VOL. 9, NO. 10, OCTOBER 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DESIGN AND CONSTRUCTION OF EGG SHAPED MICROSTRIP ANTENNA WITH CIRCULAR SLOT FOR ULTRA WIDEBAND FREQUENCY (UWB) APPLICATIONS

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ABSTRACT

We proposed an egg shaped microstrip antenna with circular slot for Ultra Wideband Frequency (UWB) applications. The Antena was investigated by performing simulation and measurement. The antenna was fabricated on Phenolic White Paper materials - FR4 with dielectric constant (ε_r) = 4.5 and thicknes of 1.6 mm. From simulations and measurements, our antenna achieved UWB operating frequency of 1000 to 2700 MHz with a bandwidth of 1700 MHz. The highest gain value located at a frequency of 1.5 GHz of 5.25 dBi. The radiation pattern of antenna is bidirectional.

Keywords: antenna, ultra wideband, slots, egg.

INTRODUCTION

One of the fundamental problems in the wireless technology being solved is the need for a wide bandwidth with high data rates. The Ultra Wideband Frequency (UWB) technology could be deployed to solve this problem. UWB is a short range communication system having a wide bandwidth. System can be categorized as an ultra wideband communication if the bandwidth is greater than 500 MHz, or a fractional bandwidth greater than 20% [1].

Microstrip antenna applied in this paper was a single microstrip patch antenna. The radiating element had an egg-shaped and a circular slot in the ground plane. The material of the antenna was FR4 substrate for achieving operating frequency of 1000 to 2700 MHz that has bandwith greather than 500 MHz and has fractional bandwidth greater than 20%.

The fractional bandwidth was calculated using the formula [2]:

$$\text{Fractional Bandwidth} = \left| \frac{2(fh - fl)}{fh + fl} \times 100\% \right| \quad (1)$$

where fh = the highest frequency (Hz) and fl = the lowest frequency (Hz).

ANTENNA DESIGN

The initial step of designing the antenna is to determine the desired operating frequency, the shape of patches, and the substrate used. The egg-shaped patch was constructed by combining a halved circle and a halved ellipse. The small circle diameter was 22, 5 mm (r = 11.25 mm) and the ellipse primary diameter was 22 mm (see Figure-1).

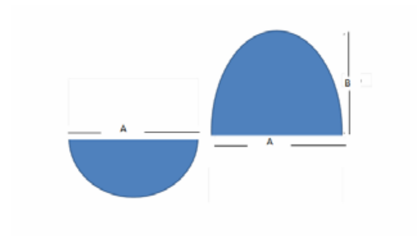

Figure-1. The structure of the egg antenna.

The minimum dimension of the ground plane required in the microstrip antenna is given by formula [3]:

$$L_g = 6h + 2R \quad (2)$$

$$W_g = 6h + \frac{\pi}{2} R \quad (3)$$

where h = thickness of substrate (mm)
R = radius of circular patch (mm)
Lg = minimum length ground plane (mm)
Wg = minimum width ground plane (mm)

The radius of the radiating element a in antenna Figure-2 can be calculated using the equation [2]:

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1{,}7726\right]\right\}^{1/2}} \quad (4)$$

h = thickness of substrate (m)
ε_r = relative permittivity of the dielectric substrate (F/m)
F = logarithmic function of the radiating element
The logarithmic function F is calculated by [2]:

$$F = \frac{8{,}791 \times 10^{9}}{f_r \sqrt{\varepsilon_r}} \quad (5)$$

f_r = operating frequency of the antenna (Hz)
ε_r = relative permittivity of the dielectric substrate

Feeding type of the egg radiating element antenna is a transmission line that has distance to the radiating element [2] [4].

Specifications of conductor and substrates materials used of antennas are as follows:

Dielectric material: Phenolic White Paper - FR 4
Dielectric constant (ε_r) = 4.5
Thickness (h) = 1.6 mm
Loss tangent ($tan\ \delta$) = 0.018

The dimensions of radiating element based on the working frequency (fr). Working frequency was 1000-2700 MHz had centre frequency of 1.85 GHz.

Using equations [1], [3] [4] and [5] for centre frequency of 1.85 GHz, the radius of the antenna patch was 22.4 mm. For transmission line width (W) of 2.75 mm for 50 Ω impedance and length (L_t) transformers channel is 0,162 λ_d, where λ_d is wavelength the centre frequency of 1.85 GHz equal to 0.0557 m so that, L = 0.162 λ_d = 19 mm. The minimum length of the ground plane dimensions (L_g) was 54.6 mm and a minimum width of ground plane (W_g) was 44.92 mm.

