THE STUDY OF GREEN BIOMASS COATED HOLLOW MICROWAVE ABSORBING MATERIAL

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ABSTRACT
In recent years, absorbing material has received great attention for various applications in electromagnetic wave, communications, radar, satellite systems, and anechoic chambers for the usage of both civil and military fields. This paper investigates the effectiveness of coconut shell-based microwave absorbing material. The absorber was prepared using elephant board with coated absorbent. Absorbent performance is predicted using the Computer Simulation Technology (CST) Microwave Studio simulation software. Wave frequency of 8GHz to 12 GHz has been chosen for the simulation and performance measurement of the absorbent. The reflectivity performances of the developed absorber are compared with the existing commercial absorbers in term of their absorption characteristics. Results obtained from this study have excellently shown that the absorption of the hollow shape can absorb the microwaves and thus, the introduced absorbing material can be used as microwave absorber.

Keywords: microwave absorbing material, green absorbing material, anechoic chamber, coated absorber.

INTRODUCTION
The microwave absorbing materials (MAMs) with electric and magnetic properties have been used primarily to absorb microwave energy at discrete or broadband frequencies. In line with the rapid increase in the use of microwave radiation for industrial and military purposes, the challenge to reduce unwanted reflections from objects in the path of radiation to be immediately necessary (Mitsuhiro and Youji, 2003). Absorbent first patented in 1936 but only after 17 years later the first absorber has become commercially available. Concerted efforts are beginning to achieve practical use of absorbent since it became an alarm during World War II (Emerson, 1973). At present, the absorber is typically used in space applications, external network upgrades, improved wide-angle radiation, increased radar, and radar termination of free space. Recently, the demands for various types of electromagnetic wave absorbers have seen tremendous growth especially in the high-speed wireless communication system for multi-wave reflection data.

Many researchers have developed a type of hexaferrite Absorbing material. Researchers also describe the use of ferrite for microwave absorption applications (Meshrum *et al.* 2004), (Lubitz and Rachford, 2002), (Naito and Suetake, 1971). The presence of both dielectric and magnetic losses in the magnetic types of materials is important in absorber (Padhy *et al.* 2014).

Absorbent used for anechoic chambers can be found with a variety of features. However, the most important thing is to get the low-reflectance absorption chamber walls at normal incidence, low forward scatter side wall at angle specular areas, floors and ceilings of low back scatter to the side walls, and as well as floor and ceiling at wide angle (Emerson, 1973). Anechoic chamber can operate at frequencies as low as 30 MHz and up to higher than 100 GHz.

A new design of absorbers offer significant performance improvements to the microwave absorption of low frequency compared to the existing ordinary pyramid absorbers. Optimization of the design parameters were performed in the -40 dB of reflectivity. Previous research has investigated alternative configuration absorbing transition geometry. This work has covered a wide range of multi-layered wedge, doubly periodic arrays of pyramid curved, multi-level arrays based on Chebychev polynomials, and geometric profile wedge after its transparency profile (Holtby *et al.* 2009). The implementation of design requires either fine control in the manufacturing process permittivity profile or profile changes to the profile geometries and using the foam from homogeneously loaded. More realistic solution would be achieved by optimizing the manufacturing process in terms of their carbon solution drainage, which causes the function of porosity foam, carbon solution viscosity and temperature used in the drying process.

Theories of microwave absorbers and radiation cross section are inspired to be feasibly studied. The main focus is on the development of several hollow shape microwave absorber. Along the way, a mixture of coating substance and materials from coconut shell are the main materials investigated in this paper. The materials are used to coat the elephant board as a function to absorb microwave radiation.

Radiation cross section of the structure can be controlled by either the shape and radiation absorbing material (RAM) cover, or structure of absorbing materials manufacturing. A layer of radiation absorbing material can be designed from knowledge of complex permittivity and permeability of specific materials and their frequency dependence (Pitman *et al.* 1991).

Unique absorbing materials and electrical design allow the absorption, attenuation, and almost catching a high percentage of waves impinged to be performed. RAM can be formulated for certain discrete absorption band microwave frequency or broadband absorption. In particular, the features of the RAM depend on the dielectric properties (permittivity of the material, ε) and magnetic properties (permeability of the material, μ). Thus, RAM can be classified in two broad categories, either dielectric or magnetic absorber (Stonier *et al.* 1991). The most importance of dielectric properties are the dielectric constant and dielectric loss tangent.

