An Improved Design of Wideband Wilkinson Power Divider with Stubs for Wireless Communication Application

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Abstract—**An improved design of wideband Wilkinson power divider with stubs concerning operating frequency of 2 to 7 GHz is presented in this paper. Power divider is designed by adding stubs at transmission line of Port 1, 2 and 3, which the position of stubs is studied for wideband application. CST Microwave Studio is used to design the proposed power divider and perform its parametric analysis. From the simulation results, the return loss is observed to be better by 1 dB and the bandwidth is 25% wider compared to the conventional Wilkinson power divider design.**

Index Terms— **Complex ratio measuring unit (CRMU); power divider; six-port network; stub**

I. INTRODUCTION

Six-port network is one of the methods to solve the problem of high-speed wireless communication systems [1]. In high-speed wireless communication system, the six-port network can be used to replace the mixer in radio frequency (RF) front-end communication system to reduce the complexity of the design, where it allows the measurement of two signals by controlling the complex ratio. This network for the specific use in communication transceivers is known as Complex Ratio Measuring Unit (CRMU) or vector voltmeter [1-7]. The six-port network can be formed by using one in-phase power divider and three quadrature couplers [2-7]. This configuration can be illustrated as in Fig. 1 [3]. As observed from Fig. 1, it has two input of complex signals noted as '*a*' and '*b*' at Port 1 and 2, respectively. While Port 3, is matched terminated. The other ports of Port 4 to 7 are acting as output ports, which commonly connected to scalar power detector.

The power divider is used to combine two input signals into one signal or split the input signal into two output signals with equal or unequal phase. In this article, the design of power divider is to split the '*a*' signal into two output signals with same phase.

Few power divider designs have been reported using multilayer technique [2-5,10]. However, this technique has led into problems such as air gap and misalignment between the substrates [8-9], which have degraded the performances of the power divider and the six-port network. Therefore, Wilkinson power divider is chosen to solve the problems as it can be designed onto single substrate. Wilkinson power divider offers good isolation performance between Port 2 and Port 3. Besides, Wilkinson power divider is compact in size, less circuitry complexity and low cost. Even though conventional Wilkinson power divider bandwidth coverage was quite wide but there is still a need to further improve its performance. Therefore, new design of Wilkinson power divider is needed to fulfill the requirement of wider band frequency applications.

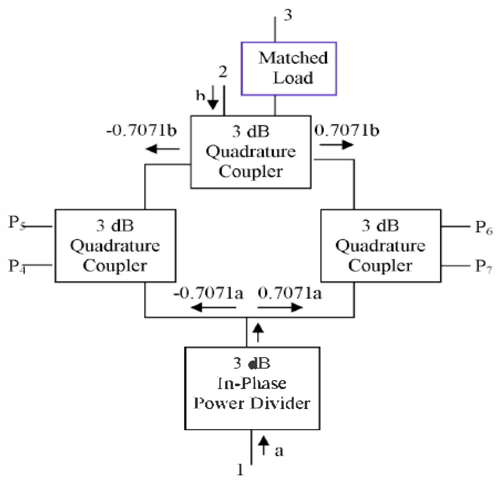

Fig. 1. The configuration of six-port network reported in [3].

Therefore, modification is made by adding two shunt stubs to the conventional Wilkinson power divider in order to enhance the bandwidth coverage [11]. The modification has led into improvement of the bandwidth coverage up to two times wider compared to the conventional Wilkinson power divider. However, the bandwidth is only cover from 1.5 to 2.3 GHz. Therefore, new design of modified Wilkinson power divider is needed to achieve wider bandwidth coverage.

In this paper, an improved design of Wilkinson power divider implementing stubs is presented. The proposed design offers wideband operating frequency and good return loss. The simulation results show that the return loss is better by 1 dB and the bandwidth is 25% wider compared to the conventional Wilkinson power divider design.

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II. DESIGN OF IMPROVED WILKINSON POWER DIVIDER

The power divider is designed onto single layer Rogers RO4003C with dielectric constant, ε_r of 3.38, substrate thickness, h of 0.508 mm, conductor coating thickness, t of 0.017 mm and loss tangent, δ of 0.0027. The design and simulation is performed using CST Microwave Studio.

