Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2023, 10(1):44-50

Research Article ISSN: 2394 - 658X

A Comparative Study on Different Absorbers used in the Design of Anechoic Chamber

Onu, Igochi Praise and Orakwue, Stella Ifeoma*

Department of Electrical/Electronic Engineering, University of Port Harcourt, Nigeria

ABSTRACT

The design of microwave absorbers is directly correlated to the general performance of an anechoic chamber for its signal absorptive capabilities.

Research has been carried out on the different materials that can be used in the design of microwave absorbers. Absorber shape is also another parameter considered in the general performance of a microwave absorber.

From this review paper, the Truncated Pyramid Absorber with Square Base using Polyurethane Foam has proven to be a suited microwave absorber to be used in an anechoic chamber for the frequency range of 1GHz to 10GHz.

Key words: Anechoic, Chamber, Microwave, Absorbers, Polyurethane

1. INTRODUCTION

Electromagnetic equipment needs to undergo a performance test to determine its working condition before they are deployed for usage. As such, a test analyzer environment had to be in place and one of these was the introduction of an Anechoic Chamber. An Anechoic Chamber is an enclosed room which is designed to prevent noise interference. These rooms are designed to absorb reflections of electromagnetic radiation and to minimize interference of energy disturbances from external sources which could get into the Chamber through small holes and from little holes around the door of the Chamber. To achieve this, the Anechoic Chamber is covered with a material that is capable of absorbing most of the incident energy to enable it to simulate a perfect free space environment with the absence of signal reflection and scattering [1]. The absorbers are one of the main components in an anechoic chamber which are used to eliminate reflected signals in the chamber. These absorbing materials are very important and ensure the accuracy of the anechoic chamber testing performance.

In the design of an Anechoic Chamber, there are some important features to be considered which are; the shape of the chamber, the absorber material and the absorber assembly [2]. Research has shown that using polyurethane material would give a better absorption of the signal compared to the biomaterials such as Rice Husk. Also, the pyramid microwave absorber has been shown to have better absorption of the signal compared to the wedge microwave absorber.

Different shapes can be fabricated as a microwave absorbers such as pyramidal, wedge, ferrite tiles, etc. These absorbers are also fabricated using different materials such as polyurethane, polyethylene, biomaterials, etc. Microwave absorbers in the frequency range of above 1GHz are used in many applications such as high-speed electronics, telecommunication, automobiles, etc.

This study considers different absorbers which can be used in an anechoic chamber. The properties to deliberate in this work are the shape of the absorber and the materials used in the fabrication of the absorbers.

2. ABSORBER CHARACTERISTICS

Different absorbing materials have their characteristic which tends to affect their reflectivity when simulated and implemented in an anechoic chamber depending on their different parameters such as operating frequency, dielectric constant and tangent loss. The most common absorber material used for low frequency (30MHz to 1000MHz) is the ferrite tile absorber material which is widely used in many EMC test chambers. Foam materials such as Polyurethane and Polystyrenes are widely used for microwave frequency (1GHz to 40GHz) [3].

The dielectric constant of a material can affect the general performance of the material as well as the velocity of the microwave signals when it moves through the absorber material. This means that a larger value of the dielectric constant would result in the microwave signal travelling at a slower velocity and would result in a denser material. Some characteristics of these microwave absorbers are the shape of the absorber, the material used in the fabrication of the absorber which determines the dielectric constant of the absorber, the operating frequency mainly the lowest usable frequency and the excitation power. The excitation power for these absorbers as seen in [4] is 0.5W. These characteristics are discussed in section 3 of this paper.

3. MICROWAVE ABSORBER SURVEY

This section discusses the literature survey based on previous works done to compare their methods and results for the properties to be considered which are the Absorber Shape and the Absorber Material.

3.1. Microwave Absorber Shape

A parametric study was carried out in [5] for a pyramidal microwave absorber to vary its parameters and determine its performance. An analysis of the microwave absorber was carried out by varying the ground height, ground length, ground width and also the length and width of the pyramid top. A model was also developed for an RF absorber which is based on the information on the absorber reflectivity. The design of the pyramid microwave absorber was done using the CST Microwave Studio 2008 software [6]. The material being used for the absorber is Carbon which has an epsilon (ε) of about 2.6 and is chosen based on the TDK Standard Material Characteristics for ICT absorber types [6].

The simulated pyramidal microwave absorber symbol is shown in figure 1, while the dimension of the sides of the pyramidal microwave absorber is shown in Table 1.

