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Optimization of pyramidal radar absorber for anechoic chamber application

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Abstract. The pyramidal radar absorber is widely used for internal wall of an anechoic chamber. Design pyramidal radar absorber for anechoic chamber application has been done. The purpose of this study is to design and optimize the pyramidal radar absorber design. In this work, the CST Microwave Studio is operated in a simulation of the pyramidal radar absorber. A carbon material with the dielectric constant of 2.9 is implemented in simulated design. The design is investigated in broadband working frequency ranging from 0 GHz to 20 GHz. The best performance of simulation pyramidal radar absorber is obtained with for average reflection loss -45.59 dB, which pyramidal and base height of 132 mm and 20 mm, respectively. Simulation results show the reflection loss and transmission loss are satisfied for a radar absorber.

1. Introduction

Research on radar is requires the support of adequate instruments and facilities. An important facility in radar research is anechoic chamber. Characterization of the antenna and several radar systems should be performed in an anechoic chamber [1-4]. An anechoic chamber is a room designed to completely absorb reflections of the electromagnetic wave. Furthermore, an anechoic chamber is designed to reduce the noise and reflection in performing the measurements of an antennas characteristic or radar component. The scale of an anechoic chamber can be a small compartment such as household microwave ovens, as well as to a large as aircraft hangars. Generally, the anechoic chamber builds up based on radar absorber materials (RAM). Currently, several types of the absorber can be found such as pyramids and a wedge shape. Pyramidal shaped electromagnetic wave absorbers are widely used for internal wall of anechoic chambers. This shape has wide frequency and wide incident angle characteristics to efficiently absorb arbitrary incoming electromagnetic wave from devices under test inside [5].

Nowadays, absorbers were made from ferrite tiles (NiZn), polystyrene, polyethylene and polyurethane which is costly [6]. In order to reduce the cost, several carbon biomass waste materials can be used as absorber material [7-8]. Due to the good characteristics such as low thermal expansion, low densities, electrical and thermal conductivities, as well as adequate corrosion resistance, and low elasticity, carbon is widely used in many applications. Our research group has optimization of the design pyramidal radar absorber.

A material is classified as dielectric if it has the ability to store energy when an external electric field is applied. Epsilon (ε) is the absolute permittivity of the dielectric, which is a measure of the electrostatic energy stored within it and therefore dependent on the material. The dielectric constant is equivalent to relative permittivity (ε_r) or the absolute permittivity (ε) relative to the permittivity of free

space (ε_0). The dielectric constant of a material affects how electromagnetic signals move through the material [9]. The epsilon and reflectivity in dB are defined in equation (1) and equation (2).

$$\varepsilon = \varepsilon_r \varepsilon_0 \qquad (1)$$

$$R = 20\,log|\,\Gamma\,| \qquad (2)$$

The purpose of this work is to present the optimum design of the pyramidal radar absorber for anechoic chamber application. The CST Microwave Studio is operated in simulation of pyramidal radar absorber. A carbon material with the dielectric constant of 2.9 is implemented in simulated design. The design is investigated in broadband working frequency ranging from 0 GHz to 20 GHz. In the next section, the pyramidal absorber design will be discussed. Research result and discussion will be presented in section three. Finally, in the last section, the finding of this work will be concluded.

2. Pyramidal absorber design

Physical or geometrical tapering of the loss material is a type of broadband impedance matching technique to minimize the reflections at the interfaces in the required pass band. In this concept, the absorber is modeled as a single structure composed of an infinite number of thin sheets (impedance transformers). According to transmission line theory, the number of impedance transformers must be infinite to smooth the impedance discontinuities at the interfaces. Adding an infinite number of layers to the absorbing structure improves the impedance matching at the cost of large material thickness in terms of the wavelength to achieve minimum reflections at the air-absorber interface [10].

