Parametric Study of a Pyramidal Microwave Absorber Design

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1. Introduction

Microwave absorbers are normally made of blocks of wave-absorptive material to avoid the reflection of electromagnetic waves incidental on it. Mainly used in anechoic chambers, it comes in various designs such as pyramidal absorber, twisted pyramidal absorber, hollow pyramidal absorber, wedge absorber, multilayer dielectric absorber, hybrid dielectric absorber, walkway absorber, and convoluted microwave absorber. Nowadays, most of the electromagnetic anechoic chamber manufacturers offer a standard microwave absorber product that is pyramidal in shape [1], which could meet specified industrial standards.

Material that are commonly used for absorber design are for instance, ferrite bless, polystyrene, conducting carbon, and other material with wave-absorption capabilities. Previous investigations related pyramidal microwave absorbers are reported, for example in [2-4]. The parametric analysis of the absorber was done by varying the ground height, ground length, ground width, and also length and width of the pyramid top. A proper model of RF absorber must be developed based on information such as absorber reflectivity, in magnitude and phase, for various angles of incidence, and for parallel and perpendicular polarizations. [5] The reflectivity, R can express the absorbing performance of the material and is a function of the complex permittivity and permeability of the material, and the frequency of the wave. [6] The reflectivity in dB unit is defined as $R = 20 \log |\Gamma|$.

2. Design Absorber

The absorber designed using CST Microwave Studio 2008 software. The design concept for this pyramidal microwave absorber is base on [7, 8]. In this paper, the material of the absorber used is Carbon which its epsilon, ε_r is assumed to be equal to 2.6.The ε_r chosen based on TDK Standard Material Characteristic for ICT absorber types [9]. It used Carbon plus nonflammable material for its TDK ICT-030 Pyramidal Absorber types. The design has ISO 14644-1 Class 5 for Clean Room Rating, also NRL 8093 and UL94HBF standard for fire retardancy [8].

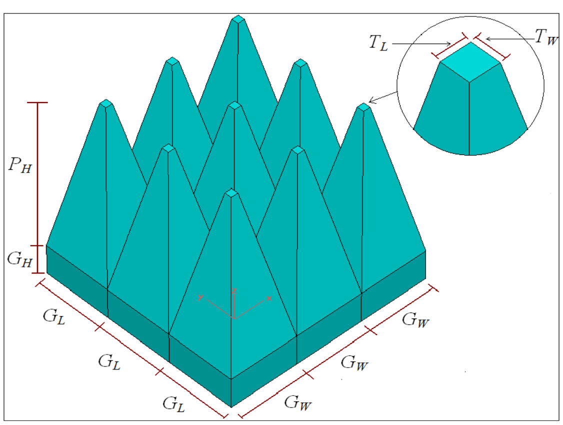

Figure 1: Symbol of the simulated pyramidal microwave absorber

The absorber set contains 9 tips per piece. Each single pyramid contains three major parts, which is ground of the pyramid (G_L, G_W and G_H), top of the pyramid (T_L and T_W), and body of pyramids (P_H) The sample of this pyramidal microwave absorber is shown in Figure 1. The overall dimensions of all microwave pyramidal absorbers are 30.0 cm length x 30.0 cm width x 30.0 cm height. Pyramidal electromagnetic performance is specified as reflectivity at normal incidence and is stated in dB. The frequency range investigated in this work is from 0.01GHz to 10.0 GHz. The pyramidal shaped absorber must be larger compared to a lowest wavelength so that the side to reflect the incident wave and the height of the pyramid must greater than the half wavelength. [10]

Table 1: Dimension of Pyramidal Microwave Absorber

	Symbol	Dimension
Top length	$\boldsymbol{T_L}$	1.0 cm
Top width	$\boldsymbol{T_W}$	1.0 cm
Pyramid height	$\boldsymbol{P_H}$	25.0 cm
Ground height	$\boldsymbol{G_H}$	5.0 cm
Ground length	$\boldsymbol{G_L}$	10.0 cm
Ground width	$\boldsymbol{G_W}$	10.0 cm

