# Rice Husks Microwave Absorbers

**Mohd Fareq Abd Malek[1], Nornikman Hassan[1], Soh Ping Jack[1], Azremi Abdullah Al-Hadi[1], Supri A. Ghani[2]**

*[1]School of Computer and Communication Engineering, Universiti Malaysia Perlis*
*[2]School of Materials Engineering, Universiti Malaysia Perlis*

## INTRODUCTION

An anechoic chamber is an RF test facility which utilizes a lining of radar absorbing material (RAM) along its wall, ceiling and floor to create an electromagnetically quiet environment, widely used to provide RF isolated test regions to simulate free-space test environment for antennas. The anechoic chamber provides a controlled environment not subjected to weather, ambient conditions and without being affected by wave reflections. The design of an anechoic chamber must take into consideration features of the room such as the shape or orientation, size of the room, the wall covering (absorber) and how the absorbers are assembled. The size of the anechoic chamber depends on the size of the objects to be tested and the frequency range of the signals used, scale models can be used, however, by testing at shorter wavelengths.

Absorbers are one of the main components in an anechoic chamber and are used to eliminate reflected signals. Electromagnetic absorbing materials are very important to ensure the accuracy of RF anechoic chamber testing performance. There are many shapes that can be fabricated as an absorber such as a pyramid, truncated pyramid, wedge, convoluted, hybrid, flat, honeycomb, oblique, and others. Microwave absorbing materials that reduce reflections of high frequency energies, are used in applications such as telecommunication, military, high speed electronics and automotive. Different absorber materials are used for the microwave range (1 GHz to 40 GHz) and for the low frequency range (30 MHz to 1000 MHz), respectively. The most common material used for the low frequency range (30 MHz to 1000 MHz) absorber is ferrite tiling (NiZn), an electrically-thin absorber material. In the microwave frequency range (1 GHz to 40 GHz), foam materials such as polyurethane and polystyrene are widely used as the absorber.

A microwave signal is reflected and absorbed in the anechoic chamber and a proper model of RF microwave absorber must be developed based on various parameters such as the absorber reflection loss, the magnitude and phase, for various angles of incidence, as well as for parallel and perpendicular polarizations. The reflection loss, R can be expressed as the absorbing performance of the material and is a function of the complex permittivity, permeability of the material, and the frequency of the electromagnetic wave.

The dielectric constant is equivalent to the relative permittivity ($\varepsilon_r'$) or the absolute permittivity ($\varepsilon'$) relative to the permittivity of free space ( $\varepsilon_0'$ ). The dielectric constant of a material also affects the velocity of microwave signal when it propagates through the material. A high value dielectric constant results in the microwave signals propagating at slower velocities, making it essentially a denser material. Dielectric loss tangent, tan $\delta$, is the imaginary part of the dielectric constant, and determines the losses of the medium.

The signals are transmitted from a first medium to a second medium, with air being the usual first medium while the second medium is a pyramidal microwave absorber. When the signal enters another medium at an angle, this will change the velocity of the signal, which causes the signal to be deflected. This phenomenon is known as refraction and the refractive index, n of a medium is a measure of how much the speed of microwave signal is reduced inside the medium. The refractive index for air is 1.00029. The refractive index of the pyramidal material should, hence, be larger than that of air.

Agriculture waste or residue is composed of organic compounds from rice straw, oil palm empty fruit bunch, sugar cane bagasse, coconut shell, and others. Rice husk from paddy (Oryza sativa) is another example of an alternative material that can use to fabricate the microwave absorber. In Malaysia, around 350,000 tons of rice husks are produced annually. Rice husks are unusually high in ashes, highly porous and lightweight, with a very high external surface area. Rice husks' absorbent and insulating properties are useful for many industrial applications.

