Performance Study of Coconut Coir Pyra-Shape Absorber Design

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***Abstract*—Agriculture waste has huge potential to be used as an alternative material for constructing microwave absorber which is typically used in an anechoic chamber. The existing microwave absorbers are normally manufactured from chemical substances. This project is proposing the use of a new composite biomass material namely coconut coir, for constructing microwave absorbers. Generally, pyramidal shape is chosen since it is commonly used in the industry. The major part of this project involves an intense study in designing and developing the best techniques to construct pyramidal shape microwave absorber. The frequency range investigated in this work is between 1GHz to 12GHz. Referring to the commercial absorber as the standard, the reflectivity performance of this coconut coir pyramidal absorber was thoroughly investigated in this research. It is then proven that the biomass material used in this study is found to have a significant impact on the microwave absorber performance.**

***Index Terms*—Microwave absorber, coconut coir, pyramidal, free space arch method.**

I. Introduction

Our daily life now is surrounded with electronics devices, from the simplest device to the complex one. These devices must undergo many tests in the laboratory before the device can be marketed to ensure its functionality, performance and interoperability. These tests are best conducted in an anechoic chamber since there is no interference from other devices.

Microwave absorbers are the main component of an anechoic chamber. It will reduce or absorb unwanted or stray radiation that may interfere with other equipment or components. Microwave absorbers can be found in many ways, including foam, rigid epoxy, plastics, and elastomers. Usually, these microwave absorbers can withstand extreme weather and temperature conditions.

A proper Radio Frequency (RF) microwave absorber model must be developed based upon parameters such as absorber reflectivity, magnitude and phase in different angles of incidence and for parallel and perpendicular polarizations [1]. They are also available in many forms, such as pyramids, truncated pyramidal, bobbin systems, hybrid absorbers, absorber types of metamaterials and others, are available as absorbers [2]-[6].

In terms of material, ferrite bless, conducting carbon, polystyrene and polyurethane are typical materials being used in the commercial absorbers. This study is about to uncover a new material that can be used to substitute chemicals and pricey materials which are currently being used commercially. In searching for a new substitute, agricultural wastes are seen to have huge potential to be developed into microwave absorber since these agricultural materials contain carbon which is essential for microwave absorber development.

Agricultural wastes are widely available, renewable and virtually free; hence they can be an important resource [7]. Nevertheless, abundant agricultural wastes were improperly disposed of and filled up landfill space. Agricultural waste which is not properly disposed or managed may initiate loads of environmental issues. Improper disposal also has a toxicity potential to plant, animals and human through many direct and indirect channels.

One of the potential agricultural wastes comes from coconut which is widely available in tropical countries. The open burning of coconut shells in many countries contributes considerably to carbon dioxide (CO_2) and methane emissions that lead to air pollution that is not only harmful, but also instigated health risk. The material of interest for this study is coconut coir.

The fibrous material found between the hard-internal shell and the outer coat of coconut is called coconut coir. Coconut coir is one of the agricultural wastes and is normally used in ropes, doormats, potting compost, mattress stuffing and sacks. Regrettably, people do not realize that coconut coir can be also used as a microwave absorber as it contains activated carbon. Carbon's highly porous nature provides a large surface area for absorption [8] which makes it an effective absorbent material.

Most of the existing microwave absorber in an anechoic chamber is not environmentally friendly as it uses chemical substances. Developing a microwave absorber using coconut coir is another alternative for making microwave absorbers without using any chemical substances and is environmentally friendly. In reality, the waste material is considered as not useful to the community. If the biomaterial can be used prudently, the

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capacity of industrial waste, as well as harmful environmental emission may be reduced [9]. Hence, the use of coconut coir to make a microwave absorber will also reduce agricultural waste and increases its usable value.

For this project, the microwave pyramidal absorbers are developed by using coconut coir as the main material and the performance of coconut coir absorber will be analysed.

II. Approach

A. Design and Simulation

Computer Simulation Technology (CST) is a high-performance analysis software package for designing, analysing and optimizing electromagnetic components and systems. This software is used in this research to design and simulate the reflectivity of the microwave absorber. By setting the dielectric constant value, the modelling and simulation can be done to get the reflectivity reading in CST. Analysis of results will be discussed to observe and conclude the performance of the microwave absorbers.

The microwave absorber shape used for this research is pyramidal shape, which is one of the commonly used shapes for microwave absorbers. Fig. 1 shows the dimension of the designed pyramidal microwave absorber. The body dimension is 7.6cm (length) × 7.6cm (width) × 5.1cm (thickness) × 16.6cm (height). These dimensions were chosen by referring to the commercial pyramidal microwave absorber.

