Reconfigurable modified wilkinson power divider using PIN diode switch

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ABSTRACT

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In this paper, a reconfigurable modified Wilkinson Power Divider (WPD) was proposed. The operating frequencies of the proposed design were either at 2.5 GHz or 3.5 GHz for Worldwide Interoperability for Microwave Access (WiMAX) applications. This proposed design is reconfigurable in terms of its operating frequency by using PIN diode switches. PIN diode switch was used in this design to reconfigure the microstrip line length. By varying the bias voltage of the PIN diode to +5 V or -5 V, the proposed modified WPD can either operate at 2.5 GHz or 3.5 GHz. Rogers RO4350 (er=3.48, h=0.508 mm) was chosen as the substrate material and copper (thickness=0.035 mm) related to patch of design. Based on simulation results obtained from the Advanced Design System (ADS) software, the modified WPD shows good S-parameter performances at 2.5 GHz and 3.5 GHz. However, the measurement results exhibit frequency shifted. Even though there is a correlation between measurement results and simulation results, the resonant frequency was shifted due to parasitic reactance of the PIN diode.

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1. INTRODUCTION

Nowadays, multiband, multiple functionalities, compact size and low cost are highly demanded in microwave industry and radio frequency (RF). Therefore, reconfigurable mobile terminals become a trend to achieve these targets. There are many reconfigurable antennas that have been demonstrated in practice and examined [1-3]. However, these reconfigurable antennas cannot be fully achieved without the aid of advanced feeding network [4-6]. WPD is one of the essential components in various microwave circuits. In antenna feeding networks, Wilkinson Power Divider (WPD) is commonly used for power combination and division [6-9].

In [10], a coupler and filter were integrated to design a power divider for radar applications. Nevertheless, the design is complex and not reconfigurable. Varactors are mostly used by the researchers in their power divider designs to achieve reconfigurable properties for power divider [11-17]. However, this led to increase in complexity of the design. In [18], a reconfigurable power divider is achieved by changing the voltage value and electrifying the upper and lower surface electrode of the liquid crystal. The fabrication

process for the design is nevertheless complex. Furthermore, in the power divider design, the PIN diode can also be used to achieve reconfigurable properties [19-23]. Therefore, this project proposed a reconfigurable modified WPD for WiMAX standards, at 2.5 GHz and 3.5 GHz. There are two conventional WPDs comprised in the proposed design. The bias voltages of PIN diode switches are varied to achieve different operating frequencies of a power divider, which reconfigured the transmission line length of modified WPD.

2. RESEARCH METHOD

In 1960, Ernest Wilkinson proposed a three-port network, Wilkinson power divider, that provides isolation between the output ports and it can be lossless as the output ports match [24]. WPD's transmission line circuit model depicted in Figure 1, where the equivalent force is delivered to the output ports [25]. Based on Figure 1, WPD's transmission line circuit model was designed at 2.5 GHz and 3.5 GHz operating frequencies.



Figure 1. The transmission line circuit model for WPD [25]

The value of the Z_0 is 50 Ω while the impedance of the quarter-wave section split transmission line becomes $\sqrt{2}Z_0=70.7 \ \Omega$ and resistor of isolation will be $2Z_0=100 \ \Omega$. WPD's perfect Scattering-matrix (S-matrix) with a matched load is shown in (1). The power divider would be lossless as the signal entered port one. The magnitude (total squares, of each component) of column one of the scattering matrix is equivalent to one [25]. The circuit was then converted to the form of a microstrip line using Advanced Design System (ADS) software based on the transmission line circuit model. Therefore, there were two designs of WPD working at different operating frequencies.

$$S = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1\\ 1 & 0 & 0\\ 1 & 0 & 0 \end{bmatrix}$$
(1)

These two designs were combined into a single design by using PIN diode switches, which reconfigured the length of the transmission line. The transmission line of port 1 was then modified for optimization. Thus, parametric study was done on the transmission line of modified WPD for optimization. Then, the proposed design was fabricated in the laboratory using substrate Rogers RO4350.

