Progress In Electromagnetics Research, Vol. 117, 449–477, 2011

RUBBER TIRE DUST-RICE HUSK PYRAMIDAL MICROWAVE ABSORBER

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Abstract—Rubber tire dust-rice husk is an innovation in improving the design of pyramidal microwave absorbers to be used in radio frequency (RF) anechoic chambers. An RF anechoic chamber is a shielded room covered with absorbers to eliminate unwanted reflection signals. To design the pyramidal microwave absorber, rice husk will be added to rubber tire dust since the study shows that both have high percentages of carbon. This innovative material combination will be investigated to determine the best reflectivity or reflection loss performance of pyramidal microwave absorbers. Carbon is the most important element that must be in the absorber in order to help the absorption of unwanted microwave signals. In the commercial

Received 8 April 2011, Accepted 13 June 2011, Scheduled 17 June 2011

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market, polyurethane and polystyrene are the most popular foam-based material that has been used in pyramidal microwave absorber fabrication. Instead of using chemical material, this study shows that agricultural waste is more environmentally friendly and has much lower cost. In this paper, three combinations of rubber tire dust and rice husk are fabricated to investigate the performance of microwave absorber reflection loss in operating in the frequency range from 7 GHz to 12 GHz.

1. INTRODUCTION

Every year, tire rubber is dumped into landfills. These wastes are non-environment friendly and hazardous to animals, soil, and community [1]. Several studies have examined various applications of recycled tire rubber in order to reduce the waste at landfills. In the United Kingdom, about 40 million tires are disposed as waste every year [2]. The increasing number of vehicles on the road worldwide will continue to increasing this waste, which will affect the environment because rubber is not easily bridgeable material and because it produces hazardous chemicals. Old tires at landfills can hold water for long periods, providing breeding sites for mosquito larvae [3]. Rainwater in tires can cause bad smells and environmental pollution [4]. Many countries have banned landfills from accepting rubber tire waste.

The advantages of rubber tire material are its lightweight, elastic, energy absorption, and sound- and heat-insulating properties [5]. Many researchers have used this material in their research in such areas as rubberized concrete [6–8], athletic facilities like jogging tracks and playgrounds [9], and synthetic reefs in marine environments [10]. This material contains carbon as its major element.

Rapid development in the telecommunication field has increased the need for RF anechoic chambers. Shielded anechoic chambers are widely used to facilitate RF-isolated test regions to simulate free-space test environments for antenna measurement [11]. Currently, there are two types of anechoic chambers in the market: the acoustic anechoic chamber and the Radio Frequency (RF) anechoic chamber. The interior surfaces (walls, ceiling, and floor) of the RF anechoic chamber are covered with radar-absorbent material (RAM) to create an electromagnetically quiet environment [12]. Microwave absorbers, the main component in anechoic chambers, are used to eliminate reflected signals. Electromagnetic-absorbing materials are crucial to ensure the accuracy of the testing performance. There are many enhanced absorber technologies in the market. In the commercial market, microwave absorbers are typically manufactured by impregnating conductive carbon into a foamed plastic medium. Polyurethane and polystyrene are the most popular foam-based material used in the fabrication of pyramidal microwave absorbers.

Agriculture waste has also been investigated to build microwave absorbers. Agriculture waste, also known as biomaterial, such as rice husks and banana leaves, is environmentally friendly material that has great potential to be fabricated as microwave absorbers. If these biomaterials can be used wisely, the amount of industrial waste will be reduced, perhaps leading to a reduction in environmentally harmful emissions. Hence, rice husk has been investigated as an alternative to the current material in order to design a low-cost microwave absorber. Rice husks consist of 92–95 percent silica, are highly porous and lightweight, and have a very high external surface area. Rice husks' absorbent and insulating properties are useful for many industrial applications [13]. For example, rice husks have been used in biomass fuels to generate power and in concrete mixtures in building construction [14–16]. Recently, rice husks have been investigated as potential materials for the pyramidal microwave absorbers [17]. 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].

A combination of rubber tire dust and rice husks may improve the design of pyramidal microwave absorbers to be used in radio frequency (RF) anechoic chambers. Microwave-absorbing materials that are used in anechoic chamber can reduce reflections of high-frequency energies. The microwave absorbers in this frequency range are used for many applications, including in telecommunications, the military, high-speed electronics, and the automotive industry. Absorber shapes also affect the performance of microwave absorbers, although most of the electromagnetic anechoic chamber manufacturers offer a standard microwave absorber product that is pyramidal in shape to meet specified industry standards. In this study, rice husk will be added to rubber tire dust to design a pyramidal microwave absorber. This innovative material combination will be investigated to determine the best reflectivity performance of microwave absorbers. Carbon, which is contained in both tire dust and rice husks, is the most important element that must be in the absorber in order to help the absorption of unwanted microwave signals. Figure 1 shows an example of waste from rice husks and carbon black from rubber tire dust.

Figure 1. Example of waste: Rice husk and carbon black from rubber tire dust.

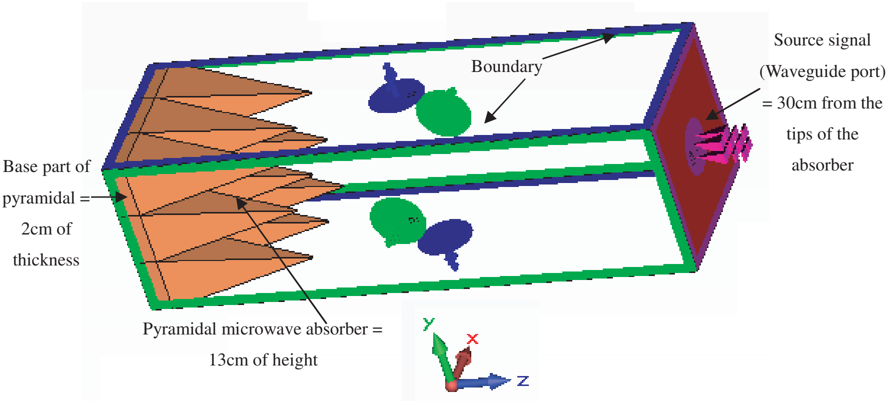

Figure 2. Simulation setup for pyramidal microwave absorber using CST microwave studio.

