Pyramidal Microwave Absorber Design for Anechoic Chamber in the Microwave Frequency Range of 1GHz to 10GHz

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Abstract—The design of microwave absorbers is directly correlated to the general performance of an anechoic chamber for its signal absorptive capabilities. However, the cost of importing the total required microwave absorber for the 5m × 4m × 3m proposed anechoic chamber in the University of Port Harcourt Nigeria is at the tune of twenty-seven thousand dollars. This research is carried out to simulate and fabricate the microwave absorber using polyurethane material and locally obtained carbon in order to reduce cost. The simulation is done using Computer Simulation Technology (CST) software for the desired frequency range of 1GHz to 10GHz. Simulation results proved to have good absorptive performance and reflectivity loss comparable to that of the conventional microwave absorber. The reflectivity performance is below -30dB across the desired frequency range. With the polyurethane material and locally obtained conducting carbon the estimated cost is five thousand five hundred dollars against the twenty-seven thousand dollars importation cost; thereby reducing the cost by more than 60%.

Index Terms—Pyramid Microwave Absorbers, Polyurethane, Carbon, Reflectivity.

I. INTRODUCTION

Electromagnetic equipment needs to undergo a performance test in order to determine its working condition before deployment. As such, a test analyser environment had to be in place and one of these is the introduction of an Anechoic Chamber. An Anechoic Chamber is an enclosed noiseless room, 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. It is covered with a material that is capable of absorbing most of the incident energy so as to enable it to simulate in a perfect free space environment with the absence of signal reflection and scattering [1].

Microwave absorbing materials used in the anechoic chamber are capable of reducing reflections of high-frequency energy. Most of the electromagnetic anechoic chamber manufacturers offer a standard microwave absorber material in the shape of a pyramid. Although there are some other absorber shapes that can be used which are wedge absorbers, ferrite absorbers and convoluted microwave absorbers.

Conventionally there are different materials which can be used in the fabrication of the absorbers; some of which are ferrite tiles (NiZn), polyethylene, polystyrene, polyurethane and many others including biomaterials (agricultural waste). The design of a proper microwave absorber must be developed based on information such as reflectivity and the important factor in determining a microwave absorber material is the high dielectric constant (ε), cost and application [2].

Most electromagnetic anechoic chambers are loaded with a standard microwave absorber product that is pyramidal in shape. The product is a solid carbon-loaded urethane foam absorber and fire-retardant chemicals that are either mixed in with the carbon solution or added as a second treatment. Of all known absorbers, pyramidal absorber provides the highest broadband performance at both normal incidence and at wide incidence angles. It is primarily used for reducing forward scattering, but offers good back scattering properties as well, making it suitable for use in all locations within an anechoic chamber. It is available in a variety of thicknesses. It provides the chamber designers with the opportunity to choose the right product for specific frequencies and incidence angles.

The product is black when made and is usually painted with a blue latex paint to improve light reflectance. At 95 GHz, the paint can degrade absorber reflectivity as much as 5 dB, so the tips are often left unpainted in chambers where millimeter measurements are to be conducted. It also has been found that if the tips are left unpainted, it minimizes tip breakage due to wear and tear found in normal chamber operations. Foam absorber is not very robust and requires a high degree of maintenance.

The modeling of microwave absorber is done with two main parameters which are the permittivity and permeability of the material [3]. The Permittivity of a material is the measure at which the material can be easy or difficult to form an electric field inside the medium and the permeability of a material is the measure at which the material has the ability to form a magnetic field inside the medium [4].

The permittivity of the material is represented by the equation below

\[ \varepsilon = \varepsilon' - j\varepsilon'' \]  \hspace{1cm} (1)

And in free space, it is represented by the value

\[ \varepsilon_0 = 8.854 \times 10^{-12} \text{ farads/meter} \]
The permeability of the material is represented by the equation below

$$\mu = \mu' - j\mu''$$  \hspace{1cm} (2)

And in free space, it is represented by the value

$$\mu_0 = 4\pi \times 10^{-7} \text{henrys/meter}$$

The reflectivity of an absorber material is represented in dB unit.