To improve the performance and enhance bandwidth of the antenna in microstrip antenna, could be done by adding a circular slot on the ground plane.

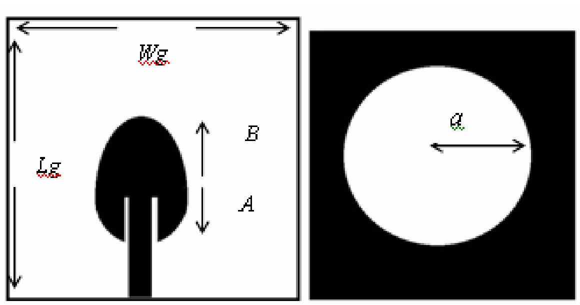

Figure-2. Egg antenna with circular slot (a) front view (b) back view.

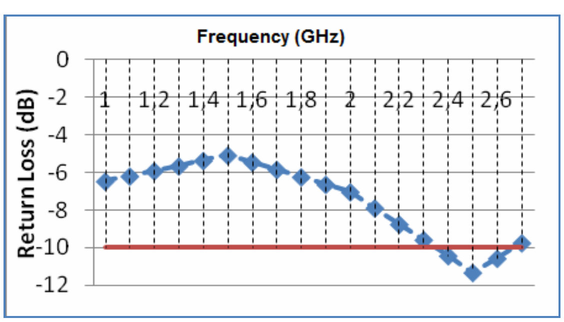

Figure-3. Return loss of the proposed antenna (before optimizations).

The simulation result of Return Loss of the proposed antenna is shown in Figure-3. It reveals that the original design did not fulfill the desired performance due to the bandwidth less than 500 MHz. Therefore, the antenna was not eligible for UWB antenna technology application. Thus, it needs to be optimized to obtain satisfactory results.

OPTIMIZATION OF MICROSTRIP ANTENNA

Optimization was done by varying the radius of the patch, the length of the transmission line, the dimensions of the circle and the ground plane slots. The dimensions of radiating elements, transmission lines, circles slot after optimization is shown in Table-1.

Table-1. Antenna dimension after optimization.

Variable	Dimension (mm)
A (primary diameter patch)	22.5
B (secondary radius patch)	22.5
L (length of the transmission line)	16
W (width of the transmission line)	2.75
Lg (minimum length ground plane)	76.8
Wg (minimum width the ground plane)	70
a (radius slot)	33.6

The simulation results of the optimized egg antenna with circular slot on the ground plane is shown in Figure-4.

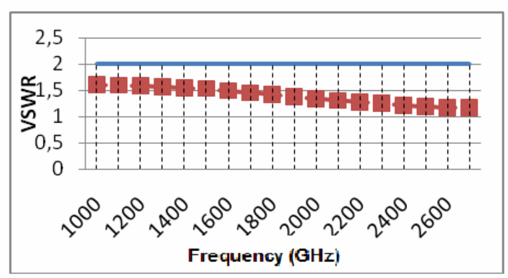

Figure-4. VSWR antenna (after optimizations).

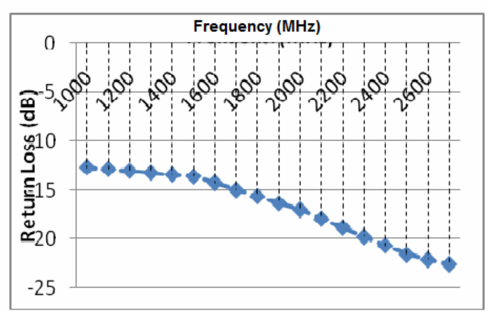

Figure-5. Return loss (after optimizations).

Since the VSWR was less than 2 (see Figure-4) and the return loss was below -10 dB (see Figure-5), it indicates that the antenna can work in a frequency range of

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1000-2700 MHz. This means that the antenna has fulfilled the initial design as a UWB antenna.

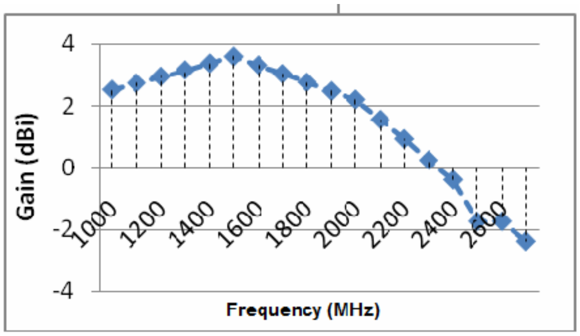

Figure-6. Gain antenna (after optimization).

The simulation shows that the proposed antenna has an average gain of 1, 59 dBi. In a UWB system such small gain (less than 3 dBi) is acceptable.

