Reflection Loss Performance and Performance Assessment of Pyramidal Microwave Absorber Using Agriculture Waste

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Abstract— Agricultural product is one of the major revenue incomes for Malaysia. The large scale production of agricultural product lead to a new by product which is known as agricultural waste. Agricultural wastes materials can be applied for many applications. This research highlighted microwave absorber application as the output using proposed agricultural wastes. Microwave absorber is the most important element in anechoic chamber to deny signals reflection. Its performance is analyzed in term of reflection loss performance using the free space measurement technique. To answer the measurement goodness in this research, Rasch measurement model is applied.

1. INTRODUCTION

This research considered the alternatives way to utilize the agricultural waste and take the advantage from the pile up of the availability of wastes. The increase production of agricultural waste raise the loses of resources and produced the environmental damage. The utilization of agricultural waste may reduce the dumping of waste and become a substitute material for commercially available microwave absorber which use 100% chemical based of plastic foamed-based materials like polystyrene or polyurethane [1]. The proposed product from the waste is microwave absorber. Microwave absorber is used as the important element in anechoic chamber which is covered on the chamber wall. The microwave absorber will act as the absorbent material to absorb the scattered incident energy. For diversification in the material for microwave absorber, several agricultural residues are used in this research which is rice husk, mixture of rice husk and rubber tire dust, sugarcane bagasse and banana leaf.

2. MICROWAVE ABSORBER FABRICATION

The grinded material of agricultural wastes is fabricated into the shape of pyramid. Besides of the material's effect in microwave absorber, the shapes of the microwave absorber will also play the important characteristics and sensitive factor which can affect the reflectivity performance of the microwave absorber [1]. Pyramidal shapes absorber are usually applied for the frequency range between 1 GHz to 40 GHz and the square based pyramidal-shaped absorbers are commonly used for frequencies below than 1 GHz [2]. The material for microwave absorber is a mixed material of agricultural wastes and chemicals. The chemicals used are polyester which functioned as the resin and methyl ethyl ketone peroxide (MEKP) which reacts as a hardener agent for the materials to be moulded into pyramid. These polyester resins are used in adhesive, finishes and moulded objects. The characteristics are including low water absorption, volume resistance, heat distortion temperature, high tensile strength and elongation at break. For each materials of agricultural waste, nine pieces of pyramidal microwave absorber is made and compiled in 3×3 arrays, making the base dimension become 15 cm width $\times$15 cm length. Figure 1 shows four different materials moulded and compiled into 3×3 arrays.

3. SAMPLE MEASUREMENT TECHNIQUES

The objective is to characterize the performance of its reflectivity for the different material microwave absorber. Every result from the measurement will demonstrate the actual performance of the microwave absorber that had been fabricated for the measurement. The measurement technique will involve two factors which were the microwave absorber electromagnetic properties and free space measurement to measure the reflectivity performances [3].

The measurement of dielectric properties is to characterize the different materials used and to define the physical and chemical properties, related to storage and loss of energy [4, 5]. For the

Figure 1: 3×3 array pyramidal microwave absorber. (a) Rice husk-rubber tire dust. (b) Sugarcane bagasse. (c) Rice husk. (d) Banana leaf.

dielectric constant measurement, open-ended coaxial probe technique was used to measure each materials of microwave absorber. The largest dielectric constant value shows by the material of rice husk rubber tire dust with $\varepsilon' = 3.28$. For banana leaves, it shows the lowest value of dielectric constant with the value $\varepsilon' = 2.33$. Dielectric constant for rice husk material is $\varepsilon' = 3.00$. From the result in Table 1, each material gives a different value of dielectric constant (ε') and loss tangent ($\tan\delta$). Rice husk material gives a higher value compared to sugarcane bagasse and banana leaves. A material with a high density will lead to a higher dielectric constant thus explains the lower value for sugarcane bagasse and banana leaves [6]. The presence of rubber tire dust will increase the dielectric constant value. The different values of dielectric constant for different materials affects the velocity of microwave signals when propagate through material of MUT (Material Under Test). A high dielectric constant cause the microwave signal travel slower and velocity of microwave signal decrease.

Table 1: Average dielectric properties (dielectric constant, ε'; tangent loss, $\tan\delta$).

Material	**Dielectric Properties**	
	ε'	$\tan\delta$
Rice Husk	2.99295	0.20614
Rice Husk Rubber Tire Dust	3.27711	0.14224
Sugarcane Bagasse	2.39184	0.14772
Banana Leaves	2.32908	0.10091

To measure reflection loss performance, a technique call free space measurement is implemented. RCS technique is used in this paper to measure reflection loss. RCS can be define as the area that can be perfectly detected back when electromagnetic waves were transmitted from its source to its target place. Result from the RCS measurement shows a good reflection loss performance as it gives an average value better than -10 dB. The highest reflection loss performance is -46.55 dB at frequency point of 7.6 GHz. The lowest reflection loss value is -28.10 dB for the frequency at 6.0 GHz. From the result, the reflection loss gets better when the frequency increased. The average value of reflection loss for rice husk rubber tire dust microwave absorber is -41.45 dB, slightly better than rice husk microwave absorber. This is due to the presence of small percentages of rubber tire dust with the ratio of 75 : 25; rice husk: rubber tire dust. The reflection loss performance for rice husk rubber tire dust gets better if the presence of rubber tire dust increased in the mix ratio between both materials [6].

