Corrugated bamboo roofing design of microwave absorber for reflection absorption

N Mohamat Kasim*, H Abdullah@Idris, M F A B Ali Mokhtar, A Ahmad, N Mohamad Noor, L Mohd Kasim, N A Ismail, N Mohd Faudzi and M N Taib
Faculty of Electrical Engineering, Universiti Teknologi MARA, Cawangan Pulau Pinang, Malaysia

*nazirah261@uitm.edu.my

Abstract. Nowadays, the resources of roofing materials are abundant, which are the essential materials to build houses. It is of great significance to develop the roofing material with absorbing function for shielding electromagnetic radiation. This study is conducted to design a corrugated bamboo roofing microwave absorber that can absorb electromagnetic wave for frequencies 1 to 12 GHz. Three types of roofing bamboo with different designs namely Model A, Model B and Model C has been developed. The size of all types of proposed roofing bamboo is 60 cm width x 60 cm in length. The design is simulated using Computer Simulation Technology (CST) Microwave Studio software. The arch method is used to analyse microwave absorber performance. It contains of a wooden structure in the shape of semi-circular for enabling the proper positioning towards transmitting and receiving the two horn antennas. Bamboo can be used as an absorbent material. The expected result for bamboo roofing microwave absorber is to get a high performance of microwave absorption which is above 20 dB. The third model or Model C has recorded the highest value of an absorption level.

1. Introduction
The microwave absorber is a major component of anechoic space which consist of a sheltered room. It is designed to disengage unwanted microwave signals that will interfere with devices under test (DUT) performance result [1]. The anechoic chamber is premeditated for the determination of services rather than as a measurement devices such as antenna impedances, beam widths and others [2]. So, the reflection of the microwave signal is absorbed by the microwave absorbers used in the anechoic space [3]. The examples of the microwave absorber requirement in the house as of parameters like the magnitude and phase for various angles, perpendicular polarization absorption performance and absorption reflection loss.

In the market, there are several types of microwave absorbers such as wedges, pyramidal, flat, and convoluted. Among the varieties that have been long in the market for business purposes are pyramid types [4]. The dielectric properties are important in the design of electrical and electronic equipment and suitable techniques for determining the dielectric properties of various materials applications have been developed. The interest of dielectric properties is describing the behavior of material subjected to the microwave frequency. The dielectric properties depend on the applied frequency, the temperature of the material, and the density, composition, and structure of the material [5].

Permittivity in some material can be describe as the interaction between microwave propagation and dielectric material capacitance. Permittivity consist of real imaginary mathematical representation. The
real part of permittivity, \( \varepsilon' \), is also called dielectric constant, determines the amount of electrostatic energy stored per unit volume in a material for a given applied field. The imaginary part permittivity represented in mathematical equation as \( \varepsilon'' \). It describes the energy loss, which is governed by the lag in the polarization upon wave propagation, as it passes through a material or dielectric [6]. The dielectric constant affects the velocity of signal when it moves through the material [7]. The permittivity is complex and generally written into the equation below.

\[
\varepsilon_r = \varepsilon'_r - j\varepsilon''_r
\]

This study focuses on the effect of different shapes of corrugated bamboo roofing to the absorption performance. Nowadays, technology like wireless communication uses electromagnetic waves to transmit and receive information signals. As a result, the electromagnetic wave radiation increases due to concerns that there will be more energy in the gesture that travels at the high frequency of the spectrum where smaller transmitter is closer to where people live and work. The commercial roofing such as zinc and ardex have been tested of their strengths in building construction, but lacking in the ability to absorb electromagnetic waves. Thus, with the plenty of natural sources in Malaysia, a product needs to be designed and built by using a corrugated bamboo roofing absorber. This is one of the solutions to prevent the electromagnetic wave in the environment.

This project has developed a corrugated bamboo roofing for an electromagnetic wave absorption and investigated the effect of bamboo roof absorption performance for the different shapes with microwave absorber for frequency range from 1 to 12 GHz. The scope of the study is to design a corrugated bamboo roof absorbers with different shapes of a commercial roof as a reference. The size of the corrugated bamboo roofing absorber is 60 cm width x 60 cm in length. The simulation for the corrugated bamboo roofing absorber is designed using Computer Simulation Technology (CST) software to predict corrugated bamboo roofing absorber performance at frequency range 1 to 12 GHz. The real measurement for the corrugated bamboo roofing absorber is by using the Arch method to determine the absorption performance while for dielectric measurement is by using a Free Space measurement method.

