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Design and Analysis of Miniaturized Hybrid Coupler at 900MHz using Stub

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Abstract - The branch line coupler is the most passive component that has abundantly of wireless applications in modern communication and microwave systems. It has the advantage of small size, light weight, simple manufacturing, easy integration and high-performance device that is used to divide or combine power simultaneously. In order to obtain miniaturization, each section of transmission line in the conventional quadrature coupler which has electrical length of 90^0 was replaced by equivalent small sections of transmission line connected in series. The result show that the size of the proposed coupler is reduced by 50% compared to the conventional design. The couplers are mostly used in the design of microwave and RF devices such as balance amplifiers, mixers, phase shifters, antenna array, frequency discriminators and many other applications. In this study, the hybrid coupler is design for 0.9GHz with impedance (Z_0) 50Ω, and substrate material used in this work is Rogers RT5880 lossy with dielectric constant ξ_r= 2.2, with thickness 0.78mm, which is useful for cellular telephone network. Simulation is done by Computer Simulation Technology (CST) microwave suit studio software.

Keywords: Branch Line Coupler BLC, Miniaturization, Microwave, RF devices, Frequency discriminators.

1. INTRODUCTION

As microwave devices become more disseminated and useful in many telecommunication aspects, there is need to have smooth power division or addition incorporated in the circuit. The branch line hybrid coupler is of paramount important in this phase, because of its ease ability to divide or combine power. It also has the advantage of light weight, simple manufacturing, easy integration and also low cost and is extensively used in microwave/millimeter wave circuit systems. Branch-line couplers (BLCs) are microwave devices that divide or combine power with 90^0 phase shifts between two output ports. BLCs are widely used in communication especially microwave applications [1]. Hybrid couplers are passive component used for power division or power combining. In power division, an input signal is divided into two (or more) output signal of lesser power, while a power combiner accepts two or more input signals and combine them at an output [23]. The (BLC) are the most passive component that finds various applications in modern microwave communication system.

These components are mostly used in microwave circuits such as balanced amplifiers, mixers, Phase Shifters, Frequency Discriminators and many other applications. Hybrid junctions have either 90^0 or 180^0 phase shift between the output ports. Quadrature hybrids are 3db directional couplers with 90^0 phase difference in the outputs. This type of hybrid is made in micro strip line or strip line form and it is also known as branch line hybrid. The operation of the branch line coupler is as follows; with all ports matched, power arriving at port 1 is evenly divided between port 2 and port 3 with 90^0 phase shifts between these inputs. No power is attached to port 4 (Isolated port).

The major drawback in designing a BLC are large size and narrow bandwidth. The circuit becomes larger as it has a quarter wavelength series and shunt transmission lines [2]. The only limitation of hybrid coupler at microwave band is its bulky size especially at low frequencies; the size of the quadrature coupler becomes larger (because the wave length is inversely proportional to the operating frequency). Miniaturization, compactness and high performances of the couplers are important factors to meet the demand of the BLCs. However, at the low frequencies the size of a conventional branch-line coupler is very large [3]. Thus, it is needed to reduce the size of the coupler to agree with the application requirement (such as mobile application requirement). This brings the need to reduce it size to ease fabrication and cost low.

In this paper, a conventional branch line hybrid coupler was design and also a proposed coupler was design with the same operating frequency (0.9GHz). To reduce the coupler size, each section of the transmission line in the conventional coupler which has an electrical length of 90^0 will be replaced by equivalent small section of the transmission line connected in series. There is 50% size reduction in the proposed coupler compared with the conventional coupler.

In this study, the hybrid coupler is design for operating frequency 0.9GHz with impedance (Z_0) 50Ω, and compared with conventional coupler design, the Rogers RT5880 lossy Substrate material with dielectric constant ξ_r= 2.2, with thickness of 0.78mm is used, which is useful for cellular telephone network. The Computer Simulation Technology (CST) microwave suit studio software was used for design and simulation.

2. MODEL DESIGN OF THE COUPLER

A 0.9GHz directional coupler has been designed. With reference to figure 1a below, the scattering matrix has the following form:

$$[S] = \frac{-1}{\sqrt{2}} \begin{vmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & j & 0 & 0 \end{vmatrix}$$

The [S] matrix above shows that all ports are harmonized and the input power is divided equally between the coupled and through outputs only. Detect that, the branch – line hybrid has a high degree of symmetry, as any port can be used as an input. The output ports will always be on the opposite side of the junction from the input port and the isolated port on the same side as the input port. This symmetry reflicated in the scattering matrix, as each row can be acquired as an inversion of the first row.

