TELKOMNIKA, Vol.16, No.6, December 2018, pp.2507~2513
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v16i6.9687

Electromagnetic Characteristics Measurement of Organic Material Absorber

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Abstract

Electro Magnetic Compatibility (EMC) Chamber requires high performance absorber material to assure the quality of EMC chamber related to Radio Frequency (RF) shielding effectiveness of the corresponding chamber. RF shielding effectiveness is measured following EN 50147-1 testing method. EMC laboratory of BPPT (Indonesian Agency for the Assessment and Application of Technology uses polyurethane absorber material which absorbs the carbon-neoprene mixture to maintain consistent RF performance over a broad frequency band, especially in the frequency range of CISPR 22 radiated emission test between 30 MHz to 6 GHz, limits in CISPR 22 (Information technology equipment-radio disturbance characteristics-limits and methods of measurement). This paper proposes alternative absorber materials based on organic materials: rice husk, coconut husk, cotton and sawn wood crumbs. In the early phase of this research, the frequency under consideration are 900 MHz and 1800 MHz. These frequencies are mostly used by mobile phone devices, therefore at this phase the resulted organic material absorber may be used for alternative mobile phone casing before to be used as absorber material for EMC laboratory in a broader frequency band. The organic materials are produced by mixing them with cement, carbon, and resin. Free space testing method is used in the measurements. Results has shown a mixture of 50% coconut husk with resin absorb the most radiated emission in 900 MHz, while 30% of coconut husk will absorb the most radiated emission in 1800 MHz.

Keywords: *electromagnetic chamber, absorber material, radio disturbance characteristics, organic material, RF shielding, mobile phone casing*

1. Introduction

Unintentional electromagnetic emission from household equipments, electronic gadgets, and the newly upcoming IoT (Internet of Things) becomes a potential disturbance in their environment, especially to other Information Telecommunication Equipments (ITE) and to human's health. There are already standard to ensure that ITE in the market is comply to a defined limit such as CISPR 22 [1], which means the radiated emission of this ITE will not disturb the other ITE in their surrounding. There are also standard available to ensure that the radiated emission of any mobile phones comply to the limit regarding Specific Absorption Rate (SAR), which means the unwanted radiated emission from a mobile phone will not have a hazardous impact to human health. SAR is the amount of EM field radiation absorbed by the human body from wireless devices [2].

The limits given in the standards are sometimes not enough to ensure that our environment is free from the unwanted radiated emission, especially when a specific condition required such as in Compatibility Electromagnetic Chamber (EMC). Therefore a good absorbers are necessary to absorb electromagnetic radiation. Currently most of the absorbers are made of polyurethane materials, which is expensive and not environment friendly compare to alternative organic material absorbers. BPPT EMC is a semi anechoic chamber with polyurethane absorbers as given in Figure 1, which is mainly functioned as a room, with reflection coefficient of the chamber absorbing walls approaching zero value, to represent a free space environment.

The reflection coefficient value varies between 0 (no reflection caused by material) and 1 (all incoming signal is reflected by the material). As a result, a smaller value of reflection

Received April 26, 2018; Revised October 4, 2018; Accepted October 29, 2018

coefficient represents a better absorber material. Figure 2 shows the reflection coefficient of absorber material material (τ) is given as follow [3].

$$|T| = |\text{reflected signal}|/|\text{incoming signal}| \quad (1)$$

Figure 1. Polyurethane absorber material in BPPT EMC laboratory

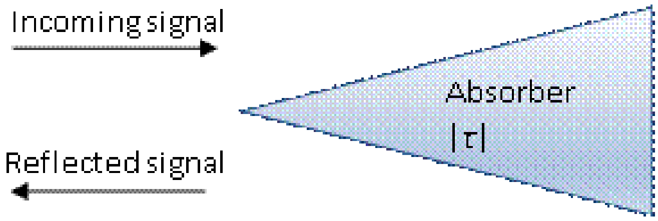

Figure 2. Reflection loss due to absorber material with reflection coefficient of τ

BPPT EMC laboratory has chosen an absorber material based on polyurethane absorber which is produced by mixing of neoprene latex with carbon not only because of a relative better absorbing performance but also because these absorber materials provide a better fire resistant and non-hygroscopic (non-strong tendency to absorb water molecules from ambient air humidity). This non-hygroscopic based absorber material becomes moisture resistant substrate, with less than 3% mass increase when subjected to 95% relative humidity at 1000 Fahrenheit for at least 240 hours [4].