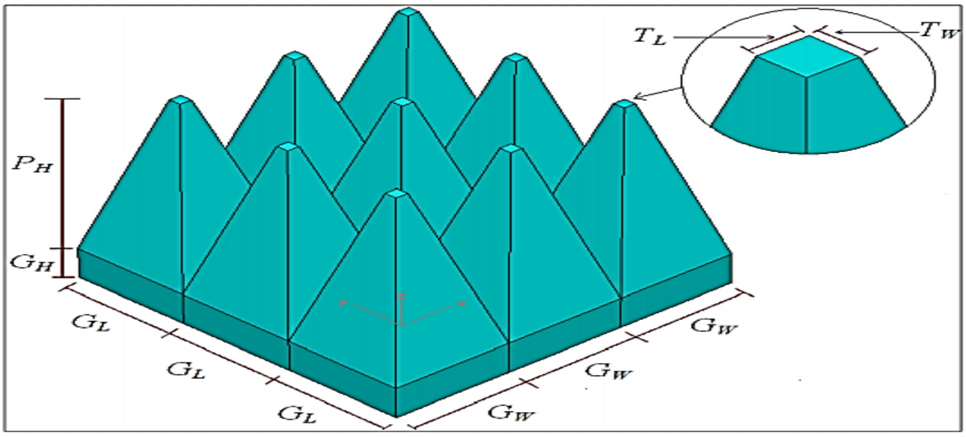

Fig. 1 Simulated pyramidal microwave absorber

Table -1Dimension of pyramidal microwave absorber

	Symbol	Dimension
Top Length	T_L	1.0 com
Top Width	T_W	1.0 com
Pyramid Height	P_H	25.0 cm
Ground Height	G_H	5.0 com
Ground Length	G_L	10.0 com
Ground Width	G_W	10.0 com

The dimension above is for one piece of the pyramidal microwave absorber and the full absorber set contains nine tips per piece having three major parts, the ground of the pyramid (GL, GW and GH), the top of the pyramid (TL and TW) and body of the pyramid (PH). This shows that the overall dimension of the pyramid absorber is 30cm in length, 30cm in width and 30cm in height. Its performance specified in reflectivity is stated in dB and the investigation is from the frequency range of 0.01GHz to 10GHz. A simulation investigation was carried out on the absorber showing the reflectivity of the different dimensions of the absorber. The reflectivity which is in dB for the pyramidal microwave absorber was investigated for (a) Pyramids height (PH) dimension sweep with fixed ground height (GH), (b) Top length (TL) dimension sweep with fixed top width (TW), (c) Top width (TW) dimension sweep with fixed top length (TL), (d) Ground length (GL) dimension sweep with fixed ground width (GW), (e) Ground width (GW) dimension sweep with fixed ground length (GL), (f) Ground height (GH) dimension sweep with fixed pyramid height (PH).

Simulation results prove that all absorbers designed are functional in the estimated frequency range of 1GHz to 10GHz and parameters such as the top width and length, and the ground width and length are not sensitive to the small-scale change of dimension.

The authors in [7] performed a design and simulation on different microwave absorber shapes and materials for the microwave frequency range of 1GHz to 10GHz to propose the best-suited absorber shape used in an anechoic chamber. In their work, performance simulation on the reflectivity for Pyramidal and Wedge absorbers was done. The Pyramidal absorbers were configured in three different configurations, namely; normal, hollow and coated truncated pyramidal absorbers. Also, the Wedge absorbers were configured in three different configurations, namely; normal, hollow and coated truncated wedge absorbers.

To determine the best performance for the frequency range, the average reflectivity equation was used at different dielectric constants.

$$AvgdB = \frac{\sum(f_{0.00} + f_{1.00} + \cdots + f_{20.00})}{1000} \quad (1)$$

From the result, it was shown that the best performance absorber for the frequency range of 1GHz to 10GHz is the Normal Truncated Pyramidal Absorber having the best reflectivity average. Table 2 and Table 3 summarize the results obtained for the Pyramidal and Wedge Microwave Absorbers [7].

