RECTANGULAR PATCH MICROSTRIP ANTENNA WITH TRAPEZOIDAL-CUT GROUNDPLANE METHOD FOR ULTRAWIDEBAND

M Rifqi Naufal[1], Agus Dwi Prasetyo[2], Trasma Yunita[3]
[1] Telecommunication Engineering , School of Electrical Engineering , Telkom University
[1]naufalrifqi@student.telkomuniversity.ac.id,
[2]adprasetyo@telkomuniveristy.ac.id, [3]trasmayunita@telkomuniversity.ac.id

Abstract

The development of telecommunication technology for wireless communication both voice and data is growth very rapidly over the last two decades. This could potentially lead to lack of sources in a particular spectrum frequency. However there are fact that show the existence of gaps in occupancy frequency, Where some spectrum usage sometimes wasted. One of the problem in wireless communication is the availability of frequency spectrum. As more and more devices go wireless, future technologies will face spectral crowding, and coexistence of wireless devices will be a major issue. Ultrawide bandwidth offers attractive solutions for many wireless communication areas. In this undergraduate thesis the antenna that has a very wide operating bandwidth can overcome the the usage of the spectrum without interfering the narrowband system, higher capacity of users so that can be suitable for wireless communication system nowdays. The technique that used to obtain a wide bandwidth is by forming the antenna groundplane into trapezoidal-cut with rectangular patch for the antenna. Designing of a microstrip antenna with trapezoidal-cut groundplane antenna that works and reviewed in the frequency range 1-12 GHz is simulated using a software to investigate and obtain an antenna design that meets the proposed specifications and is followed by the realization of the bowtie antenna structure.The antenna is realized with the FR-4 substrate with dielectric constant 4.3 and thickness of 1.6 mm. The antenna simulation shows that the antenna works at frequency 8.53 - 12 GHz with bandwidth value is 3.41 GHz, VSWR value obtained is 1.13 at frequency 10.163 GHz. In the realization of the antenna measurements were obtained bandwidth of 3.11 GHz with frequency range 8.4 - 11.51 GHz, VSWR value obtained is 1.50 at frequency 10.163 GHz. From the antenna design and realization results show that the antenna has fulfil the antenna characteristic for ultrawideband characteristic.

Keyword— ***UWB, Trapezoidal-cut structure, VSWR, Bandwidth, Returnloss.***

1. Introduction

The development of telecommunication technology for wireless communication both voice and data is growth very rapidly over the last two decades. This could potentially lead to lack of sources in a particular spectrum frequency. However there are fact that show the existence of gaps in occupancy frequency, Where some spectrum usage sometimes wasted. One of the problem in wireless communication is the availability of frequency spectrum. As more and more devices go wireless, future technologies will face spectral crowding, and coexistence of wireless devices will be a major issue. Ultrawide bandwidth offers attractive solutions for many wireless communica- tion areas. With its wide bandwidth, UWB has a potential to offer a capacity much higher than the current narrowband systems for short-range applications and also to overcome the interference from the narrowband system. This is due to the capa- bility of these license exempt wide bandwidth wireless systems to yield low cost, low energy, short range, extremely high capacity wireless communications links UWB become a technology that which is often used as technology in the wireless communicaton.

Antenna with wide operating bandwidth that may be suitable as a sensing for wireless communication has been discussed by [1]. By forming the groundplane of the antenna that The simulated results of the proposed antenna have shown wide operating frequency bandwidth from 2.9 GHz up to 16 GHz, while themeasured results ranging from 3.1 GHz up to 12 GHz omnidirectional radiation pattern of the antenna. Another refference from the groundplane modification also has been discussed in [2] that the simulated result of the proposed antenna have shown wide operating frequency from 1500 - 2700 MHz with fractional bandwidth of the antenna is 57.14% with bandwidth value is 1200 MHz and gain of the measurement antenna is 6.15 and radiation pattern of the antenna is bidirectional.

