DEVELOPMENT OF AN INDIGENOUS MICROWAVE ABSORBER

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Abstract

This paper describes the design and method in developing a low cost, reliable and good performance microwave absorber for the application in anechoic chamber room measurement. Theoretically, the absorber is designed and to be functioning at a frequency range from 1.5GHz to 15GHz (in pyramidal-shaped). However, due to the equipment limitation for measurement, the absorber is only tested for 2GHz and 10GHz frequency. The pyramidal-shaped is chosen since its performance has been proven to work at microwave frequency. A survey on materials that can be used to coat the absorber has been carried out and a variety of the materials are tested. The absorbers are made from polystyrene, which are cut into pyramidal shape and then coated with carbon. The measurement of the pyramidal absorber is carried out in order to determine its performance. Lastly, the results are compared to the commercialized absorber in terms of the absorption performance and found to be less about 22.8% and 10.9% at 2GHz and 10GHz respectively.

***Keywords**: microwave absorber, absorber material, pyramidal-shaped, low cost absorber.*

I. INTRODUCTION

In anechoic chamber, an electromagnetic (EM) wave absorber is used to absorb the reflected wave that occurs on the wall of the chamber. The demand for various kinds of electromagnetic wave absorbers has increased, particularly in industries equipped with high-speed wireless data communication systems operating at 1.9 GHz for personal handphone system (PHS) and 2.4 GHz for wireless local area networks (LANs) to suppress the delay spread due to multireflected waves [1]. The pyramidal absorber structures are normally mounted to form a continuous wall that is used to attenuate stray signals resulting from chamber confinement [2]. Since the anechoic chamber is used as a place to do a precise EM measurement, the reflected signal from the wall must be eliminated. In addition, the condition is necessitated to ensure that the wave received by the receiver is directly from the transmitter.

Normally in the absorber construction, among such materials that are used to coat the absorbers, ferrite is in the lead. However, due to high cost of the materials, their transportation and editing, beside with the big densities, force to search for alternative designs, in particular, on the basis of carbon fillers and metallized geometrical designs [3] is becoming the best inspiration for a new elucidation. The main requirements for an absorber are high absorption of electromagnetic wave, high heat conductivity and good adhesion on the substrate [4]. All these characteristics are strongly dependent on the material used, the shape and the production process of the absorber. The element that is often used in the absorber is carbon. Carbon is one of semiconductor material but it still allows a small amount of charge to flow through it. This characteristic makes carbon capability of absorption very high, thus resulting as a suitable material for the absorber. The size and dimensions of the absorber also depend on the frequency range used.

The excellent performance of pyramidal-shaped absorber is primarily the result of the multiple reflections that occur between the pyramids. Since the individually pyramid is larger compared to the wavelength, the sides of the pyramids reflect the incident wave. The wave is reflected and re-reflected many times by the sides of the adjacent pyramids. During each reflection, a portion of the wave is absorbed by the pyramid [5].
The objective of this project is to develop a low cost, reliable and good performance microwave absorber for application in the anechoic chamber. Beside that, the important characteristic of microwave absorber can be obtained by measurement and possible low cost absorber made from low cost material can be developed.

II. METHODOLOGY

All the materials chosen must be tested in terms of their resistivity. From the resistivity value, the value of the conductivity can be calculated by using equation (1) [7-9].

$$\sigma = L/RS \quad (1)$$

where,

σ = conductivity of the material
L = length of coating
R = resistivity of the material
S = thickness of coating

The resistivity of the material after being coated on the surface of the pyramidal absorber must be around 1MΩ [7] and this value is the same as resistivity for commercial absorber. They are 7 materials tested throughout this project; paddy chaff, coconut shell, bamboo, traditional toothpaste powder, coffee, coal dust and charcoal activated powder. These indigenous materials are found abundantly in Malaysia.

III. DESIGN OF ABSORBER

In this project, the pyramidal shape is used and theoretically, the estimated range of frequency supported by the low cost absorber is from 1.5GHz to 15GHz. From the literature review, the pyramidal shaped absorber must be larger compared to a lowest wavelength so that the sides of the pyramids are able to reflect the incident wave and the height of the pyramid must be greater than half the wavelength. Thus, from the equation (2), the width of the low cost absorber is equal to the wavelength of the lowest frequency which is 1.5GHz whereas from equation (3), the height of pyramid is made larger than half the wavelength of 1.5GHz as to ensure that the designated range of frequency for the absorber to be effectively functioning within the range. From equation (4), the highest frequency supported by this pyramid is determined from the acceptable width of the pyramid's tip. By taking human error into consideration during the production process of the pyramid, the acceptable width of the pyramid's tip is 2cm which is equal to the wavelength of the 15GHz frequency. Due to the equipment limitation for measurement, the frequency tested is limited to 2GHz and 10GHz only.

