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Wideband Four-Way Microstrip Power Divider for WLAN Application

Nur Ain Rosli[1], Hazila Othman[1*], N. H. Ramli[1] and Y. S. Lee[1]

[1]*Department of Electronic Engineering Technology, Faculty of Engineering Technology, Universiti Malaysia Perlis.*

ABSTRACT

The Wilkinson power divider is a well-known device in the RF and microwave community used for splitting power. It is composed of simple transmission line and isolating resistor, and takes advantages of the properties of quarter-wavelength transmission line section to perform ideal power divider characteristic. Two-way power divider or also known as Wilkinson power divider is as power divider with one input port and two output ports. Basically, Wilkinson power divider has very high isolation between its two output ports. It is also lossless if all the output port mismatched. In this project, wideband Four-way microstrip power divider for WLAN application is proposed. Four-way microstrip power divider was designed by combine or interconnecting the two-way Wilkinson power divider. Through this project, it is focus on the performances of its S-parameter which is reflection coefficient, insertion loss, isolation and also bandwidth. Simulated result of reflection coefficient, S_{11} shows a good result, 2.443 GHz with -28.641 dB and covers a wide bandwidth with 1.84 GHz which suitable for the WLAN application.

Keywords: Two-way Power Divider, Four-way Power Divider.

1. INTRODUCTION

Power dividers are generally utilized as a part of microwave and millimeter wave systems and devices for example antenna feeders, power amplifiers. In recent applications, the required channels in these multi-channel systems determinedly increase. In many occasions, number of ways is large that a single-stage control divider does not fulfill the prerequisite. Therefore, a multi-stage structure is connected. For a multi-stage power divider, interconnection lines are utilized to associate the elements of the power divider [1]-[2]. When the circuit has been reduced with their integrated semiconductor electron devices, a transmission structured with the development of circuit was recommended to prepared a guided wave over the controlled length. Microstrip structures are used in integrated semiconductor form, directly interconnected in microwave integrated circuits. In microwave and millimeter-wave system, power divider and power combiner are the main important components that were used. A conventional Wilkinson power divider is designed with the quarter-wavelength in its transmission line and has narrow bandwidth [3]-[9].

Two-way Wilkinson power divider being a lossless reciprocal three port network, it inherits all its properties which state that this type of network cannot have all the ports simultaneously matched [10]-[16]. To overcome this problem, an isolating resistor is placed between the two output ports and there is no potential difference between the output port since there are no current flows through the resistor. The resistor does not contribute to any resistive loss thus makes the ideal Wilkinson is a 100% efficient device. Even when the device is used as a combiner, the resistor also provides excellent isolation. The disadvantages of the Wilkinson power divider

*Corresponding Author: *hazila@unimap.edu.my*

are having a narrow bandwidth. By adding stub section in a quarter wavelength sections of the Wilkinson power divider, it can improve the bandwidth performances.

Therefore, the purpose of the project is to make a comparison between two-way and four-way power divider and enhanced the performances in term of reflection coefficient, insertion loss, isolation and bandwidth.

2. METHODOLOGY

2.1 Microstrip Power Divider Specification

Microstrip wilkinson power divider which include two-way and four-way power divider are designed using Advance Design System (ADS) with their specific important parameter. The important parameters that have been used in the design are dielectric material used, dielectric constant (Ɛr), substrate thickness (h), copper thickness (T) and tangent Loss (Tan δ). Table 1 shows the design specification.

Table 1 Design Spesification

Parameter	Value
Substrate Material	FR4
Dielectric Constant	4.7
Substrate Thickness	1.6mm
Copper Thickness	0.035mm

2.2 Calculation on Microstrip Power Divider Lines Feed

Two-way microstrip power divider is designed before interconnecting the others to build up the design of four-way microstrip power divider. There are several parameters needed to be calculated while designing the feeding line of microstrip power divider. The following calculation are determined the value of width and length of microstrip power divider lines feed for 50Ω, 70.7Ω.

