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THE POTENTIAL OF BIOMASS AS ANTI-MICROWAVE MATERIAL IN ORGANIC CEMENT BRICK

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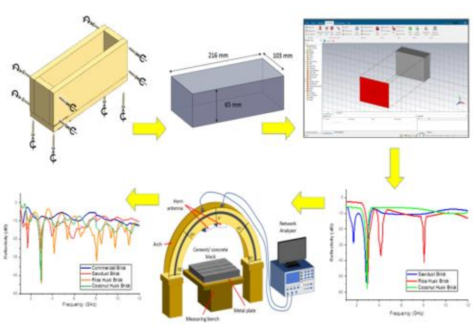
Graphical abstract



Abstract

Recently, radiation pollution has become a serious problem in which microwave radiation leads to various issues, such as health problems in humans. To address this issue, anti-microwave organic cement bricks were designed and fabricated. This study investigates the effectiveness of biomass used as absorbent materials when combined with cement to eliminate microwave radiation. Biomass materials that were indicated in this study were fine sawdust, rice husk, and coconut husk. The anti-microwave organic cement brick was designed in size of 216 mm length x 103 mm width x 65 mm thickness which is almost the same as commercial sand brick, 200 mm length x 100 mm width x 60 mm thickness. CST Microwave Studio Suite software was used to obtain the simulation results of the designed absorber. The free-space arch reflectivity measurement method was used to investigate the absorption performance of the designed anti-microwave organic cement brick in the frequency range of 1 to 12 GHz. This study evaluates the absorption performance of designed anti-microwave organic cement brick using commercial sand brick as benchmarks. The result shows that the organic cement brick which uses 20 % fine sawdust, 20 % rice husk, and 20 % coconut husk has the potential as an anti-microwave material that can reach a higher absorption performance of up to −44.36 dB compared to the commercial sand brick which only reaches absorption performance at -12.74 dB.

Keywords: Radiation pollution, biomass, microwave absorber, anti-microwave brick, sawdust, rice husk, coconut husk

Abstrak

Dewasa ini, pencemaran sinaran telah menjadi masalah serius di mana radiasi gelombang mikro membawa kepada pelbagai isu seperti masalah kesihatan dikalangan manusia. Untuk menangani isu ini, bata simen organik anti-gelombang mikro telah direka dan dihasilkan. Kajian ini menyiasat keberkesanan biojisim yang digunakan sebagai bahan penyerap apabila digabungkan dengan simen untuk menghapuskan sinaran gelombang mikro. Bahan biojisim yang ditunjukkan dalam kajian ini ialah habuk papan halus, sekam padi, dan sabut kelapa. Bata simen organik anti gelombang mikro direka bentuk dalam saiz 216 mm panjang x 103 mm lebar x 65 mm ketebalan yang hampir sama dengan bata pasir komersial, 200 mm panjang x 100 mm lebar x 60 mm tebal. Perisian CST Microwave Studio Suite digunakan untuk mendapatkan hasil simulasi penyerap yang direka bentuk. Kaedah pengukuran pemantulan lengkung ruang bebas telah digunakan untuk menyiasat prestasi penyerapan bata simen organik anti gelombang mikro yang direka dalam julat frekuensi 1 hingga 12 GHz. Kajian ini menilai prestasi penyerapan reka bentuk bata simen organik anti gelombang mikro menggunakan bata simen komersial sebagai penanda aras. Hasil kajian menunjukkan bahawa bata simen organik yang menggunakan habuk papan, sekam padi dan sabut kelapa berpotensi sebagai bahan anti gelombang mikro yang boleh mencapai prestasi penyerapan yang lebih tinggi sehingga –44.36 dB berbanding bata komersial yang hanya mencapai prestasi serapan pada -12.74 dB.

Kata kunci: Pencemaran radiasi, biojisim, penyerap gelombang mikro, bata anti gelombang mikro, habuk papan, sekam padi, sabut kelapa

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1.0 INTRODUCTION

Nowadays, technology has evolved tremendously fast, especially in the telecommunication industry. But among all of the benefits, there are also some bad effects in daily life. With the growth of the telecommunications industry as well as wireless and cordless communication, humans are easily exposed to high radiation conditions [1], [2], [3], [4], [5], [6] in which they will be surrounded by unhealthy and harmful environments. Thus, this required anti-microwave material that has the potential to absorb unwanted signals produced from radio frequency or electromagnetic radiation. Even though some people might say that they reduce the usage of gadgets in their everyday lives, humans are still exposed to the microwave radiation that's radiated from the telecommunication towers since they are built around residences, industrial areas, schools, etc. This situation has raised some concern among scientists worldwide regarding the health effects of radiation pollution [7].

Regarding the environmental and health issues that affect people, researchers have come up with some ways to prevent the issues, which are through the development of sustainable energy conservation. One of the ways is recycling solid wastes into beneficial supplementary raw materials for brand-new construction substances. Since there is an increase in waste material that can lead to pollution [8], it is better to put good use in its usage rather than dispose of it. Agriculture waste material, sometimes refer as biomass material, is made up of an organic compound that comes from living organisms such as plants and animals. Agriculture is an essential industry in Malaysia. Thus, the increase of biomass material from agro activities such as sawdust, rice husk and coconut husk cannot be avoidable. However, as all of these materials are biomass, they can be harvested directly for energy to produce heat and electricity or used in the form of residues and waste, for instance, as a replacement element in producing anti-microwave material [9].