With combining several methods from the reference, the writer then designing the Rectangular patch and adding a Trapezoidal-cut groundplane design, shape changing from the groundplane can affect several parameters of the antenna such as the gain of the antenna, the radiation pattern and widen the antenna bandwidth. This undergraduate thesis to find give a design of antenna that can be suitable for wireless communnication application. So therefore this undergraduate thesis carries out the trapezoidal-cut design to fullfill the specified specification of ultrawideband for wireless communication, antenna design is done using antenna simulator usign FR-4 substrate with material thickness 1.6 mm and relative permittivity of 4.3..

2. Research Method

2.1 Antenna Ultrawideband

Simulation design has been carried out using antenna simulation software. From figure 1 it can be seen that the proposed antenna with the Trapezoidal-Cut characteristics achieved by the method described in section 3 & 4. The antenna fabrication is designed using Epoxy - FR4 with constants dielectric (εr) = 4.3. with (h) 1.6 mm. With feedline width is 1.5 mm. The other parameters can be seen in Table 1. The comparison between the antenna it show that tha Trapezoidal-Cut Groundplane method can wider the bandwidth compare with the other method by reviewing some reference that discussed about the effect of reducing the antenna grounplane by forming the groundplane shape [3] and [4]

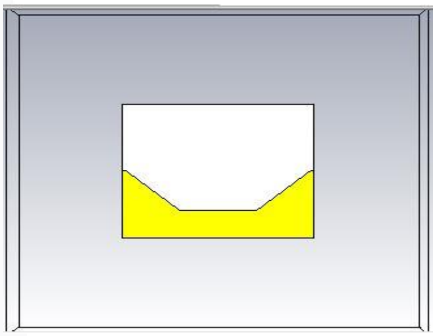

Fig. 1 – Structure of Trapezoidal-Cut Microstrip Antenna

The development of UWB has been discussed by Oliver Lodge [5] a wide variety of antennas are suitable for use in ultrawideband applications. Some of these are described elsewhere in a historical survey. UWB antennas may be classified as directional or non-directional. These classifications as well as the various types of UWB antennas will be considered in [6]. in 2002 there us a regulation for signal categorize for UWB, the bandwidth have to ≥500 MHz or have a fractional bandwidth (Bf) greater than 20 % [7]. (Bf) is a fractional bandwidth that define as a ratio of a signal bandwidth toward middle frequency and can be calculated by using,

$$Bf = \frac{\Delta}{fc} \qquad 2.1$$

Where the middle frequency (fc) and bandwidth (ΔF) is define as a working frequency range that can be determined by using

$$\Delta = f2 - f1 \qquad 2.2$$

Where (fl) and (f2) is the lower frequency and the higher frequency that received (FC) is the middle frequency or the cut off frequency, bandwidth is a range of frequencies where the antenna can transmit and receive power. UWB have so many advantages such as high data rate, small pathloss, and resist with multipath propagation, transceiver is more simple and very cheap, and low interference. Beside using Formula 2.1, fractional bandwidth can also determined by using this following formula

$$Bf = \left|\frac{2(Fh - Fl)}{Fh + Fl} \times 100\%\right| \quad 2.3$$

Where Fh is the highest frequency from the antenna and Fl is the lowest frequency of the antenna, from the equation 2.3 the fractional bandwidth of the antenna can be determined, This formula is a reference whether the antenna can be classified as an ultrawideband based on [7].

2.2 Trapezoidal-Cut Microstrip Antenna

Microstrip Antenna with Trapezoidal-Cut groundplane is one of the method to wider the bandwidth of the antenna. The design of the antenna was combine from several method in two journal[8][9]to design the optimal groundplane of the microstrip antenna in order to obtained a wider bandwidth. The first method is by modified the groundplane. The half groundplane was modified with a shorter inside that resembles to the shape of trapezoid. This form gives a smooth transition and prodices a wide impedance bandwidth. The twin triangle on the top of the trapezoidal groundplane generates an additionally resonant. By choosing the rectangular shaped dimension for the patch of the antenna. The frequency response can be improved . The second method is by cutting the sleeve of the trapezoidal . This cutting is usefull to change the antenna characteristic impedance. This traoezoidal-Cut will decrease the lower limit of the returnloss, and then the bandwidth will be widened. The Trapezoidal-Cut in order to give more resonance frequency. The last method by reducing the size of the Grounplane, by reducing the Groundplane the bandwidth value is change, the changing of the groundplane size also affect to the returnloss value . A lot of study of parametric was done to get the optimum size of the groundplane like the study that has been discussed in journal [1][8] This trapezoidal-cut shaped design is use trial and error method to defined the optimal shaped of the trapezoidal-cut method and a lot of parametric study was done to get the optimum size of the groundplane.

