Reconfigurable Feeding Network with Dual-band Filter for WiMAX Application

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Article Info	ABSTRACT
	Design and simulation for reconfigurable Wilkinson Power Divider (WPD) related to WiMAX application is proposed in this paper. This proposed design relates to dual band WiMAX frequencies at 2.5 GHz and 3.5 GHz. The main purpose of this design is to design a switchable feeding network that can cover the WiMAX standards by reconfiguring the microstrip line length using PIN diode switches. Besides, the power divider also can be design and develop as power combiner due to the passive component structure and hence reciprocal. In this proposed Wilkinson power divider, different band of frequencies for WiMAX application are obtained by using PIN diode. By turning 'ON' and 'OFF' the PIN diode, different frequencies are achieved between 2.5 and 3.5 GHz. This proposed design used Rogers RO4350 (er = 3.48, h = 0.508mm) as a substrate material and copper (thickness = 0.002 mm) related to patch of design. This simulation results showed that the S11 is less than -15dB; and S12 and S13 are better than -5dB. Based on these simulation results, the proposed WPD design using dual-band filter was well applied where it has better return loss (S11) with less than -15 dB for both WiMAX frequencies.

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1. INTRODUCTION

Nowadays, reconfigurable mobile terminals have become the trend. Therefore, in order to fulfil these targets, a lot of reconfigurable antennas have been demonstrated in practice and examined [1]-[3]. Advanced feeding network is essential to support the systems such as smart antennas and phase-array antennas to be fully achieved [4]-[6]. The Wilkinson power divider (WPD) is one of the essential components in various microwave circuits and it has been commonly used for combination and power division in antenna feeding networks [6]-[9]. The conventional Wilkinson divider utilizes two quarter-wavelength transmission lines and only operates at a certain frequency [10].

In [11], a power divider which integrates coupler and filter is designed for radar systems. However, it is not tunable and the design is more complex. In order to make the power divider tunable, there are several actions can be done, such as using varactors [12]-[15]. But by using varactors, the design of WPD would become more complex. In [14], the tunable power divider is designed by electrifying the upper and lower surface electrode of the liquid crystal (LC) and changing the voltage value [16]. However, this design would complicate the fabrication process. Furthermore, by using PIN diodes, the tunable power divider capabilities can be obtained [17], [18].

This project presents a miniaturized reconfigurable and switchable feeding network with dual-band filter for WiMAX standards, which is 2.5 GHz and 3.5 GHz. The feeding network comprises of two conventional WPD which can be individually reconfigured in length by using PIN diode switches. By adjusting the bias voltages of these PIN diodes, the operating frequency of the propose design can be altered between two different frequency bands: 2.3 GHz - 2.75 GHz and 3.25 GHz-3.9 GHz.

2. RESEARCH METHOD
2.1. Wilkinson Power Divider and Design Equation

The Wilkinson power divider, proposed by Ernest Wilkinson in 1960 gives isolation between ports in the output, is adept to match in all ports, and can be lossless when port at the output matches [19]. Figure 1 presents the equal transmission line circuit for WPD, where the force delivered to both ports at the output is equivalent [10].
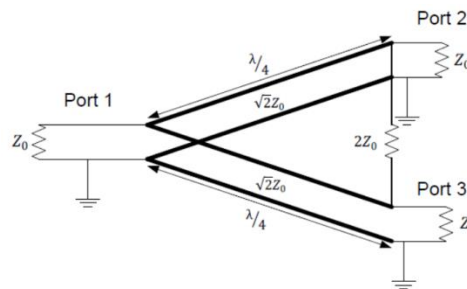

Figure 1. The circuit model of transmission line for WPD [10]

Wilkinson Power Divider is a three port network consisting one input port and two output ports as shown in Figure 1. Mostly, depend on the application using it, power is divided equally or unequally at two different working of frequencies.   At 2.5 GHz, 3.5 GHz and $Z_0 = 50 \ \Omega$ is used to design the power divider in which it needs resistor of isolation to be 2 Z0 = 100 Ω and the impedance of quarter-wave section split transmission line become $\sqrt{2}Z_0 = 70.7\Omega$. The perfect S-matrix of the Wilkinson power divider with load that is matched is shown in (1).