2. SIMULATION OF THE PYRAMIDAL MICROWAVE ABSORBER

Figure 2 shows the simulation setup of the rubber tire dust-rice husk pyramidal microwave absorber. The source signal is located in the direct path of the pyramidal microwave absorber. The set-up of this design is based on [19].

In the current work, the microwave absorbers are designed using Computer Simulation Technology Microwave Studio (CST MWS) simulation software. The design of the pyramidal absorber design shape in this work is based on the commercially available Eccosorb *VHP-8-NRL* Pyramidal Microwave Absorber [20] and *TDK ICT-030* Pyramidal Microwave Absorber [21]. The pyramidal shape has two main parts: the first part is the base part with a 5 cm length × 5 cm length × 2 cm thickness or height, and the second part is the pyramid part with a 13 cm height [22–26].

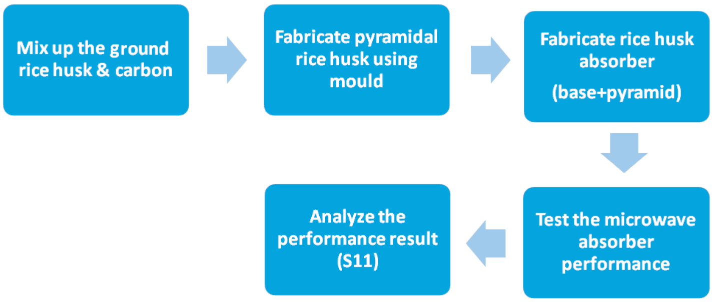

Figure 3. Development of rubber tire dust-rice husk pyramidal microwave absorber.

3. DEVELOPMENT OF PYRAMIDAL MICROWAVE ABSORBER

RF absorbers are one of the main components that are installed at the wall and floor of the anechoic chamber — sometimes called the "quiet room". This equipment has been used to eliminate reflected signals. The microwave frequency range absorber is operates in the frequency range of 1–40 GHz. There have been many investigations of the RF absorbers [27–33].

Figure 3 shows the development of the pyramidal microwave absorber. First, the ground rice husks are added to rubber tire dust (carbon black) using polyester as a bonding agent and methyl ethyl ketone peroxide (MEKP) as a hardener agent. Resins or bonding agents are used to glue the adjacent material particles and layers when fabricating using agricultural wastes, while MEKP is a colorless, oily liquid at room temperature. The mixture was fabricated into a pyramidal shape with a square base. The next step was to test the reflection loss performance of the pyramidal microwave absorber. Finally, the performance results of three different percentages of rubber tire dust and rice husks were analyzed.

There are many shapes of microwave absorber that have been used in research, including pyramids, wedges, convoluted shapes, metamaterial bases, and oblique [34–45]. The recent research by Nornikman et al. showed that rice husks can be an alternative natural material for designing a pyramidal microwave absorber. In the current work, rice husk was added to rubber tire dust in several ratios to compare its reflection loss performance. Table 1 shows the different ratios of rubber tire dust and rice husks, and Figure 4 shows the mixture of 75 percent rubber tire dust with 25 percent rice husk.

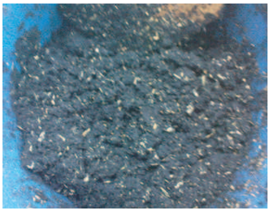

Figure 4. The mixture of 75 percent rubber tire dust and 25 percent rice husks (Mixture C).

Figure 5. Fabrication process of the pyramidal microwave absorber.

Table 1. Rubber tire dust and rice husk ratios.

Rubber tire dust-rice husk mixture	**Percentage (%)**	
	Rubber tire dust	Rice husk
Mixture A	25	75
Mixture B	50	50
Mixture C	75	25

Figure 5 shows how to fabricate the mixture into the pyramidal shape absorber mould. The equipment needed for the microwave absorber fabrication is a hand press machine, a plastic cup, a stick, a digital scale, special transparent plastic, and a pyramidal shaped absorber mould. For 50 : 50 rubber tire dust-rice husk mixture, 75 g of the rubber tire dust, 75 g of rice husk, 15 g of polyester resin, and 0.2 g of MEKP hardener are mixed into a plastic cup to make a mixed material for absorber fabrication. After that, the mixture is pressed to fabricate the pyramidal shape using the hand press machine at a material laboratory.

4. PRINCIPLE OF COAXIAL LINE

The open-ended coaxial probe is a cut off section of transmission line. The material is measured by immersing the probe into a liquid or touching it to the flat face of a solid (or powder) material. The fields at the probe end "fringe" into the material and change as they come into contact with the materials under test (MUT), as shown in Figure 6. The reflected signal (S_{11}) can be measured and is related to $\varepsilon_r{}^*$.

The open end of the coaxial line is terminated by a semi-infinite sample on a ground plane. In general, the medium between the conductors is filled by free space or lossless materials such as Teflon (PTFE). The application is based on the principle that a reflected signal through the coaxial opening will carry the desired information about the material sample at terminal surface. Thus, if the aperture admittance or reflection coefficient characteristics can be precisely formulated then, it can be used as a probe for the characterization of material samples.

