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# FOREWORD

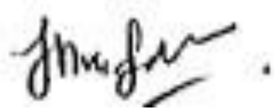
Welcome to the 16th Volume of ESTEEM Academic Journal for December 2020 issue: an online peer-referred academic journal by Universiti Teknologi MARA, Cawangan Pulau Pinang, which focusing on innovation in science and technology that covers areas and disciplines of Engineering, Computer and Information Sciences, Health and Medical Sciences, Cognitive and Behavioral Sciences, Applied Sciences and Application in Mathematics and Statistics.

It is a pleasure to announce that ESTEEM Academic Journal has been successfully indexed in Asean Citation Index and MyCite, a significant move, which will increase the chance for this journal to be indexed in SCOPUS. ESTEEM Academic Journal has also been nominated as one of the top 3 of the best science and technology journals in Universiti Teknologi MARA. Starting year of 2021, the publication issue will be moved to March and August for every year.

In this 2020, the world has been impacted on the Covid-19 issue that has changed our daily life to a new normal. Although Covid-19 issue has still affected the world not only on academician and research area, ESTEEM Academic Journal have received tremendous supports and responses from authors internationally and locally from various backgrounds in science and technology areas. Nine articles from the field of innovation in science and technology are successfully published after undergoing screening and reviewing processes that involved international and local reviewers. It is our aim to ensure that all the published articles are of the highest quality.

It is an honour to have a form of partnership and assistance from panel of international advisors and editors for this issue. Thus, I would like to take this opportunity to thank many people who have worked together for the issue to be released. In particular, my greatest thanks are due to our Rector, Professor Ts. Dr Salmiah Kasalong and the Deputy Rector of Research, Industry, Community and Alumni Network, Associate Professor Chem. Dr. Nor Aziyah binti Bakhari for their unfailing support and advice towards the successful publication of this issue. My deepest gratitude also goes to the editorial team of ESTEEM Academic Journal December 2020; Dr Syarifah Adilah, Dr Ainorkhilah, Puan Suzana, Dr Mah Boon Yih, Pn Isma Noornisa, Dr Salina and Dr Vicinisvarri Inderan for their support, commitment and expertise in making this issue published on time.

My greatest appreciation also goes to the panel of reviewers for their persevering and attentive efforts in reviewing the articles voluntarily by giving constructive and invaluable comments to ensure the quality of the articles. Finally, my gratitude goes out to the authors who have submitted articles to ESTEEM Academic Journal, for their trust in us in publishing their research works. Last but not least, as this year is ending, may the New Year bring tremendous joy and success for all of us. Happy New Year 2021! Dr.



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# CONTENT OF JOURNAL



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# Absorption Study of Triangular and Rectangular Slotted on Hollow Pyramidal Absorber

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**ABSTRACT**

*Today, electromagnetic wave theory is commonly used in many engineering devices. However, such devices produce electromagnetic (EM) radiation, damaging people's health and the impact of other electronic device's operation. Therefore, Microwave Absorber has been widely used in anechoic chamber to measure equipment radiation and prevent unwanted radiation and electromagnetic interference. This research investigates the absorption performance of pyramidal absorbers with a slotted method design. This research used rectangular and triangular slotted on the hollow pyramidal absorber. There are six types of slotted: Design 1, Design 2, and Design 3 which have triangular shapes, and Design 4, Design 5, and Design 6, have rectangular shapes. The pyramidal absorber is produced using CST Microwave Studio Suite. Afterward, the fabrication process is performed using cardboard and coated with Powdered Activated Carbon (PAC). Measurement had been done successfully via far-field measurement using an arch method at 1 GHz to 12 GHz. The slotted pyramidal absorber's absorptivity was taken in each frequency band and was tabulated in figure 10. The result is compared with their maximum absorption in each of the four frequency bands. Comparison based on slot design, triangular and rectangular each had its own advantages at a certain frequency. However, small rectangular slot of Design 1 shows consistent absorption performance at all frequency band.*

**Keywords:** *microwave absorbers; hollow pyramidal absorber; slotted; absorption performance.*

## 1. INTRODUCTION

In recent years, the development of electronic devices is rapidly growing, and that was used in the entire world, but electronic devices generate electromagnetic wave (EM) radiation that can affect people's health and cause interference in normal operation of other electronic devices. Hence, the researchers performed an analysis in the field of microwave absorption to reduce the risk of EM radiation. Theoretically, microwave absorbers are used in many applications and eliminate the unwanted radiation that could interfere with equipment system operation such as Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) test in antenna measurement setup [1].

The standard properties to develop microwave absorber must contain the magnitude, phase for various angles and perpendicular polarization, and absorption reflection loss [2]. There are many forms in designing absorber such as pyramidal absorber, wedges absorber, truncated pyramidal, convoluted, hybrid absorber, flat absorber, honeycomb, oblique absorber,

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metamaterial absorber and other. However, in the commercial or market are mostly using pyramidal and wedges microwave absorber [3]. Figure 1 shows the types of microwave absorbers with different forms.