Table 1 shows the typical chemical composition of rice husks. Carbon is the main element that helps to absorb the microwave signal. 35.77 % of rice husk consists of Carbon. In the current market, absorbers are typically manufactured by impregnating conductive carbon at the top part of the pyramidal structure. This can increase the reflection loss performance of the microwave absorber. Carbon has also the characteristic as a light absorbent material.

| Element | % |
|---|---|
| Silicon dioxide | 22.24 |
| Carbon | 35.77 |
| Hydrogen | 5.06 |
| Oxygen | 36.59 |
| Nitrogen | 0.32 |
| Sulphur | 0.02 |

*Table 1: The elements percentages of the rice husk material*

Figure 1 shows the flow of the research, starting with the collection of the agricultural waste from its natural source. The next step is to make an agricultural waste particle board from rice husk, and derive dielectric constant values of the particle boards using the Free Space Measurement Technique (FSMT). The final step is the modeling and simulation of the microwave absorber design using CST Microwave Studio simulation software and analysis of its performance.

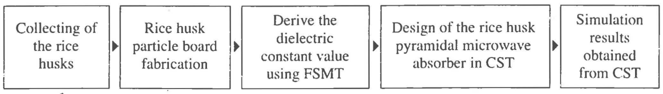


*Figure 1: Flow of the rice husk microwave absorber project.*

## 2. RICE HUSK PARTICLE BOARD

After collecting the rice husk, it is ground to ensure easy adhesion with a resin. Urea Formaldehyde (UF) is mixed with the rice husk. Phenol Formaldehyde (PF) is also used as the bonding agent, for comparison purpose. Formaldehyde is a pungent, colorless gas commonly used in water solution as a preservative and disinfectant. It is also a basis for major plastics, including durable adhesives. Urea Formaldehyde, also known as urea methanol, is a non-transparent thermosetting resin or plastic, made from urea and formaldehyde, heated in the presence of a mild base such as ammonia or pyridine.

These resins are commonly used in adhesives, finishes, and molded objects. Its attributes include high tensile strength, flexural modulus and heat distortion temperature, low water absorption, high surface hardness and elongation at break, and volume resistance. Figure 2 shows the process flow for the mixing of the materials for the fabrication of the rice husk particle board.


*Figure 2: Mixing of the materials for the fabrication of the rice husk particle board.*

The material is shaped into a square form by transferring it into a rigid frame over the hot press machine. A hot press machine is a high pressure, low strain rate material process for forming compacted materials ai high temperatures. Before the mould can be transferred into the hot press machine, a transparency plastic is placed at the top of the mould. This is to avoid the cleaving of the rice husk onto the square mould. The setting of the temperature of this machine is set to 180°C for 10 minutes. After pressing, the mould with the sample must be cooled off by transferring it to the lower section of the hot press machine. After chilling, that particle board is then taken out from the mould. In order to obtain good plots from the FSMT, the board should be trimmed at its edges.

The dimensions of the fabricated particle board are 30.3 cm width x 30.3 cm length x 1.4 cm thickness. The fabricated size of the particle board depends on the size of the horn antennas used in the measurement. With smaller horn antennas, the size of particle board should also be small. The density of particle board can also affect the value of the dielectric constant. A denser particle board results in a larger value of the dielectric constant. Figure 3 shows the fabricated rice husk particle board.

*Figure 3: The fabricated rice husk particle board.*

## 3. FREE SPACE MEASUREMENT TECHNIQUE

A free space measurement technique shown in Figure 4(a) is the technique used to derive the dielectric properties of the rice husk material. This instruments used are the Agilent E8362B PNA Network Analyzer, installed with Agilent 85071E Material Measurement software, two 2.2 GHz – 3.3 GHz horn antennas, two coaxial cables, Agilent 85052D 3.5 mm calibration kit and connectors and the Material Under Test (MUT). In the initial step, the calibrations of the coaxial cable, reference board sample and the distance between the two transmitter and receiver antennas are performed. The reason for this calibration is to remove any undesired errors, such as noise in the coaxial cable and to ensure measurement accuracy.

A full two-port calibration has been used for both the reflection and transmission measurements. Agilent 85052D Economy Mechanical 3.5 mm calibration kit with SOLT (Short – Open – Load – Trough) standard is used in this calibration setup. In the MUT calibration setup, the reference board sample, with a known dielectric constant, is placed at the center, between both the horn antennas. In this case, a copper plate is used as the reference board sample. The dielectric constant value of this reference board sample is displayed on the screen of the Agilent PNA network analyzer. After this, the reference board is then removed. The new value of $\varepsilon_r' = 1$ is obtained as the dielectric constant value of air.