The layout of Wilkinson power divider is shown in Fig 2. The overall size of the proposed power divider is 20 x 30 mm. As in Fig. 2, the line impedance for Port 1, 2 and 3 are denoted as Z_0, meanwhile the line impedance at the division part is denoted as $\sqrt{2}Z_0$. The resistor of $2Z_0$ between Port 2 and 3 is functioned to provide better isolation performance. In the proposed design, the value of Z_0 is assumed to be at 50 Ω. Thus, the value for the line impedance at the division part and the resistor of $2Z_0$ are calculated and obtained to be 70.71 Ω and 100 Ω, respectively. From the calculation, the width of transmission line of Port 1, 2 and 3, Wa is 1.14 mm, while the width of circular transmission line, Wb is 0.62 mm.

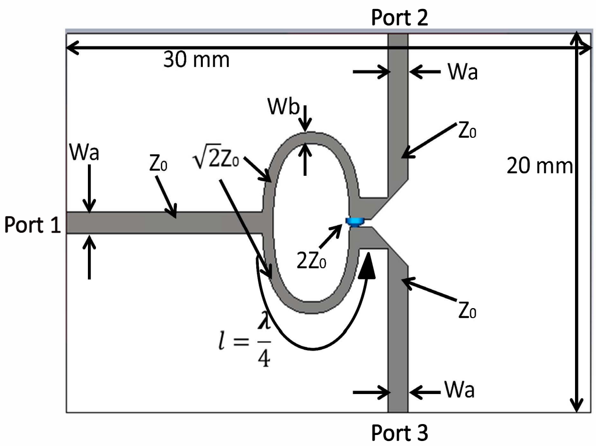

Fig. 2.The layout of Wilkinson power divider.

Modification has been made to the conventional Wilkinson power divider by adding stubs to transmission line at Port 1, 2 and 3 as shown in Fig. 3. The stubs are proposed in the modification in order to improve the matching and the bandwidth performance. The impedance of the stubs is assumed to be at 50 Ω and the length of stubs is 1 mm for stubs at Port 1 and 0.4 mm for stubs at Port 2 and 3.

One main analysis has been studied in this paper on the stubs' positions. The positions of the stubs are varied in order to obtain the best performance of the power divider cover from 2 to 6 GHz. As referred to Fig. 3, the position of the stubs at the line impedance of Port 1 is indicated by 'd' while the stubs position at line impedance of Port 2 and 3 are denoted by 'x'. The impedance of stubs is 50 Ω and the length of stubs is 1 mm for stubs at Port 1 and 0.4 mm for stubs at Port 2 and 3.

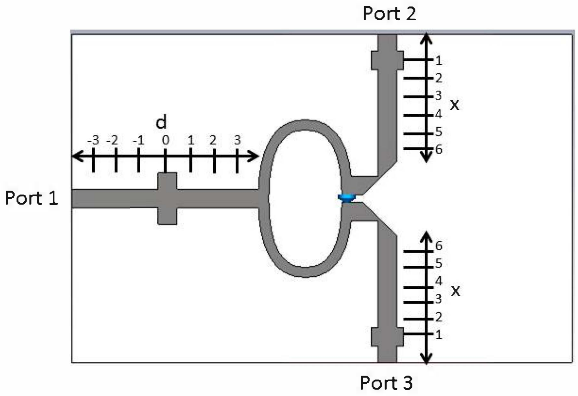

Fig. 3.The proposed of an improved Wilkinson power divider design with stubs.