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

Scattering matrix indicates that as the signal entered to the port two, it will be the same which separated into ports two and three. Port which is matched sets S11, S22 and S33 equals zero. As the signal is entered the port one, the power divider would be lossless. The magnitude (total squares each component) of column one of the scattering matrix is equivalent to one [10].

2.2. Design of Ideal WPD

Based on the Figure 2, it shows the schematic diagram and the equivalent lumped component circuit of WPD. The first step is to design the WPD by using Advanced Design System (ADS) software based on the schematic circuit below. We choose Z0 = 50Ω.
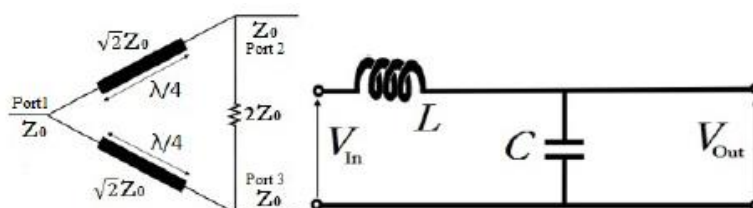

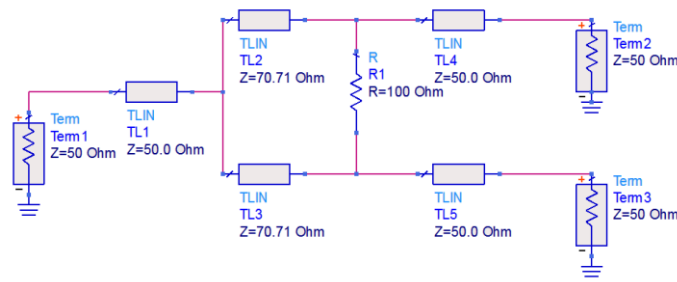Figure 2. Schematic diagram and equivalent lumped component.

Figure 3. The design for ideal WPD.

After that, the ideal WPD is tested with dual-band filter to compare the performance of the ideal WPD with the proposed power divider. Figure 4 shows the design of the ideal WPD with dual-band filter. The dual-band filter is the combination of band-pass filter and band-stop filter.
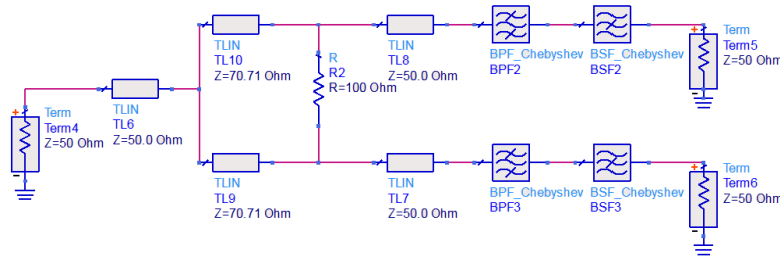

Figure 4. The ideal WPD is tested with dual-band filter.