2.1 Dimension design

The characteristics impedance of the horizontal line was obtained using equation (1) as adopted from [2]

$$\frac{Zo}{\sqrt{2}} = 35.35\Omega \qquad (1)$$

Also, the characteristics impedance of the vertical line was obtained as Z_0 = 50Ω.

However, all the dimensions of the hybrid coupler design were obtained as:

PL = 45mm.

AL = 59.8428mm.
The length of the coupler was obtained using equation (2)

L = (PL + AL +PL)/2 (2)
And the length is L = 74.9214mm.
While the width of the coupler is obtained to be W = 60mm.

2.2 STRUCTURE OF THE CONVENTIONAL BLC

In this section the structure and the design analysis of the simulated conventional BLC is presented in figure 2 a and 2b below which is developed using CST microwave suit studio.

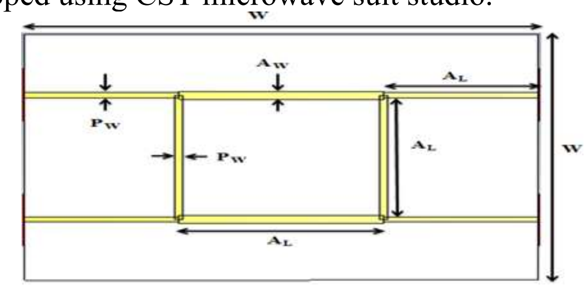

Fig. 2 (a)

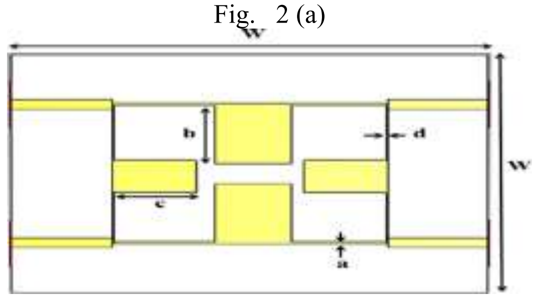

Fig. 2 (b)

Fig. 2: (a) Front View of the simulated conventional BLC (b) Perspective View of the simulated conventional BLC

3.0 DESIGN AND ANALYSIS OF PROPOSED BLC

In this section the structures and design analysis of the proposed BLC hybrid coupler will be presented.

3.1 REDUCING THE BLC SIZE USING STUB CONFIGURATION

The stub configuration technique is used to reduce the size of the simulated conventional coupler, using this technique, each section of the transmission line in the conventional BLC, which has electrical length of 90^0 was replaced with equivalent small sections of transmission line which is connected in series as shown in figure 3 a and b below.

3.1.1 Proposed Branch Line Hybrid Coupler Design

i. For the horizontal branch $Z_0 = 35.35\Omega$

Choosing M = 3 and K = 6 gives:
Based on the choosing parameters M and K, the values of Z_1 and Z_2 were obtained as;
$Z_1 = MZ_0 = 106.05\Omega$, $\theta_1 = 16.126^0$
$Z_2 = Z_1/K = 17.7\Omega$, $\theta_2 = 27.2^0$
$\theta_T = 2\theta_1 + \theta_2 = 59.5^0$

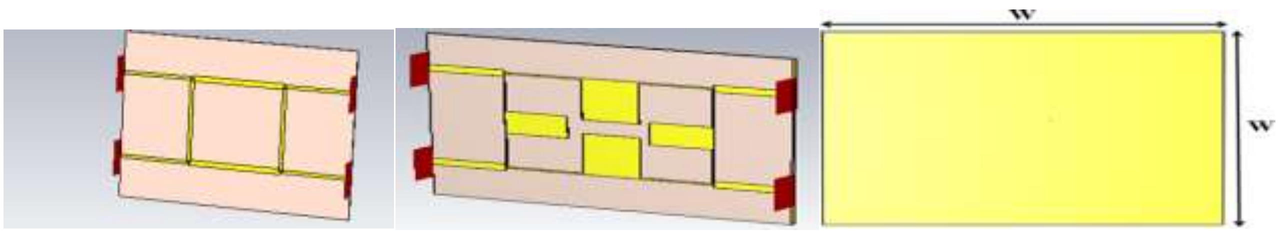

Figure 3: Design of Proposed Branch Line Coupler (BLC) with Stub (a) Front view(b) Perspective view (c) Back view

ii. For the vertical branch $Z_0 = 50\Omega$

Choosing M = 3 and K = 8 gives:

Also, in the case of vertical branch, after considering the M and K the Z_1 and Z_2 were obtained:

$Z_1 = MZ_0 = 150\Omega$, $\theta_1 = 17.186^0$

$Z_2 = Z_1/K = 18.75\Omega$, $\theta_2 = 19.793^0$

$\theta_T = 2\theta_1 + \theta_2 = 54.2^0$

Therefore, at Z_0 150Ω the width of the stub is 0.2668mm.

