A Study of Electromagnetic Absorption Performance of Modern Biomass Wall Tile

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Abstract—**Electromagnetic elimination was used to eliminate unwanted radiation that may interface with machinery or affect human health. The use of microwave absorbers has become necessary for an environment with a safe electromagnetic wave level. The objectives of this project are to design a microwave absorber as a modern biomass wall tile and to investigate the absorbing performance of the modern wall tile absorbers with different materials. The absorber was designed with similar shapes and different biomass materials. The concept of modern wall tile had been applied to design the absorbers in terms of their shape and dimension by using biomass materials. Biomass materials such as kenaf and coconut coir were used in the study due to their lightweight and environmental-friendly material behavior. The simulation was done using CST Suite Studio software to predict the preliminary result of the absorbers. The proposed designs of the modern wall tile from the CST simulation are then fabricated while the mixtures of the materials are moulded into a microwave absorber. NRL Arch free space method was used to determine the absorption performance of the modern wall tile absorbers at a frequency range from 1GHz to 12GHz. Both results of the simulation and free space measurement are analyzed and discussed. This study showed that absorber KCA has the best performance among all the absorbers with the absorption of more than -10 dB. The mixture of biomass material with carbon has a great absorption performance compared to the mixture of biomass material without carbon.**

Index Terms—**Biomass material, CST simulation, electro-magnetic elimination, free-space method, modern wall tile absorbers, microwave absorbers**

I. Introduction

Radio waves and microwaves are forms of electromagnetic energy that are collectively described by the term of radiofrequency or RF. Many telecommunication sources generate radiofrequency with different frequencies, such as FM radio, television transmitter and antenna, microwave oven, satellite link and wireless communication transceiver [1]. Rapid increases in telecommunication had led to electromagnetic pollution and it is causing significant risk to human health from the environmental RF electromagnetic fields [2].

Microwave absorbers are materials that attenuate the energy in an electromagnetic wave. It used to eliminate stray or unwanted radiofrequency or radiation either externally or internally. Absorbers have several shapes such as flat, pyramidal and wedges, but the most ideal shape of microwave absorber is pyramidal absorber [3]. The excellent performance of pyramidal-shaped absorber is primarily the result of the multiple reflections that occur between the pyramids [4]. Microwave absorbers can be classified into three types which are magnetic absorbers, dielectric absorbers and hybrid absorbers (the combination of magnetic and dielectric absorbers) [5].

Ferrite tile is an example of a magnetic type of microwave absorbers and it is the only type of tile absorbers in the current market. This ferrite tile had been known by the presence of an air gap between the tiles and this affect the absorbing performance of the ferrite tiles [6]. Ferrite tile can compress the wavelength due to its high permeability. It also has disadvantages which include weight and cost [5].

In this project, absorbers were designed as a modern biomass wall tile. The shape and dimension of the absorbers were fabricated by applying the concept of modern wall tiles that is available in the commercial market. The dimension of the tiles in terms of its length, width and thickness were also followed the standard dimension of modern wall tiles. For the absorbing materials, biomass material had been chosen with a different value of dielectric constant.

Biomass material is an organic material that comes from living organisms such as plants and animals. Kenaf (Hibiscus Cannabinus) and coconut coir were used in this project. Both kenaf and coconut coir are biomass materials. Kenaf is a sustainable green material product that's used for building and other industrial applications that have a better durable [7]. Meanwhile, coconut coir contains fibres that affect the strength of the concrete, which includes compressive and flexural strength when applied to the normal concrete [8]. The current construction of industrial evolution has caused pollution to the environment. The increase in water pollution occurs due to the metal coating industry's activities that discharged the waste into the water [9].

Manuscript received December 10, 2019; revised March 25, 2020; accepted May 9, 2020.
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doi: 10.18178/ijeetc.9.6.429-433

In dielectric materials, the main properties that enable them to be applicable as microwave absorber are the dielectric constant and the dissipation factor of energy [10]. Different sources of material have different values of dielectric constant. The dielectric constant of the material will give a different absorbing performance for the absorbers [11]. Dielectric properties measurement is an important aspect to define the physical properties of materials. Typically, there are various method that can be used to measure the dielectric properties, and for this project, the free-space method is used [12], [13].

This modern wall tile absorbers can be constructed with environmentally-friendly and renewable material that can reduce environmental pollution as well as reducing the cost of building construction. It can be owned by everyone and economical [13]. Besides, the modern wall tile absorbers have the potential to be commercialized because it provides a good absorbing performance.

II. Methodology

Based on the flowchart of the project progress shown in Fig. 1, the project started by doing some research about the microwave absorbers and data collection on the design of modern wall tile. Besides that, some research on the basic design of modern wall tiles also has been done. The information on the concept of modern wall tile in the current commercial including the shape, size and material was obtained to fulfil the scope of the project.