Banana leaves give an average value of -37.40 dB for its reflection loss performances. The value indicates a good performance in term of reflection loss as it is better than -10 dB. The highest value of reflection loss gives by banana leaves material is -43.13 dB at 6.6 GHz while the least value is -33.97 dB at frequency point of 7.4 GHz. The value of decibel is varies through the range of frequencies. Although there are fluctuations in the reflection loss values, it can be considered to give a higher value as the frequency increased.

Sugarcane bagasse as material in microwave absorber fabrication shows the worst result of reflection loss. Although the result shown is -32.33 dB comply the reflection loss as a good value, still, it is the worst if compared with the other materials used in this paper. The worst reflection loss value is -28.10 at 6.0 GHz and the best value is -38.33 dB at 8.2 GHz for banana leaves material. As previous measurement, the reflection loss is varies through range of frequency and gives a better result for the increased frequencies. Figure 2 shows the comparison of the reflection losses among the materials for fabricated microwave absorber.

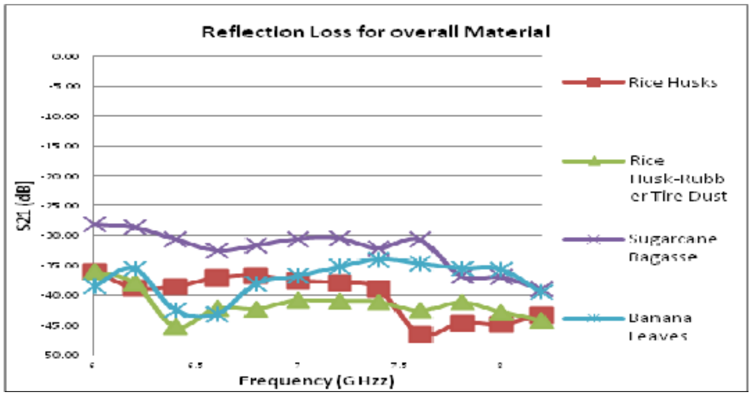

Figure 2: Reflection loss performance for the overall materials.

4. RASCH MEASUREMENT ANALYSIS

Rasch measurement model may determine the three major criteria for evaluating good measurement which are validity, reliability and significance of the RCS measurement technique. The Rasch model is a mathematical formula that specifies the form of the relationship between persons and the items that operationalize one trait [7]. Rasch measurement model is mostly used in social science educational measurement or psychometrics measurement [8–10]. Furthermore, Barrett (2003) indicates that there is suitability of Rasch measurement model in metrology measurement where it includes all theoretical and practical aspects of measurement [11]. The input from the analysis covers 12 Persons and 4 Items. Person and Item represented as 12 frequency points and four different types of materials respectively. Based on Table 2, Cronbach's alpha (KR-20) value is at 0.64 which is considered acceptable reliability at 0.64 of confidence level. Cronbach's alpha value of 0.64 is considerably higher than the acceptance level of 0.60 as agreed by Garson (1998), Gliem and Gliem (2003) and Leedy and Ormrod (2004) [12–14]. The measured value for Cronbach's alpha of 0.64 in this paper can be accepted as exploratory research while 0.80 for basic research and 0.90 for very critical issues research [9]. Material reliability of 0.52 shows the measurement technique sufficiency for number of items (materials) to measure the supposed output. It is still acceptable although the supposed reliability value is 0.60. In this Rasch measurement analysis, it is further supported by the value of z-standard = −1.4 which very near to 1 and 0 respectively. This value indicated, the assessment technique is considered as reliable in measuring the dimension exists by the materials.

Table 2: Overall summary statistics figure.

Material Reliability	0.52
Cronbach's Alpha (KR-20)	0.64
Z-Standard	−1.4

5. CONCLUSIONS

A proposed product has been successfully developed and fabricated into a microwave absorber. A low cost and environment friendly product was produced by a variety of agricultural waste materials which use a small percentage of chemicals. The microwave absorber is able to perform in the frequency range of 6.0 GHz to 8.2 GHz. This is due to the reflection loss performance's results which is better than −10 dB for each material and gives a value more than −30.0 dB.

Rice husk as microwave absorber's material gives a better result if compared to sugarcane bagasse and banana leaves. While for rice husk rubber tire dust microwave absorber is slightly better than rice husk with −1.362 dB significant. The proposed technique of measurement; RCS technique, was able to give different value of reflection loss. Based on most research, the technique of RCS measurement in free space technique is mostly used to gain the reflection loss performance and it is valid and reliable based on the Rasch measurement model; Cronbach's alpha = 0.64. This microwave absorber product can be marketed with a much lower cost and price compared to the commercial microwave absorber because the raw materials is agricultural wastes.

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