Sawdust is a waste material from the timber industry. It is produced as timber is sawn into planks at sawmills. Sawdust, which mostly comes from rubber plants, contributed to the rubber industry in Malaysia, the third largest in the world. 51% of biodegradable wastes were generated in Malaysia, and 81% were disposed of at landfills and can produce a large volume of methane, CH4 [10]. High-containing carbon material that will affect the absorption performance of the cement brick can be found in the biomass sawdust [11], [12]. According to [13], main components of sawdust is consists of 43.27 % carbon, 6.83 % hidrogen, 0.39 % oxygen, 49.11 % nitrogen, and 0.4 % sulfur. Therefore, biomass sawdust from the rubber tree potentially can be used as an absorbent material in cement brick production [14], [15].

Rice husks have been used in biomass fuels to generate power and also as concrete mixtures in building construction work. The large percentage of carbon that occurs naturally in the rice husks can potentially provide good reflection loss performance for the anti-microwave material. Rice husk has been investigated as an alternative to the current material to design a low-cost anti-microwave material. Rice husks consist of 22.24 % silica [16], [17], 35.77 % carbon, 5.06 % hidrogen, 36.59 % oxygen, 0.32 % nitrogen, and 0.02 % sulfur are highly porous and lightweight with a density of 83-125kg/m^3 [17], and have a very high external surface area. Rice husks' absorbent and insulating properties are useful for many industrial applications. For example, rice husks have been used in biomass fuels to generate power and concrete mixtures in building construction. Recently, rice husks have been investigated as potential materials for the pyramidal microwave absorbers. The large percentage of carbon that occurs naturally in the rice husks has the potential to provide good reflection loss performance for the microwave absorbers [18].

Coconut by-products such as coconut husk are one of the readily available agricultural wastes from coconut production. In Malaysia, it was estimated that 5,280 kg of coconut waste were become available per hectare per year. At present, coconut wastes are used in horticultural and agricultural applications. To make better use of this cheap and abundant agricultural waste, coconut waste is used as an anti-microwave material [19]. The coconut husk contains about 30% by weight of coir fiber and 70% coir dust. At present, coir fiber is used to make traditional coir products such as mats, rugs, and carpets. Coir dust or coco peat is mainly used for horticultural and agricultural purposes. The coco peat contains lignin, cellulose and hemicellulose. Lignin is the most stable component out of these three. In coco peat, the lignin component acts as an intrinsic bonding agent in the production of binderless composite. The presence of lignin helps the coco peat to remain stable and retain its longer durability properties. These properties of coco peat are potentially useful as an anti-microwave that is to be implemented in telecommunication industry applications. The carbon content in coco peat is 38-50 % [20]. Meanwhile, other researchers reported that coconut husk consists of 40.2 % carbon, 5.85 % hydrogen, 53.43 % oxygen, 0.5 % nitrogen, and 0.02 % sulfur [21]. Table 1 tabulated the typical chemical composition of biomass materials, which are sawdust, rice husk and coconut husk.

Table 1 The percentages of biomass materials by elements

Element (%)	Fine Sawdust [13]	Rice Husk [16]	Coconut Husk [21]
Silicon Dioxide	-	22.24	-
Carbon	43.27	35.77	40.2
Hydrogen	6.83	5.06	5.85
Oxygen	0.39	36.59	53.43
Nitrogen	49.11	0.32	0.5
Sulfur	0.4	0.02	0.02

This paper will focus on developing an anti-microwave cement brick that contains biomass material in cementitious mixtures. Cement contains conductive material, which is good for reacting with microwave radiation. However, if the conductive properties are very weak or tend to be more conductive, it will lead to poor absorption ability [22], [23]. So, mixing with biomass containing carbon will influence wave absorption. Carbon characteristics will allow small charges or currents to flow through it since carbon is a semiconductor, making it suitable for fabricating an absorber.

Studies indicate that most biomass materials contain carbon, a crucial factor that can influence dielectric loss properties [24]. Moreover, the use of biomass in this research, as well as the aerated agent, made the cement brick structure lighter and porous, which could increase the surface area, contributing to a better interaction of microwave radiation [25].

2.0 METHODOLOGY

This section will describe the method and procedure for getting the optimum results of this research, which includes exploration of cement casting methods of cement brick, physical, dielectric properties until absorption performance characterization.