Table -2 Reflectivity, S11 for truncated pyramidal absorber

Truncated Pyramidal	**Dielectric Constant**	**S11 (dB)**	
		Best *S11*	**Average *S11***
Normal	2.5	-53.58	-25.99
	2.9	-66.38	-24.85
	3.3	-61.85	-23.92
Coated	2.5	-45.43	-25.79
	2.9	-69.77	-25.02
	3.3	-63.77	-24.11
Hollow	2.5	-37.47	-21.07
	2.9	-41.47	-19.44
	3.3	-48.04	-18.73

Table -3 Reflectivity, S11 for truncated wedge absorber

Truncated Pyramidal	**Dielectric Constant**	**S11 (dB)**	
		Best *S11*	**Average *S11***
Normal	2.5	-42.91	-25.99
	2.9	-39.06	-24.85
	3.3	-36.11	-23.92
Coated	2.5	-42.83	-25.79
	2.9	-38.91	-25.02
	3.3	.35.81	-24.11
Hollow	2.5	.46.04	-21.07
	2.9	-52.25	-19.44
	3.3	-50.85	-18.73

From Table 2 and Table 3, the pyramid and wedge absorber were simulated in three types, the normal, coated and hollow and from the result, it is seen that by coating the pyramid absorber, the absorption of the electromagnetic wave would be higher compared to the other types and the wedge absorber.

In the research of [8], a design and simulation test to determine other materials and shapes which are suited for use in an anechoic chamber was investigated. It was seen that the shape of the absorbing material is the main parameter that affects the performance of the microwave absorber. A triangular microwave absorber of different base shapes was designed using CST Microwave Studio Software and is of the concept of pyramidal microwave absorber modification form [2], [9], [10].

The material of the absorber being used is the Rice Husk which is a type of agricultural waste having an epsilon (ε) of 2.9 which is the dielectric constant for the rice husk material used in the simulation. The plan view of the array triangular pyramid microwave absorber, perspective view of the array triangular pyramid microwave absorber, the plan view of the array square base pyramid microwave absorber and perspective view of the array square case pyramid microwave absorber were designed and can be seen from fig. 2 below

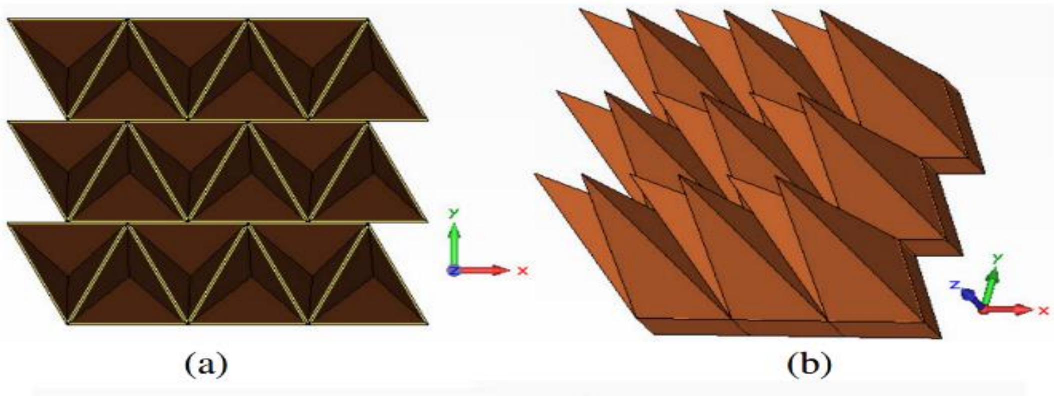

Fig. 2 (a) Plan view of array triangular pyramid absorber, (b) Perspective view of array triangular pyramid absorber

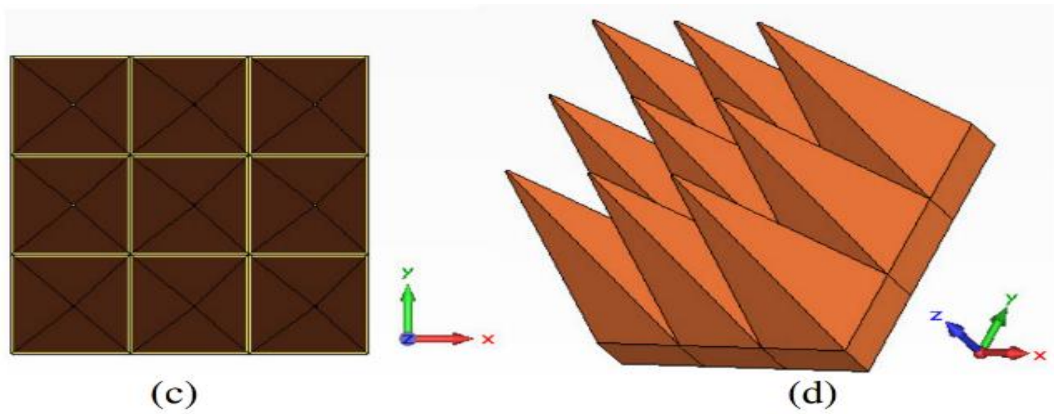

Fig. 2 (c) Plan view of square base pyramid absorber, (d) Perspective view of square base pyramid absorber

The Isosceles triangle, Equilateral triangle and square base pyramid shape microwave absorber were used to determine the best average reflection loss.