The parameters that must be considered for the free space measurement technique are the size of the horn antennas, the length of the coaxial cables and the distance between the transmitter and the receiver antennas. Figure 4(b) shows the dimensions of the horn antenna used for the free space measurement technique. The antenna dimensions that have been used for the experiment are 30.9 cm x 23.85 cm x 29.4 cm. The sizes of the antennas also affect the suitable distance between the transmitter and the receiver antennas. Smaller antennas sizes result in a shorter distance needed between the two antennas. The lengths of the coaxial cables are also important factors that need to be considered. Longer cables result in weaker signals, due to transmission line losses. The equipment must be located on a level ground, and in a straight line to provide the best performance and to ensure an accurate dielectric constant value. Hence, to obtain the best dielectric constant result, small antennas with short distance between the antennas and short coaxial cables should be used. The obtained value then can be applied for the simulation part using the CST simulation software.

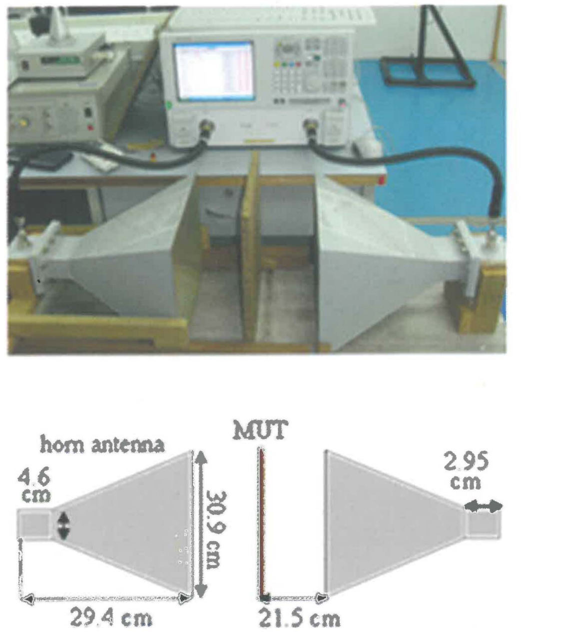


*Figure 4: (a) Free Space Measurement Technique (FSMT), to derive the dielectric constant of the rice husk,*
*(b) dimensions of the horn antennas, and the distances between the horn antennas.*

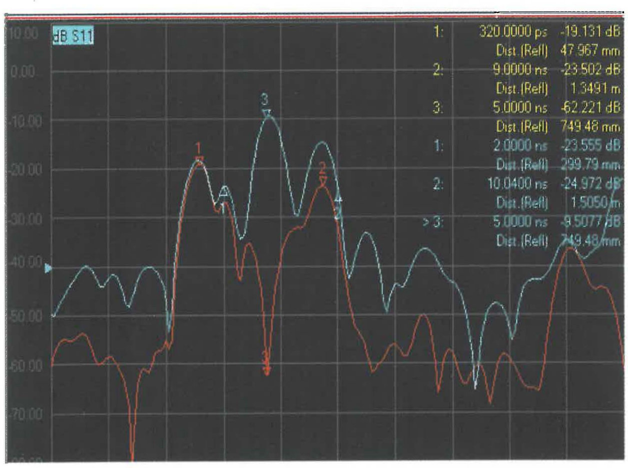


*Figure 5: The time gating setting at the PNA network analyzer.*

The distance between the two antennas needs to be considered for this technique. The distance used between the horn antennas and the particle board is 21.5 cm, while the distance between the two antennas is 43 cm. The actual distance between the particle board and the horn antennas is determined by applying the time gating setting at the PNA network analyzer, as shown in Figure 5. The PNA covers the frequency range from 2.2 GHz to 3.3 GHz, as this is the operating frequency range for the horn antennas. There are three peaks shown in the display of the network analyzer. The first peak is the response of the transmitter horn antenna; the second peak is the time domain gating feature, while the third peak is the response of the receiver horn antenna. Results better than 40 dB obtained for the differences between the non metal plate (MUT) and the metal plate (copper plate) indicate good and valid results.

The result obtained for this difference between two plates is approximately 52.7 dB, indicating a very good performance. The real and imaginary parts of the dielectric constant for the Phenol Formaldehyde (PF) – rice husk particle board (with 10% PF content) are obtained using the free space measurement technique, and are plotted in Figure 6.