It is expected that the designed biomass absorber can achieve better than the minimum of –10dB to have a good reflectivity performance microwave absorber.

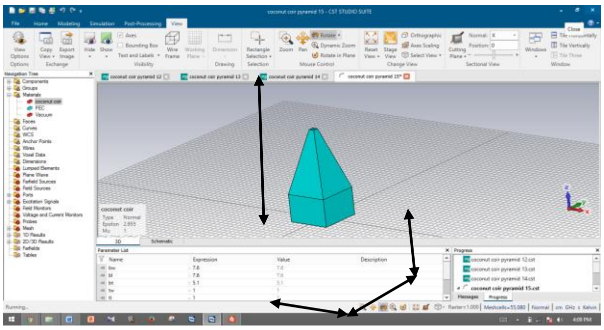


Fig. 1. The dimension of the absorber using CST software

B. Fabrication

The materials used for fabricating the designed pyramid absorber are made up of coconut coir, coconut activated carbon and starch. Firstly, the coconut coir is filtered to get the finest coconut coir grind. This is to ensure a good mixture during the mixing process later. Next, this material is then weighed carefully according to the proportion in Table I. The coconut is then mixed evenly with the coconut activated carbon before mixing them with starch. Lastly, the mixture is poured into a mould made from hard cardboard pyramid mould and then proceeds for the drying process. The drying process is critical to prolong the lifetime of the designed absorbers. These steps were then repeated to complete two sets of microwave absorbers consist of 64 units per set.

Table I shows the ratio of mixture for Design A and Design B of the coconut coir pyramidal absorber. From the table, the amount of carbon for Design B is higher compared to Design A.

Fig. 2 and Fig. 3 show two complete sets of microwave pyramidal absorbers for both designs, namely design A and B. The variable in this design is the composition ratio for activated carbon. Design B is designed with higher coconut activated carbon. The coconut coir grind and starch composition are fixed for both designs.

TABLE I: COMPOSITION RATIO FOR DESIGN A AND DESIGN B

Design	Amount of mixture (%)		
	Coconut coir	Coconut activated carbon	Starch
Design A	27.8	2.8	69.4
Design B	25.6	10.3	64.1

Fig. 2. Fabricated pyramid absorber for Design A

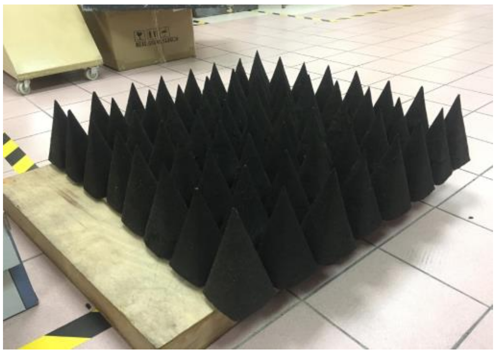


Fig. 3. Fabricated pyramid absorber for Design B

C. Measurement

The measurement methods used for measuring the performance of the coconut coir microwave absorbers are the Naval Research Laboratory (NRL) arch method and free space method.

The NRL Arch was originally designed at the Naval Research Laboratory and enables rapid, repeatable, non-destructive testing of microwave absorbent materials across a wide frequency range [9]. An NRL arch is a microwave measurement setup that can measure the free space radar reflection coefficient of flat Radiation Absorbing Material (RAM). The reflectivity test of the NRL arch is the industry standard for testing material reflectivity. As for free space measurement, it was found to be an appropriate method for determining dielectric properties.

The measurement setup comprises two horn antennas installed facing each other, absorbers to be measured and measurement software (Agilent 85071E) [10]. The two antennas are positioned in a constant distance from the testing material on a reflective metal plate below. The arc structure allows the two antennas to travel to every off-normal angle along the curve while maintaining the distance from test materials continuously.

The transmission antenna has a signal generator that sends the microwave energy to the target. The receiving antenna is connected to a signal detector which measures the remaining microwave energy after reflectivity, either the reflective metal platform or the tested material that is resting on the platform.

The size of the material being tested and the distance between the antenna and the plate are determined by the desired test frequency range. A standard 1-18 GHz setup test using a 12"·12" or 24"·24" material size and a 30"-36" plate distance antenna". Lower frequency (longer wavelength) testing would require a larger sample size and longer antenna-plate distance. A smaller arch and sample size could be used by higher frequencies.