The radii of inner and outer conductors, a and b (Figure 6) obey the inequality a, $b \ll \frac{\lambda_0}{\sqrt{\varepsilon_r}}$, $G(\varepsilon_r)$. $G(\varepsilon_r)$ (Figure 7) is the radiation conductance; C_f is the capacitance of the fringing field in the coaxial line; and $C(\varepsilon_r)$ is the capacitance of the field in the sample with ε_r. Both C and G are the function of ε_r, which depends on the permittivity of the sample. Meanwhile, C_f, C and G (conductance) depend on the dimensions of the coaxial line such as the radius of inner conductor,

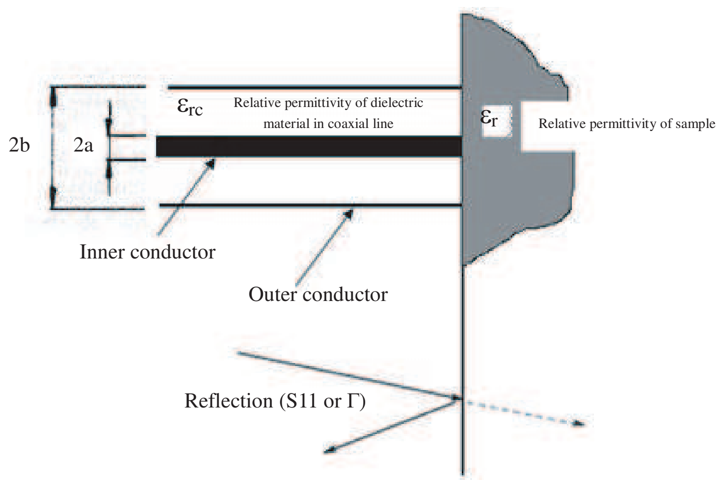

Figure 6. Configuration of a coaxial line.

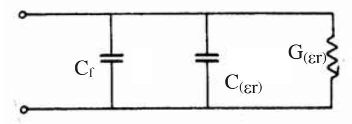

Figure 7. Equivalent circuit for the open-ended coaxial sensor.

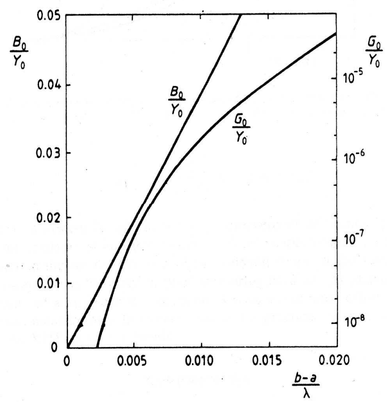

Figure 8. The end susceptance (B_0) and conductance (G_0) of an open-ended coaxial line in air. The characteristic admittance of the line is Y_0 [46].

a, and the radius of outer conductor, b, as well as permittivity of the dielectric filling the line. C_f, C_0 and G_0 in free space can be obtained through [47]. The total end capacitance C_T ($C_T = C_f + C_0$ for the case in air) and C_f can be obtained numerically [48] or simply measured [49]. Besides that, it can also be determined approximately through quasi-static analysis [50, 51]. The total capacitance, C_T ($=\frac{B_0}{\omega}$), and radiation conductance, G_0, in air can be predicted using Figure 8 [52]. C_f and G_0 can be neglected at first approximation [46]. When the sensor is contacted with the sample, the permittivity of the sample changes the end capacitance and it gives the load admittance as

$$Y = G + jB \tag{1}$$

where G and B are conductance and susceptance, respectively.

Then, the reflection coefficient is given by

$$\Gamma = \frac{-Z_0 + 1/\left[j\omega C_0(\varepsilon_r' - j\varepsilon_r'')\right]}{Z_0 + 1/\left[j\omega C_0(\varepsilon_r' - j\varepsilon_r'')\right]} \tag{2}$$

where $\varepsilon* = \varepsilon_r' - j\varepsilon_r''$.

The cross section of coaxial line is illustrated in Figure 9. It is a common two-conductor transmission system and widely used at frequencies below about 5 GHz [53]. It is possible to use up to 20 GHz if specially constructed coaxial lines are used. The dielectric filling used in most microwave applications is Polytetrafluoroethylene (PTFE) or Teflon.

The accuracy of the dielectric probe in reflection measurement of material can be verified by carrying out the error analysis. Some known dielectric material such as propanol, methanol, ethanol and water are used in the verification. These known complex permittivities for known materials are applied in the simulation using FEMLAB. The error analysis has been conducted and tabulated in Table 2 [54]. The percentage of error that is indicated in Table 2 show less than 4%, which indicates a good dielectric probe used in reflection measurement.

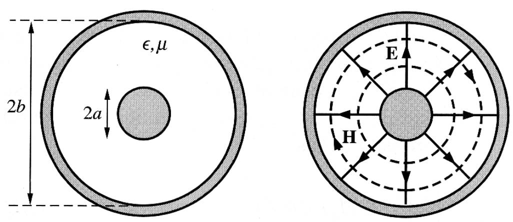

Figure 9. Coordinate system and dimensions for a coaxial line [55].

Table 2. Error analysis upon the performance of dielectric probe in reflection measurement.