3. Result and Discussion

3.1 Pyramids height (P_H) dimension sweep with fixed ground height (G_H)

Figure 2a shows the reflectivity of the pyramidal microwave absorber for 15.0 cm, 25.0 cm, and 35.0 cm of pyramid height (P_H) with fixed ground height (G_H) of 1cm from 0.01 GHz to 10.0 GHz. The graph shows that the reflectivity achieved at least -30 dB starting from the frequency of 1.5 GHz onwards for 25.0 cm of pyramid height (P_H). The graph also show that 25.0 cm pyramid height (P_H) have the best level of reflectivity compare to 15.0 cm and 35.0 cm pyramid height (P_H). It achieved an average reflectivity of -40.0 dB across frequencies from 1.5 GHz to 9.0 GHz. It also achieved the best dip in reflectivity of up to -70dB at 2.7GHz, 4.3GHz and 7.1GHz).

3.2 Top length (T_L) dimension sweep with fixed top width (T_W)

Figure 2b represents the reflectivity of the pyramidal microwave absorber for 1.0 cm, 2.0 cm, and 3.0 cm of top length with fixed top width (T_W) of 1cm from 0.01 GHz to 10.0 GHz. The graph shows that the reflectivity achieved at least -30.0 dB starting from the frequency of 1.5 GHz onwards for 1cm of top length (T_L). However, it can be seen from the simulation that the 1.0 cm top length have the best level of reflectivity across most of the frequency range, as it could achieve reflectivity beyond -50.0 dB at certain frequencies. The graph shows that the reflectivity achieved at least -30.0 dB starting from the frequency of 1.5 GHz onwards for 1cm of top length (T_L).

3.3 Top width (T_W) dimension sweep with fixed top length (T_L)

The next investigation involves the top width (T_W) of pyramidal microwave absorber dimension sweep for a fixed top length, (T_L) of 1.0 cm from 0.01 GHz to 10.0 GHz. Figure 2c show that the reflectivity for 1.0 cm, 2.0 cm and 3.0 cm of top width (T_W) of pyramidal microwave absorber. In the frequency range of 1.0 GHz to 10.0 GHz, the reflectivity of the all sample are achieved at least -25.0 dB. At the range frequency of 2GHz to 4GHz it could achieve reflectivity beyond -65.0 dB.