Another factor that affects the performance of the absorber is the material used and dielectric constant of the radar absorber. The material is understood to be absorbing microwave when the wave propagates through it. Dielectric parameter is very important in order to decide an optimum condition in designing absorber. Magnetic parameters also influence absorption in form of permeability and magnetic loss [11]. The current market microwave absorbers are designed by using plastic foamed based material like polystyrene or polyurethane. In this work, the average dielectric constant for this design is ε_r= 2.9 [12]. The pyramidal radar absorbers are designed using the CST Microwave Studio software. The design and shape of the pyramidal radar absorber are based on the TDK ICT-030 Pyramidal Microwave Absorber [13]. Figure 1 shows the simulation design of the pyramidal radar absorber using the CST Microwave Studio software.
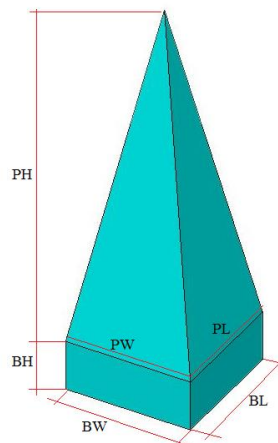

Figure 1. Design of the pyramidal radar absorber

In this work, the modeling and analysis method is implemented. This method is proposed to analyze the relationship between pyramid parameters with the radar absorption. A modeling approach which aims at the simulation optimization so as to meet required design specifications using the CST software. Table 1 shows the dimensions of the pyramidal radar absorber.

Table 1. Dimensions of the proposed radar absorber

| Parameters	Notation	Size (mm)
Pyramid Width	PW	50
Pyramid Length	PL	50
Pyramid Height	PH	132
Base Width	BW	50
Base Length	BL	50
Base Height	BH	20

3. Results and discussion

3.1. The performance of the pyramidal radar absorber with different pyramid height
The requirement for a good performance for a radar absorber is to have reflection loss results better (below) than -10 dB. The different pyramid height of the pyramidal radar absorbers is investigated and the reflection loss (S11) and transmission loss (S21) results are observed. The reflection loss and transmission loss results, for three different pyramid height (128 mm, 130 mm, 132 mm and 143 mm) are shown in Table 2, Figure 2 and Figure 3.