It was found that the isosceles triangle base pyramid absorbers gave the best average reflection loss result for the frequency range of 1GHz to 20GHz with a loss of -41.142dB compared to the equilateral triangle base pyramid absorber of -39.878dB and square base pyramid absorber of -39.423dB. Table 4 summarizes their results.

Table -4 Dimension of pyramidal microwave absorber with different base

Truncated Pyramidal	Reflection Loss (dB)		
	Isosceles Triangle Base	**Equilateral Triangle Base**	**Square Base**
0.1 to 1	-21.166	-21.839	-15.833
1 to 5	-38.518	-37.235	-34.736
5 to 10	-47.091	-43.653	-44.170
10 to 15	-44.014	-43.294	-44.170
15 to 20	-38.529	-38.457	-38.485
1 to 20	-41.142	-39.878	-39.423

According to [8], it was seen that the shape of the microwave absorber can affect the performance of the absorber and it shows the triangular base shape microwave absorber for a Rice Husk absorbing material to have a better performance if compared to the existing and commercial square base shape pyramidal microwave absorbers.

Results from table 5 show that for the frequency range of 1GHz to 10GHz, the best suitable microwave absorber shape is the Truncated Pyramid Absorber with a square base shape using Polyurethane Foam material.

Table -5 Comparison of Absorber Shape

Dielectric Constants	Truncated Wedge		Truncated Pyramid	
2.9	Normal	-39.06	Normal	-66.38
	Coated	-38.91	Coated	-69.77
	Hollow	-52.25	Hollow	-41.47
	Isosceles Base		**Equilateral Base**	
	(1-5) GHz	-38.518	(1-5) GHz	-37.235
	(5-10) GHz	-47.091	(5-10) GHz	-43.653
	Square Base			
	(1-5) GHz	-34.736		
	(5-10) GHz	-44.170		

3.2. Microwave Absorber Material

For the conventional microwave absorber which is seen from the selection guide according to [4], [11], the material used in the fabrication and simulation of the microwave absorber is Polyurethane Foam which is a lightweight, free space absorber.

In previous years, the proposed research has been done on different materials that can be used in the fabrication of microwave absorbers. Some of these are discussed in this section of this paper.

In the research of [2], a proposed material of Polyurethane Foam was used based on the conventional microwave absorber material. The results from table 2 and table 3 showed that by using polyurethane material in the fabrication of microwave absorbers, the absorption of electromagnetic waves would be high thereby leading to a good reflectivity loss.

The authors in [12] proposed examples of biomaterials which can be used as absorber materials and they were discussed and analyzed. The reflectivity of this microwave absorber was shown by comparing the TDK ICT-030 with the designed microwave absorber using CST Microwave Studio 2008 software. There are so many biomaterial types in agricultural waste and some of these wastes being used in the research [12] are rice husk ash, sugar cane bagasse, coconut shell charcoal, and Oil Palm Empty-fruit-bunch. These biomaterials are made up of organic compounds which are produced from the similar structure of materials. Table 6 shows the carbon percentage content in these various agricultural waste biomaterials.

Table -6 Percentage of carbon element in all biomaterial

Biomaterial	% carbon element in Biomaterial	Source
Rice Hush + Ash	58.01	[16]
Oil Palm Empty-Fruit-Bunch	46.5	[17]
Coconut Shell Charcoal	83	[18]
Sugar Cane Bagasse	47	[19]

All materials being used must contain Carbon and it is the major element used for the microwave absorber and it has an epsilon ε which is equal to 2.6. The absorber is designed and simulated using CST Microwave Studio with its parameters and can be seen in the fig. 3 below

