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Design Compact Monopole Antenna with Modified Trapezoidal Shaped Ground Plane for 8.5 GHz Application

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ABSTRACT

In this work, a monopole antenna with the trapezoidal shaped ground plane had been fabricated.This antenna is using the technology of microstrip for radar application. The aim of this work is to improve the gain compared with common microstrip and favored reflection coefficient bandwidth by inserting a rectangular break at the circular patch and designs a trapezoidal shape ground plane. The resonant frequency of the antenna is 8.5 GHz and the return loss is better than – 10.00 dB. The design and simulation process are using Computer Simulation Technology (CST) Microwave Studio simulation software. The results of measurement and fabrication process are compared with the simulation result. The result is important in designing an antenna that can operate in radar application using an Ultra-wideband spectrum.

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INTRODUCTION

Nowadays, due to high demand of the compact size and high gain antennas. The high gain and the compact size had been the important characteristic in designing the antennas. To achieve the compact size of the antenna design, a microstrip patch antenna had been used as it had an advantage of smaller cost and also light weight. Microstrip patch antenna consists of a radiating patch on one side of dielectric substrate which has a ground plane on the other side. The patch is generally square, rectangular, monopole (Ahmad, B.H., *et. al.*, 2013), circular (Zani, M.Z.M., *et. al.*, 2010), triangular, elliptical or unique shape such as Minkowski (Malek, F., *et. al.*, 2012), Sierpinski carpet (Saidatul, N.A., *et. al.*, 2009), Koch Fractal (Ismahayati, A. *et. al*, 2011) and others.

The design of the directional monopole antenna must meet requirement of the small size for ease of use when been used for patient monitoring since it application is for the breast cancer imaging by using the microwave frequency (Nilavalan, *et. al.*, 2007). The requirement design for the antenna is the antenna size, ultra wideband radiation for short pulse transmission, best impedance and operating bandwidth (Shannon, C. J., *et. al.*, 2005). There are so many guides on designing the radar based of directive antenna application, and type of high gain antennas for the application. An example of the high gain type is such as the horn and the Vivaldi antenna (Lizhong, S., *et. al.*, 2011), while the compact antenna such as the patch antennawith slot (Wang, H., *et. al.* 2008, Abd Aziz, *et. al*, 2013)). But it confronts a lake in its size and the limitation of the bandwidth and operating frequency (Klemm, M, *et. al.*, 2005, Lu, Y., *et. al.*, 2009).

The size of the antenna is the main attributes to be considered when designing the antenna for the breast cancer imaging using microwave based. Dramatically, the purpose of this paper is to design the compact and tolerable high gain with a favored reflection coefficient bandwidth to use in the application. The design of the trapezoidal ground plane and the parasitic element are precisely done so that the surface current will spread out to the direction needed. This process will increase the density of the radiation to favored path. The circle break and the ground plane will also increase the antenna bandwidth of the reflection coefficient.

From the literature review, it is also shown many types of the directional monopole antenna that had been designed previously. (Locatelli, A., *et. al.*, 2007) had been designed a directional planar ultra-wideband (UWB) antenna for radar applications.This antenna is focusing to increase the directivity, develop UWB antenna, acceptable return loss and gain between frequency of 6.0 GHz and 8.00 GHz.

(Mokhtaari, M., *et. al.*, 2008) had been introduced the compact UWB antenna using directional monopole at the patch and a combination of parabolic-shaped ground plane technique to get the high directivity and high gain

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Australian Journal of Basic and Applied Sciences, 8(4) Special 2014, Pages: 294-300

antenna. The return loss of this antenna is better than 9.500 dB in the frequency range of 3.100 GHz and 12.600 GHz. The proposed of this parabolic-shaped is to operate as a reflector in UWB frequency range.

(Golezani, *et. al.,* 2012) presented modified directional wide band monopole antenna for radar and also microwave imaging applications. This antenna also used the symmetrical parabolic-shape ground plane with some curve modification in the design. The advantages of this symmetrical parabolic-shaped is symmetrical and optimum convergence of the radiation pattern of the antenna. This antenna operates in the frequency range between 4.00 GHz and 9.00 GHz with high directional radiation pattern and ultra-bandwidth (UWB) effect.

A radar operates by radiate the electromagnetic energy and detected the echo return from reflecting object (Toomay, J., *et. al.,* 2004). One of the microwaves imaging application is detecting the breast cancer. Microwave breast imaging is based on the electrical property contrast between malignant breast tissues and healthy (Stang, J. P., *et. al.,* 2008, Hariyadi, *et. al.,* 2011). Thesetwo antennas are able to detect the tumors such as breast cancer in the human body. This proposed antenna works at a frequency of 8.50 GHz for radar applications with requirement of better – 10.00 dB of return loss.