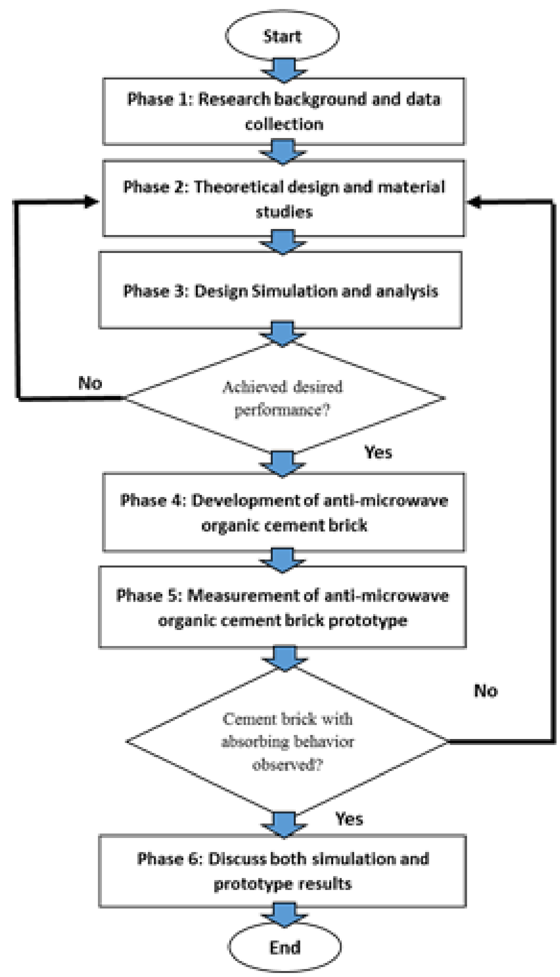

Figure 1 Flowchart of the study

The simulation using CST Suite Studio software was done as the reference before the physical development of anti-microwave organic cement brick. The dry density of anti-microwave organic cement bricks was calculated by measuring the mass and volumes of the cement bricks. The dielectric coaxial probe and the Naval Research Laboratory (NRL) Arch free space method were used for dielectric properties and absorption performance measurements, respectively. The results of absorption performance were compared with the simulation results. These processes are represented in Figure 1, and detailed descriptions will be provided afterward.

2.1 Anti-microwave Organic Cement Brick Design

Figure 2 shows the design of anti-microwave organic cement brick. The size is 216 mm length x 103 mm width x 65 mm thickness which is almost the same as commercial sand brick, 200 mm length x 100 mm width x 60 mm thickness.

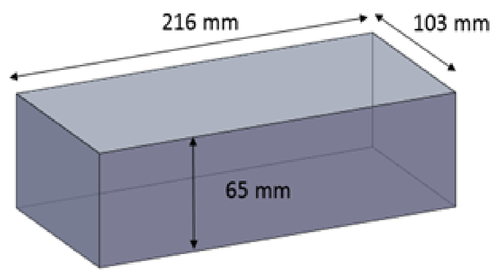

Figure 2 Design of anti-microwave organic cement brick

Figure 3 Biomass materials

In commercial sand brick development, two main materials were used: cement as the binder and sand, gravel, or crushed stone as the filler. In contrast, anti-microwave organic cement bricks were developed using biomass material as the filler, while cement was used as the binder. In addition, foam was added to the cement mixture to create a porous structure to enhance the absorption of microwave radiation. This makes the brick known as an aircrete brick, compared to commercial brick which is categorized as aggregate brick. The development process was started once the simulation was done by mixing the material required according to the ratio calculated. In this study, the organic cement bricks comprised biomass material, cement, foam and water. The biomass materials that were investigated in this study were including fine sawdust, rice husk and coconut husk, as shown in Figure 3.

A calculation was performed to determine the accurate ratio of biomass-cement-water. The weight of biomass replaces 20% ratio of cement. Previous studies demonstrate that biomass material ratios ranging from 10% to 50% enhance absorption [25], [26], [27], with a 20% ratio yielding the best absorption performance.

Foam is in the form of bubbles produced by mixing the foaming agent and water using a foam generator or some using a cement mixer to generate the foam. Foam is generally added to concrete to perform porosity structure; thus, on the other hand, it controls the density of the concrete to achieve lightweight concrete.

The cement and biomass materials were mixed up in a dry state until the mixture attained an even color throughout. Water was added to the dry mix with a water-cement ratio of 0.6. The pre-formed foam with a foaming agent-to-water ratio of 1:33 was poured into the cementitious mixture to increase the porosity with the targeted dry density of 1000 kg/m3. The mixture was mixed up uniformly and transferred into an oiled mold with a size of 216 mm length x 103 mm width x 65 mm thickness. The brick absorber is left for 24 hours to cure before demolding and measuring. 16 specimens were cast for each type of biomass material to investigate the absorption performance of the anti-microwave organic cement bricks incorporated with the biomass materials.

2.2 Dry Density and Dielectric Properties Measurements

The microwave absorption quality of a material, which controls the absorption, reflection or transmission efficiency of electromagnetic waves, is affected by its composition, structure and dielectric properties. Therefore, an analysis of the physical structure and dielectric behaviour of this organic cement brick must be evaluated. The anti-microwave organic cement bricks were measured to study the potential of biomass material as absorbent in cement brick. The dry densities were calculated using the equation (1):

$$Density, \rho = \frac{Mass, m}{Volume, v} = \frac{kg}{m^3} \tag{1}$$

The ε values of the samples were measured using dielectric coaxial probe setup for Agilent N1 500A as shows in Figure 4.

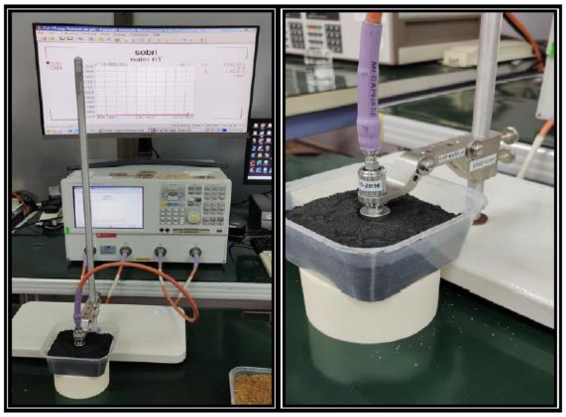

Figure 4 Dielectric coaxial probe setup for AgilentN1 500A

2.3 CST Simulation and Microwave Absorption Performance Measurements

CST Microwave Studio Software simulates the absorption performance of the anti-microwave organic cement bricks. Certain parameters need to be considered and analyzed, which are the shape, volume dimension and dielectric properties of materials.