Table 1 shows the parameters and the calculated values in the equations.

Table 1: Dimension of Stubs of the Improved BLC.

Parameters Name	Numerical Values (mm)
Width of the substrate (W)	75
Width of stub 1 (a)	1.5168
Width of stub 2 (b)	4.0516
Width of stub 3 (c)	3.9651
Width of stub 4 (d)	0.2668

Hence, from figure 3 we obtained the impedance at 106Ω, 17.7Ω, 18.75Ω and 150Ω, while the transmission lines remain at 50Ω.

Figure 3a, b and c. show the proposed branch line coupler with the stub techniques in order to reduce the size of the coupler. All the stubs, ports and ground plane are design using copper annealed. The coupler is fully grounded. The stubs designed are used to reduce the size of the coupler and maintain the resonating frequency.

4.0 RESULT AND DISCUSSION

This section will present and discuss the results obtained from the conventional Branch Line Coupler and the Proposed Miniaturized Branch Line Coupler (BLC).

4.1 **Result of Conventional Branch Line Coupler (BLC)**

The S-parameter result of the proposed branch line coupler (BLC) is shown in figure 4.4. The coupler is design with stubs to reduce overall size of the coupler and also to maintain the resonance frequency of the coupler at 900MHz which means that the proposed and improved coupler have the same application.

The reflection coefficient (S-parameter) results are shown in figure 4.2. The coupler resonated at 900 MHz with four ports. The result comprises of the S_{11} to S_{44} as the coupler have four ports which make the reflection coefficient result to be sixteen.

4.2 Result of Proposed Branch Line Coupler (BLC)

The geometry of the proposed branch line coupler (BLC) is shown in figure 4.2. The coupler consists of a substrate which is designed using Rogers RT5880, while the ground plane and the transmission lines are designed using copper annealed.