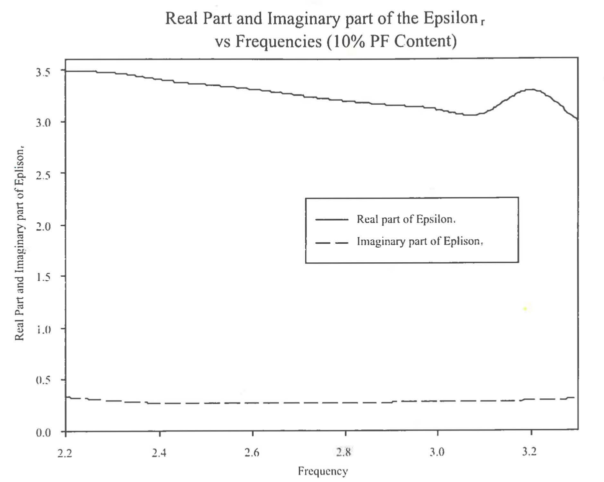


*Figure 6: The real and imaginary parts of $\varepsilon_r$ for the Phenol Formaldehyde (PF) - rice husk particle board (with 10% PF content) using the free space measurement technique.*

## 4. PARAMETRIC STUDIES

The pyramidal microwave absorbers are designed using the Computer Simulation Technology Microwave Studio 2009 (CST MWS 2009) simulation software. The design and shape of the pyramidal microwave absorber are based on the Eccosorb VHP-8-NRL Pyramidal Microwave Absorber and the TDK ICT-030 Pyramidal Microwave Absorber. The Eccosorb VHP-8-NRL absorber is designed using urethane foam as its base material, with carbon loading. The TDK ICT-030 absorber uses polystyrene as its base with carbon loading. Figure 7(a) shows the simulation design of the pyramidal microwave absorber using the CST software. Figure 7(b) shows the boundary conditions of the pyramidal microwave absorber, with port 1 as the transmitter port and port 2 as the receiver port. The value of the dielectric constant for this design is taken from the previous free space measurement technique, that is $\varepsilon_r' = 2.9$. In this design simulation, the waveguide port or the starting signal point is located as normal incident (00) with a distance of 30 cm from the origin of the pyramidal microwave absorber.

Table 2 shows the dimensions of pyramidal microwave absorber. The pyramidal shape has two main parts. The first part is the base part with 5 cm length x 5 cm length x 2 cm thickness. The second part is the pyramid part with 13 cm height. Six parameters of the pyramid must be considered before the pyramidal microwave absorber can be simulated. These parameters are the pyramid width (PW), the pyramid length (PL), the pyramid height (PH), the base width (BW), the base length (BL), and the base height (BH).

There are various factors that can affect the performance of the pyramidal microwave absorber. These parameters are the dielectric constant of the material used, the mixture of the resin percentage, the source port distance and the angles between the source signal and the surface of the pyramidal microwave absorber. The parametric study uses the parametric sweep function in the CST Microwave Studio software.

| Part | Symbol | Dimension (cm) |
|---|---|---|
| Pyramid Width | $P_W$ | 5 |
| Pyramid Length | $P_L$ | 5 |
| Pyramid Height | $P_H$ | 12 |
| Base Width | $B_W$ | 5 |
| Base Length | $B_L$ | 5 |
| Base Height | $B_H$ | 2 |

*Table 2: Dimensions of the Pyramidal Microwave Absorber.*

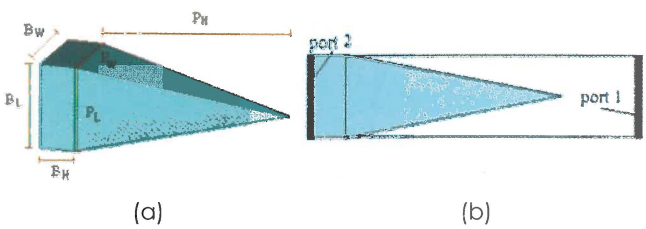


*Figure 7: a) Simulation design of the pyramidal microwave absorber using CST software. b) The boundary condition of the pyramidal microwave absorber with port 1 as the transmitter port and port 2 as the receiver port.*

