Miniaturized Microwave Meander Coupled-Line Two-Way Wilkinson Power Divider

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Abstract

Power divider is a component which divides an input signal power into two or more parts with a defined ratio and phase relationship. The Wilkinson power divider is one of the most commonly used components in wireless communication systems for power division and/or combination. It has a property of equal amplitude and phase outputs as well as reciprocal operation. This paper presents a modified Wilkinson power divider with the quarter-wavelength matching transformer section folded into a meander-coupled line configuration. Successful simulations have been performed on the configurations. The optimum configuration was then implemented and tested. Experimental results showed that the modified power divider performs well as the conventional structure at its operating frequency of 3 GHz, however, with a tremendous size reduction of 45.91%.

1. INTRODUCTION

Power dividers are widely used in dividing power from the input port to output ports of various wireless communication systems. A basic yet popular configuration is the Wilkinson power divider, WPD [1]. It is simple yet possess excellent features such as impedance match at all ports, reciprocal operation and good isolation between the output ports. The schematic diagram of a basic 2-way Wilkinson power divider is shown in Figure 1, where $Z_1 = \sqrt{2}Z_0$ and $R = 2Z_0$.

In order to achieve good isolation between the output ports, the WPD requires a quarter-wavelength matching transformer. The transformer can be of several millimetres long for designs below X-band [1]. This causes the Wilkinson power divider to be quite large. Hence, it may limit the use of the WPD when implemented in some applications such as when incorporated into microwave integrated circuits (MIC), whereby the circuit size depends heavily on the size of the power divider [2].

In order to solve this problem, miniaturizing the WPD is possible while maintaining the features of a conventional WPD [3]-[4]. Other methods proposed for planar configurations [5]-[8]. The configuration proposed in this paper is achieved by folding the quarter-wavelength matching transformer segment into a meander line.

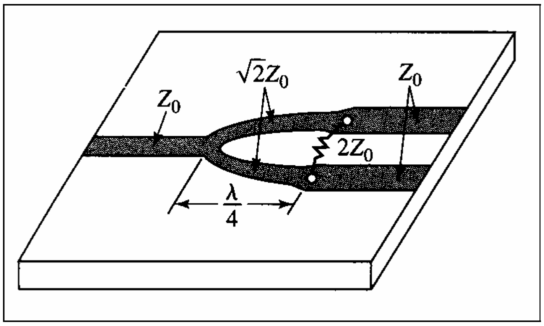

Fig. 1Q The Basic 2-Way Wilkinson Power Divider [2.]

2. DESIGN METHODOLOGY

By folding the quarter-wavelength segment of the basic WPD into a meander coupled line as proposed in [3], a modified configuration is thus formed. This is named as the Miniaturized Meander Two-Way Microwave Power Divider (2MPD), shown in Figure 2. The structure is designed with only mitered bends. The output ports are located at the opposite sides of the board.

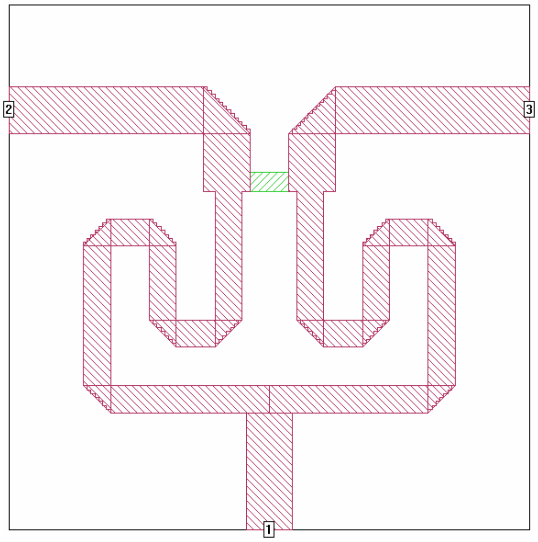

Fig. 2Q Layout of the 2MPD.

Figure 3 shows the enlarged view of the λg/4 matching transformer section that is folded into the meander-coupled line.