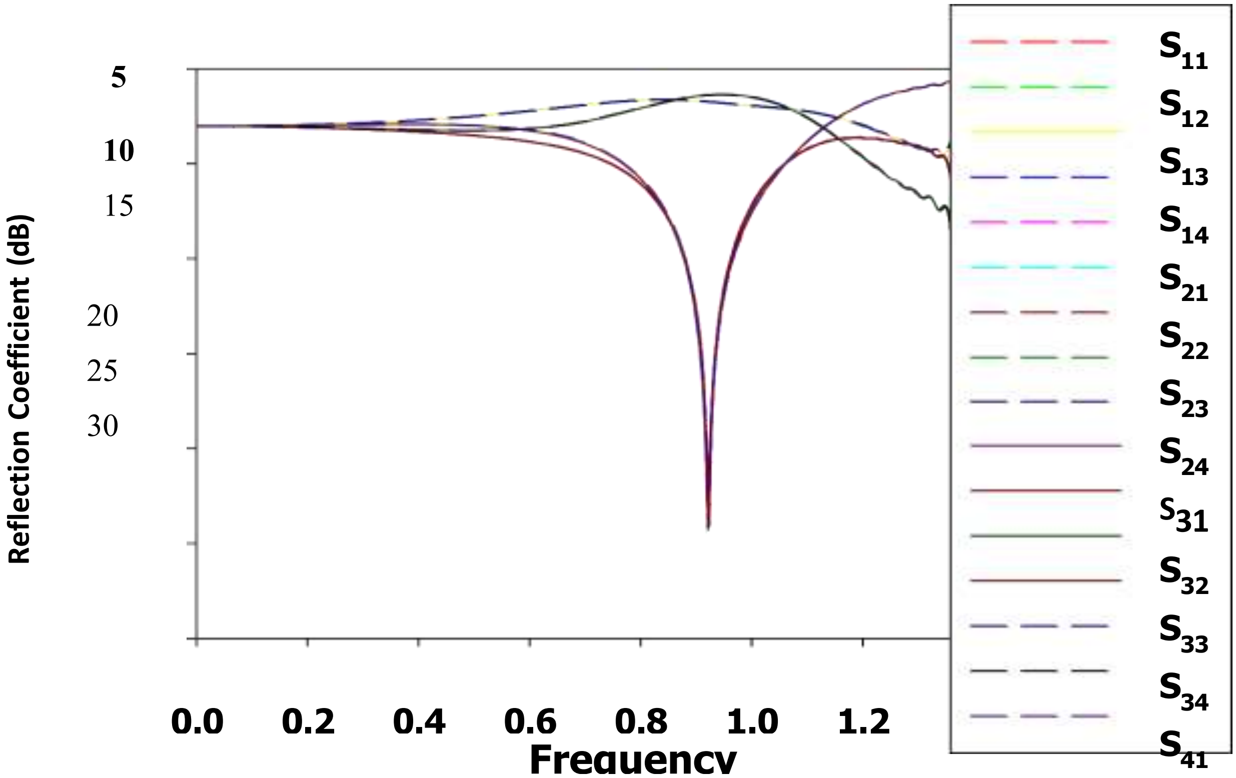

figure 4.1 S-parameter result of Conventional Branch Line Coupler (BLC).

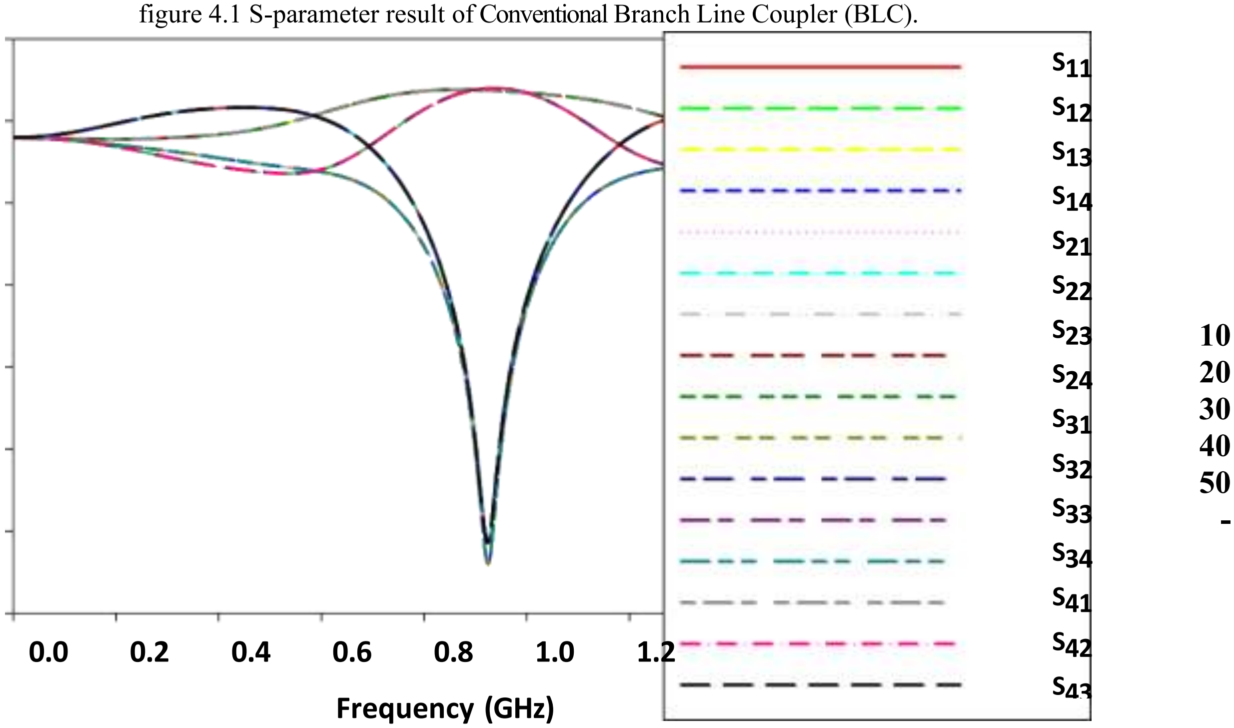

Figure 4.2: S-parameter result of Proposed Branch Line Coupler (BLC).

Conclusion

In this work, 900MHz BLC was designed and simulated using CST microwave studio suit. The proposed design was miniaturized using stub reducing size technique and simulated using the CST studio. The improved design can be used in nowadays microwave devices. The size of the improved coupler was reduced using stub size reduction technique. The improved coupler was designed and found to operate more efficiently than the proposed BLC despite the miniaturization. As it is seen from the S-Parameter graphs of the two couplers, both BLC resonates at 0.9GHz meaning they will operate and work the same despite miniaturization. The miniaturization of the improved design will ease fabrication and reduce cost.

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