Dielectric absorbers are characterized by their electric permittivity and magnetic permeability that are also called as dielectric properties on material where the electric attraction or repulsion may be sustained. The permittivity is a measure of the material effect in the electric field in the electromagnetic wave, while the permeability measures the magnetic component of the wave. Generally, the permittivity is complex and written as (ε* = ε' - j ε") where ε' is dielectric constant applied to the absorber and value ε" is attenuation of the electric field by the material (Paul Dixon). It arises from the dielectric polarization of the material.

The dielectric loss tangent shows the effectiveness of the absorber. A research of dielectric properties by Luiza de Castro Folgueras (Luiza *et al.* 2010) for microwave absorbing materials (RAM) found that a large value of imaginary component of permittivity tends to introduce large losses in material. A low dielectric loss material can be made as energy storage and it cannot dissipate the stored energy. While, material with high dielectric loss cannot store the energy efficiently, and thus, some of the energy will tend to heat the material.

Good dielectric means the loss tangent is in low loss condition. Loss tangent defined as ($\tan \delta_e = \varepsilon''/\varepsilon'$). The greater loss tangent of the material gives the greater attenuation on the wave that travels through the material. The microwave absorption enhancement in term of composite is mainly from the dielectric loss. The dielectric loss is higher when the frequency ranging is between 6GHz to 18GHz (Fan *et al.*. 2006). The loss tangent will increase gradually when the frequency is increased (Liu, Zhang, Wu, 2011).

The composites of the dielectric absorbers determine its absorption properties (Abbas *et al.*, 2006). S.M. Abbas found that the dielectric properties for the heterogeneous composite are aroused due to the interfacial polarization and relaxation.

Absorption efficiency is due to the real part (ε' and μ') of the complex dielectric (ε = ε'-jε") and (μ = μ'-jμ"). The permeability differs from unity and sometimes larger, and the imaginary part (ε" and μ") is different from zero. As a result, the layer thickness, on the order of the wavelength in the material $\lambda / \sqrt{\varepsilon'' \mu''}$, is reduced by $\sqrt{\varepsilon' \mu'}$ times, and dielectric (ε") and magnetic (μ") losses ensure the complete absorption of the incident radiation (Petrov and Gagulin, 2001).

The reflectivity of the incident wave is given by

$$reflectivity(dB) = 20 \log_{10} \frac{\left(\sqrt{-1}\right)\sqrt{\mu/\varepsilon}\tanh\left(\frac{2\pi f}{c}\right)d - 1}{\left(\sqrt{-1}\right)\sqrt{\mu/\varepsilon}\tanh\left(\frac{2\pi f}{c}\right)d + 1} \quad (1)$$

where d is the thickness of the absorbing layer, ε is the permittivity, and μ is the permeability (Fuolgueras *et al.* 2010).

Several methods for reflection decrement are proposed with the focus on analyzing some characteristics of radiation absorbing materials with variable conductivity. It has been discovered that the reflection is decreased in thickness and increased in ratio between the wavelengths. It is strongly depend on the angle of incidence and the value of reflection (Nicolaescu, Oroian, 2001). A literature related to biomaterial such as carbon that is used as a basis for the absorbent material is introduced. Additionally, a composition and differences between each material and the role of current industry in absorber development are being highlighted (Nornikman *et al.* 2008).

Approach

The green biomass coated absorbers based on coconut shell carbon powder are fabricated and coated on elephant board sheet. The complex permittivity and permeability of the absorbing material are the fundamental parameters that reflect the interaction between electromagnetic waves and materials. They are measured in this study. The S11 simulation on the coated absorber is performed by using the Computer Simulation technology Microwave Studio software (CST MWS). Free space reflectivity measurement using the arch method is used to determine the absorption performance

Four types of hollow absorber have been developed in this study. Absorber is designed in hollow pyramidal shape with triangular based, square based, hexagonal based, and wedges contours. The coating material on the elephant board is a mixture of coconut shell with activated charcoal carbon, as it is easy to be shaped with the perseveres. The hollow thickness for each shape is approximately 1.5mm. Each type of absorbers is separated into based part and pyramidal part. The dimension of triangular based shape is 15 cm length, 5 cm width, and 40 cm height as shown in Figure-1. Figure-2 shows square based shape with the dimension of 20 cm length and 5 cm width. The hexagon shape is showed in Figure-3 bearing a based dimension of 15 cm for every side. Figure-4 shows wedges shape with the dimension of 60 cm length and 20 cm width. Ultimately, all the shapes have a total heights of 45 cm.