2.3. The Proposed Design of WPD

Parametric study is done to narrow the frequency band of the WPD to make it only work at one frequency after testing it with the dual band filter. In ADS, the parameter of the power divider is tuned such as the width and the length to see the effect on the output. After that, both designs are combined to make it into one design by using pin diode to reconfigure the length of the transmission line in power divider. Figure 5 shows the circuit configuration after combined of the two power divider designs and D1-D8 are the pin diodes.
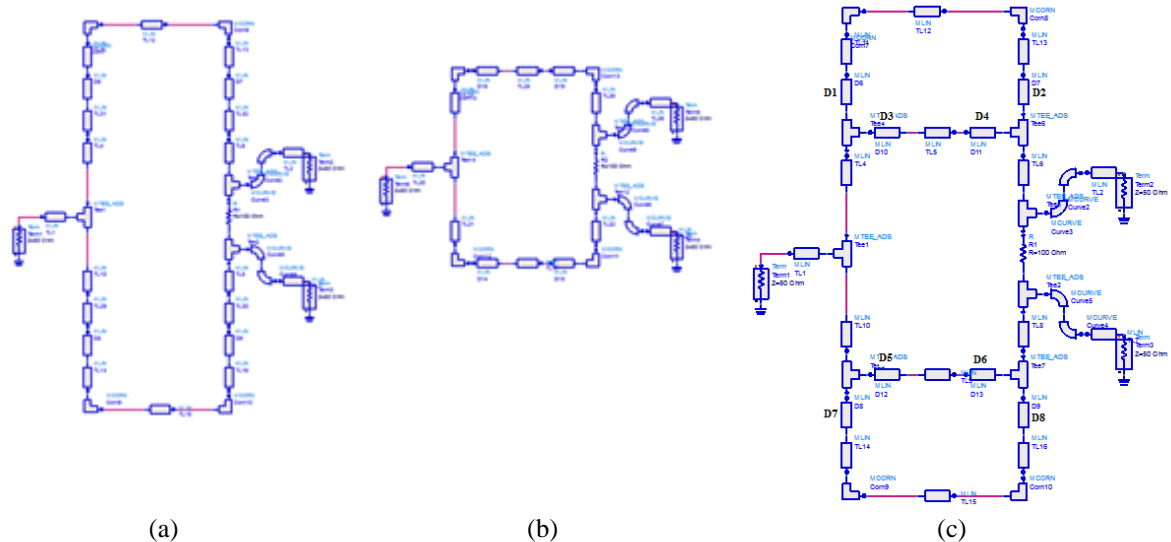

| (a) | (b) | (c) |

Figure 5. (a) WPD at 2.5 GHz, (b) WPD at 3.5 GHz and (c) The circuit configuration after combined the two WPDs.

From Figure 5 (c), when D3, D4, D5 and D6 are turned off, the power divider operates at frequency of 2.5 GHz and when D1, D2, D7, and D8 are turned off, the power divider operates at frequency of 3.5 GHz. After done with simulation of the proposed WPD's circuit, then we need to generate the circuit layout and performed electromagnetic (EM) simulation which is more accurate than circuit simulation. Figure 6 shows the generated circuit layout of the proposed feeding network in EM simulation and the position of the pin diodes, D1-D8, in the circuit layout.
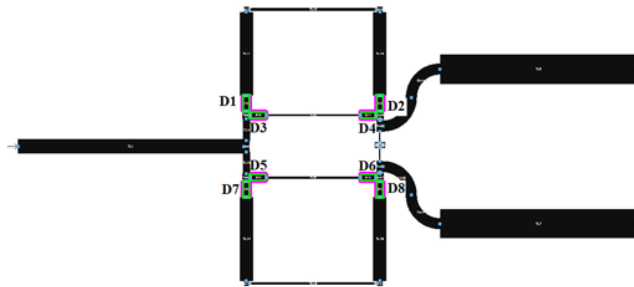

Figure 6. The circuit layout of the proposed WPD.

After that, the symbol of the layout is generated after simulation in EM. The symbol is dragged to a new schematic window and the view of the simulation can be either EM model, layout or schematic. In this simulation, the view for simulation of the circuit layout is chosen as layout. The symbol is tested with the dual band filter to analyze the performance of the proposed feeding network. Figure 7 and 8 shows the configuration of the symbol tested for WPDs operating at frequencies of 2.5 GHz and 3.5 GHz respectively.
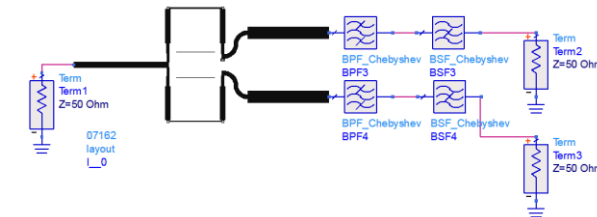

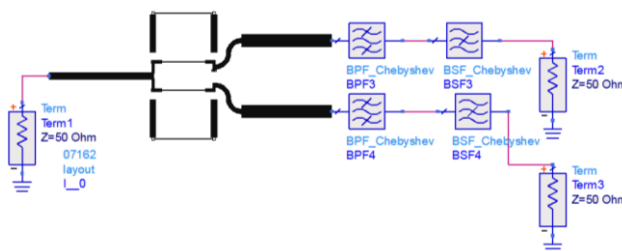Figure 7. The circuit layout with dual band filter at 2.5 GHz.