In addition, unwanted Radio Frequency (RF) emission from mobile phones has a negative impact to the human tissues, therefore SAR value of the mobile phones is very important to secure human health. Currently mobile phone casings are mainly plastics which are not environmental friendly. Alternative mobile phone casings from organic materials are necessary to solve this environmental issues.

In this paper organic materials are studied to propose a environmental friendly and cost effective as an alternative absorber material and as an alternative mobile phones casing. Three organic materials are tested in order to investigate absorbing characteristics of these organic materials. The results of these research will provide potential use of these organic materials as alternative absorber materials to replace the polyurethane absorber.

2. Proposed: Organic Materials to be used as Alternative Absorber Material

Agricultural waste, such as rice husk from paddy has been used in [5] as alternative absorber material for electromagnetic chamber in the frequency range between 1 GHz to 20 GHz. The agricultural waste has been considered as a potential alternative for electromagnetic chamber's absorber since it is more environmental friendly and has lower cost compared to the current materials such as polyurethane. In this paper rice husks of paddy has been used to make absorber pyramidal board with resin Phenol Formaldehyde (PF). The reflection loss (S11) and transmission loss of ice husks absorber with 10% of resin has been investigated. The average reflection loss is -16 dB between 0.01 and 1 GHz and -40 dB between 0.01 and 20 GHz. The average transmission loss between 0.01 and 20 GHz is -5.82 dB. If the percentage of resin is varied then the best average reflection loss between 0.01 to 20 GHz is -41.1 dB using 30% of resin PF, the worst average reflection loss at the same frequency range is -40.0 dB using 10% resin PF. The best average transmission loss is -6.85 dB using 10% resin PF.

Various agricultural waste materials are simulated in [6] using CST to investigate the reflection loss in order to be used as electromagnetic absorber material. This paper studied different shapes of absorber material, and showed that material having pyramidal shape has better reflection loss and the carbon content has different effects on the reflection and absorption properties of the absorber material. Some agricultural waste has been studied in this paper including: rubber wood sawdust, coco peat, rice husk, sugarcane bagasse, dried banana leaves and coconut shell powder. Carbon from coal has been added into the mixture of these material to increase the absorbing capability of these materials. The results are: rubber sawdust with added 43.27% of carbon has reflection loss of -25.2 dB in 1800 MHz, rice husk with 35.77% of added carbon has reflection loss of -42.54 dB in frequency range between 0.01-20 GHz.The requirement of the best microwave absorber has been given in [7] to have the average reflectivity (R) below -10 dB:

$$R = 10\log_{10}\left(\frac{P_r}{P_i}\right) \quad (2)$$

where Pr is plane wave reflected power density, Pi is plane incident power density. In [8] a magnetic wood is proposed to be used as indoor electromagnetic wave absorber to suppress the transmission and reception of cellular phone signals and also to protect the indoor wireless local area network (LAN).

In this paper, we investigate agricultural organic material namely rice husks, coconut husk, cotton and sawn wood crumbs to be considered as a potential alternative of absorber material not only for EMC chamber but also to be considered as a potential alternative of mobile phone casing to absorb unwanted electromagnetic emission in the frequency of 900 MHz and 1800 MHz.

3. Research Method

Three organic materials are tested to investigate the reflection coefficient of these materials as potential alternative absorber materials in EMC chamber or as a mobile phone casing to reduce the radiated effect of mobile phones. The radiated electromagnetic emission of mobile phones is currently measured following the limits in ANSI/IEEE C 95 referred to as 'harmful interference'. This standard is initialized in 1960 by the American Standards Association undert the co-sponsorship of the Department of the Navy and the Institute of Electrical and Electronics Engineer. In this standard some values related to permitted RF exposure of human hazardous impact are specified. The related parameters are basic restrictions (BRs are limits on internal fields and current density), maximum permissible exposure (MPEs are limits on external fields, and specific absorption rate (SAR). A better absorbing material for mobile phone casing will probably reduce the SAR values. In this paper the measurement is conducted using a Vector Network Analyzer (VNA) with two antennas and absorber materials (DUT) between the two antennas as shown in Figure 3.