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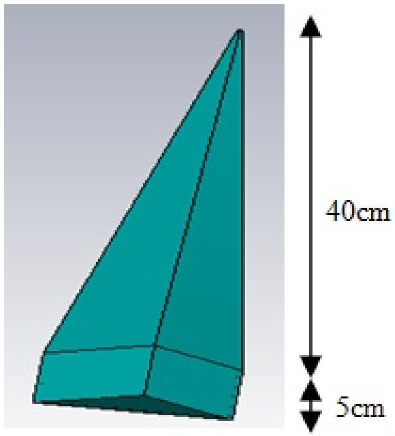

Figure-1. The pyramidal absorber triangular based shape design.

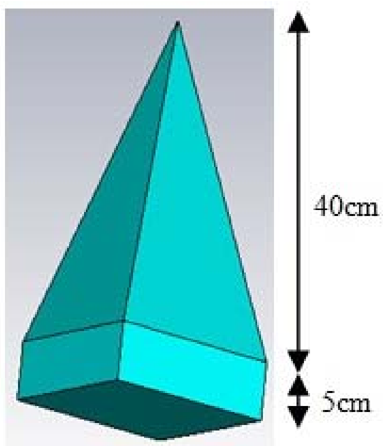

Figure-2. The pyramidal absorber square based shape design.

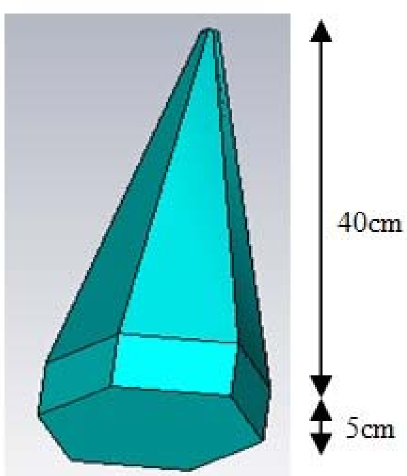

Figure-3. The pyramidal absorber hexagon based shape design.

Meanwhile, the solid wedge absorbers which are TDK IPC-045C with dimensions of 20 cm width, 60 cm long, and 45 cm height have the same dimensions as shown in Figure-4.

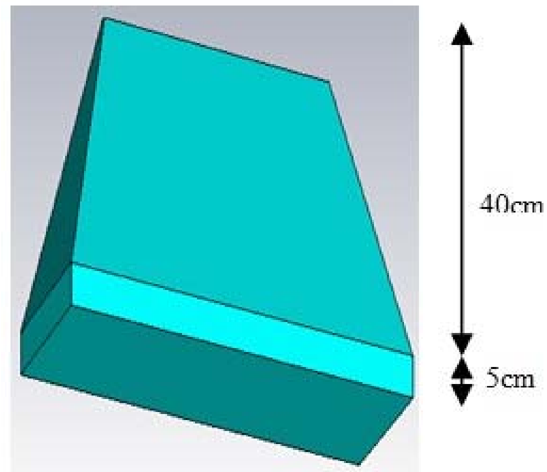

Figure-4. The wedges shaped absorber design.

All the designed absorbers are simulated using CST Microwave Studio before the fabrication. The absorbers are then coated with mixture of coconut shell activated charcoal carbon material. Carbon has the nature of the semiconductor that is suitable to change the microwave energy into thermal energy. Therefore, it manages to change the microwave to heat (Allan, 1953). The proportion of carbon and paint mixture must be handled with appropriateness. The excessive mixture leads to the difficulty of absorption to be affixed to the chamber whereas insufficient carbon removes the carbon flow.

The dielectric constant value, modelling and simulation have been set up using CST Microwave Studio to obtain the reflectivity or S_{11} result for all absorbers. Analysis on the results of reflectivity is conducted to define the overall microwave absorber performance.

Constitutive parameter of the material under test is obtained from dielectric measurement. Scattering matrix is measured by vector network analyzer (VNA) in the frequency range corresponding to the working condition of the absorber. The arch measurement methods (refer Figure 5) use VNA for reflectivity measurements. It consists of a pair of horn antenna and material measurement software (Agilent 85071E) (Hasnain *et al.* 2012). The measurement data is recorded and observed from 8 GHz to 12 GHz range. The performance of the commercial absorber IP-045C produced by TDK RF solution Inc., UiTM Branch Pulau Pinang is also investigated.