There are two methods used in this project to determine the performance of the wall tiles absorbers which are simulated by using the CST Suite Studio software and the NRL (Naval Research Laboratory) arch free-space method. CST Software is used to predict the preliminary result of the absorbers and to ensure the choosing material has coveted performance, while NRL Arch free space method is used to measure the moulded modern wall tile absorbers. Both results were analysed and discussed.

A. CST Suite Studio Software Simulation

CST software is a tool used for 3D simulation of a high-frequency component. This simulation is the forecast on how the dielectric constant and the dimension of the absorbers influence the performance of the micro-wave absorbers before the hardware implementation.

The model of the modern wall tile absorbers was designed and simulated in the CST software. Each design is applied with different values of dielectric constant. For the simulation, the value of the dielectric constant for each material is varied slightly lower and higher than the original value. The frequency range from 1 GHz to 12 GHz is chosen and the absorption level of the wall tile absorbers was displayed on the graph of magnitude (dB) versus frequency (Hz).

B. Hardware Development

Fig. 2 shows the design of a modern wall tile that has been proposed in this project. The proposed design of the modern wall tile is moulded into a microwave absorber. The shape of modern wall tiles that have been chosen was based on the shape of modern wall tiles in the current commercial market which have been used as wall tiles for home decoration.

There are various sizes of the wall tile in current commercial such as 20 cm × 20 cm, 30 cm × 30 cm, 20 cm × 30 cm, 45 cm × 45 cm and 60 cm × 60 cm. For this project, the size of 20 cm × 20 cm had been chosen since it is easy to mould compared with the bigger size of the wall tile. Next, for the thickness of the tile, a thickness of 2 cm had been chosen. According to the commercialize tile, standard tile thickness is between 1/4 inch to 3/4 inch or between 0.63 cm to 1.9 cm. Biomass material which is kenaf and coconut husk were used, and the design is applied with both materials as shown in Table I.

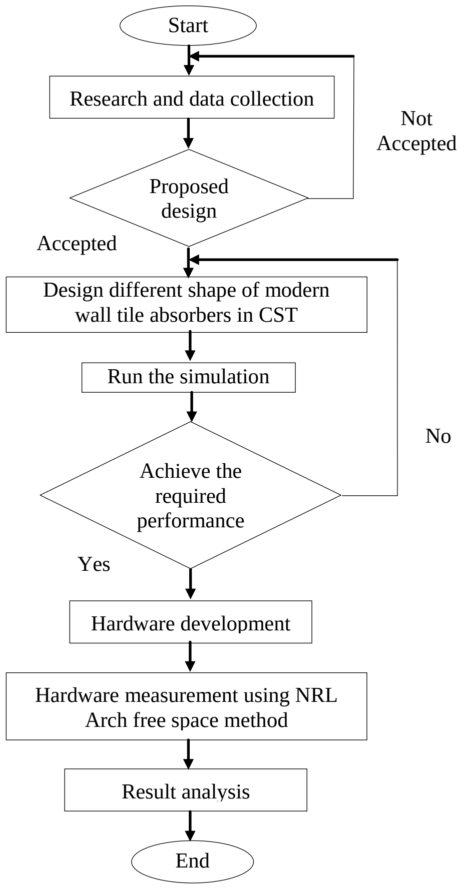

Fig. 1. Flowchart of project progress

Fig. 2. Proposed design of modern wall tile absorbers

TABLE I: MATERIAL APPLIED FOR MODERN WALL TILE

Absorber	Material
Absorber KA	Kenaf
Absorber CA	Coconut Coir
Absorber KCA	Kenaf + Carbon

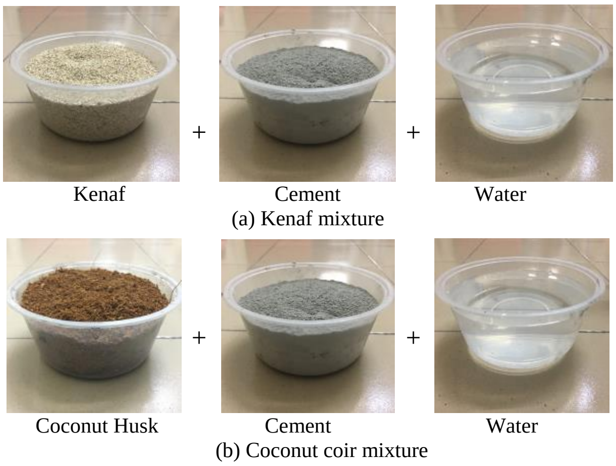

Fig. 3. Mixture material of absorbers

Fig. 4. Modern wall tile absorbers

The first step to fabricate the modern wall tile absorbers is by preparing the correct ratio of the material. Each biomass material is mixed together with cement and water. Fig. 3 shows the mixture of the material for the modern wall tile absorbers.