There are many researches that focused on the radar applicationin the antenna design such as in these following papers: (Romano, N., *et. al*, 2009, Hainovich, A. M., *et. al*, 2008, Beer, S. *et. al*. 2010, Arima, T. *et. al*, 2013).

2. Antenna Design:

The structure of the monopole antenna with the modified trapezoidal shaped ground plane is designed using CST Microwave Studio software. This antenna consists three main parts – patch antenna with feedline, substrates and the ground plane. On the front side of the antenna is a semicircular shape patch with the rectangular shape feedline. The radius of semicircular patch is 7.00 mm from calculating work while 8.00 mm of dimension after the optimization stage. Fig. 1. Shows the schematic diagram of a monopole antenna with modified trapezoidal shaped ground plane in different views.

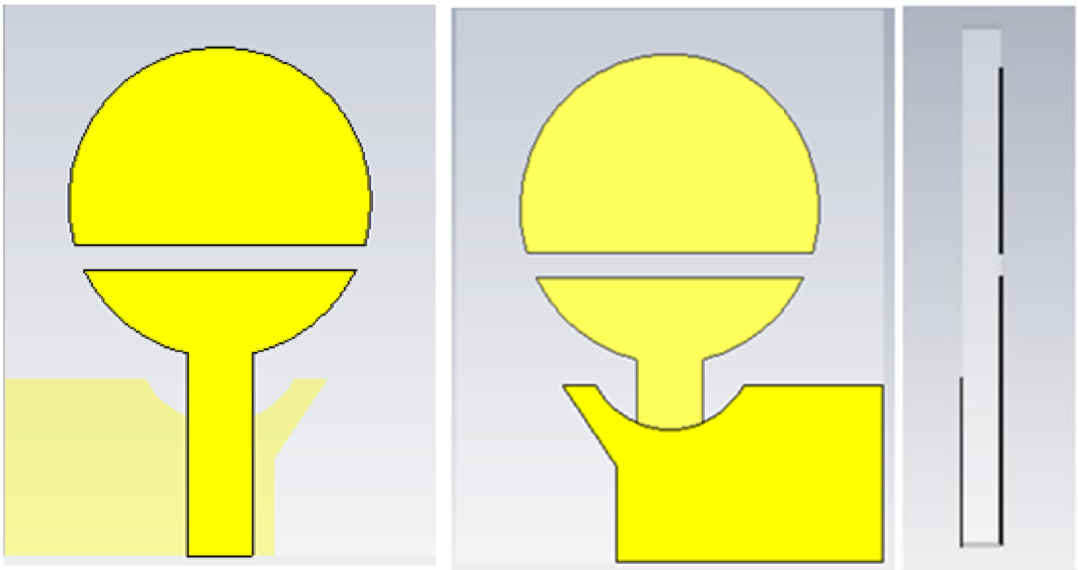

Fig. 1: Schematic diagram of monopole antenna with modified trapezoidal shaped ground plane, (a) front view, (b) back view, (c) side view.

At back side is a modified trapezoidal shape of ground plane. Planar use to compose of a semicircular monopole, fed by a 50 Ω microstrip line printed on an FR4 substrate. This ground plane and parasitic element are designed to make the surface currents of radiating elements to move toward the desired direction. The ground plane also is deformed to improve the directivity and the gain of the antenna. The right side of the ground is cut to remove the radiation in the undesired direction. The cut segment is in trapezoid shape and a semicircular break.

The technique that use is broken circle shaped and the deformed design of the ground plane to improve the reflection coefficient, bandwidth and gain of this compact antenna. The requirement reflection coefficient bandwidth of the antenna must more than 0.5 GHz at 8.5 GHz and gain of the antenna is reached over 1.3 dB of gain at the desired frequencies. Fig. 2 and Table 1 shows the proposed antenna specifications and antenna structure.