Figure 5 shows the configuration of free space arch reflectivity measurement to determine the absorption performance of the organic cement bricks. The required frequency range for this study is from 1 to 12 GHz. This frequency range was chosen because it covers multiple frequency bands (L, S, C and X bands), commonly used in various telecommunications and radar applications. This wide range allows the study to evaluate the effectiveness of the materials across a wide spectrum of potential real-world applications [28], [29], [30], [31]. Besides, 1 to 12 GHz range is a standard frequency range used in many microwave absorber studies, making the results comparable with other research and industrial standards. This ensures that the findings can be validated and compared against existing materials and technologies [32].

2 pairs of horns are placed at a fixed distance from the material that is going to be tested or called as Material Under Test (MUT). The horn is mounted on the circular arch and will act as an antenna to transmit and receive electromagnetic wave signals. The transmitting horn will transmit the microwave signal to the material, and the remaining wave will be reflected in the receiving horn. The reflection is then measured. The reflectivity measurement indicates the absorption performance of the anti-microwave organic cement bricks. In this study, the materials were measured at an incidence angle of 0°, commonly stated as a normal incidence angle. This is because the absorber works most effectively when the incident electromagnetic wave impinges directly on them where the incident angle is configured at 0°. The size of the measuring bench is 600 x 600 mm, and the number of cement bricks must cover the metal plate on the measuring bench in order to get a precise measurement.

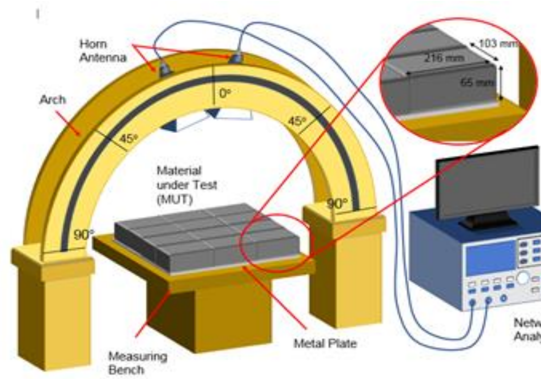

Figure 5 Free space arch reflectivity measurement configuration

Figure 6 shows the arrangement of anti-microwave organic cement bricks in a flat position to match the dimensions of a commercial flat absorber. The commercial absorber and bricks were measured in decibel (dB) that represent to reflectivity. The results were reported the minimum, maximum and average values of reflectivity. Minimum values of reflectivity indicates as maximum values of absorption performance while maximum values of reflectivity point to the minimum values of absorption performance. While the average values were referred to the sum of reflectivity values across 1 to 12 GHz frequency divided by the numbers of reflectivity data set.

Figure 6 Anti-microwave organic cement brick at flat position

3.0 RESULTS AND DISCUSSION

This section discusses the physical, dielectric properties, and absorption performance of anti-microwave organic cement brick in terms of simulation and measurement results based on commercial flat absorbers as benchmarks. The absorption performance for each prototype is measured and compared with simulation results obtained from CST Microwave Studio software and also with free space arch reflectivity measurement results. The reflectivity measurement is then plotted with Origin Pro 2021 Software.

3.1 Physical and Dielectric Properties of Anti-microwave Organic Cement Bricks

Table 2 shows the dry density of individual biomass material and developed organic cement bricks. In overall, all anti-microwave organic cement bricks are categorized as lightweight cement brick with dry density below 1800 - 2000 kg/m³ [11], [33]. From the table, the lowest value of biomass material density is 162 kg/m³ and 930 kg/m³ for organic cement bricks density. These lowest values were achieved by rice husk material and cement bricks. The results indicate that rice husk is lighter with high porosity and less dense than fine sawdust and coconut husk. A large number of porous structures can promote microwave absorption capacity [34].

Table 2 Dry density of biomass materials and respective bricks

Density (kg/m³)	Fine Sawdust	Rice Husk	Coconut Husk
Biomass Material	352	162	333
Organic Cement Brick	1062	930	1004

For dielectric properties, the results of dielectric constant, ε', dielectric loss, ε" and loss tangent, tanδ of anti-microwave organic cement bricks were tabulated in Table 3.

Table 3 Dielectric properties of anti-microwave organic cement bricks

Material Under Test (MUT)	Dielectric Constant, ε'	Loss Factor, ε"	Loss Tangent, tan δ = ε"/ε'
Fine Sawdust	1.8020	1.1511	0.6388
Rice Husk	3.1801	2.1469	0.6751
Coconut Husk	2.2253	5.1229	2.3021

Dielectric properties represent the ability of the materials to store and dissipate electric energy, as well as the efficiency of the materials in converting electromagnetic energy into heat. The results indicate that 20 % rice husk cement brick has a larger dielectric constant of 3.1801, followed by 2.2253 for 20 % coconut husk cement brick and 20 % fine sawdust cement brick at 1.8020. The existence of silica in the chemical compositions of the rice husk contributes to high insulating properties, which is expressed in the high value of the dielectric constant.