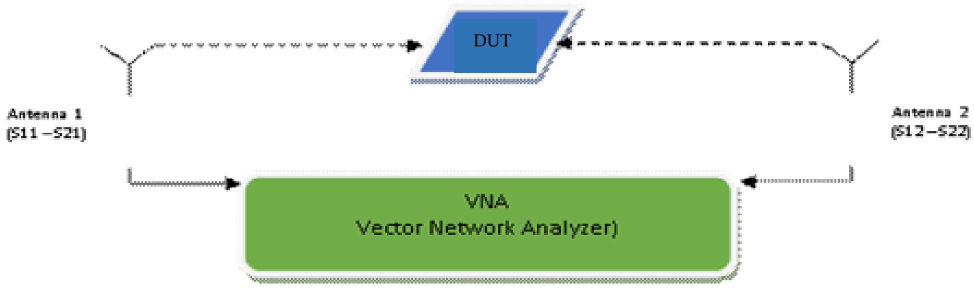

Figure 3. Measurement setup of organic Absorber Material (AM) using Vector Network Analyzer (VNA)

Besides performing measurements of the organic absorber materials referring to CISPR 22, the organic materials are tested for their reflection coefficient with VNA for mobile phones frequencies, namely 900 MHz and 1800 MHz. Parameters S11, S12, S21 and S22 are measured by setting the VNA in the S-parameter mode as shown in Figure 4.

S parameters describe the relationship of input-output from Port 1 and Port 2. The reflection coefficient is represented by parameter S11, which is defined as the ratio between input signal measured in Port 1 and output signal measured in Port 1. While parameter S21 is the forward transmission coefficient and is defined as the ratio between output signal measured in Port 2 and input signal measured in Port 1. Parameter S12 is the reversed transmission coefficient and is defined as the ratio between output signal measured in Port 1 and input signal measured in Port2. Parameter S22 is the output reflection coefficient and is defined as the ratio between output signal measured in Port2 and input signal measured in Port2. S11^2 is reflection, S21^2 is transmission. Absorption (or Absorbance) is calculated by 1-[|S11|^2+|S21|^2]. Figure 5 shows the measurement setups of antennas and the absorber materials.

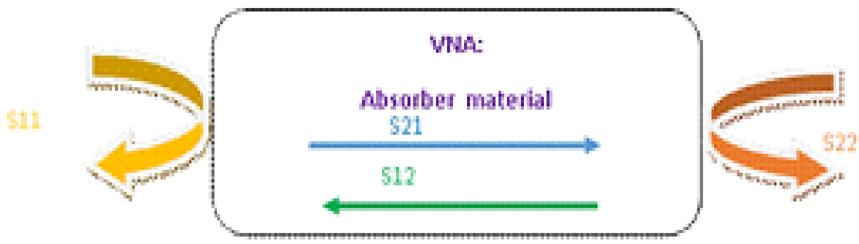

Figure 4. S-parameters of VNA measurements

Figure 5. Setup measurement with VNA for S-parameters

4. Results and Discussion

In BPPT EMC laboratory, there are 3 (three) different organic absorber materials have been tested, namely Rice husk, wood Saw husk without carbon, Rice husk, wood Saw husk with carbon, Cotton husk, Coconut husk (30% and 50%), and Ferrite (as reference).

4.1. Rice and Wood Saw Husk

Rice and wood saw husk are tested for S-parameters especially S11. The measurement has been conducted for both specimens:

a. rice and wood saw husk mixture without carbon as shown in Figure 6,
b. rice and wood saw husk mixture with carbon as shown in Figure 7.

A comparison has been made for the difference of each mixture.