The following variables are used in the formula below:
h = substrate thickness
Ɛr=substrate dielectric constant
Z_o = characteristic impedance
$Ɛ_{ff}$= effective permittivity
c = speed of light
W = width of microstrip line feed
L = length of microstrip line feed

i. Microstrip synthesis, (H);

$$H=\left[\frac{z_0\sqrt{2(\varepsilon_r+1)}}{119.9}\right]+\frac{1}{2}\left[\frac{\varepsilon_r-1}{\varepsilon_r-1}\right]\left(\frac{\ln(\frac{\pi}{2})+\frac{1}{\varepsilon_r}\ln 4}{\pi}\right) \quad (1)$$

ii. Width of microstrip line feed, (W);

$$W=\left[\left[\frac{e^{H}}{8}-\frac{1}{4e^{H}}\right]^{-1}\right]\times 1.6mm \quad (2)$$

iii. Effective permittivity, (ε_{eff}) ;

$$\varepsilon_{eff}=\frac{\varepsilon_r+1}{2}\left(1-\frac{1}{2H}\left[\frac{\varepsilon_r-1}{\varepsilon_r+1}\right]\left(\ln\frac{\pi}{2}\right)+\frac{1}{\varepsilon_r}\ln\left[\frac{4}{\pi}\right]\right)^{-2} \quad (3)$$

iv. Effective permittivity, (ε_{eff}) ;

$$\lambda_g=\frac{c}{f\sqrt{\varepsilon_{eff}}} \quad (4)$$

Table 2 illustrated the calculated value for width and length for Wilkinson power divider when the value of impedance is 50Ω and 70.7Ω.

Table 2 Wilkinson Power Divider calculated value for Width and Length

Impedance	**Width (W)**	**Length (L)**
50Ω	2.91mm	25.75mm
70.7Ω	2mm	17.75mm

2.3 Design Layout

Microstrip power divider is designed by using Advance Design System (ADS) software. Both two-way and four-way microstrip power divider have been designed on the schematic diagram before it generated to the layout. Gerber Tool software is used to convert the layout of the design before printing process for fabrication. Figure 1 and Figure 2 shows the design of two-way microstrip power divider and four-way microstrip power divider were built in the schematic diagram before it generated into the layout design.

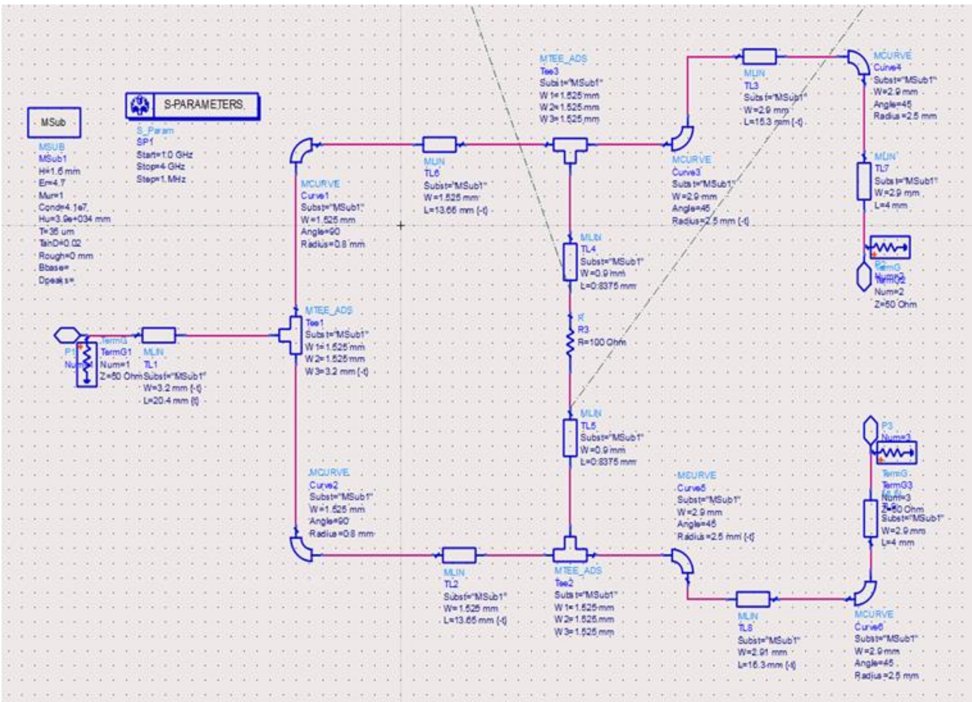


Figure. 1. Two-way Microstip Power Divider Design in Schematic Diagram.