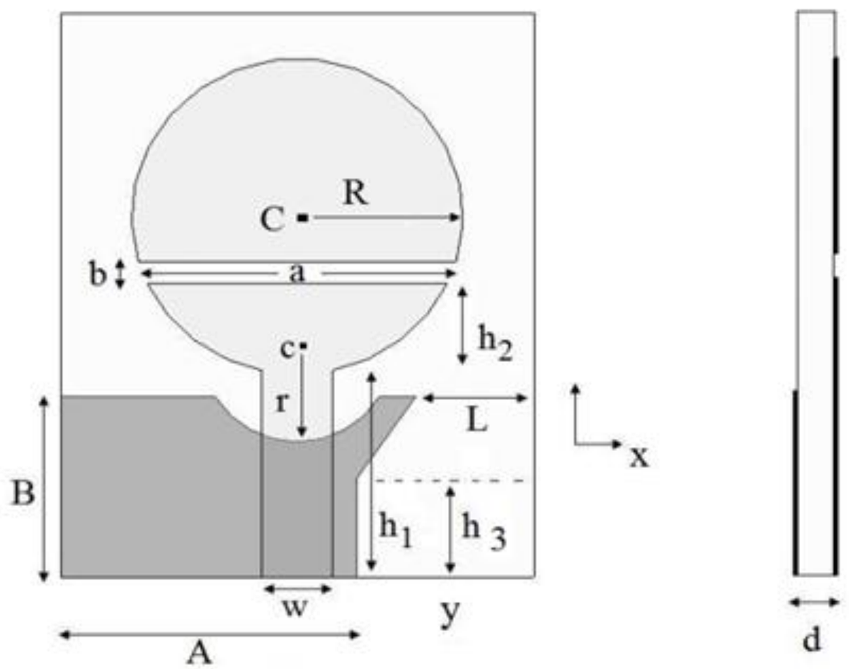

Fig. 2: The dimension of monopole antenna with modified trapezoidal shaped ground plane.

Table 1: Dimension ofMonopole Antenna with Modified Trapezoidal Shaped Ground Plane.

Parameters	Actual dimension from calculattion (mm)	Optimization dimension (mm)
Impedance matching width, *w*	3.063	3
Length of ground plane, *A*	12.5	12.5
Width of ground plane, *B*	8.534	8.0
Radius circle, *R*	7.0	8.0
Circle break dimension, *a* and *b*	*a* = 13.4 *b* = 1	*a* = 15.4 *b* = 1.5
Height of trapezium, h_1 and h_3	h_1=9.16 h_3=3.86	h_1=9.16 h_3=3.86
Length of trapezium, *L*	5.0	5.0
Height of break, h_2	3.86	3.79

Result:

This section focused on the resonant frequency, return loss, radiation pattern and also the gain performance of the monopole antenna with the modified trapezoidal shaped ground plane. Fig. 3 shows the return loss of the monopole antenna with the modified trapezoidal ground plane. The bandwidth of this antenna is 562 MHz between 8.047 GHz and 8.628 GHz.Even though the actual maximum resonant frequency is 8.335 GHz with return loss - 12.253 dB, but for radar application, the desired resonant frequency is at 8.5 GHz with return loss - 11.230 dB. Besides that, the results from the radiation pattern (simulation) is shown in Fig. 4. The pattern shows that it has the directional antenna design.

Fig. 5 shows the fabricated directional monopole antenna with the trapezoidal ground plane. This fabricated antenna is using the same material and the same substrate like his simulation design. This antenna is used FR-4 substrate because of lightweight and low cost. Fig. 6 shows the return loss of the directional monopole antenna with trapezoidal ground plane (measured by network analyzer).

Table 2 represents the comparison result between simulation and measurement of the antenna.The gain of the fabricated antenna is 1.860 dB while the simulation result is 2.324 dB.During calibration with spectrum analyzer, the results obtained are better than simulation. Return loss that obtained is - 14.376 dB at a frequency of 8.5 GHz. The bandwidth for measuring antenna is 1.86 dB. Fig. 7 shows the measured radiation pattern for monopole antenna with modified trapezoidal ground plane.