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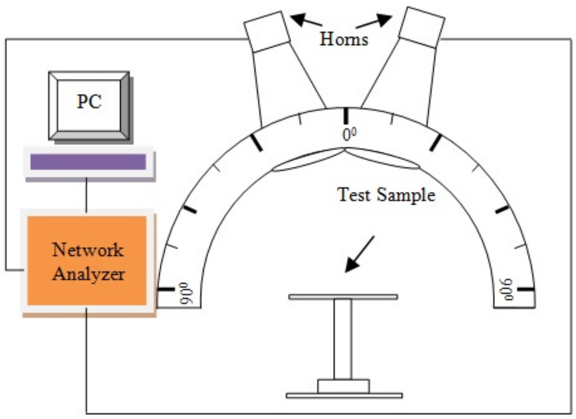

Figure-5. The arch measurement methods.

RESULTS AND DISCUSSION

Simulation and measurement

Figure-6 shows simulation results of predicted performance of absorbing material with varying the epsilon value (ε) or dielectric by using CST software. The lower value of epsilon indicates the better absorption performance.

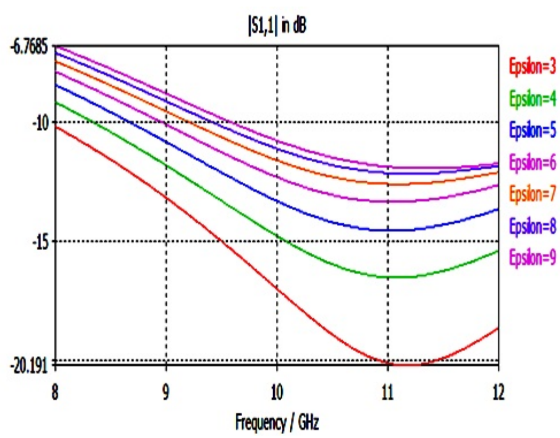

Figure-6. S11 simulation results of absorbing materials for epsilon 3 to 9.

Figure-7 shows the dielectric measurement result of the elephant board with green-absorbing coated in which the dielectric or epsilon value served as simulation variables. The minimum value of dielectric is 4.6 at frequency of 8.42 GHz and the maximum value of dielectric is 5.07 at frequency of 9.58 GHz. In the simulation, all absorbers are labeled with a thickness of 1.5 mm and epsilon is set to average value of 4.83.

Figure-7. Dielectric for elephant board with mixture of green-absorbing paint.

The measurement of absorber is conducted to determine the performance of absorbent sheet materials. Figure-8 and Figure-9 show the absorption of material of uncoated and coated elephant board sheets in the Transverese Electric (TE) mode. The average and maximum absorption of coated elephant board sheet at frequency of 11.4 GHz is -3.5 dB and 5.1 dB, respectively.

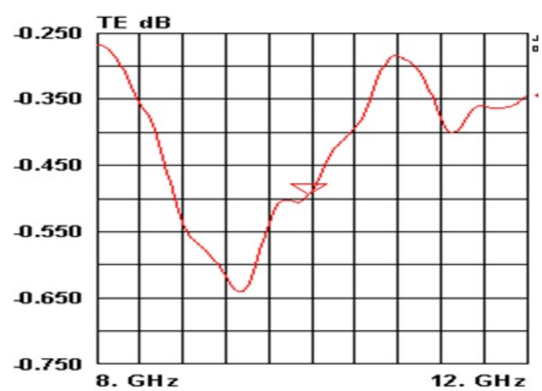

Figure-8. Absorption results of uncoated elephant board sheet

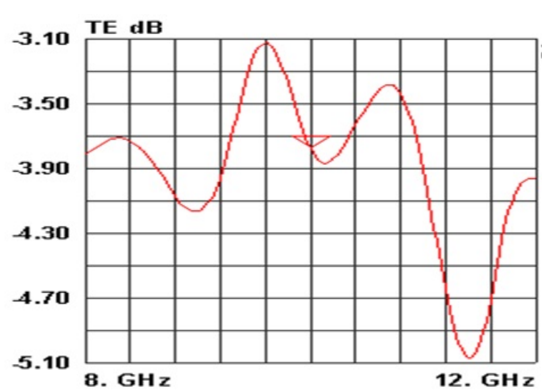

Figure-9. Absorption results of coated elephant board sheet.