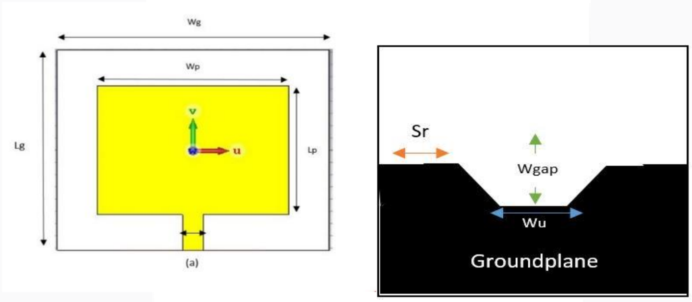

Fig. 2 – UWB Antenna That Proposed

To achieved the characteristic of the Ultrawideband the Groundplane of the antenna is been modified like an erupted mountain shape (Trapezoidal-Cut) by using trial and error method referring from the last refference [9]. The shape of the Trapezoidal is been optimized to achieved the specified bandwidth. The dimension of the Trapezoidal-Cut groundplane is been optimized to achieved a wider bandwidth . Basic antenna shape is an rectangular with a strip line feeder.

3. Design and Simulation of The Antenna

The purpose of this research is to get a microstrip antenna with a wider bandwidth by comparing four types of groundplane models, which are model (a), model (b), model (c), model (d), the models of the antenna that be observed are rectangular micsrostip antenna patch with full groundplane, antenna model (b) is half groundplane the modification of model a by reducing the groundplane size into half, next antenna model (c) is trapezoidal groundplane, the modification of model b by forming the groundplane into trapezoidal with sleeves, and the last model is microstrip antenna model (d) that is trapezoidal-cut by cutting the sleeves from model (c)

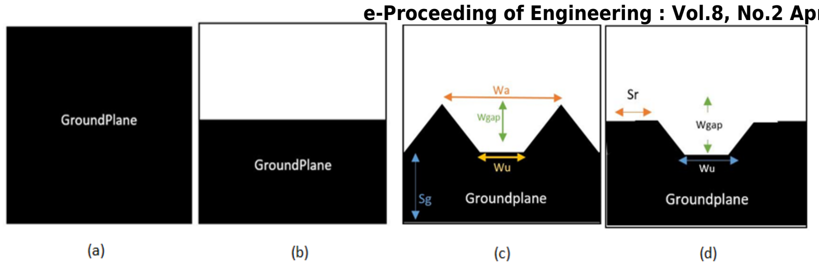

Fig. 3 – Antenna Model (a); Antenna Model (b); Antenna Model (c); Antenna Model (d)

Table 1 - The Specification of The Antenna

No	Parameter	Specification
1	Frequency	1 – 12 GHz
2	Bandwidth	UWB
3	Return Loss	≤ -10 dB
4	VSWR	≤ 2
5	Radiation Pattern	Omnidirectional

3.1 Antenna Model 1

Before designing the final design of the antenna several steps were performed to compare the capability of each design. The result of the initial value of the antenna model is not optimal with returnloss value -11.83 dB. So therefore the optimiation are needed to obtained a optimal performance of the antenna.The optimization was done by changing the dimension of the antenna, the patch of the antenna and also the feederline so that the antenna has a good performance, the returnloss value from antena optimization is -14.58 dB the intial and optimization value can be seen in Table 2. From the optimization value it can be seen that there is an improvement, the more greater value from the specified returnloss value, so the antenna have a more better performance too, because less power that reflected from the antenna and more transmitted power from the antenna, The graphic comparison of returnloss value of initial value and optimization value of antenna can be seen in Fig 4. From the optimization it can be seeen wether there is improvement in returnloss but the bandwidth is still narrow and not achieved the specified bandwidth specification based on Table 1