Figure 2 shows the circuit configuration of reconfigurable modified WPD with positions of PIN diodes (D1-D8) and the circuit prototype. Based on Figure 2, the proposed power divider operates at 2.5 GHz when D3, D4, D5, and D6 were switched off and operates at 3.5 GHz when D1, D2, D7, and D8 were switched off. Figure 3 (a) and (b) show the circuit configurations when the power divider operates at 2.5 GHz and 3.5 GHz, respectively.



Figure 2. (a) The circuit configuration of reconfigurable modified WPD, (b) Circuit prototype



Figure 3. The circuit configurations when the power divider operates at (a) 2.5 GHz, (b) 3.5 GHz

3. RESULTS AND DISCUSSION

Based on Figure 2, there are two modified WPDs were combined into a single design. By using the PIN diode, the power divider's transmission line length was reconfigured. The operating frequency of the proposed designs was controlled by PIN diodes D1 to D8. The power divider proposed in Figure 3 was simulated for S-parameters, return loss (S11), insertion loss (S12, S13), and isolation (S23).

Figure 4 (a) and (b) show the simulation results for S11, S12, S13, and S23 at 2.5 GHz and 3.5 GHz respectively. Based on Figure 4, the simulation result S11 for modified WPD at 2.5 GHz was -23.823 dB, S23 was -13.647 dB, S12, and S13 was -3.919 dB. Whereas simulation result of modified WPD's return loss at 3.5 GHz was 21.309 dB, S23 was -14.105 dB, S12, and S13 was -3.971 dB. After designing using ADS software, the proposed design was fabricated to validate with the simulation results. The prototype from Figure 2 (b) was measured using a vector network analyzer (VNA) for S-parameters return loss (S11), insertion loss (S12, S13), and isolation (S23). Figures 5 and 6 show the comparison between the measurement results and simulation results, S11, S12, S13, and S23 at 2.5 GHz and 3.5 GHz respectively.

Based on Figure 5, the frequency for modified WPD at 2.5 GHz was shifted around 300 MHz compared to simulation results. The measurement result S11 for modified WPD at a resonant frequency of 2.19 GHz was -38.737 dB, S23 was -11.194 dB, S12, and S13 was -4.0175 ± 0.0145 dB. Meanwhile, based on Figure 6, the frequency was shifted about 700 MHz for modified WPD at 3.5 GHz. The measurement result of modified WPD's return loss at a resonant frequency of 2.82 GHz was 34.942 dB, S23 was -17.212 dB, S12, and S13 was -4.062 ± 0.168 dB. The frequency shifted is due to the parasitic reactance (inductance or capacitance) of the PIN diode. In future work, Microelectromechanical Systems (MEMS) devices can be used to replace the diodes. Furthermore, there were slightly different for insertion loss between S12 and S13 in measurement results, which indicate that the prototype was fabricated and soldered component almost symmetrically. Table 1 shows the comparison in the performance of simulation results with the measurement results.



Figure 4. Simulation results of S11, S12, S13 and S23 for modified WPD at, (a) 2.5 GHz, (b) 3.5 GHz



Figure 5. The comparison of simulation and measurement results (a) S11, (b) S12



Figure 5. The comparison of simulation and measurement results (c) S23 for modified WPD at 2.5 GHz (continue)



Figure 6. The comparison of simulation and measurement results (a) S11, (b) S12 and (c) S23 for modified WPD at 3.5 GHz

Table 1. Comparison in the performance of simulation and measurement results

	Simulation		Measurement	
Operating frequency	2.5 GHz	3.5 GHz	2.19 GHz	2.82 GHz
S1 1	-23.823 dB	-21.309 dB	-38.737 dB	-34.942 dB
S12/S13	-3.919 dB	-3.971 dB	$-4.0175 \pm 0.0145 dB$	$-4.062 \pm 0.168 \text{ dB}$
S23	-13.647 dB	-14.105 dB	-11.194 dB	-17.212 dB

Reconfigurable modified wilkinson power divider using PIN diode switch (N. Edward)

4. CONCLUSION

The design of reconfigurable modified WPD using PIN diode switches has been successfully designed, simulated, measured, and investigated. Two modified WPDs were integrated into a single design using PIN diodes, which reconfigure the length of WPD's transmission line. The simulation results showed good agreement for both frequencies with return loss more than 20 dB, insertion loss less than 4 dB, and isolation less than -10 dB. Even though there was frequency shifted in measurement, the measurement results still correlated with the simulation results.

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