Comparison of Egg-Shaped Microstrip Antenna with and without a Circular Slot

Table-2. Antenna bandwidth using slots and without slot from simulation.

Types of slots	**Band-width** (MHz)	**Fractional Bandwidth**	**Maximum Gain** (dBi)	**Polarization/ Radiation Pattern**
Without slot	0	0	-3.4588	Ellipse/ Bidirectional
With circular slot	1000-2700	91.89	3.59	ellipse /Bidirectional

Table-2 shows that addition of a circular slot could enhance the bandwidth and increase the gain. But the circular slot does not change the antenna polarization, which is elliptical.

It is proved that the use of slot, especially a circular one can increase the bandwidth of a microstrip antenna significantly that works on the UWB application.

ANALYSIS AND DISCUSSIONS

Egg Microstrip Antenna with Circular Slot

Based on the measurement results, Egg microstrip antenna with circular slot has a bandwidth of 1700 MHz shown in Figure-7.

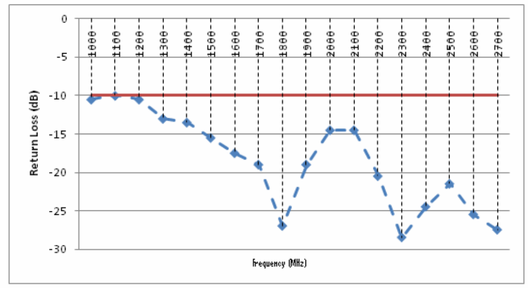

Figure-7. Return loss from measurement.

Figure-7 shows that the frequency range of a return loss ≤ -10 dB lies at 1000-2700 MHz with a fractional bandwidth of 91.89%.

The gain of an egg-shaped microstrip antenna with circular slot from measurements in 1000 - 2700 MHz is shown in Figure-8.

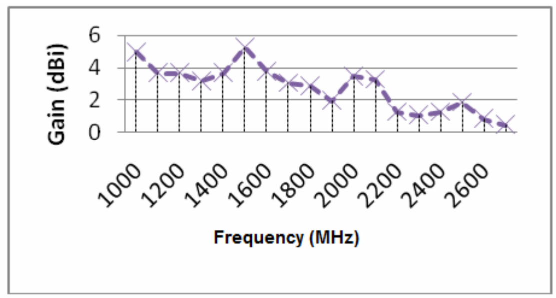

Figure-8. Gain from measurement.

The results show that the average antenna gain increases up to 2.35 dBi. The largest gain is 5.25 dBi at 1500 MHz. The polarization and radiation pattern will be determined based on this frequency using a polar diagram.

Measurement result of radiation pattern on horizontal and vertical direction at 1500 MHz is depicted in Figure-9.

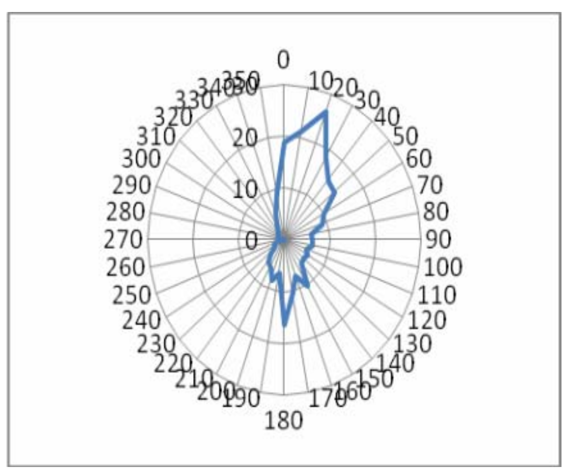

Figure-9. Horizontal radiation pattern of the antenna from measurement.

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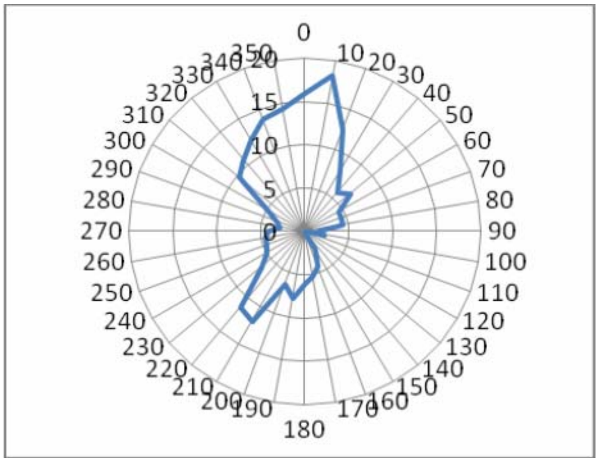

Figure-10. Vertical radiation pattern of the antenna from measurement.

