W1=2.9103mm
L2=16.635mm
W2=4.8193mm
L2=16.2822mm

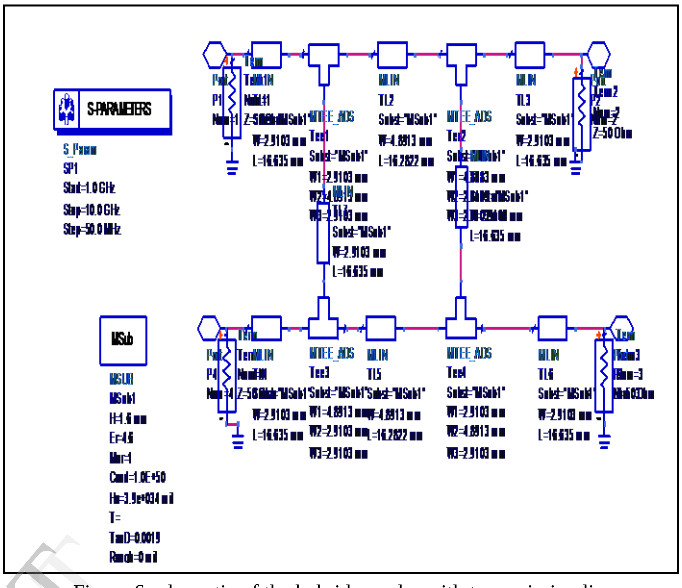


Figure 6.schematic of the hybrid coupler with transmission line (Microstripline)

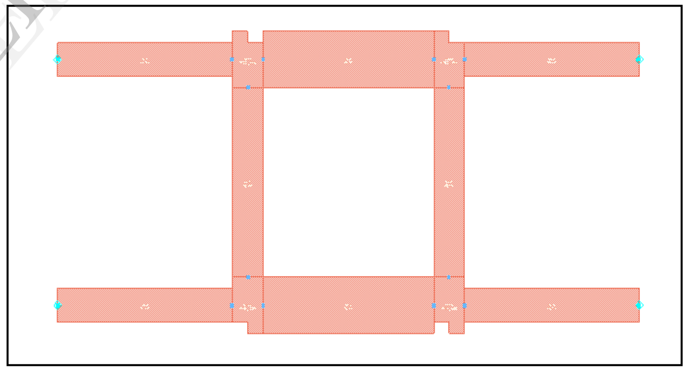
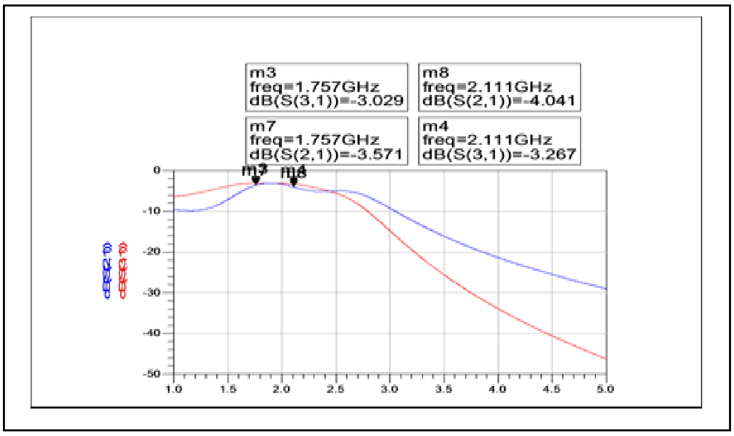


Figure 7.layout for hybrid coupler a. microstip line

IV. RESULTS



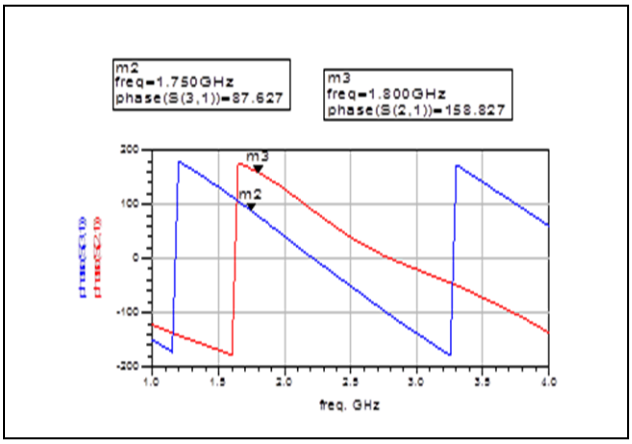


Figure9 phase difference between two ports

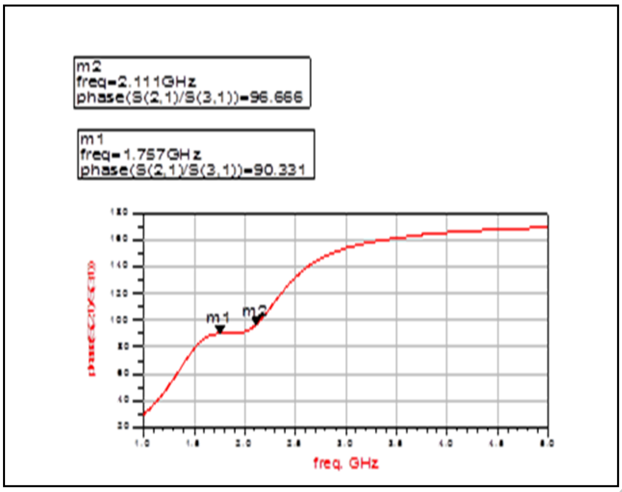


Figure10 90 degree phase difference between two ports

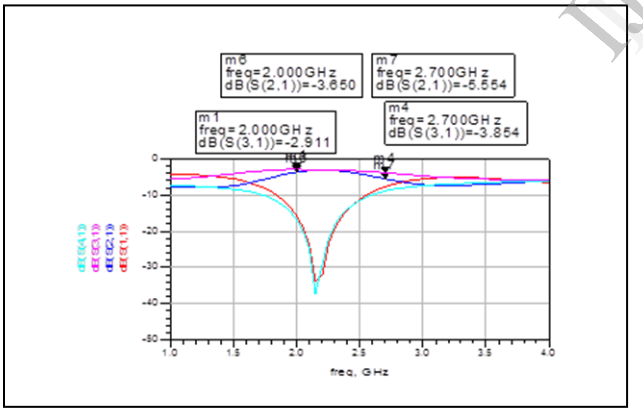


Figure11 3dB attenuation between different ports.

A. *TableI.*

RESULT ANALYSIS

SR.NO	***Parameters***	***Calculated (dB)***	***Simulated(dB)***
1	Return loss	11.52	15.882
2	Insertion loss	4.131	3.614
3	Coupling factor	3.358	2.911

V. CONCLUSION

In this paper hybrid coupler with compact sized is designed and simulated.3dB attenuation and phase difference is observed from the s parameter graphs. Further improvement can be possible by using better fabrication technique. Hybrid coupler by using microstrip line is fabricated with FR substrate. Simulation is done in ADS software. we can believe that given coupler can plays different applications i.e. in MMIC and MIC circuit where compact size is required the proposed coupler can also be implemented by using different technologies like CPW, strip line etc.

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