III. RESULTS

Fig. 4 to Fig. 6 respectively illustrates the S_{11}, S_{23} and, S_{21} and S_{31} performances for the proposed power divider at different position of 'd'. As observed in Fig. 4, as the stub is positioned at d = 1, the reflection coefficient at input port (S_{11}) shows bandwidth coverage from 1 to 6 GHz with performance less than -10 dB. Meanwhile, when the stub is positioned at lower value of d, as example, at d = -3, the performance of the S_{11} is observed to be worse compared to the stub at d = 1. Where, the bandwidth covers only from 1 to 4.8 GHz. Whilst, as observed in Fig. 5 and Fig. 6, the S_{23}, S_{21} and S_{31} results also show their best performances when the stub is positioned at d = 1, where the S_{23} is less than -10 dB between frequency range 2 GHz to 6.2 GHz, meanwhile S_{21} and S_{31} are at -3 ± 1 dB across 1 to 9.3GHz. Thus, based on the analysis of the obtained results from Fig. 4 to Fig. 6, stub position will be fixed at d = 1. In the proposed design, as at d = 1, the best performance is achieved compared to other value of 'd'.

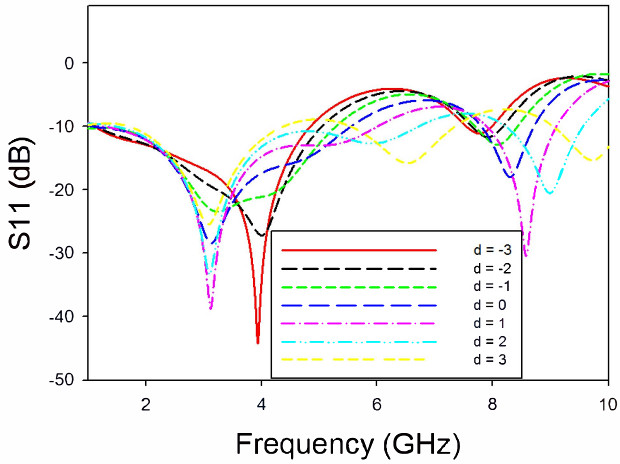

Fig. 4. The reflection coefficient at input port (S11) at different position of 'd'.

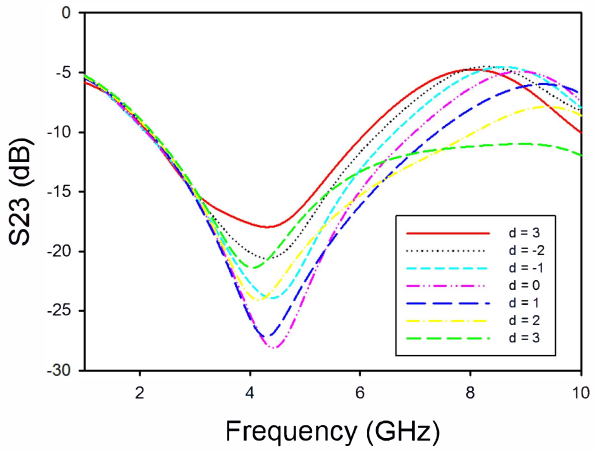

Fig. 5. S_{23} results at different position of ‘d’.

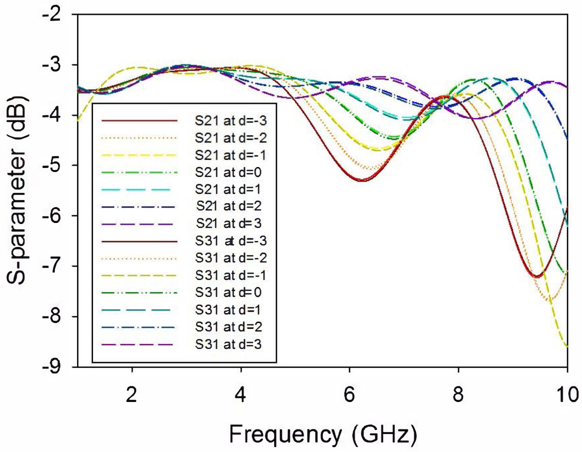

Fig. 6. S_{21} and S_{31} results at different position of ‘d’.