Figure 8. The circuit layout with dual band filter at 3.5 GHz.

3.   RESULTS AND ANALYSIS
3.1. The Proposed Design of WPD

It has been analyzed that the transmission line at port 1 effect the most to make it narrow band. That's mean this power divider does not have the same impedance with the conventional Wilkinson power divider. That is because the transmission line at the ports of the conventional Wilkinson power divider are Z_0 which is 50 Ω, but after tuning the width and length of the transmission line, it will not have the same impedance. Therefore, for the conventional power divider, all transmission lines will be in the same width and length of the transmission line. But, for this design to have narrow frequency band, the transmission line

at the ports does not have the same size, which means that, port 1 have different values of impedance than port 2 and 3. After tuning the transmission line at the ports, port 1 have different dimension than port 2 and 3. But, for port 2 and port 3, it has the equal dimension of transmission line even after tuning. That is because it is to achieve the same output at port 2 and port 3. After that, both designs are combined to make it into one design by using pin diode to reconfigure the length of the power divider. From the analysis that have been made, it is found that the transmission line of the ports plays important role in getting narrow band.

The proposed power divider in Figure 5 (c) is simulated to obtain the S11, S12, S13 and S23 at 2.5 GHz and 3.5 GHz. When pin diode D3, D4, D5 and D6 are turned off, the power divider will operate at 2.5 GHz as shown in Figure 5 (a). When pin diode D1, D2, D7 and D8 are turned off, the power divider will operate at 3.5 GHz as shown in Figure 5 (b). The following Figure 9 and 10 shows the result for S11, S12, S13 and S23 at 2.5 GHz and 3.5 GHz respectively. The pin diode in the design is assumed as switch on and off to switch the frequency either 2.5 GHz or 3.5 GHz.
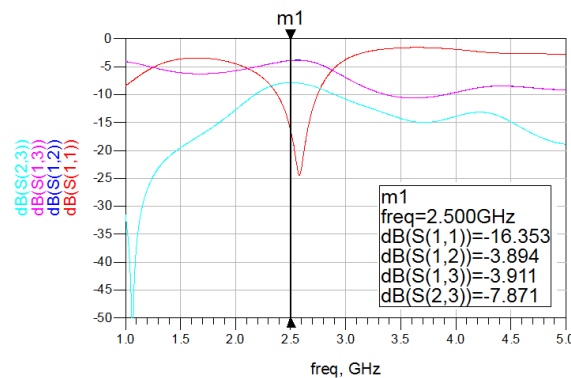

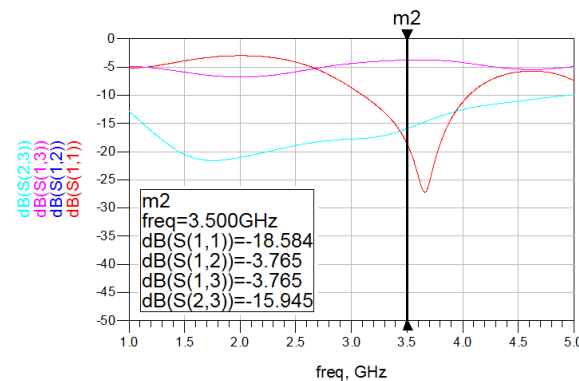Figure 9. S11, S12, S13 and S23 results for WPD at 2.5 GHz.

Figure 10. S11, S12, S13 and S23 results for WPD at 3.5 GHz.