Figures 9 and 10 are polar diagrams of an antenna radiation pattern from measurement at 1500 MHz. The antenna radiation pattern is bidirectional. This means that the antenna has maximum radiation intensity in both directions.

SIMULATION AND MEASUREMENT

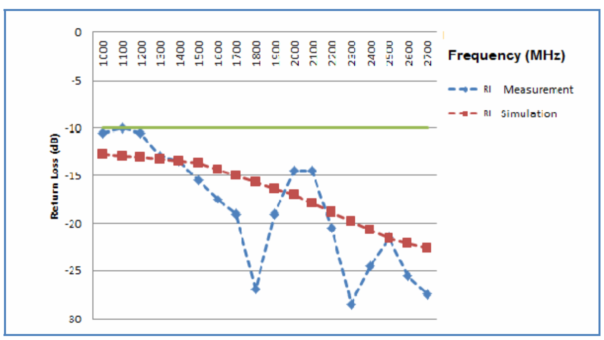

Figure-11. Return loss from simulation and measurement.

Figure-11 shows the comparison between the simulation and measurement results of the return loss showing discrepancies between simulation and measurement results. However, the simulation and measurement results indicate that the return loss of ≤ -10 dB lies in frequency range 1000 - 2700 MHz. Therefore, the antenna can be considered as a UWB antenna.

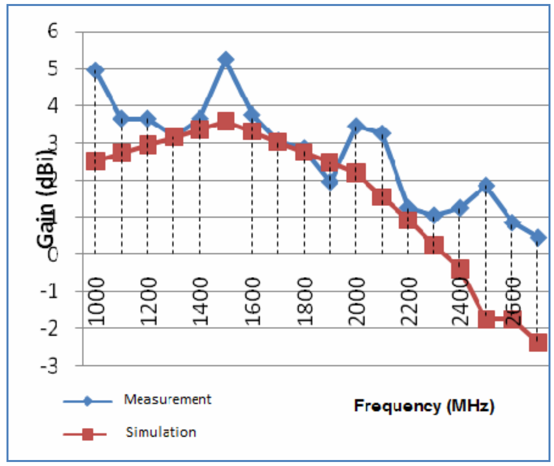

Figure-12. Antenna gain from simulation and measrement.

Figure-12 shows that there is a difference between the simulation and the measrement results on antenna gain. Yet, the trend is similar.

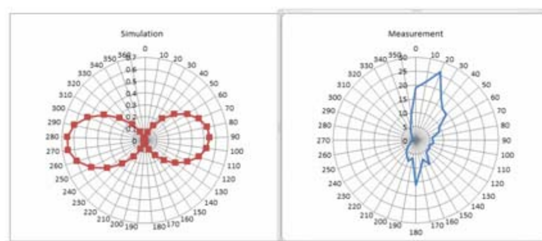

Figure-13. Horizontal radiation pattern comparison from simulation and measurement results.

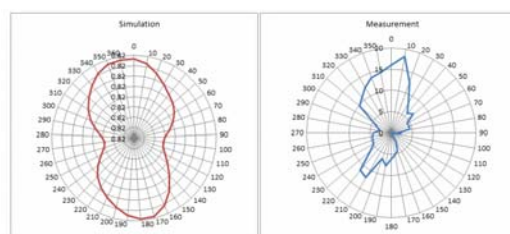

Figure-14. Vertical radiation pattern comparison from simulation and Measurement results.

Figure-14 shows that there is a difference radiation pattern of the antenna between simulation and measurement results, but they are still bidirectional.

CONCLUSIONS

Based on simulation and measurement of the proposed egg-shaped microstrip antenna with a circular slot, it can be concluded as follows:

a) Egg microstrip antenna with circular slot, is fabricated using FR-4 material with dielectric constant values (ε_r) = 4.5, at a frequency of 1000-2700 MHz, the antenna radiating element dimensions optimized are shown in Table-1.

b) Adding circle slot and varrying it dimension affect the bandwidth and antenna gain but did not affect the polarization and radiation pattern of the antenna.

c) Egg microstrip antenna with circular slot antenna work on the 1000 - 2700 MHz, a bandwidth of 1700 MHz and a fractional bandwidth of 91.89%. Gain at a frequency of 1.5 GHz is 5.25 dBi with bidirectional radiation pattern and ellipse polarization.

d) The circular slots applied in egg microstrip antenna fullfiled the UWB requirement.

ACKNOWLEDGEMENT

The Author wish to express sincere thank to University of Brawijaya, for their support with Contract Number: SK Rektor No 236, 2014.

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