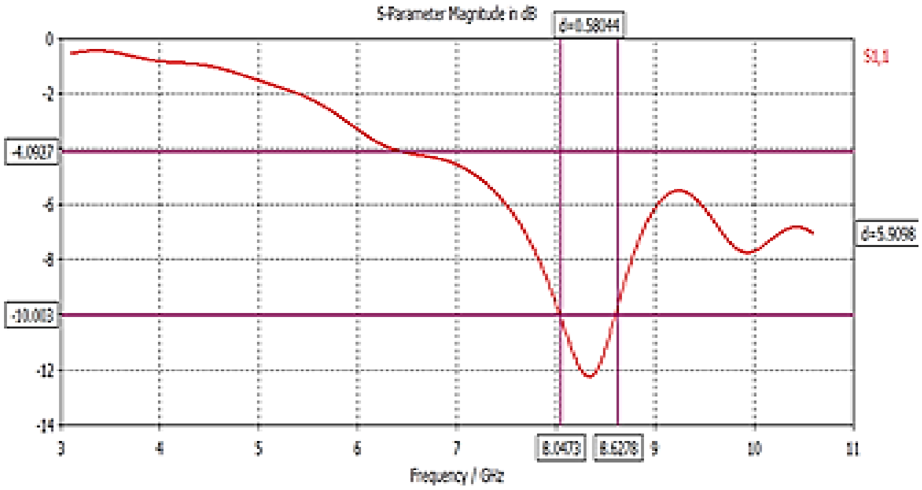

Fig. 3: Return loss of the monopole antenna with modified trapezoidal ground plane.

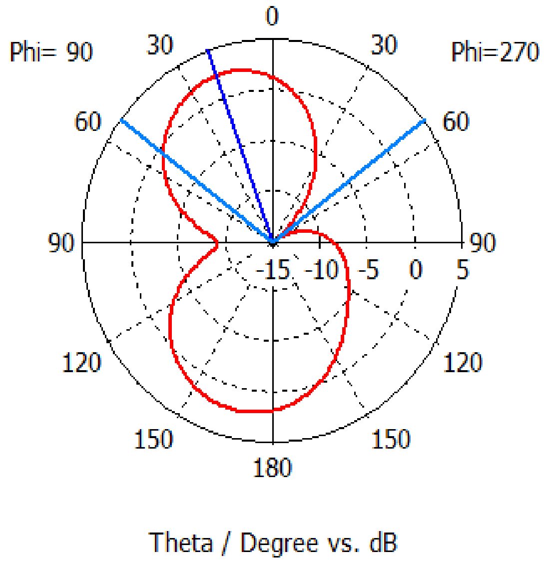

Fig. 4: Radiation pattern of the monopole antenna with modified trapezoidal ground plane (simulation).

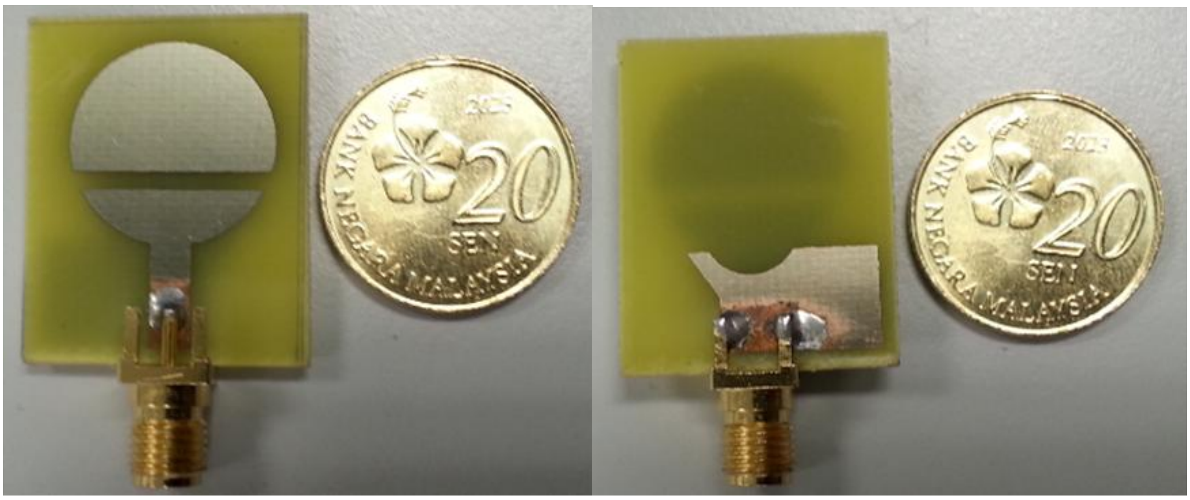

Fig. 5: Fabricated monopole antenna with modified trapezoidal ground plane, (a) front view and (b) ground plane view.