Width of the pyramid = wavelength of the lowest frequency supported (2)

= c/f

(c is speed of light and f is frequency at 1.5GHz)

Length of the pyramid = half of the lowest wavelength (3)

= λ/2

Highest frequency supported by the pyramid = speed of light/acceptable width at the tip (4)

= c/λ

Through out this project, the absorbers used are made by polystyrene, which are cut into pyramidal shaped and then coated with carbon material. The dimensions of the microwave absorber that has been designed is shown in Figure 1.

A. Absorber Measurement

The measurements of absorbers are conducted to determine the performance of the low cost pyramidal absorber. The dimension of the sample to be tested is 60cmx60cm and to achieve the dimension required, nine absorbers are needed. The sample of nine absorbers is shown in Figure 2. The best location of absorber to be placed is determined when the reflection signal is at maximum level. The location of maximum reflection signal can be found when metal plate is placed in front of the antenna. The metal plate is adjusted until the maximum level of signal occurs. Then, the absorber is placed at the location where the maximum reflections occur. In order to reduce errors in the reflected signal, the direct path between the horn antennas is eliminated by placing a metal plate between the two antennas. For better measurement, the metal plate must be grounded so that the electromagnetic induced on the plate can flow directly to the ground. The measurements were conducted by dividing the area of the absorber into different sector such as A, B, and C as shown in Figure 3. This measurement was conducted for two frequencies, which are 2GHz and 10GHz. The average value is then calculated by adding all the data value and divide with number of data that had been taken as shown in equation (5). Before determining the absorption rate, the power transmitted is measured by a direct connection of the transmitter's cable and receiver's cable. The absorption rate is then calculated by using equation (6).

$$Average\,Value(dBW) = \left[\frac{Total\ PRx(dBW)}{No\ of\ Data}\right] \qquad (5)$$

$$Attenuation(dB) = P_{Tx}(dBW) - P_{Rx}(dBW) \qquad (6)$$

where,

P_{Tx}= Maximum power transmitted
P_{Rx}= Average power received for sample

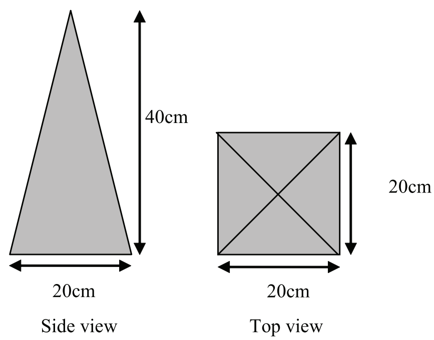

Figure 1: Dimensions of a low cost pyramidal absorber

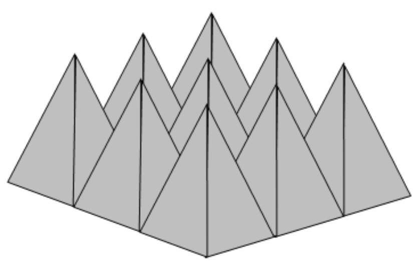

Figure 2: The sample of nine absorbers for measurement

After all the measurements to the sample of low cost absorbers have been done, the commercial absorber is tested. The available commercial absorber at UiTM Pulau Pinang is IP-045C which is produced by TDK RF solution Inc. The dimension of the commercial absorber is 60cmx60cmx45cm. The data of the results from the measurement for both absorbers are analysed and compared to determine the reliability and performance of the low cost absorber. Equation (7) is used to compare the low cost absorber and the commercial absorber.

$$PercentageDifferent = \left[\frac{P_C - P_L}{P_C}\right] x100\% \qquad (7)$$

Where
P_C = Average Power received by commercial absorber
P_L = Average Power received by low cost absorber

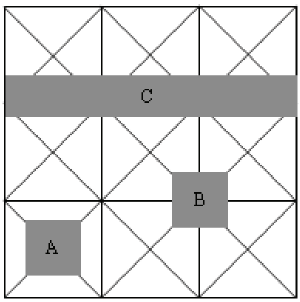

Figure 3: Three sectors of absorber for measurement

IV. RESULTS AND DISCUSSION

The results are divided into two parts which are material research results and absorber measurement results.

A. Material Research Results

All the materials are tested as mentioned in section 3.1. From seven of the materials that have been tested, three of them are non conductive material. They are paddy chaff, coal dust and coconut shell. By referring to the Table 1 through Table 3 which are for bamboo, traditional toothpaste powder and coffee, the resistivity measured are out of range and hence they are negligible to be used as the material for the absorber. The charcoal activated powder has shown an expected resistivity as in Table 4. The ratio of 1:1.3 for the painting of the carbon is chosen in the next stage of development.