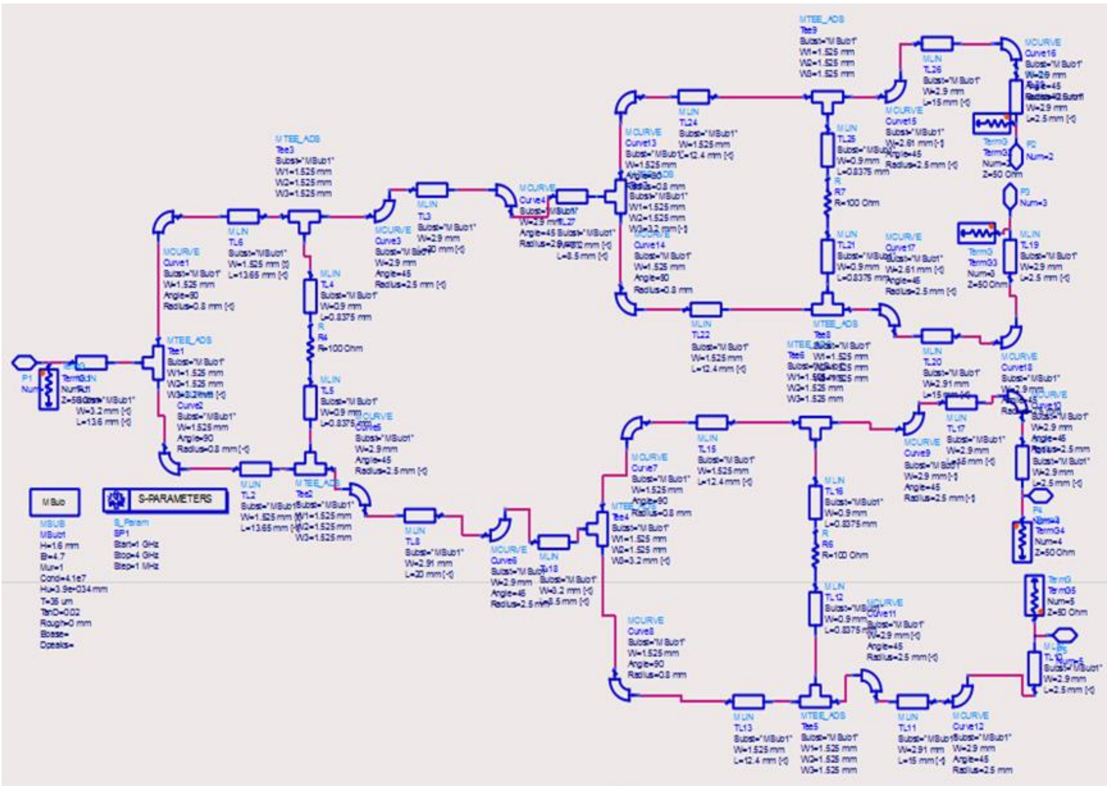
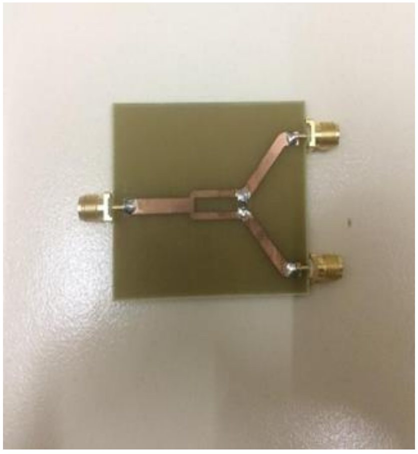
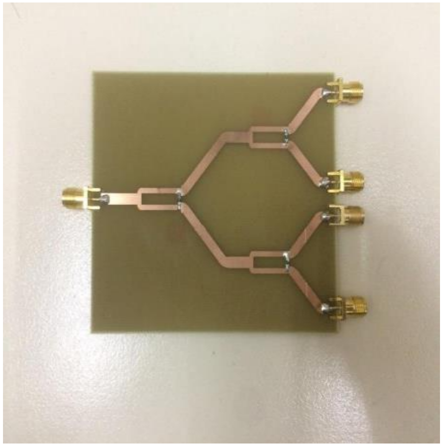


Figure 2. Four-way Microstip Power Divider Design in Schematic Diagram.

