International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

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THOMSON REUTERS

[Ganesh, *et al.*, 9(2): February, 2020]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DESIGN AND SIMULATION OF BRANCH LINE COUPLER FOR MIXER APPLICATION

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DOI: 10.5281/zenodo.3688438

ABSTRACT

A single section branch line coupler is proposed for performing Mixer operation in wireless communication and Radar applications. The branch line coupler is a type of qudrature hybrid coupler. In this work, it is designed on a 1.6 mm thick FR4 substrate at 1 GHz frequency and the simulation is carried-out in schematic and layout levels using Advanced Design System software. The scattering parameters are analyzed in the frequency range 0.5 GHz to 1.5 GHz for the excitation of four ports and the scattering matrix is obtained at 1 GHz designed frequency. The coupling factor, isolation and directivity are calculated from the scattering parameters.

KEYWORDS: Branch Line Coupler, Coupling factor, Isolation, Scattering matrix.

1. INTRODUCTION

The branch line coupler is a type of 90 ° or quadrature hybrid coupler which has four ports. It is a passive device. The power enters through the any one of the input ports is divided equally between the two output ports with quadrature phase difference and the remaining port is isolated. It is used mostly in the Mixer section at RF and Microwave Frequencies. The applications of the coupler are I/Q signal splitter or combiner, single antenna transmitter system. A quadrature branch line coupler had been designed on a RT Duroid substrate at 2.4 GHz frequency for the S band application and the designed coupler had the scattering parameters of S_{11} and S_{22} below -20 dB and S12 & S13 values were – 3dB [2]. A double-section branch-line coupler had been designed on a FR-4 substrate using ADS software for the wireless application and the designed coupler had the reflection coefficient and isolation below -10 dB [3]. A miniaturized branch line coupler had been designed at 0.6 GHz frequency for wireless communication application and the designed structure had reduced the occupied area to 12.3% of the conventional design. The magnitude and phase difference between S_{12} & S_{13} are 3±0.4 dB and 90° ±1° respectively. The bandwidth of the coupler is 125 MHz [4]. A single band branch line coupler had been designed on a FR-4 substrate at 5.8 GHz frequency using ADS Software and the length of the coupler was reduced by 50% compared to that of conventional coupler [5]. A dual band branch line coupler had been proposed with combination of Pi and T stub lines for GPS and Satellite applications. It had been designed at the centre frequency of 1.36/3.98 GHz and used FR-4 substrate with dielectric constant of 4.4 [6]. In this work, a branch line coupler is designed at 1 GHz frequency on a 1.6 mm thick FR-4 substrate with a dielectric constant of 4.4. The design and simulation is carried out using ADS software. The scattering parameters are obtained for the schematic and layout level simulations. The coupling factor, isolation, directivity and transmission factor are calculated from the scattering parameters.

2. DESIGN AND SIMULATION

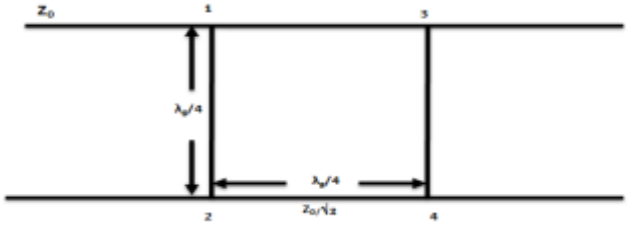

Figure 1 Geometry of Branch Line Coupler

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Table 1 Design Specification

Frequency	1 GHz
Substrate	FR4
Dielectric constant	4.4
Loss tangent	0.02
Substrate height	1.6mm
Conductor thickness	35µm