The return loss of proposed WPD at 2.5 GHz is about -16.353 dB, S23 is -7.871 dB, S12 and S13 is -3.9025 ± 0.0085 dB. Meanwhile, the return loss of WPD at 3.5 GHz is about -18.584 dB, S23 is -15.945 dB, S12 and S13 is -3.765 dB. In the EM simulation, it is found that the center frequency of the return loss is shifted to the left compared to circuit simulation. Therefore, in order to obtain the center frequency of the return loss at 2.5 GHz in EM simulation, we must obtain the center frequency higher than 2.5 GHz in circuit simulation. Then, the center frequency will be at 2.5 GHz for the return loss in EM simulation, same goes with center frequency at 3.5 GHz. Figure 11 and 12 shows the EM simulation's result, S11, S12, S13, and S23 at 2.5 GHz and 3.5 GHz respectively. Compared to results in Figure 9 and 10, it shows that the center frequency did shifted when in EM simulation.
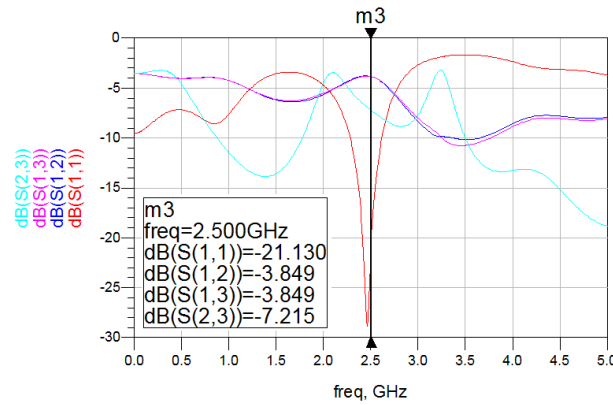
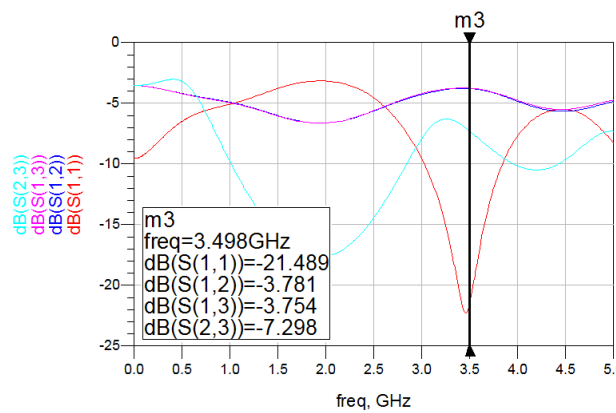Figure 11. Simulation result, S11, S12, S13, and S23 at 2.5GHz.

Figure 12. Simulation result, S11, S12, S13, and S23 at 3.5GHz.

The return loss for the proposed WPD at 2.5 GHz is -21.13 dB and at 3.5 GHz is -21.489 dB. The value for S12 and S13 for 2.5 GHz is -3.849 dB and for 3.5 GHz is -3.781 dB and -3.754 dB respectively. S23 that we get for the proposed power divider that operated at frequency 2.5 GHz is -7.215 dB and at 3.5 GHz is -7.298 dB. After that, the symbol of the layout is generated after simulation in EM and tested with the dual band filter. The following figures, Figure 13 and 14 show the results, S11, S12 and S13 for the proposed WPD which is tested with dual-band filter operates at frequency of 2.5 GHz and 3.5 GHz.
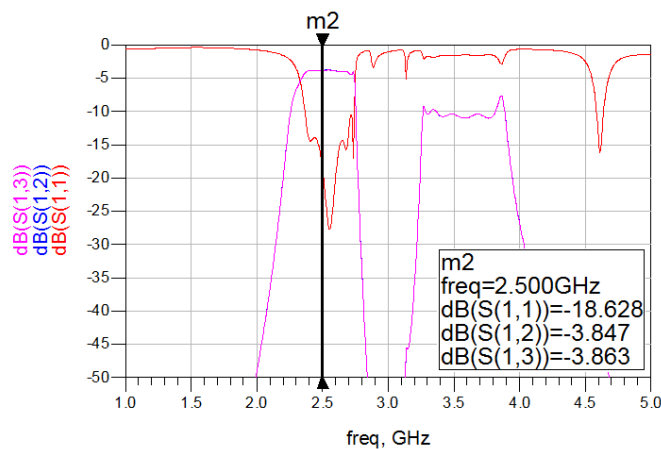