For the loss factor, ε" the highest value is 5.1229 achieved from coconut husk cement brick while 2.1469 and 1.1511 are for rice husk and fine sawdust cement bricks, respectively. The main factor that contributes to the loss factor is carbon, as this element is present in all three materials [13], [16], [21]. It can be seen that besides carbon, oxygen influences the dissipation loss [35] of the rice husk and coconut husk materials, as these materials show a larger loss factor than fine sawdust, which only has less than 1 % oxygen element. However, the nitrogen element in biomass materials, especially in fine sawdust with a higher percentage of nitrogen, may contribute less as it tends to affect the magnetic loss than dielectric loss [36], [37].

A larger loss tangent was achieved at 2.3021 by coconut husk cement brick, followed by rice husk and fine sawdust cement bricks at 0.6751 and 0.6388, respectively. Loss tangent has direct relation to microwave absorption as it represents the amount of energy lost as heat, showing a material's ability to absorb microwave energy and convert it into heat. Thus, loss tangent is an important parameter when designing microwave applications.

3.2 Commercial Flat Absorber

Figure 7 shows the measurement result of a commercial flat absorber size 600 mm width x 600 mm length x 60 mm thickness. The commercial flat absorber, which has a thickness comparable to commercial and organic cement bricks, was measured as the reference to validate the effectiveness of the cement bricks as cement-based composites absorber. The minimum absorption value is at reflectivity - 3.76 dB at a frequency of 1.46 GHz, while the maximum absorption value is at reflectivity - 73.56 dB at 11.7 GHz. Considering data results from 2 GHz frequency, the overall absorption performance of commercial absorber shows a huge reflectivity range between -16 dB to - 74 dB. The reasons of considering data results from 2 GHz were explained in the Section 3.4 where the data sets of commercial sand and organic cement bricks were reported.

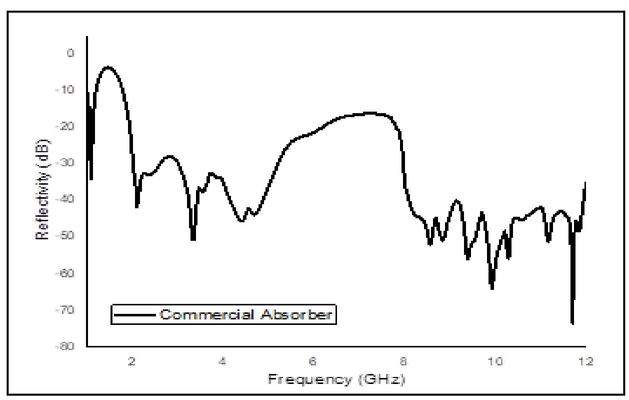

Figure 7 Commercial flat absorber measurement result.

3.3 Absorption Performance CST Simulation Results of Anti-microwave Organic Cement at Flat Position

The simulation results of fine sawdust, rice husk and coconut husk anti-microwave organic cement bricks were generated in Figure 8 at a flat position. The fine sawdust cement brick represents in dotted red line, rice husk cement brick in single orange line and coconut husk cement brick in double green line graphs.

Based on the maximum value of absorption performance, coconut husk brick slightly shows the highest at a reflectivity of -57.74 dB at a frequency of 2.93 GHz, followed by rice husk brick at a reflectivity value of -54.36 dB with frequency of 2.96 GHz and fine sawdust brick at reflectivity -53.55 dB with frequency of 2.82 GHz. Neglecting the results from 1 to 2 GHz, the lowest minimum absorption value was achieved from rice husk cement brick at -3.08 dB at a frequency of 2.02 GHz, followed by coconut husk at a reflectivity of -6.45 dB at a frequency of 3.45 GHz. At the same time, fine sawdust has a minimum absorption value at reflectivity -10.11 dB at a frequency of 2.12 GHz. To present a clear picture of the absorption performance, Tables 4 and 5 tabulated the maximum and minimum values of absorption performance of CST simulation by band.

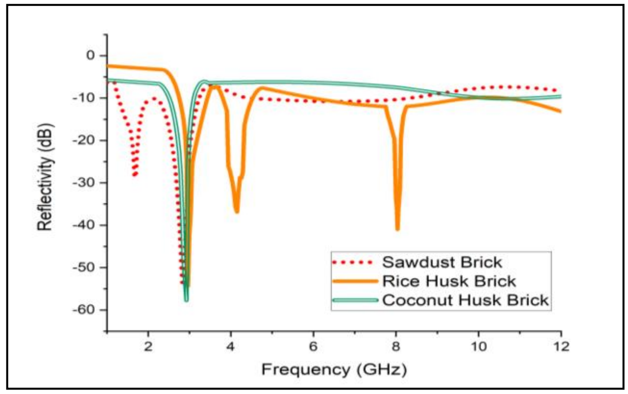

Figure 8 Simulation results at the flat position

Table 4 Absorption performance simulation of anti-microwave cement brick with fine sawdust, rice husk, and coconut husk biomass material in separate frequency bands (maximum value)

Material Under Test (MUT)	L Band (1 – 2 GHz)	S Band (2 – 4 GHz)	C Band (4 – 8 GHz)	X Band (8–12 GHz)
Fine Sawdust	28.76	53.55	19.80	19.37
Rice Husk	3.06	54.36	36.88	40.97
Coconut Husk	6.42	57.74	16.47	19.15