Figure 6. Rice and wood saw husk w/o carbon

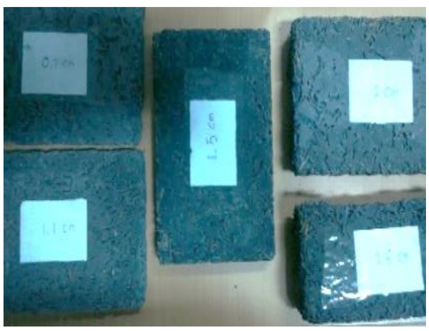

Figure 7. Rice and wood saw husk w/ carbon

4.2. Comparison between Rice and Wood Saw Husks Absorption Capability

Organic absorber materials from rice and wood saw husk has been made as a plate of mixtures with weight of 50 gr, 75 gr and 100 gr. The measurements setup is given in Figure 8 and the result is given in Table 1.

Figure 8. Measurement setup of organic material absorbers

Table 1. Measurement results of absorbance capability of rice and wood saw husk w/o carbon

	Organic material absorber types	Weight (grams)	Absorbance	
			900 MHz (dB)	1800 MHz (dB)
1	Rice husk without carbon	50	-23.8971	-29.2222
		75	-22.741	-30.3687
		100	-22.8416	-27.9225
2	Wood Saw Husk without carbon	50	-21.7823	-29.611
		75	-21.9538	-29.2163
		100	-23.035	-27.2351

As shown in Figure 4 the reflection of material is given by [$|S11|^2$] and the transmission is [$|S21|^2$]. Absorption of each type of material is calculated by 1-[$|S11|^2$+[$|S21|^2$]. Table 1 gives the absorbance of rice husk and wood saw husk without carbon in various weight for frequency of 900 MHz and 1800 MHz.

Six different types of organic absorber materials have absorption between 21.7823 to 23.8971 dB in the frequency of 900MHz. In frequency 1800 MHz the absorbance is between 27.2351 to 30.3687 dB. The 50 gr rice husk without carbon has the highest absorbance capability for 900 MHz namely 23.8971 dB. While the 75 gr rice husk without carbon has the highest absorbance capability for 1800 MHz namely 30.3687 dB. Thereafter a measurement test has been conducted by adding carbon and varies the thickness of organic material absorber. The results of this measurement is given in Table 2.

Table 2. Measurement Results of Absorbance Capability of Rice and Wood Saw Husk w/carbon

	Organic material absorber types	Weight (cm)	Absorbance	
			900 MHz (dB)	1800 MHz (dB)
1	Rice husk with carbon	0,7	-21.779	-32.765
		1	-21.001	-31.968
		1,5	-20.761	-31.492
		2	-20.337	-31.537
		2,5	-21.210	-31.874
2	Wood Saw Husk with carbon	0,7	-20.676	-31.770
		1	-20.776	-34.294
		1,5	-20.361	-32.815
		2	-19.339	-33.445
		2,5	-20.161	-32.113

Table 2 shows different performance of rice husk and wood saw husk with carbon in various thickness. Ten different types of organic absorber materials have reflection coefficient between -19.339 to 21.779 dB in the frequency of 900 MHz. In frequency 1800 MHz the reflection coefficient is between -31.492 to -34.294 dB. The 0.7cm of rice husk with carbon has highest absorbance capability for 900 MHz namely -21.779 dB. While the 1 cm wood saw husk with carbon has the lowest reflection coefficient for 1800 MHz namely -34.294 dB.

4.3. Comparison between Coconut Husk and Cotton Absorption Capability

In addition, other types of organic absorber materials have been tested namely a mixture of coconut husk with resins, cotton and as a reference ferrite material is used as given in Figure 9.