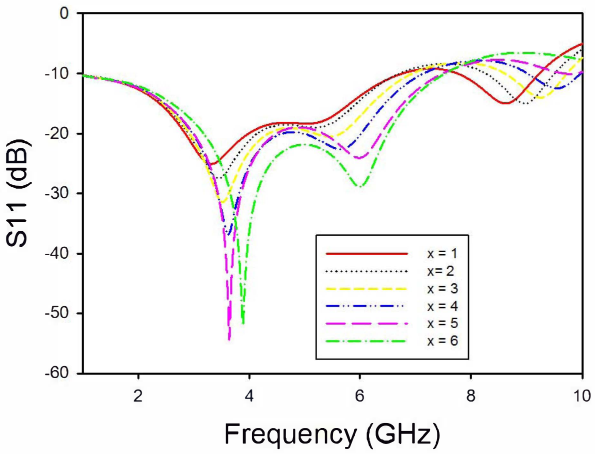

Fig. 7. The reflection coefficient at input port (S11) at different position of ‘x’.

Fig. 7 to Fig. 9 respectively illustrates the S_{11}, S_{23} and S_{21} and S_{31} performances for the proposed power divider at different position of ‘x’. As observed in Fig. 7, when the stubs are placed at x = 6, the S_{11} displays wideband performance covering from 0.77 GHz to 7.54 GHz with performance less than -10 dB. Meanwhile, as the stubs are changed to position of x = 1, the S_{11} covers only from 0.85 GHz to 6.77 GHz which is less by 0.84 GHz bandwidth compared to when stubs are positioned at x = 6. Fig. 8 and Fig. 9 show the results of S_{23}, S_{21} and S_{31} performances. As shown in both figures, the best performance is at x = 6 with S_{23} lower than -10 dB across frequency 2 to 6.8 GHz, meanwhile S_{21} and S_{31} are at -3 ± 0.6 dB between frequency of 0 GHz to 8.2 GHz. Thus, based on the analysis results obtained from Fig. 7 to Fig. 9, stubs position will be fixed at x = 6. In the proposed design as at x = 6, the best performance is achieved compared to other value of ‘x’.

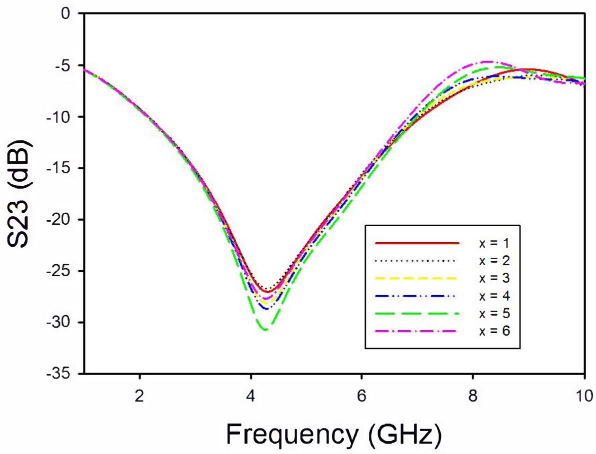

Fig. 8. S_{23} results at different position of ‘x’.

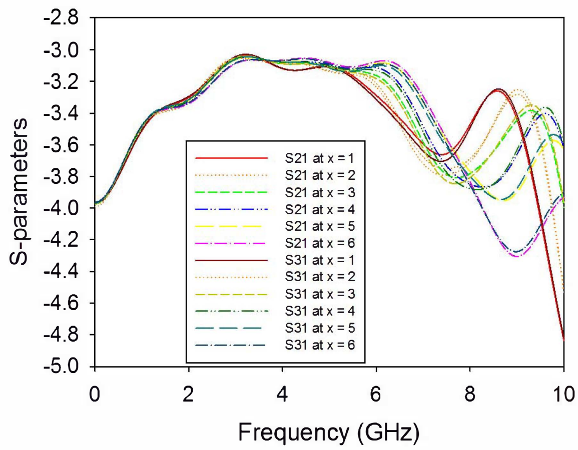

Fig. 9. S_{21} and S_{31} results at different position of ‘x’.