The two-way and four -way of microstrip power divider is designed on the schematic diagram using ADS software. The parameter dielectric constant (Ɛr) = 4.7, substrate thickness (h) = 1.6 mm and copper thickness (T) = 0.035mm. The feeding line of power divider is calculated for 50Ω and 70.7Ω based on equation (1) to (4). For the two-way power divider design, the quarter wavelength has been applied. Four-way microstrip power divider is designed with combining the design of two-way microstrip power divider with straight quarter wavelength with one input port and four output port. 100 Ω SMD resistor was soldered between each of the two output ports. The design has one input port and four output port while the two -way power divider have one input port but only two output port. Two-way power divider and four-way power divider were fabricated on the FR-4 and each of the port were soldered with SMA connector for the measurement purpose.The prototype were measured using Network Analyzer. Figure 3 demonstrated both of the microstrip power divider.



(a)



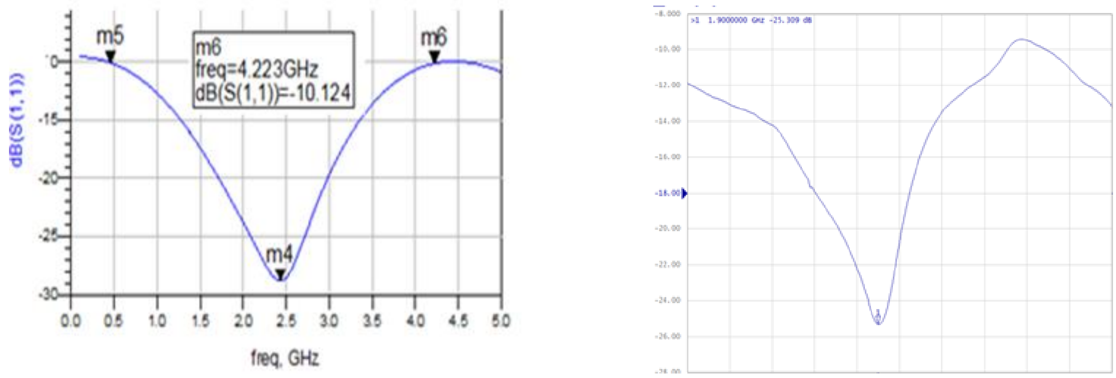
(b)

Figure 3. (a) Two-way Microstrip Power Divider (b) Four-way Microstrip Power Divider.