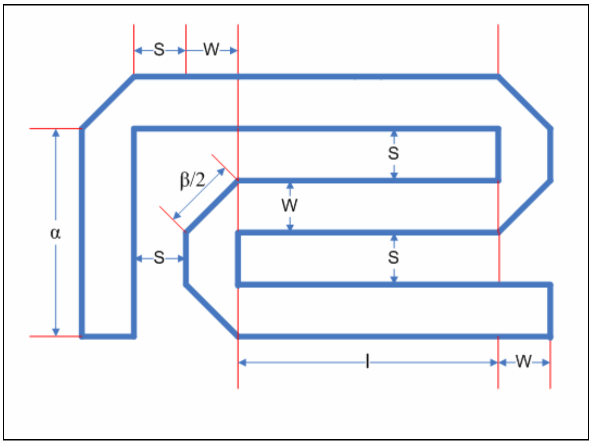

Fig. 3Q Enlarged view of the λ_g/4 matching transformer section.

In Figure 2, the λ_g/4 matching transformer section is folded into a meander-coupled line with assigned parameters. The sum of each parameter is equivalent to the length of λ_g/4. The relationship of the parameters and the λ_g/4 matching transformer has been developed as follows [9]Q

$$\alpha + 3S + 3l + 2\beta + 2W = \lambda_g/4 \tag{1}$$

where β is the length of the bend, W is the width of the microstrip line, l is the length of the commensurate line, α is the required branch line length for the coupled structure and S is the coupling distance.

The dimensions can be calculated as followsQ

$$S = 0.0153\,\lambda_g \tag{2}$$

$$\beta = \sqrt{W^2 + W^2} \tag{3}$$

$$\alpha = \lambda_g / 16 \tag{4}$$

$$l = \frac{\lambda_g / 4 - 2\beta - 2W - \alpha - 3S}{3} \tag{5}$$

The design procedures for the 2MPD are thus described. Firstly, determine S from the design frequency using (2). Hence, W can be calculated from the microstrip line design equation available in the literature [10]-[13]. Then, β is determined using (3) while α is calculated using (4). From (5), l can be calculated since all the other parameters are known.

3. ELECTROMAGNETIC SIMULATIONS

The electromagnetic simulation of the 2MPD was carried out using commercial software [14]. The software provides solutions for high-frequency electromagnetic (EM) analysis. The layout of the 2MPD is shown in Figure 4 while the simulated results are shown in Figures 5 and 6, and Table 1. The 2MPD was further fine-tuned to improve its performance by adding a length of W to the λ_g/4 matching transformer line. For the 2MPD, the ports are excellently well matched with excellent return losses well below -20 dB, indicating less than 1% of the power is reflected back. The insertion loss showed that the power divider divides the power equally, with slight transmission loss of approximately 0.17%. The S_{23} and S_{32} showed that the output ports have good isolations. From Table 1, it can be seen that with a maximum allowed power division loss of 2% (or -3.2 dB), return loss and isolation below -10 dB, the percentage operational bandwidth of the power divider is 84.30%.

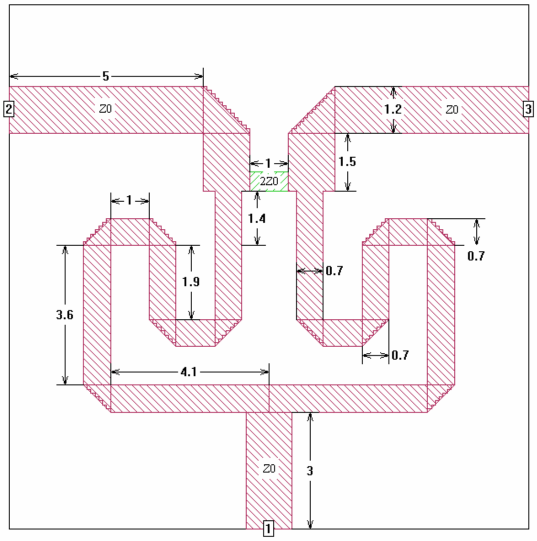

Fig. 4Q Layout of 2MPD with dimension in mm.

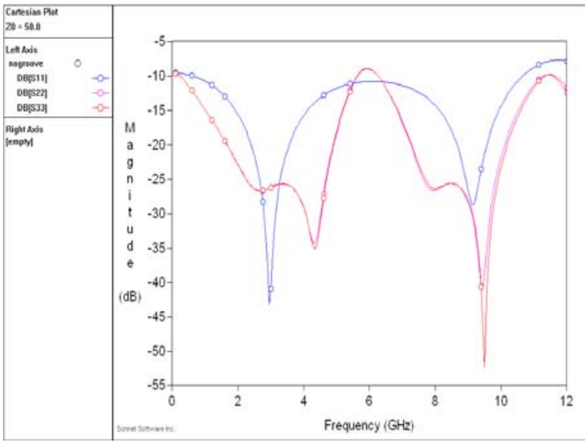

Fig. 5Q Simulated Return Losses of the 2MPD.