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Figure-10, 12, 14, and 16 represent the S11 or reflectivity simulation result for elephant board coated with green absorbing paint in pyramidal triangular based shape, square based shape, hexagonal based shape, and wedges shape, respectively. Figure 18 represents the S11 or reflectivity simulation result for the IP-045C wedges absorber.

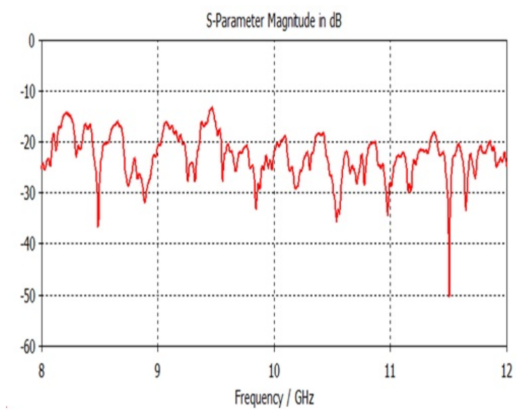

Figure-10. S11 or reflectivity simulation result for the pyramidal absorber triangular based shape.

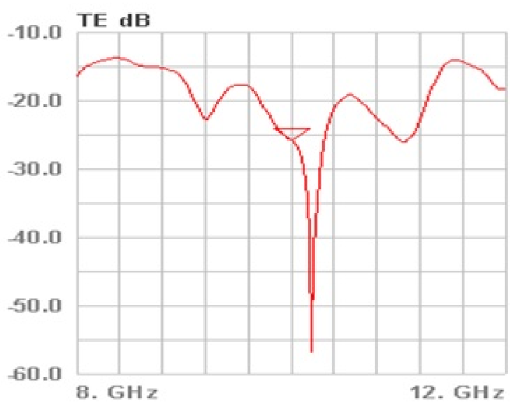

Figure-11. Measured reflectivity for the pyramidal absorber triangular based shape.

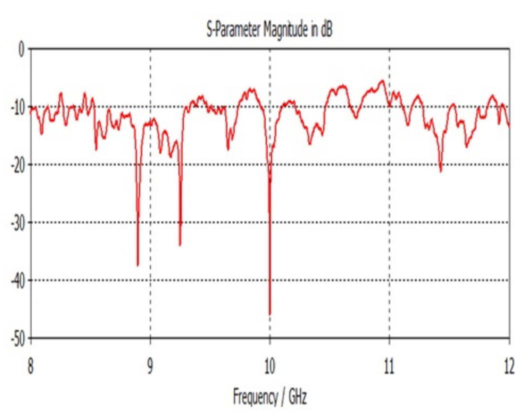

Figure-12. S11 or reflectivity simulation result for the pyramidal absorber square based shape.

Figure-13. Measured reflectivity for the pyramidal absorber square based shape.

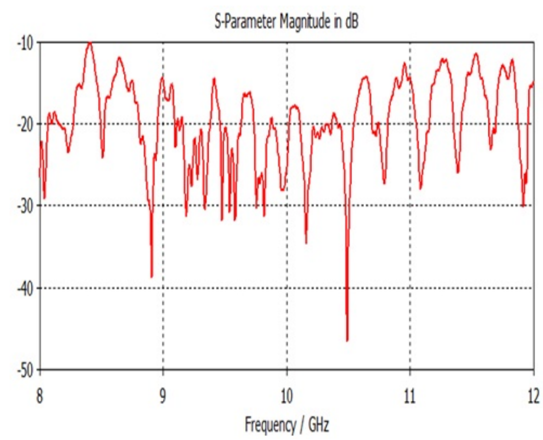

Figure-14. S11 or reflectivity simulation result for the pyramidal absorber hexagon based shape.

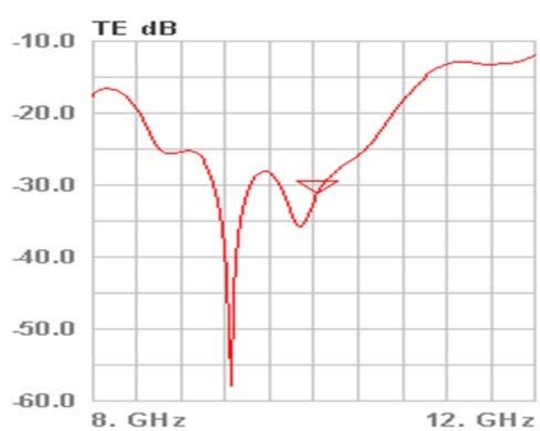

Figure-15. Measured reflectivity for the pyramidal absorber hexagon based shape.