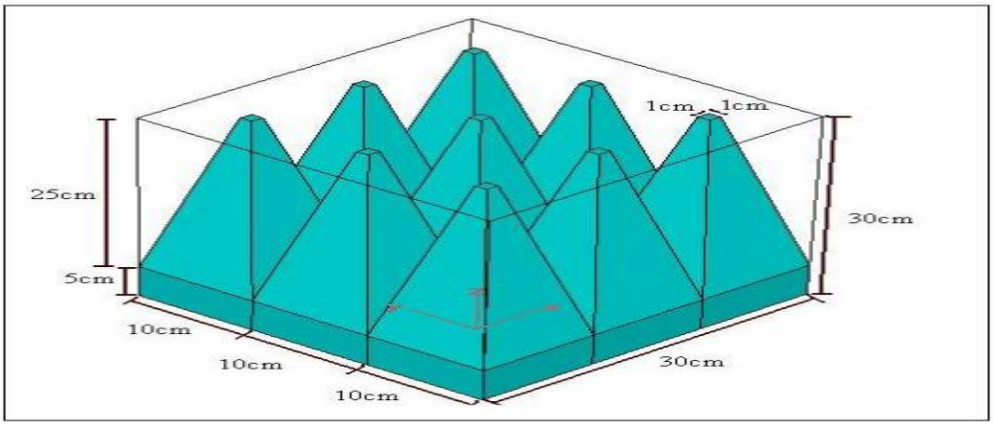

Fig. 3 Pyramidal Microwave absorber using CST Software

The simulated result proved that the reflectivity performance of the pyramidal absorbers from the frequency range of 0.01GHz to 10GHz and the reflectivity of the conventional microwave absorber is mostly below -25dB.

Table -7 Reflectivity of TDK ICT-030 and designed absorber

Frequency Range (GHz)	Reflectivity – TDK ICT – 030 (dB)	Reflectivity – designed absorber using CST Microwave Studio Simulation (dB)
1 – 2	-25	-20
2 – 5	-35	-35
5 – 10	-40	-30

From Table 7, it can be seen that the reflectivity of both the TDK ICT-030 and the designed microwave absorber does not have many discrepancies. This can then be said that biomaterials are also a very good candidate for microwave absorbers which would replace commercial microwave absorbers in terms of reflectivity and cost-effectiveness.

An Evaluation of the absorption property of Coir according to [13], which is an agricultural waste used in the manufacturing of pyramidal absorbers in anechoic chambers. Agricultural waste such as coir is a non-dangerous natural source of lossy carbon that can be utilized for the absorption of electromagnetic waves. Coir originates from the husk of coconuts which makes up the fibrous husk of the coconut shell, coconuts are the most generally developed nut in the world and they contribute fundamentally to the economy of numerous tropical regions [14].

A comparison was conducted to evaluate coir as a microwave absorbing material and also coir as an agricultural waste which is inexpensive and not dangerous to health. The absorption properties of coir were compared with polyurethane which is the commercial material used in the fabrication of pyramidal absorbers in anechoic chambers. The other organic materials being compared to analyze the properties of coir are rice, corn and lentils. The purpose of the research was to measure the S21 parameters which are associated with the frequency response, which provides information on attenuation in a rectangular waveguide [15].

It was proven that the coir samples have the best approximate behaviour to that of the polyurethane samples. The rice, corn and lentils samples have almost similar behaviour amongst them but way below the dB level that the coir and polyurethane samples show. Also, the frequency response of the empty waveguide (i.e., no sample, air) has a higher waveguide compared to that of the coir and polyurethane [13].

It was realized that an organic material Coir will have a similar performance behaviour as that of polyurethane material of a conventional microwave absorber [4], as such, manufacturing of a microwave absorber based on coir is feasible since it has a non-hazardous impact on health as well as it being less expensive to acquire.

4. CONCLUSION

This paper shows a review and survey of different techniques and designs for the designing of an efficient microwave absorber used in an anechoic chamber. The review was based on some characteristics in choosing the suited absorber such as the absorber shape and the absorber material. Results show that the truncated pyramid absorber is best suited for use in an anechoic chamber for the frequency range of 1GHz to 10GHz using Polyurethane Foam. Further research shows that biomaterials such as agricultural waste can be used as an absorber material although not as efficient as a conventional absorber using polyurethane foam and have a close similarity in the reflectivity of the absorber. Nevertheless, further research can be carried out for an efficient microwave absorber and put into consideration the cost-effectiveness.

REFERENCES

[1]. Dash G., (2005): "How RF Anechoic Work", Ampyx LLC. Available at: alum.mit.edu.

[2]. Nornikman, H., Malek, F., Soh, P. J. and Azremi, A. A. H., (2009): "Performance Simulation of Pyramidal and Wedge Microwave Absorbers", 3rd Asian Modelling Symposium (AMS 2009). Bandung, Indonesia, 25th – 26th May 2009, pp. 649 – 654.