2. Methodology

2.1 Absorber design

A few types of the corrugated bamboo roofing had been designed with different shapes. Figure 1 shows the design for the Model A, Model B and Model C. The size for all types of the corrugated bamboo roofing absorber is 60 cm width x 60 cm in length.

![Model A](image1.png)
![Model B](image2.png)
![Model C](image3.png)

**Figure 1.** Models of corrugated bamboo roofing

2.2 Simulation and measurement

An analysis of results in CST software is implemented after the optimization process. There are certain parameters that need to be considered in terms of shape, dimension and material properties of the microwave absorber. The free space arch reflectivity measurement method is used to analyze microwave
absorber performance as per figure 2. The arch contains of a wooden structure is in the shape of semi-circular for enabling the proper positioning towards transmitting and receiving the two horn antennas. The absorber is placed at the centre of the arch and antennas are perpendicular to the simple to measure the absorption level. The signal is transmitted and reflected back from the absorber. The set-up includes the Agilent Network Analyzer and coaxial cable with the frequency ranges from 1 GHz to 12 GHz [8].

![Figure 2. Free space arch reflectivity measurement setup](image)

2.3 Hardware
Figure 3 shows the fabrication of three different shapes corrugated bamboo roofing used in this project. There are three models which are Model A, Model B and Model C.

![Figure 3. Fabrication of corrugated bamboo roofing](image)

3. Simulation result
Figure 4 shows a simulation for every model of the corrugated bamboo roofing. By referring to the simulation result, it shows the absorption performance of the absorber. The focus frequency range is from 1 to 12 GHz.
Figure 4. Simulation result for all models of corrugated bamboo roofing

Table 1. Simulation result for all models of corrugated bamboo roofing

|      | Simulation Result (dB) |
|------|------------------------|
| Model A | Min: -3     | Max: -30  |
| Model B | Min: -5     | Max: -36  |
| Model C | Min: -5     | Max: -40  |

Table 1 shows the simulation result for each model. Based on the simulation results for every model of the corrugated bamboo roofing, the minimum absorption for Model A is -3 dB and Model B and Model C indicates an absorption value that is -5 dB. The highest value of an absorption level is gathered from the Model C with a value of -40 dB, followed by Model B, at -36 dB and -30 dB from the Model A.

4. Measurement results
After the development and fabrication process, the different shapes of corrugated bamboo roofing were measured by the Arch Measurement Method to see whether the absorption performance is similar or not to the simulation results.

Figure 5. Measurement results for 0°
Figure 6. Measurement results for $15^\circ$

Figure 7. Measurement results for $30^\circ$

Figure 8. Measurement results for $45^\circ$
Figure 5, 6, 7 and 8 show the absorption performance results for all model of corrugated bamboo roofing at 0°, 15°, 30° and 45° angle of the transmitting antenna. From the graph in figure 5, it shows that the minimum absorption value recorded at -2dB from Model A and B and the maximum absorption value is at -36 dB from Model C at 0° angle. Figure 6 shows the minimum absorption value recorded at -1 dB from Model A and the maximum absorption value is at -37 dB from Model C. Same goes to figure 7 and 8 which is Model A recorded the minimum absorption at -2 dB for 30° and 45° angle, meanwhile the maximum absorption value for Model C, is -34 dB at 30° angle and -25 dB at 45° angle.

Table 2. Absorption performance

| Absorber | 0° | 15° | 30° | 45° |
|----------|----|-----|-----|-----|
|          | Min | Max | Min | Max | Min | Max |
| Model A  | -2dB| -30dB| -1dB| -25dB| -2dB| -27dB| -2dB| -22dB|
| Model B  | -2dB| -34dB| -2dB| -35dB| -4dB| -32dB| -2.5dB| -23dB|
| Model C  | -4dB| -36dB| -6dB| -37dB| -5dB| -34dB| -3dB| -25dB|

Table 2 shows the results of minimum and maximum measurement values of corrugated bamboo roofing at 0°, 15°, 30° and 45° angle of the transmitting antenna with a frequency ranging from 1 GHz – 12 GHz.

5. Discussion and conclusion
The shape designs for corrugated bamboo roofing microwave absorber is important to get the best performance as the microwave absorber. Other than that, the natural plant such as bamboo has the potential to be used as absorbent material as the corrugated roof absorber. The investigation was conducted on all different shapes of corrugated bamboo roofing to identify which shape has a high absorption performance. At the measurement level, all models show that the corrugated bamboo roofing microwave absorber can absorb electromagnetic wave in the range of frequency 1 to 12 GHz. The Model C has recorded the maximum absorption at all angles which are -36 dB, -37 dB, -34 dB and -25 dB respectively. Therefore, the goal of this project to compare the performance of the different shapes is achieved.

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