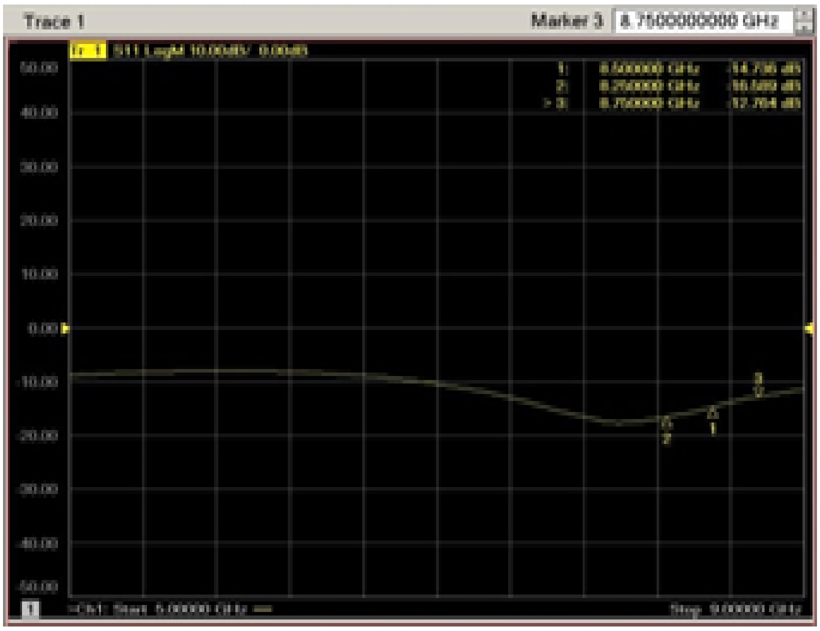

Fig. 6: Return loss of the directional monopole antenna with trapezoidal ground plane (measured by network analyzer).

Table 2: Comparison Result Between Simulation and Measurement.

Parameters	Simulation	Measurement
Resonant frequency	3.063	3
Return loss	12.5	12.5
Bandwidth	8.534	8.0
Gain	7.0	8.0

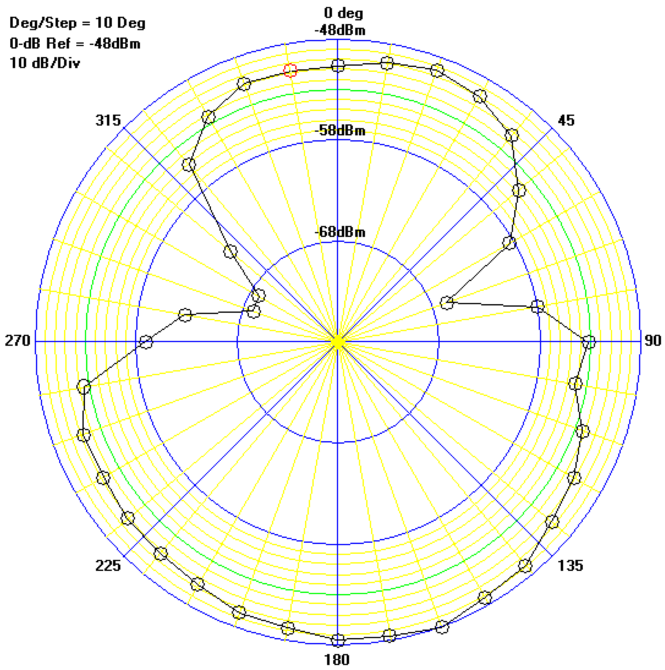

Fig. 7: The radiation pattern of the monopole antenna with modified trapezoidal ground plane (measured).

This simulated and the fabricated antenna can increase its parameters performance by applyingother techniques such as stacked patch, coplanar waveguide-fed or integrate split ring resonator (SRR) structure of the patch antenna. This proposed microstrip antenna capabilityto integrate with other devices such as an oscillator (Yoo, S. -S.,*et. al*, 2011),amplifier (Othman, A. R., *et. al.*, 2013, Othman, A. R., *et. al*, 2010), RF filters (Zakaria, Z., *et. a.l*, 2013, Zakaria, Z.., *et. al*, 2012, Zahari, M. K.., *et. al*, 2013), and also RF switch (Shairi, N. A., *et. al.* 2013, Misran, M. H.., *et. al.* 2011) to generate a complete system of the RF front-end transceiver.

Conclusion:

The monopole antenna for radar Application was fabricated and simulated successfully. Comparison between simulation and fabrication also been done to show the performance of the antenna. The ground plane of the antenna is designed in order to achieve a directional radiation and high gain. Using break on the circular patch and the top semi-circular element as a parasitic element, also deforming the ground plane, very good reflection coefficient bandwidth is obtained. For measurements confirm that a reflection coefficient is better than – 10.00 dB at 8.5 GHz, gain of the antenna has reached over 1.3 dB. We have achieved our objective in design and fabricate the directional monopole antenna for radar application. We manage to get the desire gain, bandwidth and return loss from the simulation and measurement process.

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