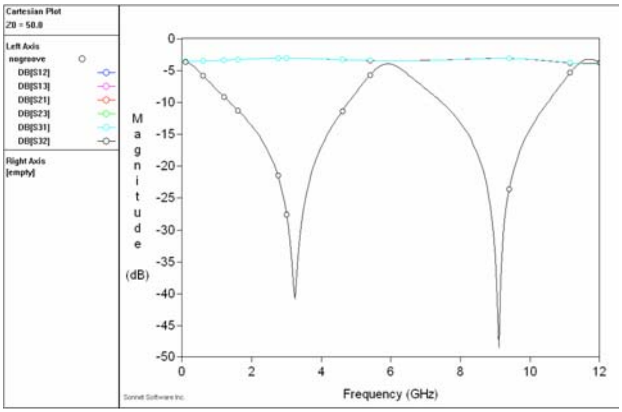

Fig. 6Q Simulated Insertion Loss and Isolation of the 2MPD.

TABLE 1QSIMULATED RESULTS OF 2MPD.

S-Parameters	Values at f_0 = 3 GHz	-10 dB level Bandwidth
S_{11}	-40.95 dB	0.65 GHz to 10.65 GHz
S_{22}	-26.17 dB	0.25 GHz to 5.6 GHz
S_{33}	-26.17 dB	0.25 GHz to 5.6 GHz
S_{12} & S_{21}	-3.03 dB	1.75 GHz to 4.3 GHz
S_{13} & S_{31}	-3.03 dB	1.75 GHz to 4.3 GHz
S_{23} & S_{32}	-27.54 dB	1.4 GHz to 4.75 GHz

4. MEASURED RESULTS

The 2MPD with f_0=3 GHz and Z_0=50Ω was fabricated on a 0.51 mm thick Taconic RF-30 board which has relative permittivity of 3.0 and conductor thickness of 35 µm. The physical dimension of the 2MPD determined from formulations (2) to (4) are shown in Table 2. The photograph of the fabricated structure is shown in Figure 7.

The return loss results measured from using Marconi Network Analyzer are tabulated with the simulated results in Table 3. The measured results displayed on the Network analyzer are shown in Figures 8 to 10. From Table 3, it can be seen that the measured results obtain are well below -20 dB, which represent a reflected power signal of less than 1%. The input return loss differs by 16.54 dB from the simulation results. The output return losses at Port 2 and Port 3 differ slightly by 1.3245 dB and 0.1145 dB, respectively.

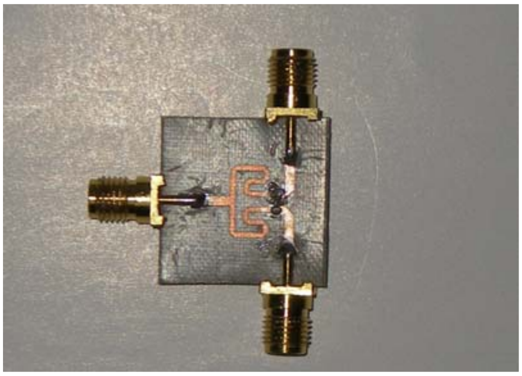

Fig. 7Q Photograph of the Fabricated 2MPD.

TABLE 2QPHYSICAL DIMENSIONS OF 2MPD.

Design Parameters	Dimension, mm
Length of $\lambda_g/4$ line	16.2
Width of $\lambda_g/4$ line, W	0.7
Coupling Distance, S	1.0
Branch line length, α	4.1
Commensurate line, l	1.9

TABLE 3QRETURN LOSS VALUES AT 3 GHZ.

Return Loss	Simulated, dB	Measured, dB
S_{11}	-40.95	-23.46
S_{22}	-26.17	-24.85
S_{33}	-26.17	-26.06

Fig. 8Q Measured Input Return Loss Response.