Known material	Using measured ε_r obtained from commercial HP probe in Finite Element Method (FEM) simulations	Using calculated ε_r obtained from literatures in FEM simulation
	$\left\lvert\frac{\Gamma_{Measured}-\Gamma_{FEM}}{\Gamma_{Measured}}\right\rvert \times 100\%$	$\left\lvert\frac{\Gamma_{Measured}-\Gamma_{FEM}}{\Gamma_{Measured}}\right\rvert \times 100\%$
Propanol	$\sim 1.7\%$	$\sim 2.9\%$
Ethanol	$\sim 1.4\%$	$\sim 3.7\%$
Methanol	$\sim 2.2\%$	$\sim 2.8\%$
Water	$\sim 2.4\%$	$\sim 2.8\%$

5. DEFINING THE DIELECTRIC PROPERTIES

Dielectric properties measurement is an important factor in defining the physical and chemical properties that are related to storage and loss energy in respect to different kinds of materials. The dielectric constant is equivalent to relative permittivity (ε_r), or the absolute permittivity (ε) is relative to the permittivity of free space (ε_0) [56–65]. The dielectric constant of a material also affects the velocity of microwave signals when it moves through the material. A high dielectric constant makes the microwave signal travel more slowly. In other words, the velocity will decrease [66] because a higher dielectric constant means a denser material. The dielectric constant value depends on what material is applied to the design application. Every material has a unique set of electrical characteristics that are dependent on the electromagnetic properties of many dielectric and magnetic materials. There are many mechanisms which can change the dielectric properties of a material.

The real part of the permittivity, ε', termed dielectric constant, determines the amount of electrostatic energy stored per unit volume in a material. The imaginary component of the permittivity, ε'', is called loss factor and governed by the lag in polarization upon application of the field and the energy dissipation in association with charge polarization. This energy loss appears as an attenuation of the applied field and is usually measured relative to the dielectric constant in terms of the loss tangent, $\tan\delta$. In terms of an electric circuit, $\tan\delta$ represents the resistive part of the impedance and is directly proportional to the electrical conductivity. Loss tangent refers to the dissipation of power or energy from incident waves. A very important element in microwave absorption, the loss tangent, transforms incoming microwave energy into heat. The overall losses based on dissipation usually involve the influence of permittivity and conductivity of the materials [67–75]. The formula on loss tangent, $\tan\delta$ is shown as

$$\tan\delta = \frac{\varepsilon_r{}''}{\varepsilon_r'} \tag{3}$$

where ε_r' = real part component of permittivity and ε_r'' = imaginary component of permittivity.

The most commonly used theoretical model for calculating the complex permittivity is the dielectric mixture model. The dielectric mixture is described in terms of the fractional volume and permittivity of each constituent. Here, the Lichtenecker's dielectric mixture model is proposed [76].

$$\ln\varepsilon^* = v_1 \ln\varepsilon_1 + v_2 \ln\varepsilon_2 \tag{4}$$

The symbol used in the Lichtenecker's dielectric mixture model applies to two component mixtures, which represent the complex permittivity of the mixture. ε_1 is the permittivity of medium 1, and ε_2 is the permittivity of medium 2. The v_1 and v_2 are the fractional volume of the respective components, where $v_1 + v_2 = 1$ is the mixture of rubber dust and rice husk.

At microwave frequencies, different measurement techniques can be used, including the free space measurement technique, the resonant cavity technique, the transmission line technique, and the dielectric probe technique [77]. This work uses the Agilent dielectric probe technique with Agilent Technologies 85070 measurement software to define the dielectric constant and tangent loss. The 85070E has a frequency range of 200 MHz to 20 GHz. This dielectric probe features a hermetic glass-to-metal seal, which makes it resistant to corrosive or abrasive chemicals [78]. Figure 10(a) shows the configuration of the Agilent dielectric probe. First, the dielectric probe is connected to the network analyzer using a coaxial cable. Figure 10(b) shows how the dielectric constant was defined. Dielectric constant for the 50% rubber tire dust −50% rice husk mixture is measured by using the PNA network analyzer from Agilent Technologies with the probe attached. Next will be the 25% rubber tire dust −75% rice husk mixture, and last the 75% rubber tire dust −25% rice husk mixture.

The dielectric constant and tangent loss for three different compositions of mixture of rice husks and rubber tire dust are as shown in Table 3 and Figure 11. Figure 12 shows the variation of dielectric constant with frequency for different percentage of mixture rubber tire dust and rice husk. It can be observed that the dielectric constant increases with the percentage of rubber tire dust in the mixture. The

(a) (b)

Figure 10. (a) Calibrating the probe using a network analyzer with Agilent Technologies 85070 measurement software. (b) Defining the dielectric constant (real part, ε'_r and imaginary part, ε''_r) of the pyramidal microwave absorber using the dielectric probe.

Table 3. Dielectric properties for different ratios of rubber tire dust and rice husk.

Percentage of mixture (%)		Dielectric constant	Tangent Loss
Rubber tire dust	Rice husk		
75	25	3.43	0.048
50	50	2.67	0.076
25	75	2.08	0.103

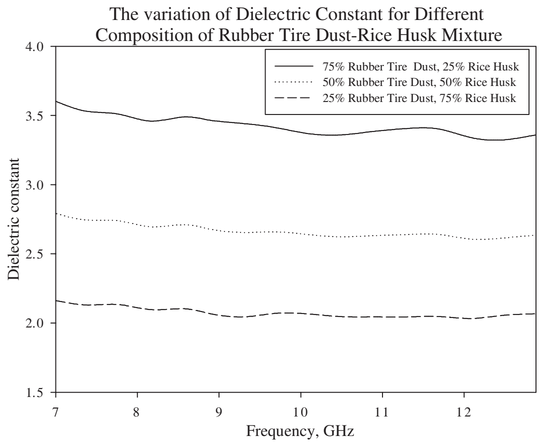

Figure 11. The dielectric constant, ε_r of different ratios of rubber tire dust and rice husk for the pyramidal microwave absorber.

measurement is taken from the range of 7–13 GHz with 51 frequency intervals. The ratio of 75 : 25 rubber tire dust-rice husk mixture shows the dielectric constant which is $\varepsilon_r = 3.43$, Meanwhile, the ratio of 25 : 75 rubber tire dust-rice husk mixture indicate the lowest dielectric constant which is 2.08. Figure 13 illustrates the calculated tangent loss, $\tan\delta$, using Lichtenecker dielectric mixture model for three ratios as mentioned in Equation (4). The ratio 25 : 75 of rubber tire dust-rice husk has the highest tangent loss which is 0.103, and then followed by 50 : 50 which is 0.076, and 25 : 75 which is 0.048. Figure 14 shows the measured tangent loss of pure rubber dust and rice husk. The average of tangent losses of pure rubber tire dust and rice is 0.031 and 0.134, respectively. This indicates that the tangent loss of pure rice husk is significantly greater than pure rubber dust.