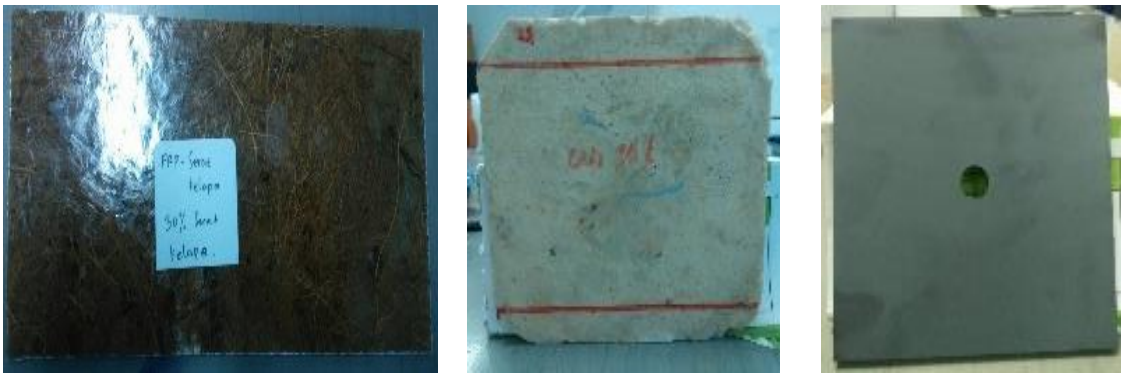

Figure 9. Organic material absorbers: coconut husk, cotton and ferrite for testing

The testing method is using VNA to measure the S-parameters in particular the forward reflection coefficient S11. Ferrite material is measured as a reference of the absorption capability. The results of measurement is given in Table 3.

Table 3 shows that in frequency of 900 MHz the absorbance capability of cotton has the best average value of -32.93 dB, which is approximately 8 dB less than the absorbance of ferrite as a reference. However, the 30% coconut husk has the best absorbance capability with average value of -31.21 dB in 1800 MHz, which is much better performance than ferrite as a reference. These coconut husk mixtures have better values of reflection loss than rice husk or wood saw husk with carbon in frequency 900 MHz and 1800 MHz.

Table 3. Measurement Results of Absorbance of Coconut Husk, Cotton and Ferrite (as reference)

Frequency	Type of Materials	Absorbance (dB)		
		Min	average	Max
900 MHz	30% coconut husk	-30.14	-32.19	-30.14
	50% coconut husk	-29.39	-30.98	-29.39
	Cotton	-31.19	-32.93	-31.19
	Ferrite (reference)	-23.95	-24.12	-23.95
1800 MHz	30% coconut husk	-32.20	-31.21	-32.20
	50% coconut husk	-23.03	-22.38	-23.03
	Cotton	-26.42	-25.71	-26.42
	Ferrite (reference)	-21.00	-20.51	-21.00

Eventhough the test results of rice husk materials in BPPT EMC laboratory has higher reflection loss than rice husks in [5] and similar result for natural rubber materials compared to [6], it has shown that organic absorber materials such as rice husk, wood saw husk, coconut husk and cotton may become a more environmental friendly alternatives for absorber in EMC chamber or in mobile phones casing. The result in this paper is still a preliminary results and will be improved in the future by performing a finer mixtures of either coconut husk, rice husk, wood saw husk, and carbon in the correspondence frequency, and a better resin for additives. These organic absorber materials may be used to build a mini EMC chamber and mobile phones casing. In the measurements, the value of uncertainty [9-10] is necessary to be defined before the results of measurement will be analyzed in order to maintain the quality of every EM testing by generating replica data. Furthermore a research may be conducted to compare the absorbance capability of organic material and either metamaterial [11] or planar multilayered electromagnetic wave absorbers [12] in order to be used as alternative absorber in the future

5. Conclusion

Measurement test for rice husk and wood saw husk with VNA for absorption capability has shown that a mixed layer of rice husk without any additional carbon (50 grams weight) may absorb radiated emission in 900 MHz by reflection loss of -21.779 dB. But the cotton based absorber has better reflection loss of -32.93 dB in 900 MHz. In contrary the 1800 MHz radiated emission will be absorbed more with 30% coconut husk. In order to have a better absorber based on these organic materials for both mobile phone frequencies (900 MHz and 1800 MHz), a mixture of coconut husk and wood saw husk may be used. In addition, rice husk and coconut husk may become a potential alternative for mobile phones casing to reduce 'unwanted radiated emission' from mobile phones and at the same time will reduce the SAR values.

Acknowledgement

The authors would like to thank the support and work of Raksa Reza Pratama from Politeknik Negeri Bandung, during his Internship period in PTE BPPT to perform absorbance measurements of various materials. We also would like to thank the support of Center of Electronics Technology of BPPT especially PTE Director Mr. Yudi Purwantoro, PTE Head of Division Mr. Achmad Wibisono for their continuous support in the activities related to Electromagnetic Compatibility Laboratory.

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