$$R = 20 \log|\Gamma'|$$  \hspace{1cm} (3)

where $\Gamma'$ is the reflection coefficient which is the ratio of the amplitude of the reflected wave to the amplitude of the incident wave and is represented by the equation below

$$\Gamma' = \frac{\zeta_{i-1}}{\zeta_{i+1}}$$  \hspace{1cm} (4)

II. PYRAMIDAL ABSORBER DESIGN

The design of the microwave pyramidal absorber was done using Computer Simulation Technology (CST) and is based on the concept of TDK ICT 030 [5-7]. The design is in three configurations: using Polyurethane material, Carbon material and Polyurethane with Carbon materials. There are two parts to the design. The upper part which has the pyramidal shape and truncated at the top of the pyramid with the dimension of 250mm (25cm) height and the lower part which has the base of the pyramid absorber with the dimension of 50mm (5cm) height. The dimension of the designed absorber is 300mm x 300mm x 300mm (30cm x 30cm x 30cm).

The lower part of the absorber which is the base has a dimension of 100mm (10cm) length x 100mm (10cm) width x 100mm (10cm) height. The upper part of the absorber has a dimension of 10mm (1cm) length x 10mm (1cm) width x 250mm (25cm) height.

The material used in the design of the absorber is Polyurethane having an epsilon ($\varepsilon$) value of 3.5 with a frequency range of 1GHz to 10GHz. The design has 9 pieces of the pyramid of 10cm x 10cm x 30cm each. Carbon element which is also found in polyurethane foams was used with its epsilon ($\varepsilon$) value at 2.6.

The simulated result of the microwave absorber of Fig. 1 is shown in three different configurations: using Polyurethane material, Carbon material and Polyurethane with Carbon material.

A. Simulated Reflectivity Performance of Polyurethane

The simulated result in Fig. 2 represents the reflectivity performance of the designed Pyramidal Microwave Absorber with Polyurethane material of dielectric constant (epsilon) $\varepsilon\rightharpoonup = 3.5$.

From the graph, the pyramidal microwave absorber produced the best performance at -56.712dB at frequency 6.652GHz. It also shows a good absorber performance at higher frequencies below -30dB from 3GHz frequency.

B. Simulated Reflectivity Performance of Carbon

The simulated result in Fig. 3 represents the reflectivity performance of the designed Pyramidal Microwave Absorber of Fig. 1 with Carbon material of dielectric constant (epsilon) $\varepsilon\rightharpoonup = 2.6$.

From the graph, the pyramidal microwave absorber produced the best performance at -61.944dB at frequency 6.653GHz which is similar to that of Carbon. It also shows a good absorber performance at higher frequencies below -30dB from frequency 3GHz.

C. Simulated Reflectivity Performance of Polyurethane with Carbon

The simulated result in Fig. 4 represents the reflectivity performance of the designed Pyramidal Microwave Absorber in Fig. 1 with Polyurethane material and Carbon element of dielectric constant (epsilon) $\varepsilon\rightharpoonup = 3.5$ and 2.6.

From the graph, the pyramidal microwave absorber produced the best performance at -68.488dB at frequency 7.39GHz which is similar to that of Carbon. It also shows a good absorber performance at higher frequencies below -30dB from 3GHz frequency.

This means that Polyurethane with Carbon would produce a better reflectivity loss compared to that of polyurethane only. The result shows that at almost all frequency especially at high frequency, the reflectivity loss is below -30dB proving a good performance of this absorber using Polyurethane material with Carbon Element. This result also proves to have a good reflectivity performance similar to that of the conventional pyramid absorber.

III. CONCLUSION

In this work, several design factors are seen to influence the reflectivity performance of a microwave absorber. Some of these factors are dielectric constant, the microwave absorber material, the shape and dimension of the microwave absorber. The result shows the reflectivity performance is below -30dB for the frequency range of 1GHz to 10GHz especially at high frequency. The Polyurethane with Carbon material showed to have the best reflectivity performance as proven by this work.
Fig. 2 Simulated Reflectivity Performance of Polyurethane

Fig. 3. Simulated Reflectivity Performance of Carbon

Fig. 4. Simulated Reflectivity Performance of Polyurethane with Carbon

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REFERENCES


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