[3]. Boon-Kuan, C. and Hean-Teik, C. (2004), "Design and Construction of a Multipurpose Wideband Anechoic Chamber", Antennas and Propagation Magazine, IEEE. – Volume 45, Issue 6. pg. 41-47.

[4]. ETS-Lindgren™ (2003): "Microwave Absorber Selection Guide". Available at: https://www.mdltechnologies.co.uk/technical-docs/Microwave-Absorber-Brochure.pdf.

[5]. Nornikman, H., Soh, P. J., Azremi, A. A. H., Husna, M. R. N. and Liam, O. S., (2008): "Parametric Study of Pyramidal Microwave Absorber Design", International Symposium on Antennas and Propagation (ISAP 2008) Taipei. Taiwan, 2008. Available at: http://ap-s.ei.tuat.ac.jp/isapx/2008/pdf/1645388.pdf.

[6]. TDK RF Solution Inc., (2007): "EMC Component Radio Wave Absorber and Selection Guideline of Electromagnetic Absorbers", 001-03 / 20070302 / e9e_bdj_003, 2007.

[7]. Nornikman, H., Soh, P. J. and Anuar, M. S. (2009): "Performance Simulation of Pyramidal and Wedge Microwave Absorbers", 3rd Asia Int. Con. on Mod. & Simulation. DOI 10.1109, pp. 649-654.

[8]. Nornikman, H., Soh, J. and Azremi, A. A. H. (2014): "Potential Types of Biomaterial Absorber for Microwave Signal Absorption", Conference paper, January 2008.

[9]. Nornikman, H,, Malek, F., Soh, P. J., Azremi, A. A. H., Wee, F. H. and Hasnain, A., (2010): "Parametric Study of Pyramidal Microwave Absorber using Rice Husk", Progress in Electromagnetics Research. PIER 104, pp. 145-166.

[10]. Nornikman, H,, Malek, F., Soh, P. J., Azremi, A. A. H., Wee, F. H. and Ahmad, R. B., (2010): "Microwave Wedge Absorber Design using Rice Husk – An Evaluation on Placement Variation", 2010 Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC 2010). Beijing, China, 12th - 16th April, 2010, pp. 927 -930.

[11]. Laird (2018): Laird Performance Materials. Available at: https://pm.lairdtech.com/rfmicrowave-absorbers-dielectrics/microwave-absorbing-foams/broadband-free-space-reflectivity-absorbers/eccosorb-hr.

[12]. Nornikman, H., Malek, F., Soh, P. J., Azremi, A. A. H. and Ismahayati, A. (2014): "Reflection Loss Performance of Triangular Microwave Absorber", Conference Paper, November, 2010.

[13]. Simón J., Villanueva J., Arriaga-Trejo I. A., Flores-González J. R., Alvarez-Flores J. L., Hernández-Gómez E. S., Piña R. and Flores-Troncoso J., (2016): "Evaluation of Coir as Microwave Absorber", Microwave and Optical Technology Letters. Volume 58 Issue 6, pg. 1450–1453.

[14]. The Spruce (2019): *What is Coir?* Available at: https://www.thespruce.com/what-is-coir-1403141.

[15]. Karris, S. T. (2014): "Engineering Electromagnetics with Introductions to S-parameters", RF ToolboxVR, and SimRFVR, 1st ed., Orchard Publications, 2014.

[16]. Bronzeoak, G. (2003). Rice husk ash market study—a feasibility study internal report. *UK Companies, EXP*, *129*.

[17]. Nornikman, H., Soh, P. J., & Azremi, A. A. H. (2008). Potential types of biomaterial absorber for microwave signal absorption. *Universiti Malaysia Perlis*, *IXCRI UMS*, *2*.

[18]. Satya Sai, P. M., Ahmed, J., & Krishnaiah, K. (1999). Rebuttal to Comments on "Production of Activated Carbon from Coconut Shell Char in a Fluidized Bed Reactor". *Industrial & Engineering Chemistry Research*, *38*(3), 1169-1171.

[19]. Ferraz, L. R., de Oliveira, D. D. S., Silva, M. F., Rigo, E., Di Luccio, M., Oliveira, J. V., ... & Treichel, H. (2012). Production and partial characterization of multifunctional lipases by Sporobolomyces ruberrimus using soybean meal, rice meal and sugarcane bagasse as substrates. *Biocatalysis and Agricultural Biotechnology*, *1*(3), 243-252.