The scattering parameter and phase difference performances of the proposed design of improved Wilkinson power divider design are plotted in Fig. 10 and Fig. 11. As in Fig. 10, the reflection coefficient at input is lower than -10 dB over the frequency range cover from 0.79 GHz to 7.5 GHz. In addition, the S_{21} and S_{31} are obtained to be at -3 ± 1 dB and the S_{23} result performs less than -10 dB from 2.2 to 6.8 GHz. Meanwhile, as observed in Fig. 11, the phase difference between Port 2 and Port 3 shows that the value is at 0° ± 0.3° from 1 GHz to 7.5 GHz. As the value is almost 0°, it shows that the output at Port 2 and Port 3 are in-phase.

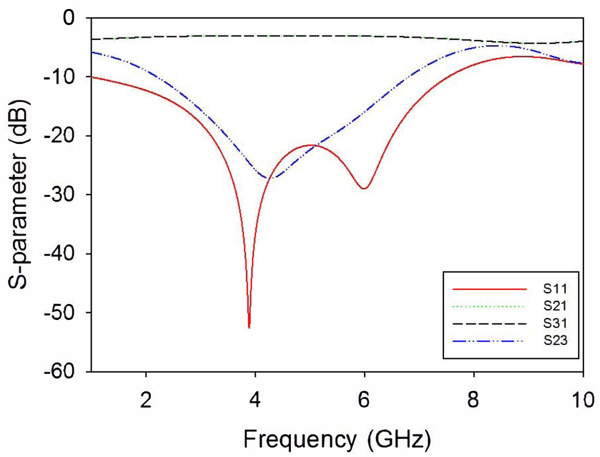

Fig. 10. S-parameter results for improved proposed design.

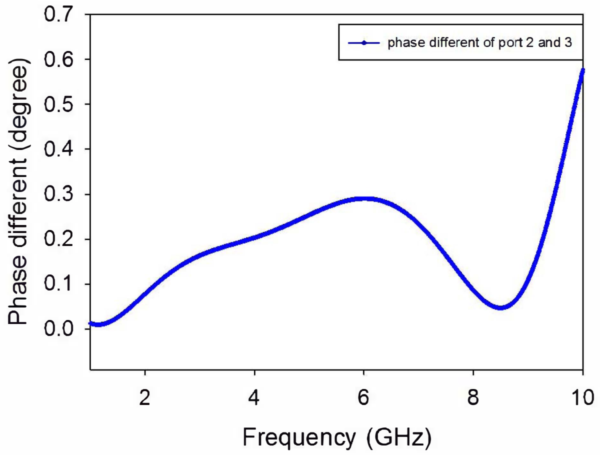

Fig. 11 Phase difference between Port 2 and Port 3.

The comparison between the conventional Wilkinson power divider and proposed design of improved Wilkinson power divider is summarized in Table 1. As observed in Table 1, the proposed power divider shows similar isolation performance as conventional design. Meanwhile, the S_{11} of the proposed design is better by 1 dB compared to conventional Wilkinson power divider [12]. In addition, S_{21}, S_{31} and S_{23} show both power dividers are having the similar performance. The proposed design performs 2 to 7 GHz bandwidth, which is 25% wider than conventional design.

Table 1. Comparison of the proposed design and the conventional Wilkinson power divider design at center frequency of 4 GHz

Parameter	Conventional Wilkinson	Proposed Design
S_{11}	⩽ -11.7 dB	⩽- 12.7dB
$S_{21}$and S_{31}	-3 dB ± 0.5dB	-3 dB ± 0.5dB
S_{23}	⩽ -10 dB	⩽ -10dB
Phase Difference	0° ± 0.4°	0° ± 0.3°
Operating frequency	2.5 – 6.5 GHz	2 – 7 GHz

IV. Conclusion

The design of proposed power divider with additional of stubs at line impedance of Port 1, Port 2 and Port 3 is presented in this article. The proposed design is designed and simulated by using CST Microwave Studio. The use of stubs has improved the bandwidth up to 25% wider compared to the conventional Wilkinson power divider design. Besides, the proposed power divider offers better reflection coefficient by 1 dB compared to the conventional Wilkinson power divider design.

Acknowledgment

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