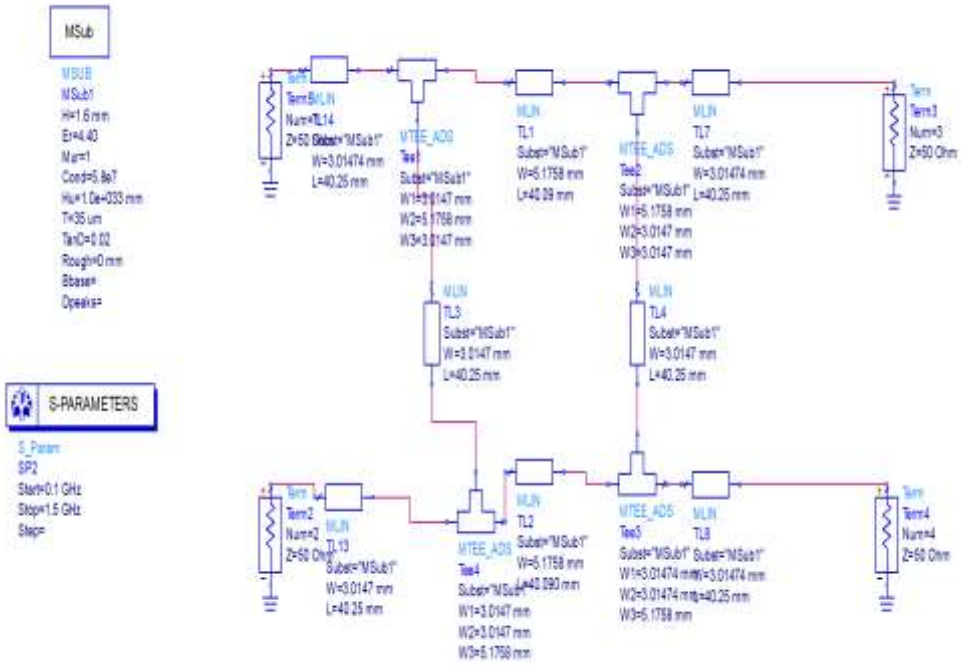

Figure 2 Schematic Diagram of the Coupler

The branch line coupler is a signal coupler or divider which has four ports. The geometry of the coupler is shown in Figure1. The signal fed to port 1 is split equally into port 3 and 4 with one of the outputs exhibiting a 90° phase shift. The port 2 is an isolated port. The design specifications of the coupler are shown in Table.1. The coupler is designed at 1 GHz frequency on a 1.6 mm thick FR-4 substrate with a dielectric constant of 4.4.and height of 1.6 mm. All the four ports are terminated by a 50 Ω impedance and the characteristic impedance of the line is also 50 Ω.

Table 2 Dimensions of the Coupler

Parameter	Shunt Arm	Series Arm
Z0 (Ω)	50	35.35
L (mm)	3.01474	5.1758
W (mm)	40.25	40.090

The design and simulation of the coupler is carried out using ADS software. The impedances of the transmission line are calculated for the given specification. The impedance of the transmission lines are synthesized into physical parameters using Line Calculator option in the software. The calculated coupler line impedance and

ISSN: 2277-9655
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their physical dimensions are shown in Table. 2. The schematic diagram of the designed coupler is shown in Figure 2. The schematic is designed with the help of microstrip library option in the software. The series and shunt arms of the coupler are connected with the mainline using a microstrip T-junction. The Scattering parameters of the coupler are measured in the frequency range 500 MHz to 1500 MHz. The design is optimized at center frequency 1 GHz by tuning the values of series and shunt arm dimensions. The layout of the deigned coupler is shown in Figure 3.