Table 5 Absorption performance simulation of anti-microwave cement brick with fine sawdust, rice husk, and coconut husk biomass material in separate frequency bands (minimum value)

Material Under Test (MUT)	L Band (1 – 2 GHz)	S Band (2 – 4 GHz)	C Band (4 – 8 GHz)	X Band (8–12 GHz)
Fine Sawdust	6.06	10.11	17.72	16.35
Rice Husk	2.41	3.08	16.61	18.81
Coconut Husk	5.77	6.45	15.22	16.47

3.4 Absorption Performance Measurement of Anti-microwave Organic Cement at Flat Position

Figure 9 represents the measurement results for each biomass material anti-microwave organic cement brick compared to the absorption performance of commercial brick at a flat position. The comparison aims to demonstrate that cement bricks with biomass materials could enhance the microwave absorption properties of commercial bricks. The thickness of the commercial brick is used as a reference to determine the thickness of other materials under test (MUT). It is crucial to maintain the consistency in thickness to ensure that the transmission distance of wavelength remains the same, making the sample comparable for analysis.

For commercial sand brick, the result shows that the minimum absorption value is at reflectivity -2.49 dB at a frequency of 1.67 GHz. Meanwhile, the maximum absorption value is at reflectivity -12.74 dB at a frequency of 12 GHz, respectively. From the results, the average absorption performance is – 8.71 dB for the 1 to 12 GHz frequencies range. Anti-microwave organic cement brick with 20 % fine sawdust measurement result shows that the minimum absorption value is at reflectivity -2.35 dB at a frequency of 1 GHz. In contrast, the maximum absorption value is at reflectivity -24.77 dB at a frequency of 2.82 GHz, respectively. From the results, the average absorption performance is – 10.76 across the 1 to 12 GHz frequency range. The measurement result for anti-microwave organic cement brick with 20 % rice husk in a flat position shows the minimum absorption value at reflectivity -0.77 dB at a frequency of 1.42 GHz, while the maximum absorption value is -44.36 dB at a frequency of 2.96 GHz. From the results, the average absorption performance is -13.32 dB across the 1 to 12 GHz frequency range. For anti-microwave organic cement brick with 20 % coconut husk measurement result, the minimum absorption value is -0.53 dB at frequency 1.42 GHz while the maximum absorption value is -42.74 dB at frequency 2.93 GHz. From the results, the average absorption performance is -11.85 dB across the frequency range of 1 to 12 GHz.

For analysis of the overall absorption performance where the reflectivity range was observed for each type of cement brick, only data starting at 2 GHz and above were considered. In many cases, researchers decide to disregard microwave absorption results between 1 and 2 GHz [28], [30], [38], [39]. This decision is often made because lower frequencies are more susceptible to noise and interference from numerous sources, which can impair the quality and dependability of the obtained data [40]. This is reflected from the results of minimum absorption values for commercial flat absorber, commercial sand brick and organic cement bricks that showed in between 1 to 2 GHz frequency. Commercial sand brick and coconut husk cement brick show a narrow reflectivity range between -5 dB to -12 dB and -6 dB to -17 dB, respectively. Both graphs are relatively constant and almost flat as they have fewer sharp dips and spikes. Meanwhile, for fine sawdust cement brick, the reflectivity range is between -6 dB to -20 dB, with the graph showing a sharp dip at certain frequencies, indicating a significant reduction in reflectivity and representing the performance of microwave absorption. As for rice husk cement brick, the reflectivity range is between -5 dB and -28 dB, which is widely compared to others. The pattern is quite the same as fine sawdust cement brick, but the reflectivity of rice husk cement brick rapidly fluctuates, showing that its ability to absorb electromagnetic waves varies significantly.

An important consideration in designing advanced microwave absorption materials is a narrow and wide reflectivity range across a broad frequency range. Materials with a narrow reflectivity range that exhibit small changes of reflectivity across a wide range of frequencies might have stable and consistent absorption at various frequencies. This type of material will be optimized to absorb as much electromagnetic energy as possible since it has potential for wideband microwave absorption application [41]. Meanwhile, for materials with a wide reflectivity range, it may be useful for applications that require control of electromagnetic waves across a broad frequency range, enabling its use in various electromagnetic interference reduction applications such as radar stealth [41], [42].

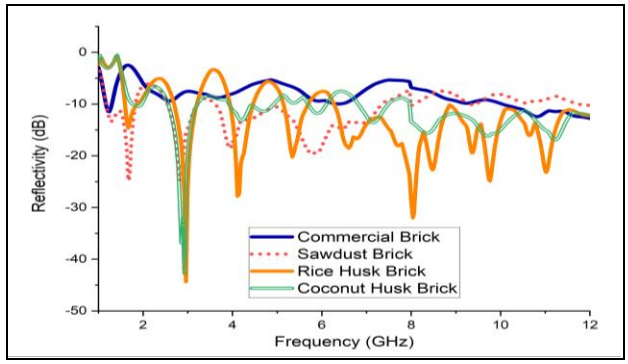

Figure 9 Reflectivity measurement results for each biomass material anti-microwave organic cement brick at a flat position