Table 2: Antennna Model 1 Before and After Optimization

	Value (mm)		
Variable	**Initial**	**Optimization**	**information**
Wp	14.17	13.96	Patch Width
Lp	10.76	10.50	Patch Length
Wg	23.77	19.8	Ground Width
Lg	20.1	16.3	Ground Length
Wf	3.11	1.5	Feedline Width

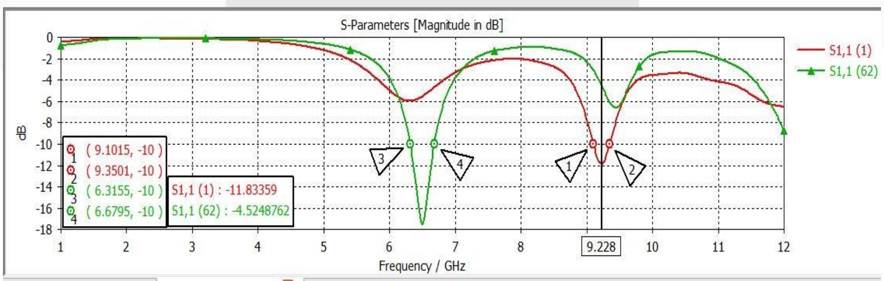

Fig. 4 – Returnloss Value of Antenna Model 1 Before And After Optimization

3.2 Antenna Model 2

Antenna model 2 is thr next stage from the antenna mode l. In this step, the antenna model 2 is the modification from antenna model 1, in this stage the groundplane of the antenna is been reduce into half groundplane, but the initial value from the halfgroundplane antenna is based on the optimization value from antenna model 1, from the initial value, the antenna has value of returnloss is -7.911, it can be seen that the value is not achieved its specified specification, so therefore optimization are needed, the optimization precess is done by changing the dimension of the groundplane and patch of the antenna, the antenna optimization has a value of returnloss -26.13 dB, the comparison value of initial value and optimization can be seen in Table 3. The graphic comparison of returnloss between intial value and optimization value of antenna model 2 can be seen in Fig. 5. From the optimization result it can be seen wether there is an improvement in the bandwidth from model 1, but there is a frequency shift from model 2.

Table 3: Antennna Model 2 Before and After Optimization

	Value (mm)		
Variable	**Initial**	**Optimization**	**information**
Wp	13.96	16.12	Patch Width
Lp	10.50	12.76	Patch Length
Wg	19.8	35.72	Ground Width
Lg	16.3	31.12	Ground Length
Wf	1.3	1.3	Feedline Width

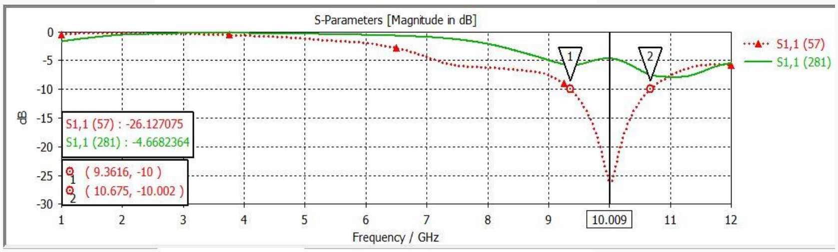

Fig. 5 - Returnloss Value of Antenna Model 2 Before and After Optimization.