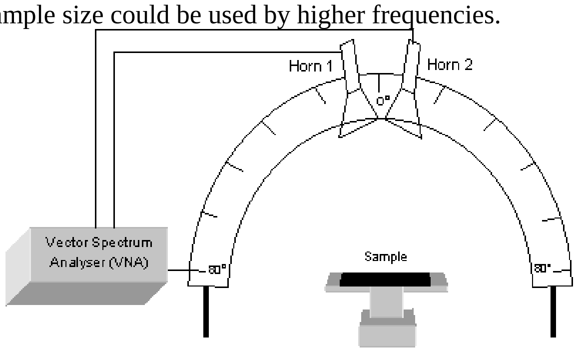
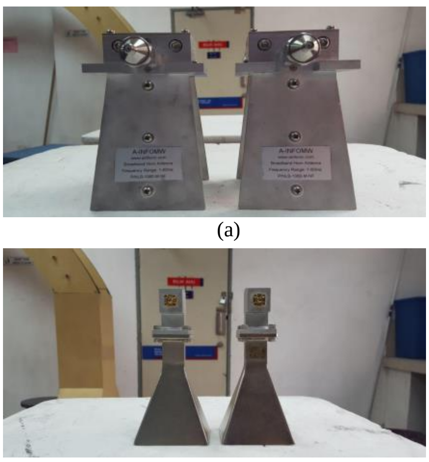


Fig. 4. Arch measurement method

As shown in Fig. 4, an NRL arch consists of a transmit and receive antenna and a metal plate-oriented antenna.

Fig. 5 (a) shows the horn antennas that were used for measuring within the frequency range of 1GHz to 8GHz. The horn antennas in Fig. 5 (b) were used for measuring within the frequency range of 8GHz to 12GHz. The fabricated absorbers are placed under the arch and are measured at few different angles of 0°, 30° and 60°.



(a)

(b)

Fig. 5. Horn antennas for 1GHz to 8GHz and 8GHz to 12GHz.

The free space techniques used in this research can deliver excellent results through millimetre waves for non-magnetic material. This installation uses a flat sheet or a material placed in the centre of the antennas facing each other. The variability of reflecting and transmitting signals allows the electric permittivity of the material and its magnetic permeability to be calculated.

Basically, the operating principle is like the transmission line, but the free-space signal is used instead of using fields found in the cable. The sample does not have to be machined to fit the reduced dimensions of a transmission line or cavity in such high frequencies. It provides easier characterization at very high frequencies (up to hundreds of GHz).

In comparison, wireless and noncontact technologies are used. A large, uniform, flat and parallel sample is required. Since the configuration has no connector, an ad-hoc free-space adjustment package is used. Measuring the transmission phase is much more straightforward plus good measurements can be done in free space eliminating the problem of sample fit. Typically, measurements of free space are performed in anechoic chambers, involving both measurements of reflection and transmission, and providing information on the sample's characteristics of absorption and surface impedance.

III. Results

In this research, the reflectivity measurements were carried out at three different angles 0°, 30° and 60°. Fig. 6 shows the experimental result measured at 0° for both design A and design B of pyramidal absorbers. The minimum reflectivity is –1.6751dB while the maximum reflectivity is –51.7334dB for design A. As for design B, it shows greater performance than design A where the minimum reflectivity value is –16.7407dB and maximum reflectivity is –55.6953dB. This result also illustrates that the reflectivity is evenly distributed throughout the measured frequency of 1GHz to 12GHz for both design A and B.

The next experimental result is collected by measuring at 30° as depicted in Fig. 7. The minimum and maxi-mum reflectivity value for design A is –2.0531 dB and –8.5624dB, respectively. Whilst for design B, the same improvement pattern is seen where the minimum reflectivity value has improved dramatically to –20.049 dB while the maximum reflectivity rose to –60.1923dB.

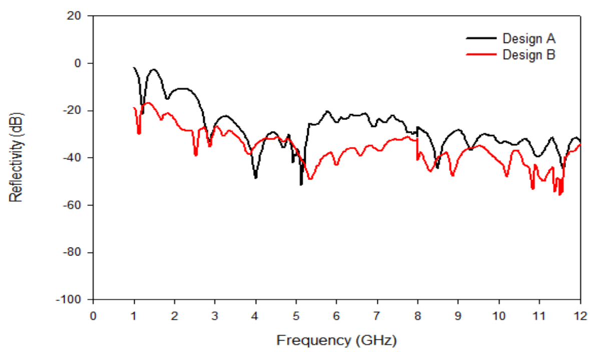


Fig. 6. Reflectivity for 0° measurement angle

The last measured angle is at 60° and the result is shown in Fig. 8. It displays that the highest reflectivity for design A is at –80.10262dB and the lowest value of the reflectivity is 9.0173dB. As for this measured angle for design B, the minimum value of reflectivity has lessened by −2dB and the maximum reflectivity value is −50.1093dB.