Table 2. Performance of the radar absorber with different pyramid height

Characteristics	Pyramid height			
	PH=128 mm	PH=130 mm	PH=132 mm	PH=134 mm
Average refection loss (dB)	-42.72	-44.97	-45.59	-44.97
Best point for refection loss (dB)	-61.68	-74.05	-90.57	-77.67
Average transmission loss (dB)	-7.26	-7.13	-7.10	-7.16
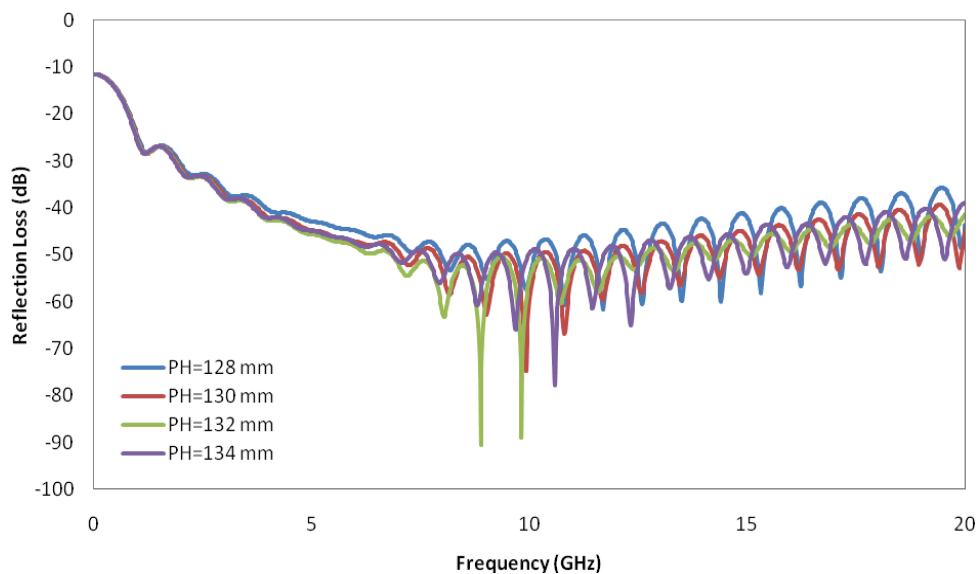
Figure 2. Reflection Loss for several of pyramid height (PH)
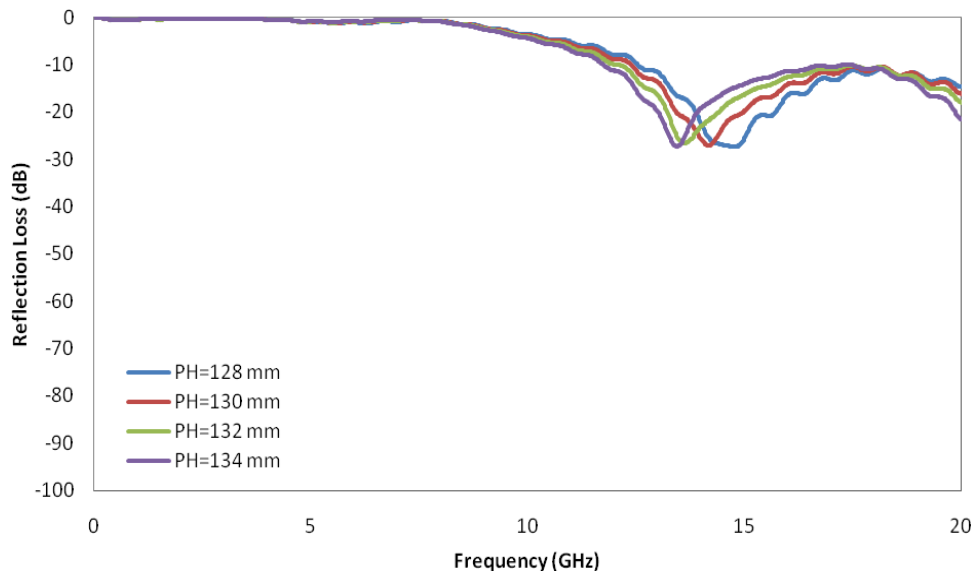
Figure 3. Transmission Loss for several of pyramid height (PH)

For all the frequency range 0 GHz to 20 GHz, the average reflection loss result with a different pyramid height of the pyramidal radar absorber has been done simulated. The best average reflection result occurs at the pyramid height 132 mm, with a value of -45.59 dB. The worst average reflection loss result occurs at the pyramid height 128 mm. The best point of the reflection loss occurs at pyramid height 132 mm in 8.88 GHz, with a value of -90.57 dB. The average transmission loss result of the pyramidal radar absorber is -7.17 dB, for the 0 GHz to 20 GHz frequency range.

3.2. The performance of the pyramidal radar absorber with different base height
The different base height of the pyramidal radar absorbers is investigated. The characteristic of the proposed absorber in term of reflection loss (S11) and transmission loss (S21) are observed. The simulated results for both reflection loss and transmission loss for several base heights (18 mm, 20 mm, 22 mm and 24 mm) are shown in Table 3, Figure 4 and Figure 5.