3.3 Antenna Model 3

Antenna model 3 is the next stage from the antenna mode l. In this step, the antenna model 3 is the modification from antenna model 2, in this stage the groundplane is been modifid into trapezoidal groundplane, this shape is like a mountain that has sleeves, the initial value from the trapezoidal groundplane antenna is based on the optimization value from antenna model 1, , there is variableis need to be added for this trapezoidal method, namely Sg, Wgap, Wu, Wa, Ta. From the initial value, the antenna has value of returnloss is -5.203 dB, it can be seen that the returnloss value is not achieved the specified specification, so therefore optimization are needed, the process of the optimization is been done by optimizing Sg, Wgap, Wu, Wa, Ta variables by using trial and error method. From the optimization value it can be seen that the returnloss value of the antenna is -28.71 dB The comparison between initial value and optimization can be seen in Table 4. The graphic comparison of returnloss between intial value and optimization value of antenna model 3 can be seen in Fig. 6. From the optimization result, there is an improvement in the bandwidth from model 1 and 2, but there is a frequency shift from model 3. The bandwidth value has achieved the specification of ultrawideband.

Table 4: Antennna Model 3 Before and After Optimization

	Value (mm)			Value (mm)	
Variable	Initial	optimization	Variable	initial	optimization
Wp	13.96	13.96	Sg	4	5.3
Lp	10.50	10.50	Wgap	2	4.75
Wg	19.8	19.8	Wu	1	3.75
Lg	16.3	16.3	Wa	3	8.75
Wf	1.5	1.5	Ta	0	0

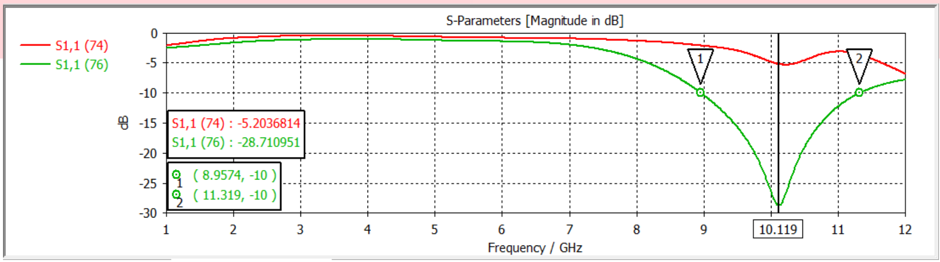

Fig. 6 – Returnloss Value of Antenna Model 3 Before and After Optimization.

3.4 Antenna Model 4

Antenna model 4 is the last stage from the antenna method. In this step, the antenna model 4 is the modification from antenna model 3, in this stage the groundplane is been modified into trapezoidal-cut groundplane, this shape is done by cutting the sleeves of antenna model 3, the initial value from antenna model is based on the optimization value from antenna model 1, There is variables needed to be added to design antenna model 3, namely Wgap, Wu, Sr, this variable is done by using trial and error method. From the initial value, the antenna has value of returnloss is -10.93 dB, but the bandwidth is still not wide, so therefore optimization are needed. The process of optimization is done by changing the variable value of Wgap, Wu, Sr, from the optimization value it can be seen that the returnloss value of the antenna is -23.71 dB, the value comparison from initial value and optimization can be seen in Table 5. The graphic comparison between intial and optimization value of antenna model 3 can be seen in Fig.7. From the optimization it can be seen there is a significant improvement in the bandwidth from model 1, 2 and 3, but there is a frequency shift from model 4. From the bandwidth it can be seen that the bandwidth has achieved the specification of ultrawideband antenna based on Table 1. The result and analysis of the antenna performance will be analyzed at the next chapter.

Table 5: Antennna Model 4 Before and After Optimization

	Value (mm)			Value (mm)	
Variable	Initial	optimization	Variable	initial	optimization
Wp	13.96	13.96	Wf	1.5	1.5
Lp	10.50	10.50	Wgap	2.5	4.8
Wg	19.8	19.8	Wu	1.5	3.98
Lg	16.3	16.3	Sr	6.5	9.5