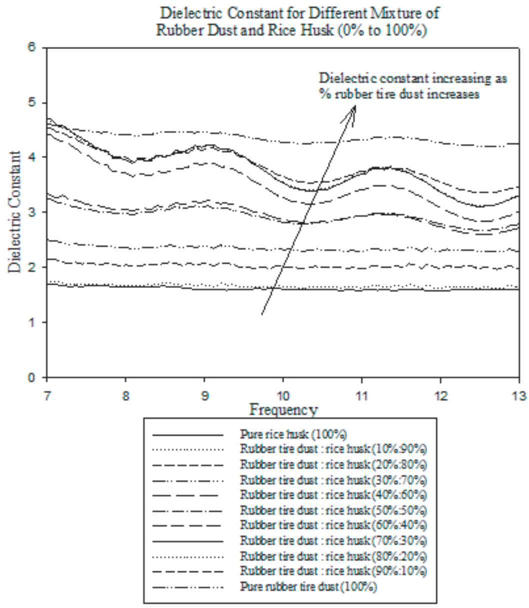

Figure 12. The dielectric constant of different percentage mixture of rubber tire dust and rice husk (0% to 100%).

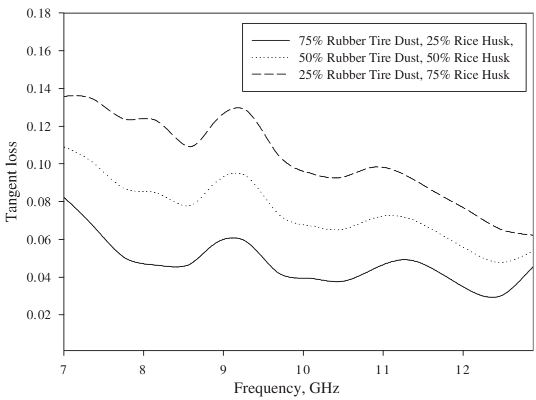

Figure 13. The calculated tangent loss, $\tan\delta$, using Lichtenecker's dielectric mixture model for different ratios of rubber tire dust and rice husk for the pyramidal microwave absorber.

6. MEASUREMENT OF REFLECTION LOSS

The reflection loss performances are compared using different ratios of rubber tire dust and rice husks. Twenty-one frequencies are measured

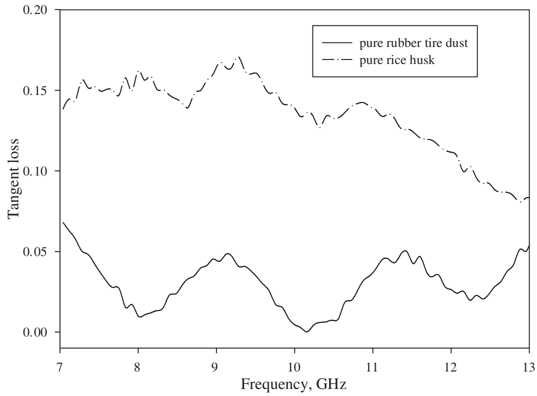

Figure 14. The measured tangent loss, $\tan\delta$, for pure rubber dust and rice husk.

from 7–13 GHz at increments of 0.25 GHz. The requirement for a good microwave absorber performance is that it has reflection loss results better than -10 dB, which indicates that the efficiency of the absorbing performance is 90 percent. In general, the absorber reflection loss required to achieve a specific chamber performance varies with the size and shape of the shielded enclosure.

Radar Cross Section is defined as the area that can be perfectly reflected back when an electromagnetic wave is transmitted from its source to its target position. Radar is a method of determining the presence, location, velocity, and other characteristics of a target through the use of equipment that operates at microwave frequencies by radar and is reflected from the target/object back to the radar [79]. The equipment used was an Agilent $E8362B$ PNA network Analyzer; two 10 m coaxial cables, a pair of horn antennas for transmitting and receiving, reference metal (reference RCS target), and a tripod for holding the horn antennas and reference metal [80]. The angle between the horn antennas and the pyramidal microwave absorber was 60°. The distance between horn antennas and pyramidal microwave absorber was 1 meter. Figure 15 shows the RCS measurement setup.

For the measurement, nine pieces of pyramidal microwave absorbers are located at the reference metal with area of 15 cm^2. Six different points (Point A to Point F) are taken in this measurement, as shown in Figure 16 and Table 4, to ensure the accuracy of the measurement. All points will give the reflection loss performance for the pyramidal microwave absorber.

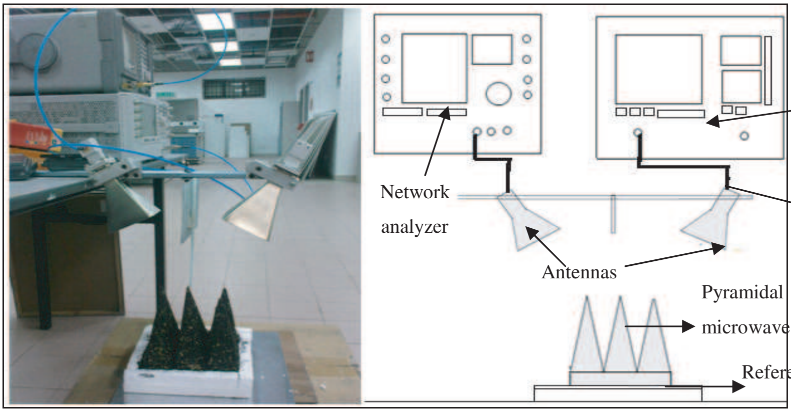

Figure 15. Reflection loss measurement setup using the Radar Cross Section (RCS) technique.