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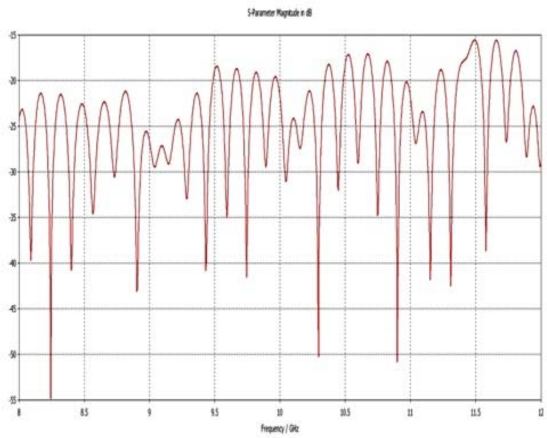

Figure-16. S11 or reflectivity simulation result for the wedges absorber shape.

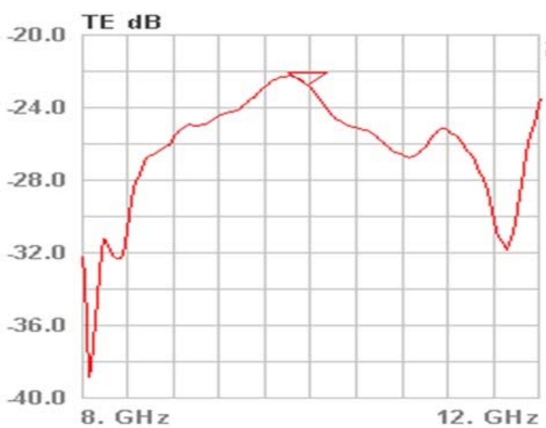

Figure-17. Measured reflectivity for the wedges absorber shape.

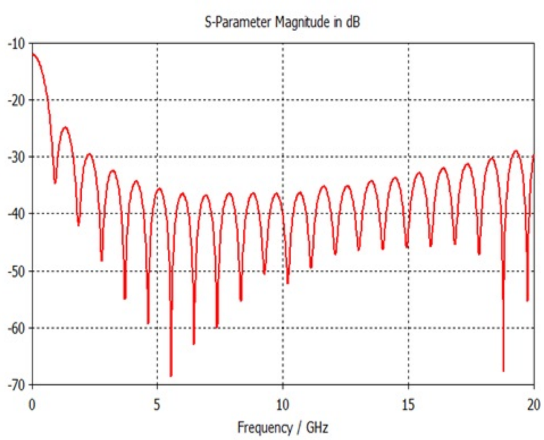

Figure-18. Simulation result for the IP-045C wedges absorber shape.

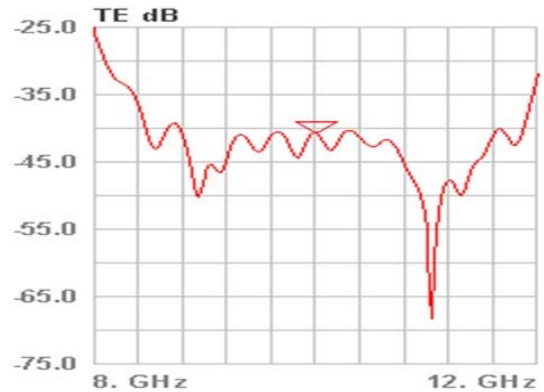

Figure-19. Measurement result for the IP-045C wedges absorber shape.

The comparison of simulated S11 or reflectivity for pyramidal triangular based shape, square based shape and hexagonal based shape are shown in Table-1. The ranges of reflectivity are -14 to -50 dB, -6 to -40 dB, -10 to -46 dB and -16 to -55 dB respectively. While, the range of reflectivity for wedges absorber is -12 to -55 dB. At the 10 GHz simulation, the result for pyramidal triangular based shape, square based shape, hexagonal based shape, wedges shape and IP-045C wedges absorber are -25 dB, -46 dB, -27 dB, -25 dB and -41 dB, respectively.

Table-1. Simulation S11 results for different absorber shapes.