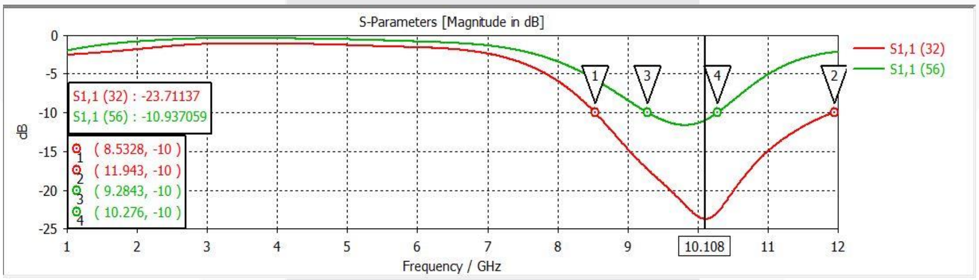

Fig. 7 – Returnloss Value of Antenna Model 4 Before and After Optimization

4. Measurement Result

The simulated antenna was fabricated using 1.6 mm FR-4 epoxy, that can be seen in Fig. 7. The measuremetnt result are shown in Fig. 8. Until Fig. 11. It can be seen that from antenna model 4, the measurement result is quite similiar with the simulation result. Fig 8. The measured result is different from the simulation, the measurement result is narrower than the simulation. The measurement result is performed at the frequency 1 - 12 GHz, however based on the simulation, the measurement was performed at frequency 6.2 – 6.8 GHz for microstrip antenna with full groundplane and 8.4 – 12 GHz for trapezoidal-cut this frequency shift occur due to the changing in groundplane.

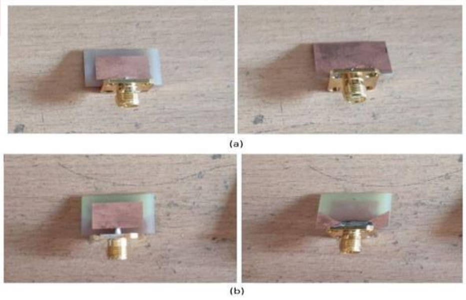

Fig. 8 – Fabricated Antenna (a) Rectangular Antenna with Full Groundplane, (b) Half Groundplane, (c) Trapezoidal Groundplane, (d) Trapezoidal-Cut Groundplane

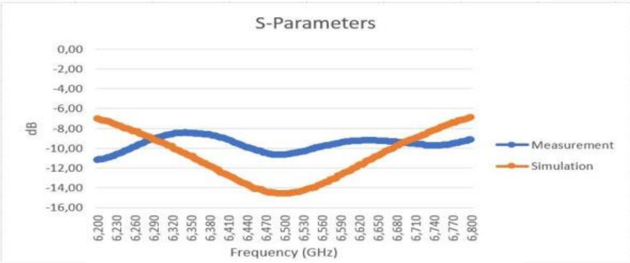

Fig. 9 – The Comparison Result between Measured and Simlated Sntenna Model 1

It can be seen from Fig. 9, the bandwidth comparison between simulation and measurement of microstrip antenna model 1 based on returnloss. From the graph it can be seen that the measurement result of the microstrip antenna model 4 has a narrow bandwidth with different frequency range that is at frequency 6.2 - 6.25 GHz with bandwidth value is 0.05 GHz and fractional bandwidth is 0.86%, and from frequency 6.44 - 6.54 GHz with bandwidth value is 0.10 GHz with fractional bandwidth Value is 1.56%, it can be seen from the bandwidth value and the frequency range that. Otherwise from the simulation has a bandwidth value is 0.38 GHz and fractional bandwith value is 6.67% with frequency range 6.30 - 6.68 GHz.

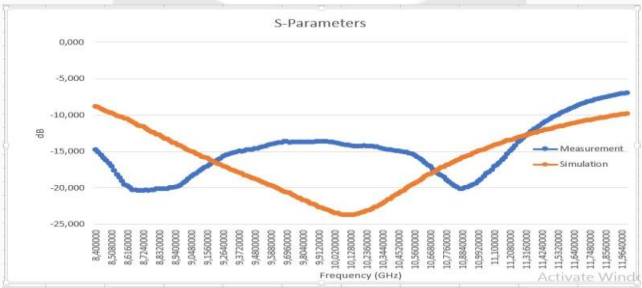

Fig. 10 – The Comparison Result Between Measured and Simlated Antenna Model 4

From Fig.10, is the bandwidth comparison between simulation and measurement of microstrip antenna model 4 method based on returnloss. From the graph it can be seen that the simulation result of the microstrip antenna with trapezoidal-cut has a wide bandwidth with frequency range 8.53 – 12 GHz, bandwidth value is 3.41 GHz and has fractional bandwith value is 33.73%, otherwise from the measurement result has a bandwidth value 3.11 GHz with frequency range 8.4 – 11.514 GHz and fractional bandwith value is 31.27%.