Then, the mixture of the material is poured into a mould with a size of 20 cm width × 20 cm length × 2 cm thickness. Carbon also has been used in this project and adds together with the mixture of the material. The mixture of the material is left to dry for a few days before being tested under NRL Arch. Fig. 4 below shows the absorbers that have been arranged to form a suitable size for the test.

C. NRL Arch Free Space Method

To measure the absorption of the absorbers, NRL Arch is used. NRL method is a free space measurement that is the standard used by industry for testing the reflectivity of the material or for testing the efficiency of the Radar Absorbing Material (RAM). It has a very simple measurement procedure where the material that will be tested is placed on the plate and the reflected signal is measured.

NRL Arch consists of two antennas that are transmitted and receive antenna faces toward a metal plate. The transmit antenna is connected to the signal generator and sends the microwave energy to the material under test while the receive antenna is connected to the signal detector and measure the excess microwave energy after the reflection. The two antennas were placed at a constant distance from the absorbers under test as shown in Fig. 5 above. The size of wall tiles absorbers set under test is 24 inch × 24 inch or 60 cm × 60 cm with a frequency range from 8 GHz to 12 GHz is used.

Fig. 5. NRL arch

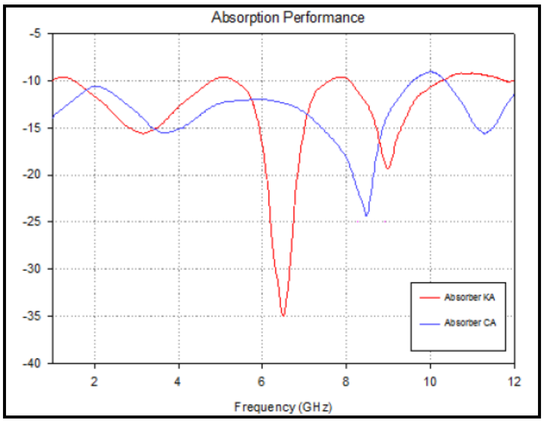

Fig. 6: Simulation result of modern wall tile absorbers

TABLE II: ABSORPTION DATA OF SIMULATION RESULT

Material	Dielectric Constant (ε)
Kenaf	2
Coconut Coir	2.6

III. RESULT AND DISCUSSION

The performance of modern wall tile absorbers with two different materials has been measured and discussed in this section. The simulation for the absorbers was done by using CST software, while the hardware of the absorbers was tested by using the NRL arch free space method. For the hardware, the measurement has been tested at an angle of 0°. Frequency range from 1GHz to 12GHz is selected for simulation and NRL Arch free space measurement. The result of the simulation and measurement were analysed and discussed.

A. Simulation Result

For the simulation part, the absorption performance of the absorbers has been simulated on the design with two different materials. Both materials have a different value of dielectric constant as shown in Table II. Fig. 6 shows the graph of the absorption performance of the simulation result for Absorber KA and CA.

Based on the simulation result shown in Fig. 6, for L band, Absorber CA has the best absorption performance with the minimum absorption of –10.62 dB at frequency 1.8 GHz and maximum absorption of –13.90 dB at 1 GHz. For S band, Absorber KA has the best absorption performance with the minimum absorption of –11.67 at 2 GHz and maximum absorption of –15.60 dB at 3.2 GHz. Next, for C band, the best absorption shows by Absorber CA with the minimum absorption of –11.98 dB at 11 GHz and maximum absorption of –18.12 dB at 8 GHz.

Lastly, for X band, the best absorption also shows by Absorber KA with the minimum absorption of –9.21 dB at 12 GHz and maximum absorption of –19.38 dB at 8.5 GHz.

For the overall performance of the absorbers, which is measured with the frequency range from 1 GHz to 12 GHz, both absorbers have the best absorption performance. Table III shows the absorption data of the simulation result.

TABLE III: ABSORPTION DATA OF SIMULATION RESULT

Absorber	Minimum to maximum absorption (dB)			
	L band (1-2GHz)	S band (2-4GHz)	C band (4-8GHz)	X band (8-12GHz)
KA	-9.62 ~ -10.00	-11.67 ~-15.60	-9.62 ~ -35.00	-9.21 ~ -19.38
CA	-10.62~ -13.90	-10.63~ -15.51	-11.98 ~ -18.12	-9.06 ~ -24.32

B. Measurement Result at 0 Degree (0°)

Fig. 7 shows the measurement result of the absorption performance of the modern wall tile absorbers at 0°. For L band, Absorber CA has the best absorption performance with the minimum absorption of –3.65 dB at frequency 1.1 GHz and maximum absorption of –7.76 dB at 2 GHz. Next, Absorber KCA shows the best absorption performance for S band, C band and X band. For S band, Absorber KCA shows the minimum absorption of –9.22 at 3.5 GHz and maximum absorption of –23.84 dB at 2.6 GHz. For C band, Absorber KCA shows the minimum absorption of –12.43 dB at 4.5 GHz and maximum absorption of –44.75 dB at 7.25 GHz. Lastly, for X band, Absorbers KCA shows the minimum absorption of –17.26 dB at 9.9 GHz and maximum absorption of –35.02 dB at 11.5 GHz.