Absorber	*S11* (dB)	
	Range of reflectivity (GHz)	*10 GHz*
The triangular based shape	-14 dB (9.46 GHz) to -50 dB (10.5 GHz)	-25 dB
The square based shape	-6 dB (10.94 GHz) to -40 dB (10.3 GHz)	-46 dB
The hexagon based shape	-10 dB (8.4 GHz) to -46 dB (10.49 GHz)	-27dB
The wedges shape	-16 dB (11.5 GHz) to -55 dB (8.22 GHz)	-25dB
The IP-045C wedges absorber	-12 dB (8 GHz) to -55 dB (8.1 GHz)	-42dB

Figure-11, 13, 15, and 17 represent the measured reflectivity for pyramidal triangular based shape, square based shape, hexagonal based shape, and wedges shape, respectively, by using the elephant board coated with thick layer of coating absorbent. Figure 19 represents the reflectivity measurement result for IP-045C wedges absorber.

The comparison of reflectivity measurement for pyramidal triangular based shape, square based shape, hexagonal based shape, and wedges shape are shown in Table 2. The ranges of the reflectivity for those shapes are

-14 to -57 dB, -8 to 65 dB, -12 to -58 dB and -22 to -38dB, respectively. The range of reflectivity for IPC-045C wedges absorber is -25 to -68 dB. The TDK IPC-045C wedges absorber has the value of reflectivity of -40 dB for the frequency range of 8 GHz to 12 GHz. At the 10 GHz measurement, the results for pyramidal triangular based shape, square based shape, hexagonal based shape and wedges are -26 dB, -47 dB, -32 dB, 23dB and -41 dB, respectively.

Table-2. Measurement results for different absorber shapes.

Absorber	*S11* (dB)	
	Range of reflectivity (GHz)	*10 GHz*
The triangular based shape	-14 dB (8.4 GHz) to -57 dB (10.2 GHz)	-26 dB
The square based shape	-8 dB (12 GHz) to -65 dB (9.98 GHz)	-47 dB
The hexagon based shape	-12 dB (12 GHz) to -58 dB (9.26 GHz)	-32 dB
The wedges shape	-22 dB (9.8 GHz) to -38 dB (8.1 GHz)	-23dB
The IP-045C wedges absorber	-25 dB (8 GHz) to -68 dB (11.06 GHz)	-41dB

CONCLUSIONS

This work discuss the contribution of pyramidal absorbing material which can absorb the energy in the microwave frequency range of 8GHz to 12 GHz. The reflectivity is also depends on the surface of absorbers.

From the result, the reflectivity of all prototypes is almost similar to the simulation. At 10 GHz, the difference of S11 result obtained from measured reflectivity and simulation of the pyramidal absorber is 1 dB for triangular based shape, 1 dB for square based shape, 5 dB for hexagon based shape, 2 dB for wedges shape and 1 dB for the IP-045C wedges absorber. The result from both simulation and measurement also shows that the pyramidal absorber with square based shape is the best absorption throughout the simulation and experiments for 10 GHz. Besides that, the result shows the testing prototypes absorber is capable to absorb the reflection at the frequency of 8GHz to 12GHz. The research has also proven that the coconut shell activated charcoal carbon material coated to elephant board is capable to absorb microwave radiation.

Further investigation need to be done for determining significant factors to improve the reflectivity. Nonetheless, the usage of agriculture's waste is potentially to create awareness on the green technology and energy efficiency. This investigation contributes to the pyramidal design of radiation absorbing material that able to absorb the energy generated in the microwave frequency range between 8GHz to 12 GHz. The reflectivity is also depending on the surface of absorbers design.

From the results obtained, the reflectivity of all prototypes is almost similar to the performed simulation. At 10 GHz frequency, the result of reflectivity measurement of pyramidal absorber with triangular based shape is 1 dB difference, square based shape is 1 dB difference, hexagon based shape is 5 dB difference, wedges shape is 2 dB difference, and the IP-045C wedges absorber is 1 dB difference. The result shows that the pyramidal absorber with square based shape is the best absorber in terms of absorption based on the simulation and experiments done at 10 GHz compare to others. Besides, the result also shows the testing prototypes absorber is capable to absorb the reflection at the frequency of 8GHz to 12GHz. The research has also proven that the mixture of coconut shell activated charcoal carbon material that is coated to elephant board is capable to absorb microwave radiation.

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