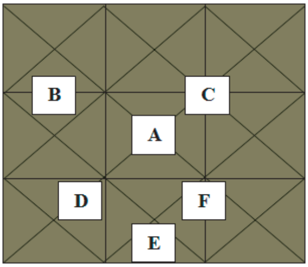

Figure 16. Six points on the pyramidal microwave absorber (Point A to Point F).

Table 4. Location of the ten points for the RCS method.

Point Name	Point Location
A	Highest peak
B	Between two peaks
C	Among four peaks
D	Between the highest and lowest peak points
E	The side of the absorber
F	Random point

7. RESULTS AND DISCUSSION

The reflection loss results are obtained from experiments using the radar cross section measurement method. Figures 17–19 show the

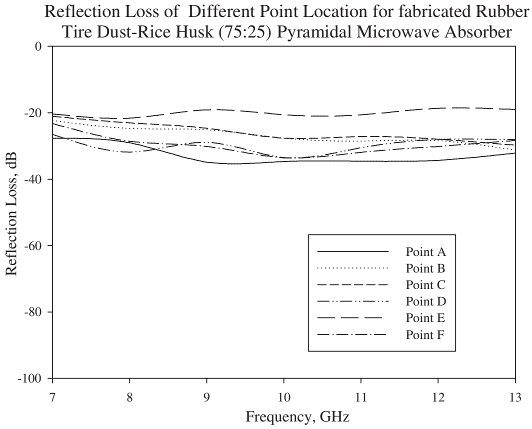

Figure 17. Reflection loss of different point locations for fabricated rubber tire dust-rice husk (75 : 25) pyramidal microwave absorber.

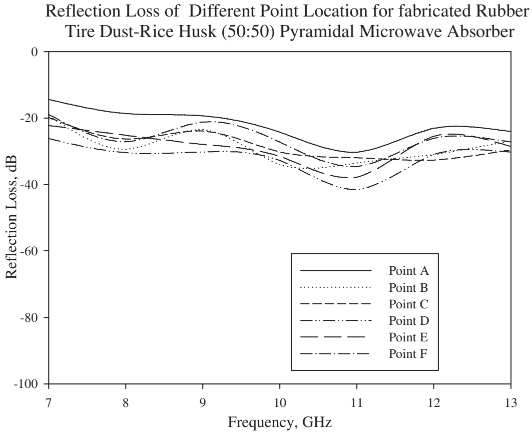

Figure 18. Reflection loss of different point locations for the fabricated rubber tire dust-rice husk (50 : 50).

reflection loss of different point locations for fabricated rubber tire dust-rice husk pyramidal microwave absorber. The reflection loss values in increments of 0.25 GHz for the frequencies from 7.0 to 13.0 GHz are obtained.

Figure 17 and Table 5 show the measurement results of the reflection losses of the fabricated rubber tire dust-rice husk (75 : 25) pyramidal microwave absorber at different location points. The reflection loss results obtained are in the range of −19.0 dB to −35.0 dB for the frequencies from 7.0 to 13.0 GHz. For the fabricated rubber tire

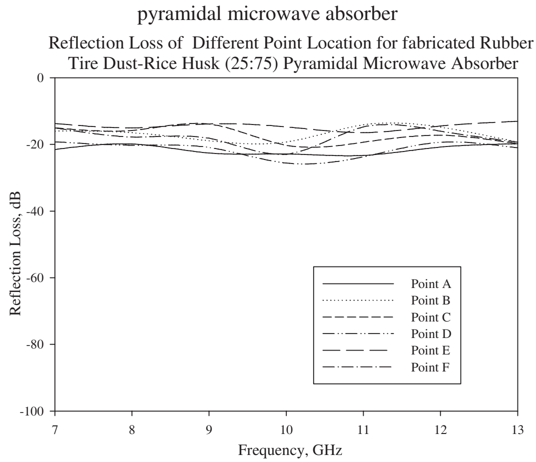

Figure 19. Reflection loss of different point locations for the fabricated rubber tire dust-rice husk (25 : 75) pyramidal microwave absorber.

Table 5. Reflection loss of dielectric point locations for fabricated rubber tire dust-rice husk (75 : 25) pyramidal microwave absorber.

Frequency (GHz)	Reflection Loss of Different Point Locations (dB)					
	A	B	C	D	E	F
7	−27.74	−22.37	−21.13	−26.53	−20.37	−23.28
8	−29.07	−24.74	−23.08	−31.89	−21.64	−28.65
9	−34.89	−25.13	−24.71	−28.91	−19.13	−30.18
10	−34.70	−27.67	−27.67	−33.57	−20.65	−33.61
11	−34.64	−28.54	−27.18	−30.54	−20.63	−31.94
12	−34.35	−28.42	−28.01	−28.07	−18.66	−30.17
13	−32.16	−31.23	−29.79	−28.14	−19.05	−28.37
Average (7 to 13)	−32.51	−26.87	−25.94	−29.66	−20.02	−29.48

dust-rice husks pyramidal microwave absorbers, the highest average reflection loss result is achieved at Point A with −32.51 dB, while point E shows the lowest reflection loss result with −20.02 dB. Figure 18 and Table 6 show the measurement results of the reflection losses of the fabricated rubber tire dust-rice husk (50 : 50) pyramidal microwave absorber at different location points. The reflection loss results obtained are in the range of −14.0 dB to −42.0 dB for the

Table 6. Reflection loss of dielectric point locations for the fabricated rubber tire dust-rice husk (50 : 50) pyramidal microwave absorber.