## 4.1 RESIN PERCENTAGES

| Resin | The different resin percentages in the rice husk-resin mixture |
|---|---|
| Urea Formaldehyde (UF) | 10% |
| | 20% |
| | 30% |
| Phenol Formaldehyde (PF) | 10% |
| | 20% |
| | 30% |

*Table 3: Parametric study for different resin percentages of the pyramidal microwave absorber.*

The first investigation is to compare the different resin percentages in the rice husk-resin mixture, as shown in Table 3. Two resins are used in this measurement: the Urea Formaldehyde (UF) and the Phenol Formaldehyde (PF). The percentages considered in this parametric study are 10 %, 20% and 30% of the resin respectively. The three different resin percentages are used to observe the dielectric constants of the rice husk-resin mixtures.

## 4.2 DISTANCE - SIGNAL SOUCE & PYRAMID SURFACE

The distance between the signal source, which is the starting transmit point or starting port, and the surface of pyramidal microwave absorber is an important parameter that can affect the performance of the microwave absorber. This is shown in Figure 8. In this investigation, three values of distances are considered: 30 cm, 60 cm and 90 cm, respectively. The 10% PF content is used for the PF – rice husk pyramidal microwave absorber.

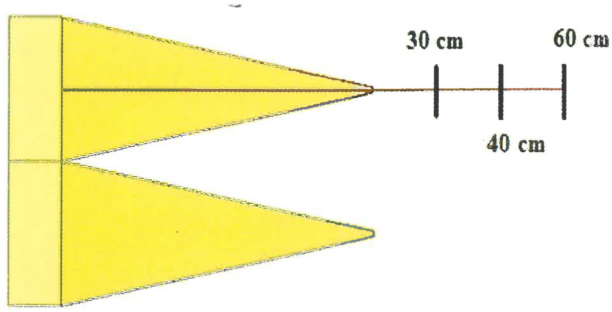


*Figure 8: Distance between the signal source and the pyramidal microwave absorber.*

## 4.3 SIGNAL SOURCE ANGLES

Three different angles between the signal source (the starting port) and the surface of the pyramidal microwave absorber are investigated in this parametric study. The angles selected are 0°, 30° and 45° respectively. The 0° is the normal incidence while the 30° and 45° are the oblique incidences. The distance between the signal source and the pyramidal microwave absorber is set to 30 cm. The 10% Phenol Formaldehyde (PF) content is used for the PF – rice husk pyramidal microwave absorber. Figure 9 shows the different angles that are used in this parametric study.

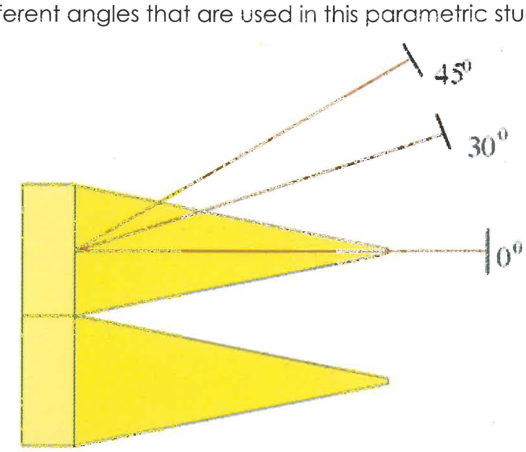


*Figure 9: Angles between the signal source and the surface of the pyramidal microwave absorber.*

## 5. CONCLUSION

Rice husks have been mixed with different percentages of resins to make a rice husk – resin particle board. Urea Formaldehyde (UF) and Phenol Formaldehyde (PF) are investigated as the resins used in the rice husk – resin particle board. A free space measurement technique has been used to derive the dielectric constant of the resin - rice husk particle board. Simulations have been performed using the CST software, where the dielectric constant value of the rice husk – resin mixture has been taken from the free space measurement technique. Various parameters that affect the performance of the pyramidal microwave absorber are described. These are the dielectric constant of the mixed resin – rice husk particle board, the mixed resin percentages, the source - port distance and the angles between the source signal and the surface of the pyramidal microwave absorber. The results indicate that the rice husks have a great potential to be used as the material in a microwave pyramidal absorber.

**Acknowledgement**
This article is a modified version of the original which was published in Progress in Electromagnetic Research (PIER)