Table 3. Performance of the radar absorber with different base height

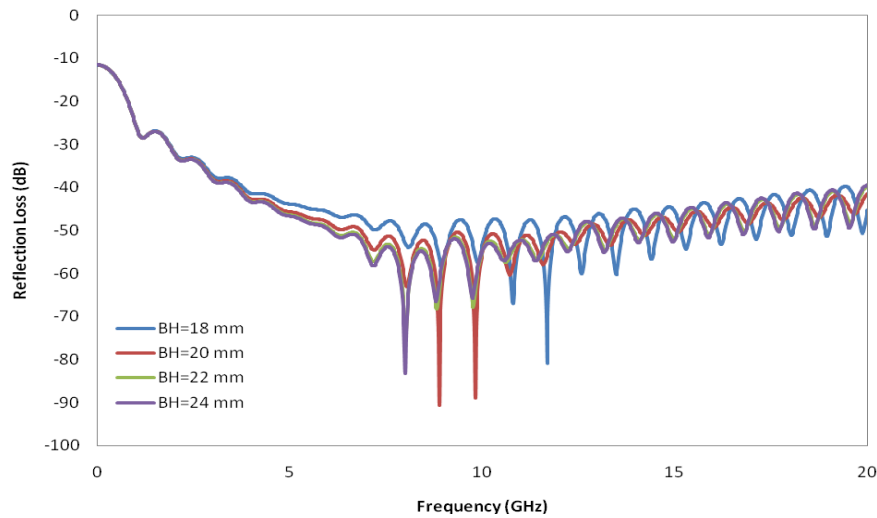| Characteristics	Base height			
	BH=18 mm	BH=20 mm	BH=22 mm	BH=24 mm
Average refection loss (dB)	-44.25	-45.59	-45.98	-46.10
Best point for refection loss (dB)	-80.83	-90.57	-68.28	-83.20
Average transmission loss (dB)	-7.13	-7.10	-7.08	-7.15

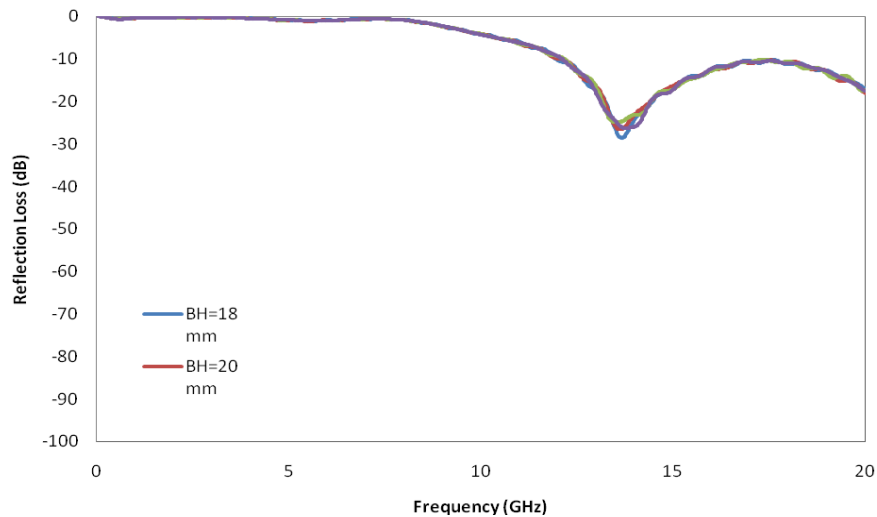**Figure 4.** Reflection Loss for several of bases height (BH)

Figure 5. Transmission Loss for several of bases height (BH)

In investigating the working frequency ranging from 0 GHz to 20 GHz, the reflection loss for several base heights of the pyramidal radar absorber has been simulated. The optimum reflection loss is obtained of -46.10 dB at the height of base 24 mm. On the other hand, the minimum reflection loss is obtained of -44.24 dB for 18 mm of pyramid height. The best point of the reflection loss founded at base height 20 mm in 8.88 GHz, with a value of -90.57 dB. The average transmission loss result of the absorber of -7.12 dB in working frequency 0 GHz to 20 GHz.

4. Conclusion
A simulation work in determining the effect of different pyramidal height and base height has been carried out. From the findings, different pyramidal and base height is produced a variety of reflectivity performance. The best performance of simulation pyramidal radar absorber is pyramidal height 132 mm and base height 20 mm with average reflection loss -45.59 dB.

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