Frequency (GHz)	Reflection Loss of Different Point Locations					
	A	**B**	**C**	**D**	**E**	**F**
7	−14.43	−19.37	−19.84	−26.22	−22.26	−18.96
8	−18.67	−29.44	−26.36	−30.46	−25.22	−27.13
9	−19.38	−23.48	−23.94	−30.28	−28.02	−21.24
10	−24.27	−34.09	−30.28	−32.79	−31.56	−27.29
11	−30.29	−33.51	−32.00	−41.56	−37.80	−34.59
12	−23.11	−31.03	−32.67	−30.99	−25.50	−26.12
13	−24.06	−26.96	−29.64	−30.28	−28.57	−27.25
Average (7 to 13)	−22.03	−28.29	−27.82	−31.80	−28.42	−26.08

Table 7. Reflection loss of dielectric point locations for the fabricated rubber tire dust-rice husk (25 : 75) pyramidal microwave absorber.

Frequency (GHz)	Reflection Loss of Different Point Location					
	A	**B**	**C**	**D**	**E**	**F**
7	−21.54	−16.01	−15.07	−19.25	−13.74	−15.04
8	−19.87	−16.51	−15.84	−20.29	−15.03	−17.82
9	−22.60	−18.91	−13.88	−20.94	−13.86	−18.16
10	−22.84	−19.29	−20.30	−25.63	−14.78	−22.98
11	−23.33	−14.10	−19.35	−23.74	−16.47	−14.72
12	−20.79	−14.82	−17.26	−19.36	−14.48	−16.06
13	−19.80	−19.29	−19.79	−21.02	−13.07	−19.35
Average (7 to 13)	−21.54	−16.99	−17.36	−21.46	−14.49	−17.74

frequencies from 7.0 to 13.0 GHz. For the fabricated rubber tire dust-rice husks pyramidal microwave absorbers, the best average reflection loss result is achieved at Point D with −31.82 dB, while point A shows the worst reflection loss result with −22.03 dB.

Figure 19 and Table 7 show the measurement results of the reflection losses of the fabricated rubber tire dust-rice husk (25 : 75) pyramidal microwave absorber at different location points. The reflection loss results obtained are in the range from −13.0 dB to

Table 8. Average reflection loss of different ratios of the fabricated rubber tire dust-rice husk pyramidal microwave absorber.

Frequency (GHz)	**Average Reflection Loss with Different Ratios of Rubber Tire Dust: Rice Husks**		
	75:25	**50:50**	**25:75**
7	−23.57	−20.18	−16.78
8	−26.51	−26.21	−17.56
9	−27.16	−24.39	−18.06
10	−29.65	−30.07	−20.98
11	−28.91	−34.96	−18.62
12	−27.95	−28.27	−17.13
13	−28.12	−27.79	−18.72
7 to 13	−27.41	−27.40	−18.27

−26.0 dB for the frequencies from 7.0 to 13.0 GHz. For the fabricated rubber tire dust-rice husks pyramidal microwave absorbers, the best average reflection loss result is achieved at Point A with −21.54 dB, while Point E shows the worst reflection loss result with −14.49 dB.

Figure 20 and Table 8 show the average measurement results of the reflection losses of the fabricated pyramidal microwave absorber at different rubber tire dust-rice husk ratios. The 75 : 25 ratio of rubber tire dust to rice husks shows the best reflection loss result, while the 50 : 50 ratio reflection loss result is only 0.01 dB. These two percentage results are considered acceptable and are better than that of the 25 : 75 ratio of rubber tire dust to rice husks, which have the worst performance at −18.27 dB for the average result.

The ratios of 75 : 25 and 50 : 50 rubber dust/rice husk mix absorber materials are found very close to the RF properties of the pure rice husk absorber [17]. However, the ratio of 25 : 75 rubber tire dust/rice husk mix absorber RF properties is dramatically different. It can be illustrated by Figure 14 where the loss tangent of pure rice husk is much greater than pure rubber tire dust. The rubber with little percentage like 25% and 50% do not take effect in dielectric property in mixture. It is dominated by the pure rice husk which has greater loss tangent as shown in Figure 14. When the pure rubber dust beyond 50% and go to 75%, the effect of rubber dust in mixture become significant and account for the significant gap between the ratio of 75 : 25 and 50 : 50 as well as 25 : 75 as shown in Figure 20.

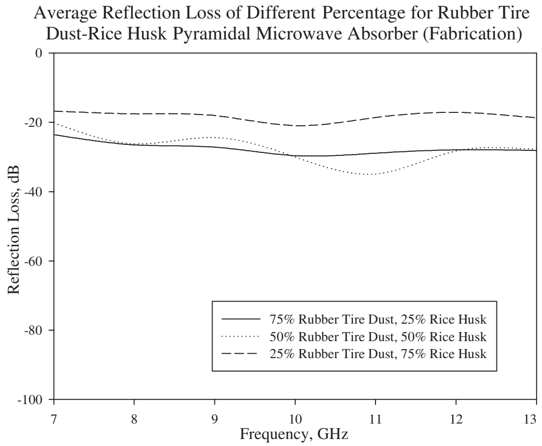

Figure 20. Average reflection loss of different ratios of the fabricated rubber tire dust-rice husk pyramidal microwave absorber.