Table 1: The resistivity of bamboo

Sample	Ratio	Resistivity(MΩ)
1	1:1	13.7
2	1:1.5	6.4

Table 2: The resistivity of traditional toothpaste powder

Sample	Ratio	Resistivity(MΩ)
1	1:0.25	28
2	1:1	25
3	1:1.5	18
4	1:2	17

Table 3: The resistivity of Coffee

Sample	Ratio	Resistivity(MΩ)
1	1:1	160
2	1:2	109
3	1:3	72
4	1:4	31

Table 4: The resistivity of Charcoal Activated Powder

Sample	Ratio	Resistivity(MΩ)
1	1:1	14
2	1:1.3	0.98
3	1:1.5	0.76

B. Absorber Measurement Results

Three categories of measurement are taken which are measurement at 10GHz frequency, measurement at 2 GHz frequency and measurement of commercial absorber.

C. Measurement at the 10GHz Frequency

At 10GHz frequency, the distance from the antenna to the maximum level of microwave signal is 26cm and the signal level is -22.1dB. By connecting the transmitter's cable to receiver's cable directly, the transmitted power measured at the receiver is -7.7dB.

D. Measurement at the 2GHz frequency

At 2GHz frequency, the same measurements are also conducted. The distance from the antenna to the maximum level of microwave signal is 50.8cm and the maximum signal level is -8.5 dB. The transmitted power measured at the receiver is -7.5dB when both transmitter and receiver are directly connected.

By using equation (2) and equation (3), the average value of power received and the absorption rate for frequency 10GHz and 2GHz are calculated and tabulated as shown in Table 7 and Table 8 respectively.

Table 7: Average value of power received for low cost absorber

Frequency(GHz)	Average value(dB)
2	-35.8667
10	-45.35

Table 8: Rate of Absorption for low cost absorber

Frequency(GHz)	Absorption rate(dB)
2	28.3667
10	37.65

E. Measurement of Commercial Absorber

From the measurement that has been done to the commercial absorber, the power received for measurement at 10GHz and 2GHz are as shown in Figure 4 and Figure 5 respectively.

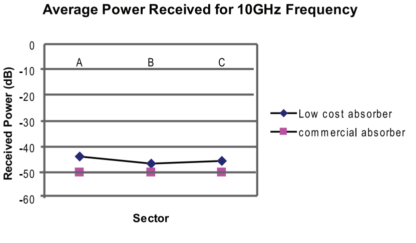

Figure 4: Graph of average power received at 10GHz

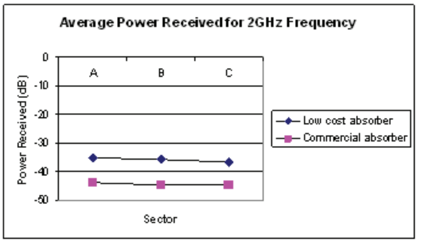

Figure 5: Graph of average power received at 2GHz

The average value of power received and the absorption rate at 2GHz and 10GHz frequency for commercial absorber are as shown in Table 9 and Table 10 respectively.

Table 9: Average value of power received for commercial absorber

Frequency(GHz)	Average value(dB)
2	-44.2571
10	-49.9714

Table 10: Rate of absorption for commercial absorber.

Frequency(GHz)	Absorption rate(dB)
2	36.7571
10	42.2714

The percentage difference of performance between low cost absorber and commercial absorber in percentage is calculated as shown in Table 11.

Table 11: The comparison of performance between low cost absorber and commercial absorber

Frequency(GHz)	Different (%)
2	22.827
10	10.933

From the results, the material that is suitable for coating to the absorber is charcoal activated carbon. The ratio of 1:1.3 for the painting of the carbon is chosen for the absorber development. This type of carbon material has good conductivity as compared to the other materials. Then, the measurements to determine the absorber performance were carried out. From Table 7, the average value of power received at 10GHz is lower than the average value for 2GHz and by referring to the Table 8, the absorption rate at 2GHz is slightly lower than absorption rate for 10GHz. This implies that the performance of low cost absorber at 2GHz is lower than 10GHz. The imprecise cutting edge of the pyramidal-shaped absorber due to human error during construction has also affected the performance of the absorber. However, this is just the beginning of low cost absorber development and further improvement would be done in the future. By comparison with the commercial absorber, the performance of the low cost absorber at 10GHz is found to be 10.933 percent less whereas at 2GHz is 20.827 percent less. The result also revealed that the minimum reflection power and the absorption rate up to 37.65dB at 10GHz and 28.3667dB at 2GHz and this shown the viability of the studies since the absorber is produced from a low cost material.

V. CONCLUSION

The project can be concluded such that the low cost absorber can be functioning effectively at the frequency of 2GHz and 10GHz. This also has proven that the low cost absorbers which have been developed are able to perform very well for microwave signal measurement. In the application of antenna measurement, an 'L' shaped holder with absorber prototype has been constructed as shown in Figure 9 (dimension 100cmx100cmx200cm). The 'L' shaped holder has wheels beneath it so it can be moveable. Due to that, it can be placed anywhere without modifying the existing wall and this could overcome the reflection problem effectively.

Figure 9: Prototype for used in the laboratory

VI. ACKNOWLEDGMENT

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VII. REFERENCES

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