Figure 13. The results S11, S12, and S13 of the circuit layout tested with dual band filter at 2.5 GHz.
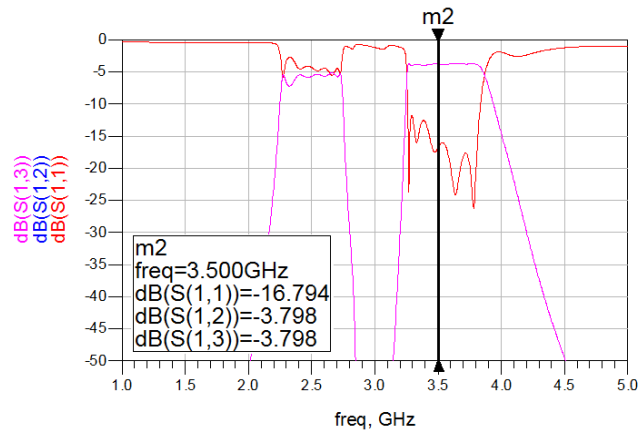
Figure 14. The results S11, S12, and S13 of the circuit layout tested with dual band filter at 3.5 GHz.

Based on the results that we get in Figure 13, when the proposed WPD operating at 2.5 GHz is tested with dual-band filter, only at 2.5 GHz frequency band of the dual band filter is turned on and it turned off the other frequency band. Meanwhile, when the proposed WPD operating at 3.5 GHz is tested with dual-band filter, only at 3.5 GHz frequency band of the dual band filter is turned on and turned off the other frequency band.

3.2. Design of Ideal WPD

Figure 15 and 16 shows the return loss, S11 and insertion loss, S12, S13 for both frequencies at 2.5 GHz and 3.5 GHz for an ideal transmission line respectively. It can be seen that both frequencies have return loss about -100 dB.
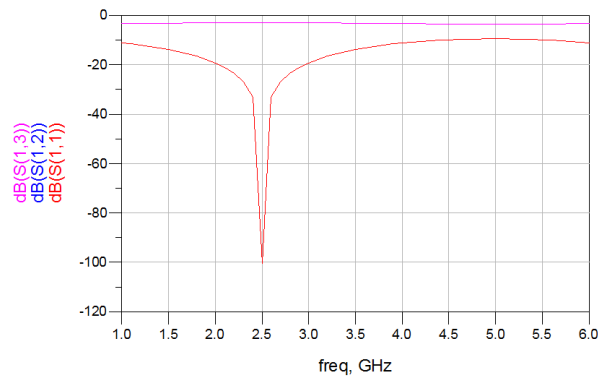

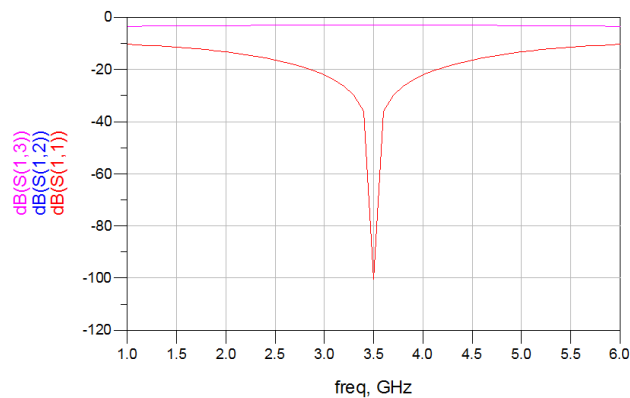Figure 15. S11, S12, and S13 results for ideal WPD at 2.5 GHz.

Figure 16. S11, S12, and S13 results for ideal WPD at 3.5 GHz.