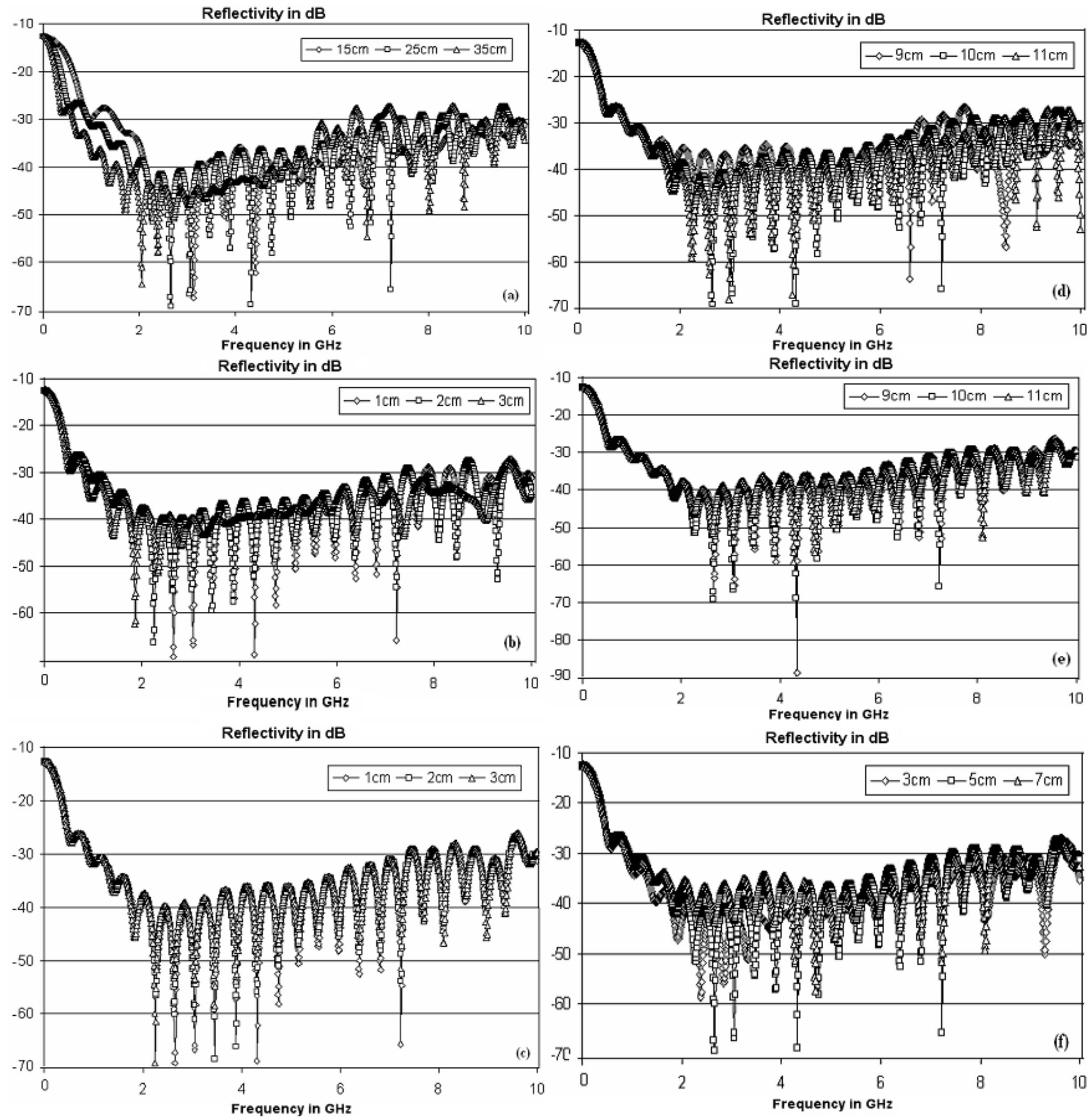

Figure 2: Reflectivity in dB for pyramidal microwave absorber: **(a)** Pyramids height (P_H) dimension sweep with fixed ground height (G_H), **(b)** Top length (T_L) dimension sweep with fixed top width (T_W), **(c)** Top width (T_W) dimension sweep with fixed top length (T_L) **(d)** Ground length (G_L) dimension sweep with fixed ground width (G_W), **(e)** Ground width (G_W) dimension sweep with fixed ground length (G_L), **(f)** Ground height (G_H) dimension sweep with fixed pyramid height (P_H).

3.4 Ground length (G_L) dimension sweep with fixed ground width (G_W)

Shown in Figure 2d is the reflectivity of the pyramidal microwave absorber for 9.0 cm, 10.0 cm and 11.0 cm of ground length (G_L) dimension sweep with fixed ground width (G_W) of 10.0 cm from 0.01 GHz to 10.0 GHz. From the simulation, 10.0 cm and 11.0 cm ground length (G_L) pyramidal microwave absorber have the best level of reflectivity across most of the frequency range, which is simulated from 0.1 GHz to 10 GHz. Not much change in reflectivity has been observed, as all dimension guaranteed a minimum level of -30dB reflectivity between 1.0 GHz to 6.5 GHz. All results also show amazing similarities in terms of reflectivity response in the frequency domain.

3.5 Ground width (G_W) dimension sweep with fixed ground length (G_L)

Figure 2e shows the reflectivity of the pyramidal microwave absorber for 9.0 cm, 10.0 cm and 11.0 cm of ground width with fixed top ground length from 0.01 GHz to 10.0 GHz. All sample of ground length (G_L) pyramidal microwave absorber indicate a similar reflectivity behavior.

3.6 Ground height (G_H) dimension sweep with fixed pyramid height (P_H)

Based on the results in Figure 2f, the 5.0 cm ground height have the best level of reflectivity across most of the frequency range, as it could achieve reflectivity beyond -30.0 dB from 0.5 GHz to 10.0 GHz. This graph show the reflectivity of the pyramidal microwave absorber for 3.0 cm, 5.0 cm and 7.0 cm of ground height (G_H) dimension sweep with fixed pyramid height (P_H) of 25.0 cm from 0.01 GHz to 10.0 GHz.

4. Conclusion

From the simulation, all absorbers designed are functional in the estimated frequency range from 1.5 GHz to 6.5 GHz. It is also found out that parameters such as the top width and length, and the ground width and length, are not sensitive to small scale change of dimension.

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