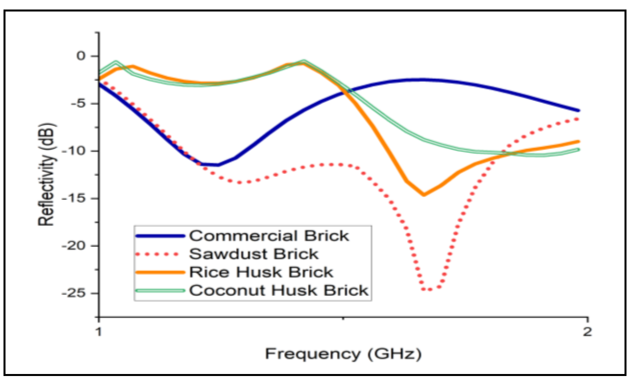

Figure 10 Reflectivity measurement results for each biomass material anti-microwave organic cement brick at L-band

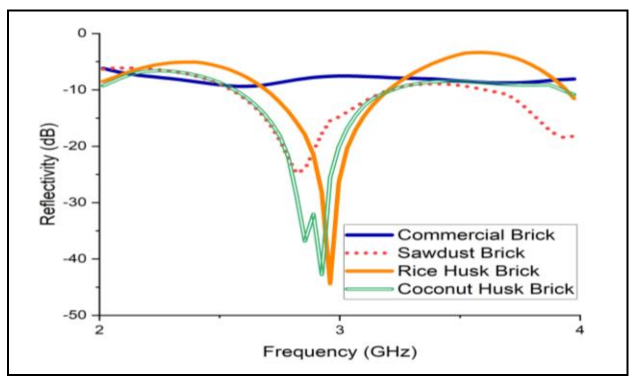

Figure 11 Reflectivity measurement results for each biomass material anti-microwave organic cement brick at S-band.

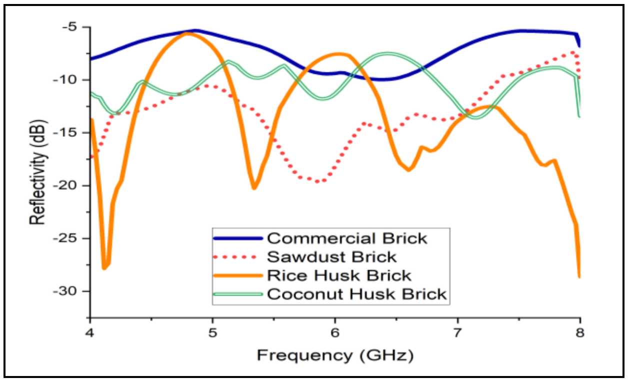

Figure 12 Reflectivity measurement results for each biomass material anti-microwave organic cement brick at C-band

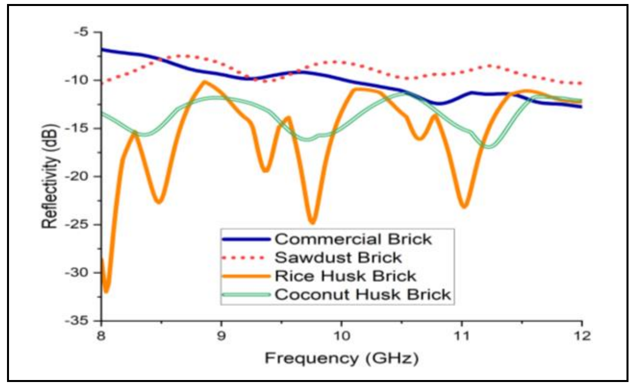

Figure 13 Measurement results for each biomass material anti-microwave organic cement brick at X-band

Figures 10, 11, 12, and 13 represent the respective reflectivity measurements of anti-microwave organic cement bricks for the L-band, S-band, C-band, and X-band. In L-band, it can be said that the reflectivity for all bricks drops around the frequency of 1.2 GHz to 1.3 GHz, also at 1.7 GHz for all bricks except commercial sand brick. The same happens in the S-band, all organic cement bricks drop around the same frequency at 2.8 GHz to 2.95 GHz. Meanwhile, in C-band and X-band, the reflection value for each brick does not fall in the same frequency range but it varies according to the type of bricks. As previously discussed, rice husk cement bricks show fluctuation in a wide reflectivity range while fine sawdust and coconut husk cement bricks represent almost stable signals with a narrow reflectivity range. The changes across the frequency range happen because of the properties of the bricks and the material itself such as the intrinsic properties, thicknesses of the bricks, geometry, and surface roughness [43], [44], [45], [46]. Details were tabulated and plotted in Tables 6, 7, Figures 14 and 15.

Table 6 Absorption performance data of commercial brick and anti-microwave cement brick with fine sawdust, rice husk, and coconut husk biomass material in separate frequency bands (maximum value)

Material Under Test (MUT)	L Band (1 – 2 GHz)	S Band (2 – 4 GHz)	C Band (4 – 8 GHz)	X Band (8–12 GHz)
Commercial Brick	11.4782	9.3837	9.9688	12.7445
Fine Sawdust	24.7557	24.7738	19.6674	10.272
Rice Husk	14.6412	44.3637	27.8375	31.9748
Coconut Husk	10.4443	42.7397	13.5816	16.9529