3. RESULTS AND DISCUSSION

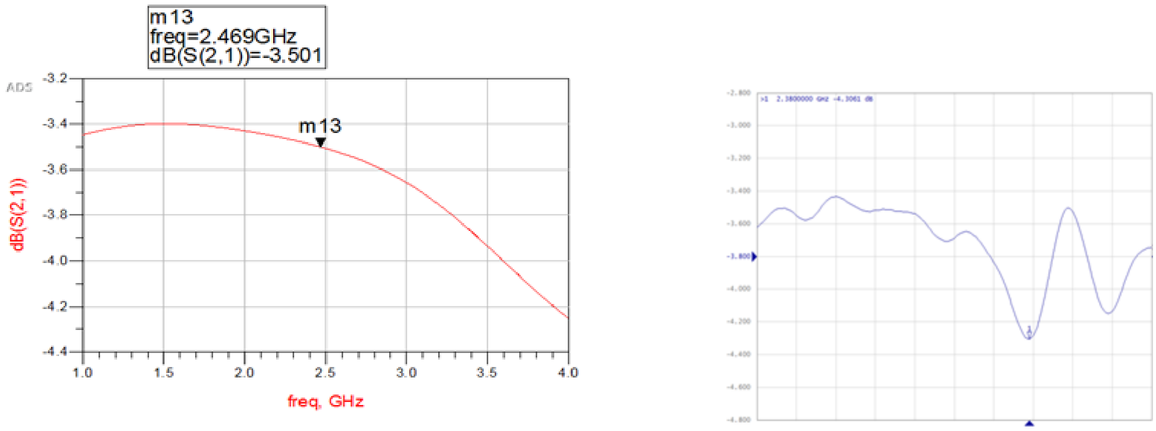
3.1 Two-way Microstrip Power Divider

Figure 4, Figure 5 and Figure 6 shows the simulated and measured result of reflection coefficient (S11), insertion loss (S21), isolation (S23) of two-way microstrip power divider. As shown in Table 1, the measured result of return loss is operated at 1.9 GHz with magnitude -25.309 dB totally shifted from the simulated result. The simulated result of insertion loss (S21) is 2.469 GHz with -3.501 dB but shifted to 2.78 GHz with –4.430 dB. Then, for the isolation of port 2 and port 3, the result is shifted to 2.11 GHz with –24.212 dB. The results of simulated and measured have several discrepancy due to error while fabricating the prototype. For the two-way microstrip power divider, the simulated result obtained from the reflection coefficient (S11), inser-tion loss (S21) and isolation (S23) shows that there are a large and wide bandwidth from the characteristic analyze.



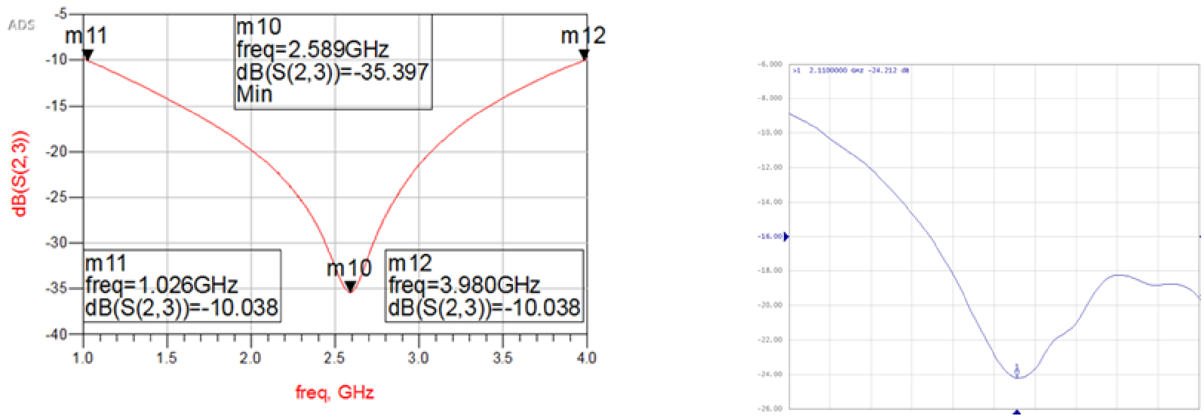
(a) (b)

Figure 4. (a) Simulated result of reflection coefficient (S11) (b) Measured result of reflec-tion coefficient (S11).



(a) (b)

Figure 5. (a) Simulated result of insertion loss (S21) (b) Measured result of insertion loss (S21).



(a) (b)

Figure 6. (a) Simulated result of isolation (S23) (b) Measured result of isolation (S23).

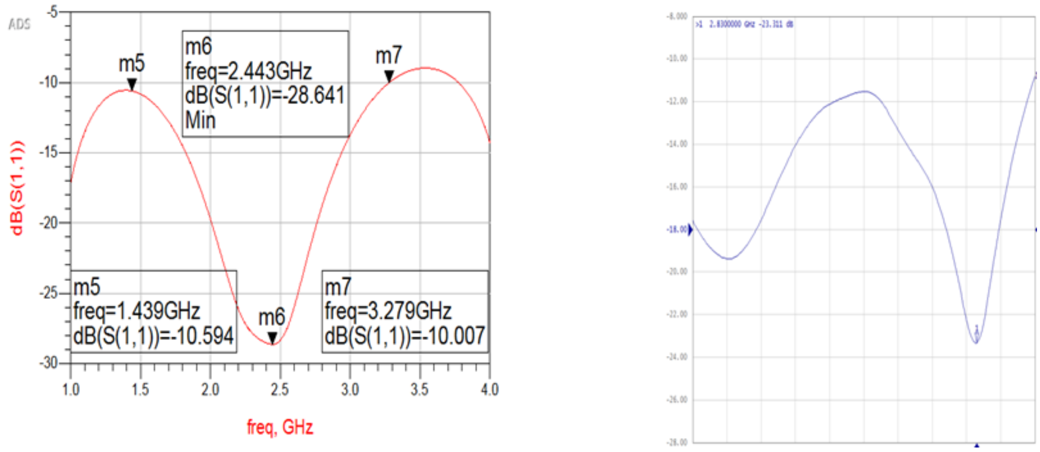
Table 3. Simulated Result Versus Measured Result of Two-way Mi-crostrip Power Divider