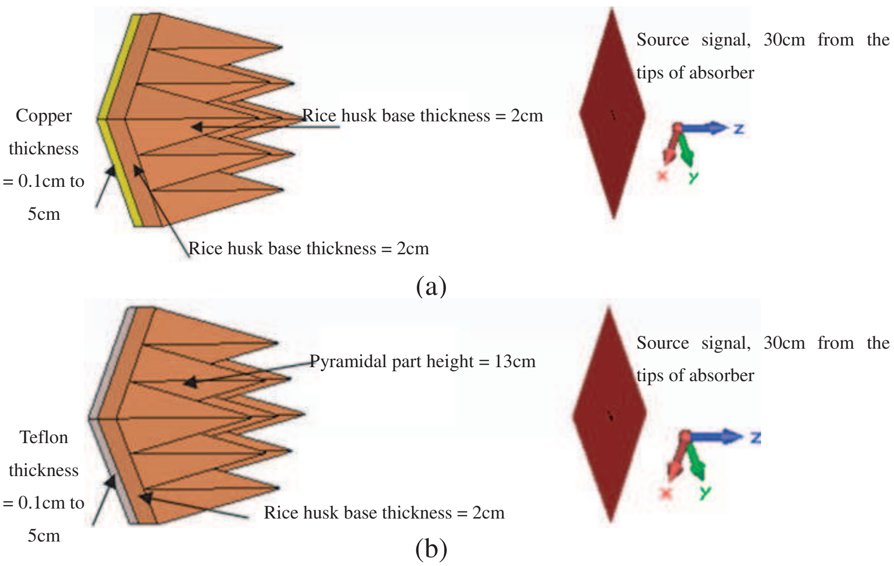

Figure 21. (a) CST MWS simulation with (a) copper base and (b) Teflon base, respectively.

Some simulations have been conducted using CST MWS to investigate the effect of material which lay a base for the absorber. There are two types of materials are used as a sample as base in simulation, i.e., copper and Teflon. The simulation regions have been setup as shown in Figures 21(a) and (b) for copper and Teflon base, respectively. The source is placed apart from absorber's tip and their interval is fixed at 30 cm for both cases. The source is a brownish rectangular plane as shown in Figure 21. It was designed in accordance with the shape of the aperture rectangular horn antennas as shown in Figure 15. In addition, rice husk base is fixed at 2 cm for both cases. The simulation was conducted within the frequency range from 0.01 GHz to 20 GHz. In addition, the thickness of copper and Teflon base vary from 0.1 cm to 5 cm. the simulated results are as shown in Figure 22 and Figure 23.

It can be noticed that the thickness is not a significant factor in determining the reflection loss, since the thickness of copper and Teflon base in Figures 21(a) and (b), respectively do not take effect upon the reflection loss. It shows that the trendline of reflection loss with frequency shows no difference for all the thickness of base as which listed in figure. It can be explained further by comparing Figure 22 with Figure 23. The range of reflection loss appear the same from 0.01 GHz to 20 GHz for different thickness of material as base. The variation of base thickness for different material also account for the similar range of reflection loss as shown in Figure 22 and Figure 23. It attributes to the heavy absorbency of the rubber dust-rice husk absorber which account for the trivial reflected signal against the base. High tangent loss in Figure 13 illustrates the greatness of absorbency of the rubber tire dust-rice husk mixture in dissipating the penetrated signal before it interacts with the base.

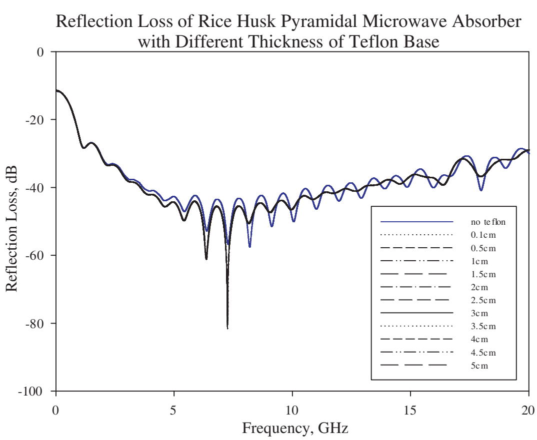

Figure 22. The response of simulated reflection loss varies with frequency toward different thickness of Teflon base.

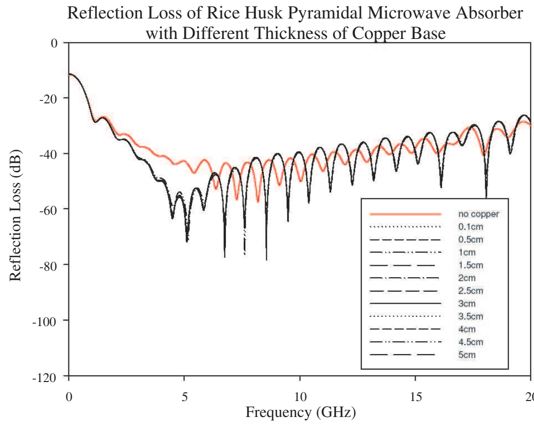

Figure 23. The response of simulated reflection loss varies with frequency toward different thickness of Copper base.

8. CONCLUSION

From the reflection loss performance in the measurement segment using the radar cross section method, the rubber tire dust has the potential to be used as an alternative material in designing the pyramidal microwave absorber. The reflectivity or refection loss results obtained for the rubber tire dust-rice husks pyramidal microwave absorbers are significantly better than 10 dB (i.e., the threshold dB for the characteristics of microwave absorbers). The reflection loss results obtained from the fabricated rubber tire-rice husks pyramidal microwave absorbers are also reasonable.

Using recycled materials, such as rubber tires and rice husks, can reduce landfill waste, help to maintain the environment and community's good health, and significantly reduce the cost of the production of the microwave absorber compared to using the existing expensive material, polyurethane and polystyrene.

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