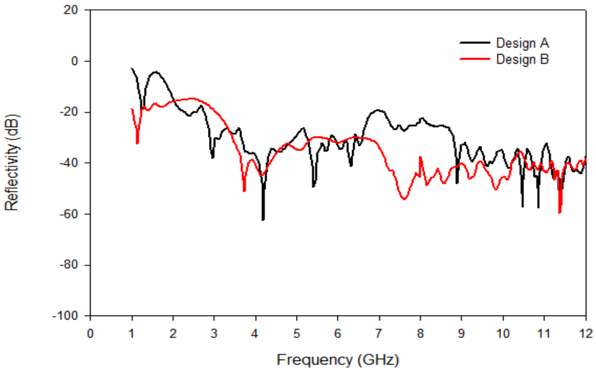


Fig. 7. Reflectivity for 30° measurement angle

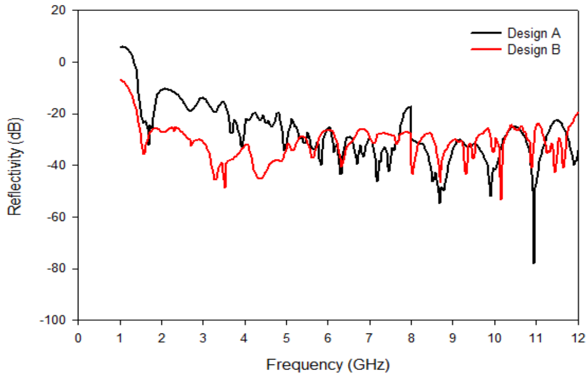


Fig. 8. Reflectivity for 60° measurement angle

Table II shows the minimum and maximum reflectivity values at a different range of frequencies for design A and B. From this table, the minimum reflectivity for both designs has achieved the minimum reflectivity based on benchmarking with commercial absorbers of at least −10dB. In comparison between the two designs, design B shows the greatest performance compared to design A. As for design B, it has the maximum reflectivity of −55.6953dB at a frequency range of 8GHz to 12GHz and a minimum value of −16.7407dB at a frequency range of 1GHz to 2GHz.

TABLE II: MINIMUM AND MAXIMUM REFLECTIVITY FOR DESIGN A AND DESIGN B

Frequency (GHz)	Design A		Design B	
	Min (dB)	Max (dB)	Min (dB)	Max (dB)
1-2	-1.6751	-21.5437	-16.7407	-29.9292
2-4	-10.8239	-48.9155	-24.1101	-39.0915
4-8	-20.3141	-51.7334	-31.135	-49.04
8-12	-26.8779	-44.418	-31.7887	-55.6953

TABLE III: MINIMUM AND MAXIMUM REFLECTIVITY MEASURED AT DIFFERENT ANGLES

Angle	Design A		Design B	
	Min (dB)	Max (dB)	Min (dB)	Max (dB)
0°	-1.6751	-51.7334	-16.7407	-55.6953
30°	2.0531	-68.5624	-20.049	-60.1923
60°	9.0173	-80.10262	-2	-50.1093

TABLE IV: REFLECTIVITY PERFORMANCE FOR COMMERCIAL MICROWAVE ABSORBER [19]

Frequency Range (GHz)	1-2	2-4	4-8	8-40
Reflectivity (dB)	-30	-40	-45	-50

Table III shows the comparison of minimum and maximum reflectivity when measured at different angles of 0°, 30° and 60°. From this table, it indicates that when the microwave absorbers are measured at different angles, the performances of the absorbers are still significant.

Table IV depicts the reflectivity for commercial absorber ETS-Lindgren EHP-8PCL High Performance Microwave Absorber with frequency ranges from 1GHz to 40GHz. From this table, the reflectivity performance of this commercial absorber ranges from −30dB to -50 dB within 1 to 12 GHz. Along these lines, unmistakably the coconut coir pyramidal absorbers have a comparable performance like the commercials.

IV. CONCLUSION

The performance of the designed pyramidal absorbers using coconut coir has been analysed. The analysis response investigation was benchmarked with commercial absorbers available in the market. The results were found to be comparable.

Both designs have shown good performance with reflectivity greater than −10dB within the frequency range of 1GHz to 12GHz. Nevertheless, design B has shown an impressive performance over design A.

In a nutshell, coconut coir has been proved to have boundless potential to be an alternative for microwave absorber which is not only having good reflectivity performance but also environmentally friendly.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Juliana Md Sharif carried out the critical revision of the paper and acted as the main supervisor; Dayana Kamarul Bahrin carried out experiments, data collections and analysis; Mas Izzati Fazin provide technical support; Rohaiza Baharudin performed literature surveys; Ida Rahayu Mohamed Noordin, Asmalia Zanal drafting the paper; Hasnain Abdullah provide the conception and granted final approval of the version to be published. All authors co-wrote the paper. All authors have also read and approved the final version.

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