S-Parameter	**Simulated Result**		**Measured Result**	
	Frequency (GHz)	**Magnitude (dB)**	**Frequency (GHz)**	**Magnitude (dB)**
Reflection coefficient (S_{21})	2.433	-28.815	1.9	-25.309
Insertion Loss	2.469	-3.501	2.78	-4.43
(S_{21}&S_{31})				
Isolation(S_{23})	2.589	-35.397	2.11	-24.212

3.2 Four-way Microstrip Power Divider

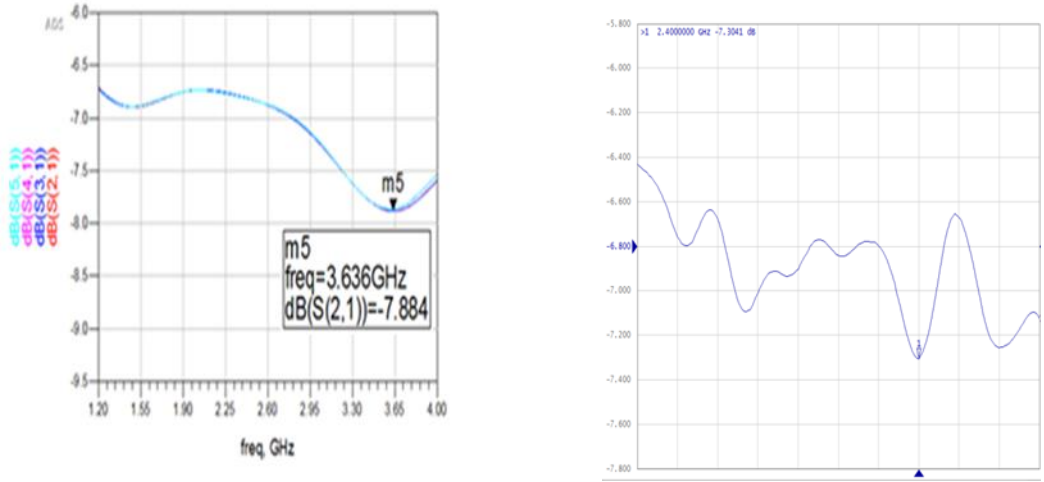
Figure 8, Figure 9 and Figure 10 shows the simulated and measured result of reflection coefficient (S11), insertion loss (S21, S31, S41, S51) and isolation (S23, S45) of fourway microstrip power divider. The measured result of reflection coefficient is 2.83GHz totally shifted from the simulated result (2.44GHz). Figure 8 is illustrates the bandwidth value obtained from reflection coefficient (S11). The highest frequency obtained is 3.279 GHz and the lowest frequency is 1.439 GHz. The bandwidth of reflection coefficient is 1.84 GHz. It is achieved the objective of the project which is to design wideband four-way microstrip power divider.

As shown in Figure 9, the simulated insertion loss (S21, S31, S41, S51) is at 3.63GHz with -3.501 dB but shifted to 2.4 GHz with –7.3041 dB which is suitable to operate in WLAN application. The bandwidth value from the insertion loss (S21, S31, S41, S51) seems to be wide because there is definitely under -6 dB with no high-est and lowest frequency. Then, for the isolation of port 2 and port 3, the measured result shifted to 2.87 GHz with –54.601 dB as shown in Table 4. The bandwidth simulated result of isolation S23 at port 2 and port 3. The maximum frequency ob-tained is 4.232 GHz while the minimum frequency is 1.175 GHz. The value of band-width for this isolation is 3.06 GHz. The bandwidth simulated result of isolation S45 at port 4 and port 5 is absolutely same with port 2 and port 3. The value of isolation for port 4 and port 5 is 2.87 GHz with -43.112 dB.