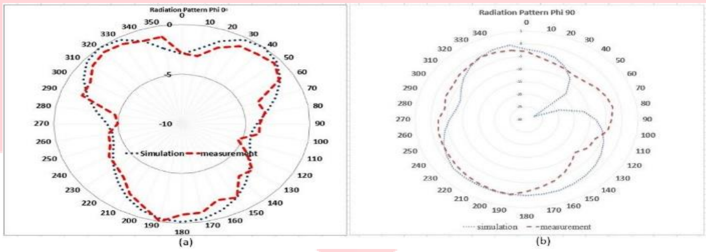

Fig. 11 – The Radiation Pattern of Simulated and Measured Result From Antenna Model 4, (a) Azimuth, (b) Elevation

The antenna radiation pattern measured at 10.20 GHz, it can be seen from Fig. 12. The radiation pattern of antenna model 3 is more like omnidirectional in elevation plane and more like bidirectional in azimuth plane, the electromagnetic energy radiate to the front and rear of the antenna in azimuth plane and and all directions in the elevation plane. This can be occured because the affect of forming the shape of the groundplane, because the groundplane function of the antenna is as a reflector which minimizes the backward radiation.

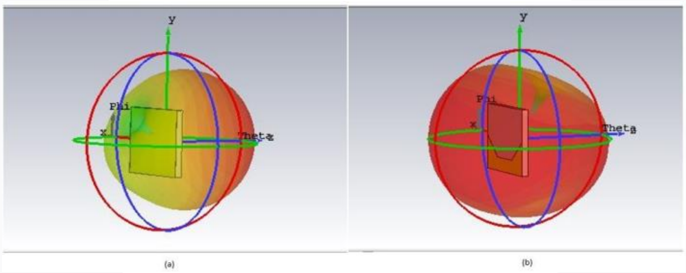

Fig. 12 – The Gain of Simulated and Measured Result From: (a) Antenna Model 1, (b) Antenna Model 4

From gain simulation result that can be seen in Fig. 12, microstrip antenna with full groundplane method has 2.714 dB gain power at frequency 6.5 GHz, and from the simulation of microstrip antenna with trapezoidal-cut groundplane method has 3.196 dB gain power to theta negative at frequency 10.20 GHz. Otherwise from the simulation result, microstrip antenna model 1 method has 2.252 dB gain power at frequency 6.5 GHz and microstrip antenna model 4 has gain of the antenna is 7.34 dB gain power to theta negative at frequency 10.10 GHz, based on the calculation by using Equation (2.7) and (2.8). it can be seen that the radiation pattern from the antenna model 4, simulation and measurement has gain power to theta negative, this can be occur because the affect from modifying the groundplane of the antenna.

6 Conclusion

This research has designed a rectangular patch with trapezoidal-cut groundplane for UWB application, the antenna is designed with FR-4, from this undegraduate thesis the simulation result and measurement result of the antenna is quite different, with bandwidth value of the antenna model 4 is 3.41 GHz from the simulation and 3.11 GHz from the measurement result. Model 4 antenna has achived the UWB fractional bandwidth minimum value which is 20%, the fractional bandwidth from antenna model 4 is 33.73% from simulation and 31.27% from measurement, another specification for UWB also has been achieved from antena model 4, which is the intended radiation pattern for UWB is omnidirectional, from the simulation and measurement, the antena model 4 has bidirectional radiation pattern in azimuth plane and omnidirectional in elevation plane. The changing of groundplane structure affect the gain value of the antenna model 4, gain value that obtained from the simulation is 3.196 dB gain power to theta negative and gain value from the measurement is 7.34 dB gain power to theta negative at frequency 10.10 GHz. It can be concluded that the antenna model 2 has fulfil the intended specification for UWB application.

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