For the overall performance of the absorbers, which is measured with the frequency range from 1 GHz to 12 GHz, Absorber KCA has the best absorption performance among all the absorber. Table IV shows the absorption data of the measurement result at 0°. Table IV shows the absorption data of the measurement result at 0°.

By comparing the absorption performance of the Absorber KA with the Absorber KCA, absorber KCA shows an increase in the absorption performance for all types of band. Absorber KCA had been applied to the same biomass material as absorbers KA, which is kenaf. Then, by adding some carbon to the mixture of material, it shows better and great absorption compares to a mixture of material without carbon. The result proved that a great performance of the microwave absorbers obtained by adding carbon to the mixture of the material.

The performance of the absorbers is influenced by their shape and material. Therefore, based on the objective of this project which is to investigate the performance of the modern wall tile absorbers with different materials, the result of the absorption performance of the absorbers is rearranged according to their material, as shown in Fig. 7.

Fig. 7 shows the graph of measurement results for modern wall tile absorbers. The design has been tested with the same shape. Based on the graph, it shows that the same shape of modern wall tile absorbers resulted in different absorption performance according to the materials.

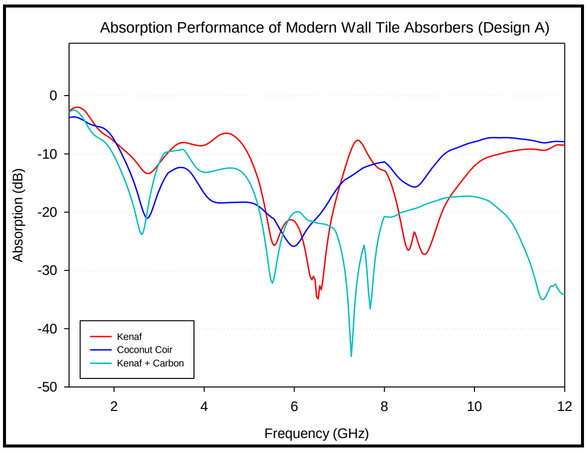

Fig. 7. Measurement result of modern wall tile absorbers 0°

TABLE IV: ABSORPTION DATA OF MEASUREMENT RESULT AT 0°

Absorber	Minimum to maximum absorption (dB)			
	L band (1-2GHz)	S band (2-4GHz)	C band (4-8GHz)	X band (8-12GHz)
KA	-1.99 ~ -7.94	-7.94 ~ -13.38	-7.63 ~ -34.90	-8.46 ~ -27.25
CA	-3.65 ~ -7.76	-7.76 ~ -21.00	-11.42 ~ -25.86	-7.21 ~ -15.69
KCA	-2.48 ~ -10.57	-9.22 ~ -23.84	-12.43 ~ -44.75	-17.26 ~ -35.02

IV. CONCLUSION

The proposed designs of modern wall tile have been successfully developed and moulded into microwave absorbers. The performance of modern wall tile absorbers has been analyzed and discussed. All the absorbers represented with different absorption performance, and among all the absorbers, Absorber KCA has the best performance with the absorption of –10 dB. However, at a certain frequency, the absorption of Absorber KCA is more than –10 dB. The observation shows the same design of modern wall tile absorber with different material give a different absorption performance. Therefore, the absorption of the modern wall tile absorbers was influenced by their shape and material of the absorbers is proven through this project.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Linda Mohd Kasim and Hasnain Bin Abdullah wrote the manuscript with input from all authors; Hasnain Bin Abdullah, Azizah Ahmad and Nur Hashira Narudin contributed to the design and implementation of the research; Noor Azila Ismail and Norhayati Mohamad Noor processed the experimental data and performed the analysis; Linda Mohd Kasim and Nazirah Mohamat Kasim performed the measurements. All authors contributed to the final version of the manuscript.

ACKNOWLEDGMENT

The authors would like to express their appreciation to Kementerian Pengajian Malaysia FRGS/1/2017/TK10/ UITM/03/7 and all parties involved, especially the Microwave Laboratory Universiti Teknologi MARA Cawangan Pulau Pinang staff throughout the research was carried out.

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