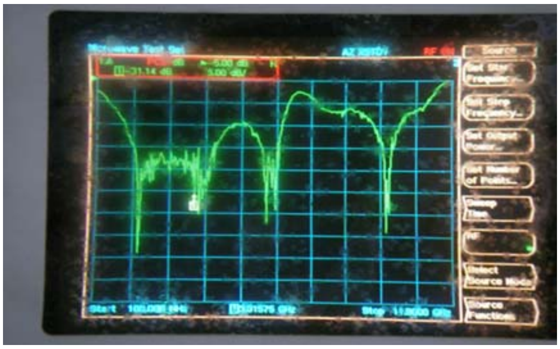

Fig. 9Q Measured Output Return Loss Response at Port 2.

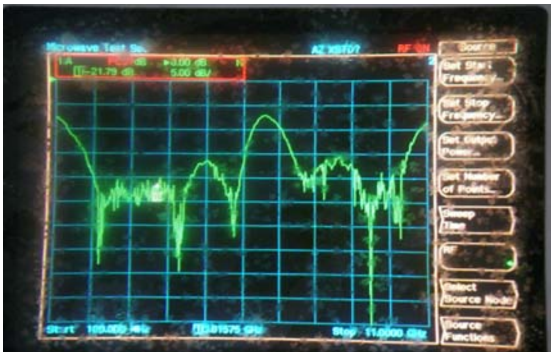

Fig. 10Q Measured Output Return Loss Response at Port 3.

The slight differences may be caused by the fabrication tolerances such as during wet-etching process of removing the unwanted copper using ferrite chloride, and the soldering of the tiny chip isolation resistor.

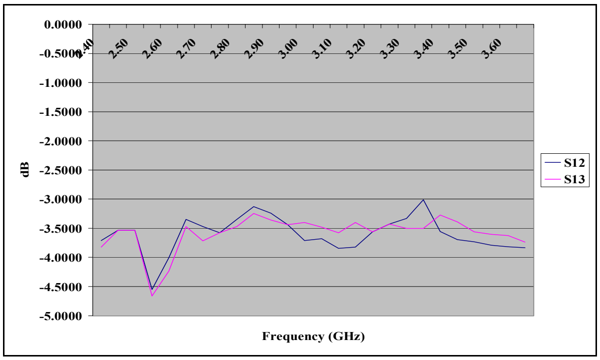

Fig. 11Q Measured S_{21} and S_{31} of the 2MPD.

The S_{21} and S_{31} measurements were performed using the MST 532 Trainer. The insertion loss was measured from 2.4 GHz to 3.65 GHz with a step of 0.05 GHz. The results tabulated in Table 4 and plotted in Figure 11, showed that the measured power almost equally splits at 3 GHz with a low loss of 7.45% at Port 2 and lower loss of 4.26% at Port 3.

TABLE 4Q S_{21} AND S_{31} VALUES AT 3 GHZ.

Insertion loss	Simulated, dB	Measured, dB
S_{21}	-3.03	-3.71
S_{31}	-3.03	-3.40

Figure 12 shows the percentage of power variation between the output ports of the power divider. The maximum percentage variation was acceptable at 11.43%, which is also equivalent to -12.4336 dB variations at 2.7 GHz. The percentage variation at the specified operating frequency of 3 GHz was 7.23% (-11.4086 dB variation), which is acceptable.

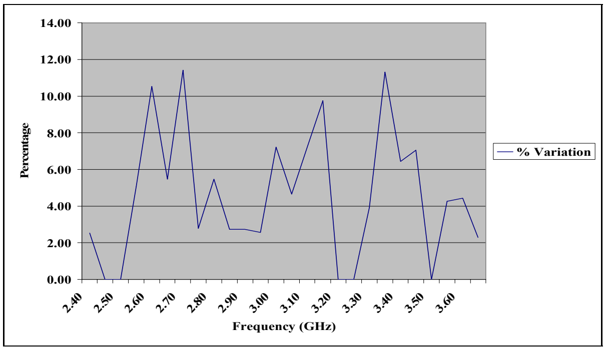

Fig. 12Q Percentage power variation between the output ports of the 2MPD.

5. CONCLUSION

A 2-way miniaturized meander microwave power divider has been successfully designed, simulated and tested. The proposed configuration is achieved by folding the quarter-wavelength segment of the conventional structure into a meander-coupled line. It is not only physically smaller than the conventional structure, but also performs well as its corresponding conventional Wilkinson power divider. The proposed divider can be designed and tuned conveniently using the derived expressions.

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