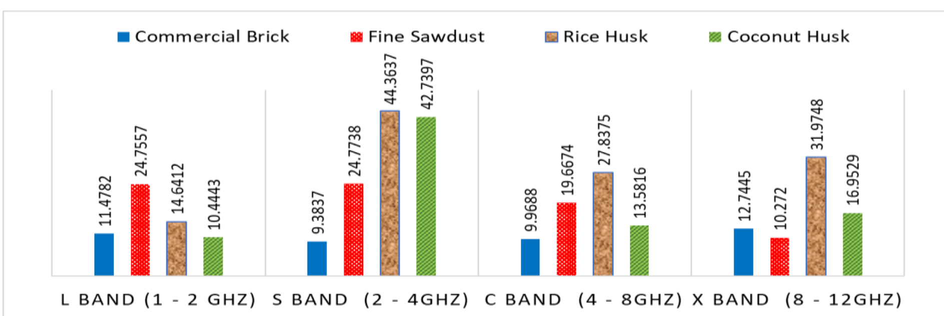

Figure 14 Absorption performance data for each type of cement brick by band (maximum value)

Table 7 Absorption performance data of commercial brick and anti-microwave cement brick with fine sawdust, rice husk, and coconut husk biomass material in separate frequency bands (minimum value)

Material Under Test (MUT)	L Band (1 – 2 GHz)	S Band (2 – 4 GHz)	C Band (4 – 8 GHz)	X Band (8–12 GHz)
Commercial Brick	2.4854	6.1696	5.3347	6.7897
Fine Sawdust	2.3516	6.1103	7.3179	7.4718
Rice Husk	0.772	3.3431	5.6312	10.1543
Coconut Husk	0.5255	6.611	7.496	11.3671

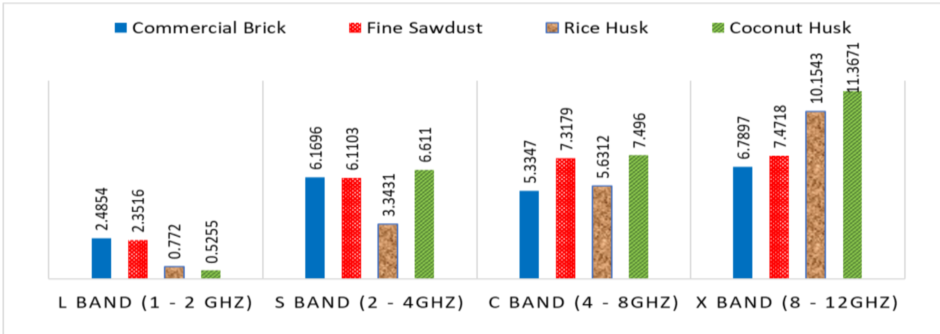

Figure 15 Absorption performance data for each type of cement brick by band (minimum value)

Table 6 shows the recorded value of the maximum absorption performance of commercial sand brick and anti-microwave organic cement brick with 20 % fine sawdust, 20 % rice husk, and 20 % coconut husk biomass material in separate frequency bands. The table clearly shows that the anti-microwave organic cement bricks have the potential to perform as absorbing material compared to commercial sand brick, which can achieve up to -20 to -40 dB as their average absorption performance with the maximum value at -44.36 dB achieved by rice husk organic cement brick.

At the L-band, organic cement brick containing 20 % fine sawdust gives the best absorption performance of -24.76 dB at a frequency of 1.67 GHz. At the S-band, organic cement brick containing 20 % rice husk with an absorption performance of -44.36 dB at a frequency of 2.96 GHz shows the best result. The same goes for the C-band, organic cement brick containing 20 % rice husk giving an absorption performance of -27.84 dB at a frequency of 4.12 GHz. In the X-band, the best result is still shown by 20 % rice husk organic cement brick with an absorption performance of -31.97 dB at a frequency of 8.04 GHz. Overall, anti-microwave cement brick containing 20 % rice husk offers the best results compared to commercial cement brick and organic cement brick with 20 % fine sawdust and 20 % coconut husk, as can be seen in Figure 14. In observing the results by bands, the S-band shows the increment of absorption performance for all organic cement bricks. Anti-microwave cement brick containing 20 % rice husk and 20 % coconut husk shows a rising and falling pattern in the same band where the absorption increases from the L-band to the S-band before dropping at the C-band. It then slightly increases at the next band, which is X-band.

Table 7, Figure 15 represent the commercial sand brick and the influence of 20 % fine sawdust, 20 % rice husk and 20 % coconut husk in anti-microwave organic cement brick towards the performance of absorption for the minimum value of reflection in every frequency band. Overall, organic cement brick with 20 % coconut husk gives the higher value of minimum data, as shown in Table 7 and Figure 15. This result shows that the absorption performance rate of organic cement brick with 20 % coconut husk has the potential to be improved if further research is continued. All cement bricks show an increase in absorption value from L-band to S-band.

4.0 CONCLUSION

From this study, it can be concluded that the organic cement brick which using fine sawdust, rice husk, and coconut husk as its materials has potential as anti-microwave absorber that can absorb microwave signals at a frequency range of 1 to 12 GHz, which reaches to – 44.36 dB compared to the commercial brick which is reached at -12.74 dB. Overall, the fine sawdust, rice husk and coconut husk anti-microwave organic cement bricks can achieve their optimum absorption performance value at S-band which is -24.77 dB, - 44.36 dB and - 42.74 dB, respectively. For future work, these organic cement bricks with biomass materials can be proposed for further investigation by exploring the filing ratio, different thickness, geometric design and other factors to achieve the desired absorption performance for commercial use with advantages as anti-microwave appliance.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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