When the dual band filter is attached to the proposed WPD's ports, only one frequency band will be turned on and the other band will be turned off. The dual band filter is operated at 2.5 GHz and 3.5 GHz. If the dual band filter is attached to the proposed WPD of 2.5 GHz, only the frequency band of the filter at 2.5 GHz will be turned on. But, by using the conventional design of WPD, it cannot turn off one of the band. Figure 17 and 18 shows the S11, S12 and S13 results for ideal WPD with dual band filter at 2.5 GHz and 3.5 GHz respectively. It proved that the ideal WPD that is connected to the dual band filter can't turn off any one of the frequency band.
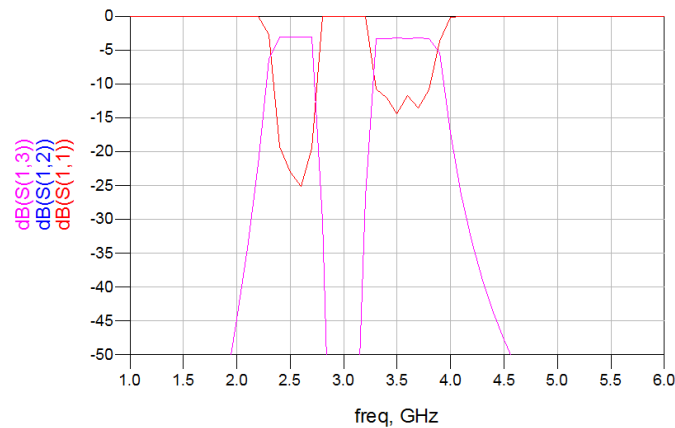

Figure 17. S11, S12, and S13 results for ideal WPD with dual band filter at 2.5 GHz.
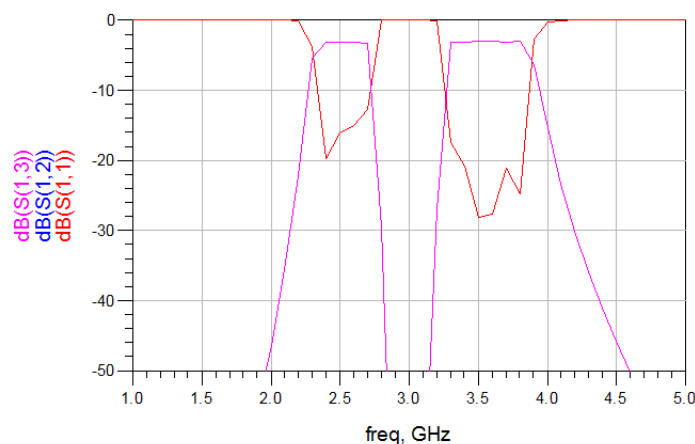

Figure 18. S11, S12, and S13 results for ideal WPD with dual band filter at 3.5 GHz.

Table 1 shows the comparison of this work with previous work on the reconfigurable feeding network. In [17], the design is based on the conventional WPD and used pin diode as the tuning element. The conventional WPD has a wideband frequency. So, it cannot work with dual-band filter and can only reconfigure the operating frequency of the power divider.

Table 1. Comparison with previous work.

	[17]	This work
Type of power divider	Conventional Wilkinson power divider	Modified Wilkinson power divider
Tunable element	Pin diode	Pin diode
Type of frequency band	Wideband	Narrowband
Tunable properties	Operating frequency of power divider	Operating frequency of power divider and frequency band of dual-band filter
Work with dual-band filter	No	Yes

4. CONCLUSION

The design of the Reconfigurable Feeding Network with dual band filter for WiMAX Applications have been successfully designed, simulated, and investigated. Two of Wilkinson power dividers are designed and combined by reconfiguring the length of the transmission line using PIN diode. The conventional WPD has wideband frequency, but for this WPD design, it requires narrowband frequency either at frequency of 2.5 GHz or 3.5 GHz. The simulation results of the switchable feeding network showed good agreement for both frequencies with the return loss below -20 dB and S12/S13 better than -10 dB that have been achieved.

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