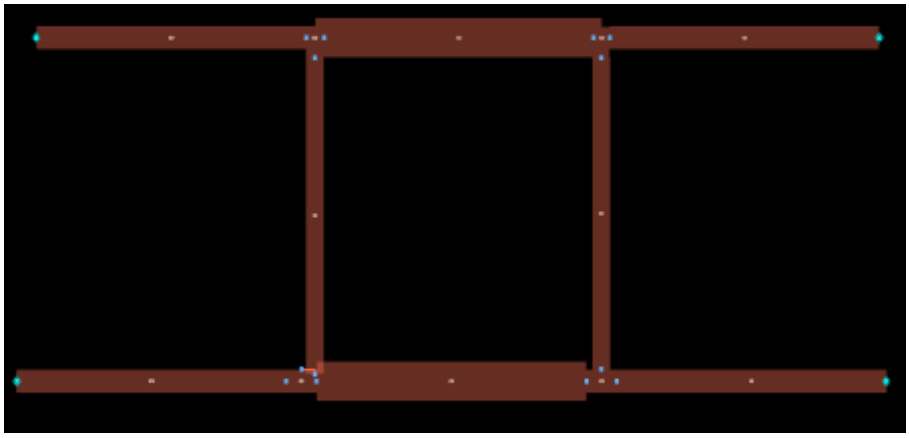

Figure 3 Layout of the Coupler

3. RESULTS AND DISCUSSION

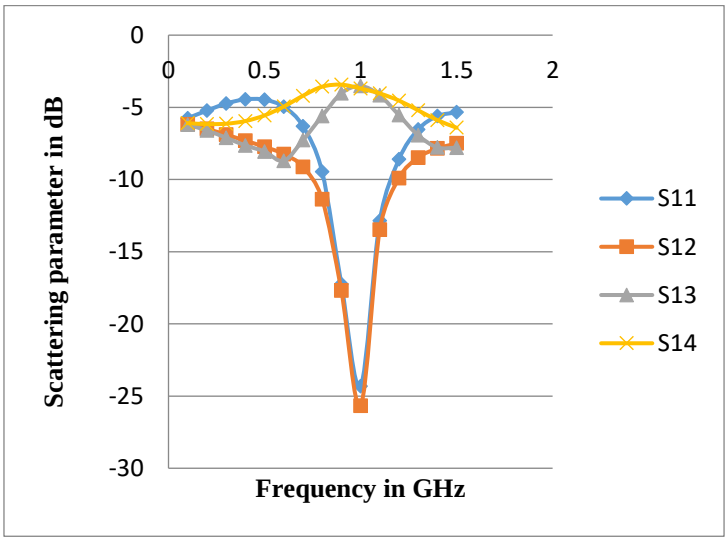

Figure 4 S-Parameters of Port 1 Excitation

The output parameters of a coupler are coupling factor, isolation, directivity and transmission factor and are obtained from the scattering parameters. The ideal branch line coupler should have higher isolation and directivity, 3- dB coupling and phase quadrant. The scattering parameters of the coupler are plotted in Figure 4 for the excitation of first port. The return loss of approximately – 4.44 dB is obtained at the input port of the coupler. The isolation of approximately –26 dB is obtained at the isolation port. The coupling factor of – 3.61 dB is obtained in the primary coupling port and – 3.74 dB is obtained in the auxiliary coupling port. The directivity of the coupler is 22. The above results are same for the excitation of different input ports. So the designed coupler acts as a reciprocal device because it has the ability to set any port as input, output and isolation for the same designed frequency. The scattering matrix of the designed coupler is shown in the equation (1). From the S-matrix, it is observed that there is slight variation in the theoretical and

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practical values of the scattering parameters. The variation in the result is due to usage of approximate dimension of the coupler and loss tangent of the dielectric material.

$$S=\begin{bmatrix} 0.06\angle 61.314^\circ & 0.05\angle 161.612^\circ & 0.66\angle 84.3980^\circ & 0.65\angle 9.14500^\circ \\ 0.052\angle 161.61^\circ & 0.06\angle 53.6750^\circ & 0.65\angle 9.14500^\circ & 0.66\angle 76.7490^\circ \\ 0.66\angle 84.3980^\circ & 0.65\angle 9.14500^\circ & 0.06\angle 61.318^\circ & 0.05\angle 161.612^\circ \\ 0.65\angle 9.14500^\circ & 0.66\angle 76.7490^\circ & 0.05\angle 161.612^\circ & 0.06\angle 53.6780^\circ \end{bmatrix} \quad (1)$$

Table 4 Comparison of Results

Parameters	This Work	Ref.[4]	Ref.[2]
Frequency	1 GHz	0.6 GHz	2.4 GHz
Reflection Coefficient in dB(S11)	-25 dB	Below -10 dB	Below -10 dB
Isolation in dB	-25 dB	Below -10 dB	Below -10 dB
Coupling factor	3+0.6 dB	3+0.4 dB	3 dB
Bandwidth (S11 below -10 dB)	400 MHz	125 MHz	900 MHz

The output parameters of the designed branch line coupler are compared with the related references [4] and [2] and the values are listed in Table 4. The designed branch line coupler has a bandwidth of 400 MHz, reflection coefficient and isolation of – 25 dB and the coupling factor of 3.6 dB. So the simulated coupler has satisfied the theoretical values of 3 dB coupling factor.

4. CONCLUSION

A 3 dB branch line coupler are designed at 1 GHz frequency on a 1.6 mm thick FR4 sibstrate. The design and simulation of the coupler are carried out using ADS software. The scattering parameters, isolation, coupling factor and directivity are obtained for the designed coupler and the simulation results are verified at the schematic and layout level. Finally, the scattering matrix of the coupler is found and there is a slight variation in the simulation and theoretical result due to the usage of approximation dimension and loss tangent of the dielectric. The proposed branch line coupler can be easily implemented by using standard fabrication techniques. The designed coupler is suitable to perform Mixer operation in wireless applications at 1 GHz frequency.

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