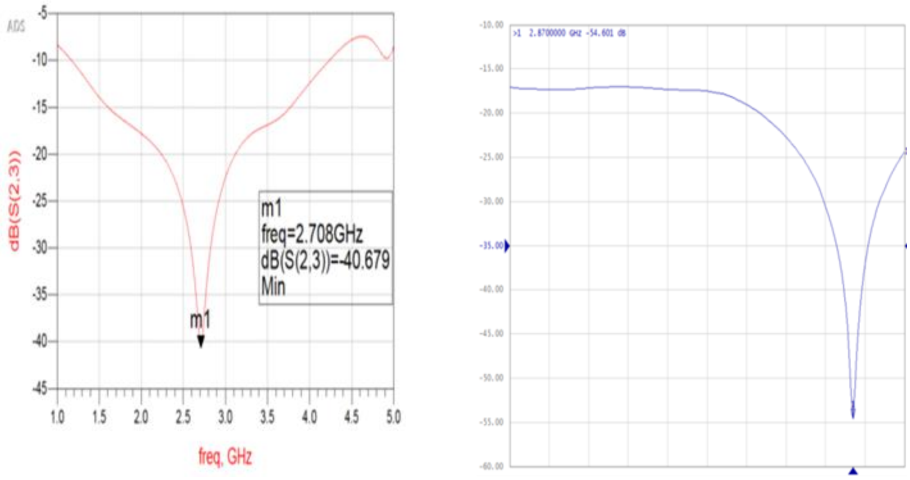
(a) (b)

Figure 7. Simulated result of reflection coefficient (S11) of four-way power divider. (b) Simulat-ed result of reflection coefficient (S11) of four-way power divider.



(a) (b)

Figure 8. (a) Simulated result of insertion loss (S_{21},S_{31},S_{41},S_{51}) of four-way power divider (b) Measured result of insertion loss (S_{21},S_{31},S_{41},S_{51}) of four-way power divider.



(a) (b)

Figure 9. (a) Simulated result of isolation (S23) of four-way power divider (b) Measured result of isolation (S23) of four-way power divider

Table 4. Simulated and Measured Result of Four-way Microstrip Power Divider

S-Parameter	Simulated Result		Measured Result	
	Frequency (GHz)	Magnitude(dB)	Frequency (GHz)	Magnitude(dB)
Reflection coefficient (S_{11})	2.443	-28.641	2.83	-23.311
Insertion Loss	3.63	-7.884	2.4	-7.3041
(S_{21},S_{31},S_{41},S_{51})				
Isolation (S_{23})	2.708	-40.679	2.87	-54.69
Isolation (S_{45})	2.709	-40.06	2.87	-43.11

4. CONCLUSION

The wideband four-way microstrip power divider is proposed. Basically, the four-way microstrip power divider is developed as the two-way microstrip power di-vider is combined. The two-way power divider is also known as Wilkinson power divider with one input port and two output port. But for the four-way power divider have five port which is one port of input port and four output port. It contains of several parts which is input port with 50 Ω feeding line, quarter wavelength with 70 Ω feeding line and 100 Ω isolation resistor and four output ports connected to the SMA connector on the feeding line. The advantage of the wilkinson power divider is has high isolation between his two output ports. However, the power divider is also has a drawbacks which is a narrow bandwidth. By designing the four-way microstrip power divider with quarter wavelength, the wide bandwidth is achieved. Fourway microstrip power divider is designed and simulated using Advance Design System (ADS) soft-ware and had been measured using Vector Network Analyzer so it can operates for WLAN application. Based on the observation, the simulated and measured results are obtained and seems to be balanced. For good performance of power divider for return loss and isolation must be lower deep below - 10 dB and for insertion loss must below -3 dB. All the parameters which is reflection coefficient, insertion loss and iso-lation were simulated and achieved the result of 2.443 GHz with - 28.641 dB, 3.636 with -7.884 dB and 2.709 with -40.679 respectively. All the parameters are able to operate in WLAN frequency range even though there are shifted when the measure-ment process. A wide bandwidth is achieved in the range of 1-3 GHz. So, the objec-tive of the project to design wideband four-way microstrip power divider is successfully attained.

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