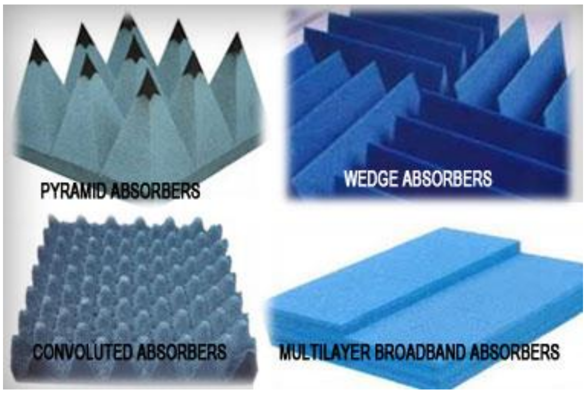


Figure 1: Types of microwave absorbers.

A considerable amount of literature has been published on microwave absorbers. These studies can investigate the absorber's behaviour by changing their shape and material. The previous research shows the pyramidal shape is most absorptive than any other shape because the pyramid height is approximately equal to λ / 4, where λ is the free space wavelength, and the incident wave is at normal incidence to the internal chamber surface [3]. The cone must be of sufficient size to absorb the wavelength for a different wavelength [3].

Radiation absorbing material (RAM) is significant to control the absorptivity of the absorber. The common material as a RAM was used in the absorber is ferrite and plastic-based [6,7]. However, this material is from a chemical composition that is not environmentally friendly and expensive. Therefore, the development of biomass absorbers like carbon, bamboo, clay, and cardboard is an alternative way to create economic and environment friendly absorbers. In the current study, biomass absorber is made from rice husk, dried banana leaf, rubberwood sawdust, and coconut shell as the primary material are friendly environment [8,9]. One of the biomass materials was suggested by the researcher in their studies is coconut shell carbon because that material has good absorbing properties [8]. Dielectric properties of rice husk are measured early to find out the dielectric constant. The performance of microwave absorber relies on the dielectric properties of the material, which is capable of penetrating, reflect, and absorb electromagnetic radiation. The dielectric constant is the ratio between the permittivity of the medium to the permittivity of the free space. Equation (1) shows the equation of the dielectric constant of the material.

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_o} \tag{1}$$

One of the antenna design is a slotted array which is used to enhance the performance of the antenna. The geometry and arrangement of a slotted array are designed based on frequency used and wavelength. The basics of antenna design are used to create a new slotted array method on absorber [9]. The study about the slotted array method on absorber has been done by a researcher that makes the slot on pyramidal absorber [11,13]. There are different absorptivity

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performance on absorber when slotted array and non-slotted is used [10]. Slot triangles were formed using the Sierpinski principle used by previous researchers [11]. Figure 2 shows some of the Sierpinski triangle forms [11]. The rectangular slot is designed by using the formula length (L) = λ / 2, and their height must be lower than lambda (λ). Figure 3 shows the dimension of the single rectangular slot design [9].

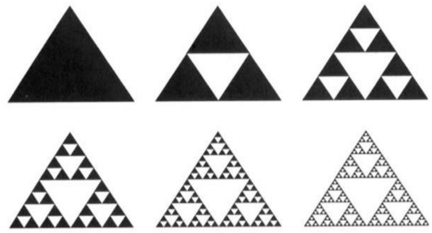

Figure 2: Sierpinski triangle form.

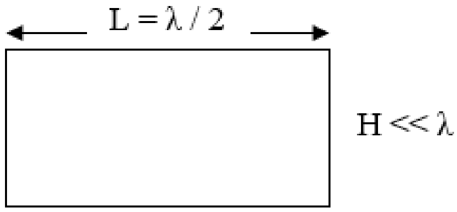


Figure 3: Rectangular single slot dimension.

Frequency selective surfaces (FSS) have numerous applications in several microwave and optical systems. Most frequency selective surface structures have one or more dielectric substrates [12]. By using ferrite materials, one can change the spectral properties of these structures without physically altering them. An applied magnetic field (dc bias) on the ferrite substrate changes its properties and hence the electrical dimensions of the elements comprising the periodic structure. Thus, by simply applying a dc bias, the transmission and reflection properties of the periodic structure can be changed. This leads to a tuning mechanism that allows the designer, by varying the externally applied dc magnetic field, to obtain a more desirable frequency response. The FSS is designed to reflect and absorb the incident wave [13].

In this work, we analyze and characterize the slotted array on a hollow microwave absorber. The cardboard is used as a hollow pyramidal absorber, and it was coated with carbon to enhance the absorptivity. Carbon is the semiconductor element and has a high resistance which is convenient as an absorbing material [14]. Semiconductor element has a good dielectric property, which is capable of penetrating, reflecting and absorbing electromagnetic radiation. There two methods are slotted on the absorber, which is rectangular and triangular-shaped. The measurement method to measure the absorptivity is an arch method, and it is commonly used by most researchers. The comparison of these slots was shown on the result and analyzed by their absorptivity performance.

## 2. METHODOLOGY

The design and simulation process were conducted through the software Computer Simulation Technique (CST). The software was used to ensure that the absorber achieved the desired performance. In addition, the performance of the slotted pyramidal absorber can be analyzed in the CST software simulation result. After the simulation part has been done, absorber manufacture can already be made with the slotted method on the hollow pyramidal absorber. This project used cardboard as a pyramid hollow to perform the light pyramidal absorber. Then, a slotted design on the absorber was cut using a cardboard cutter. Powdered Activated Carbon (PAC) was coated on the pyramid absorber. Finally, the measuring process was carried out using the arch method and the frequency range of tests 1 – 12 GHz. Figure 4 shows the flowchart of this research project.

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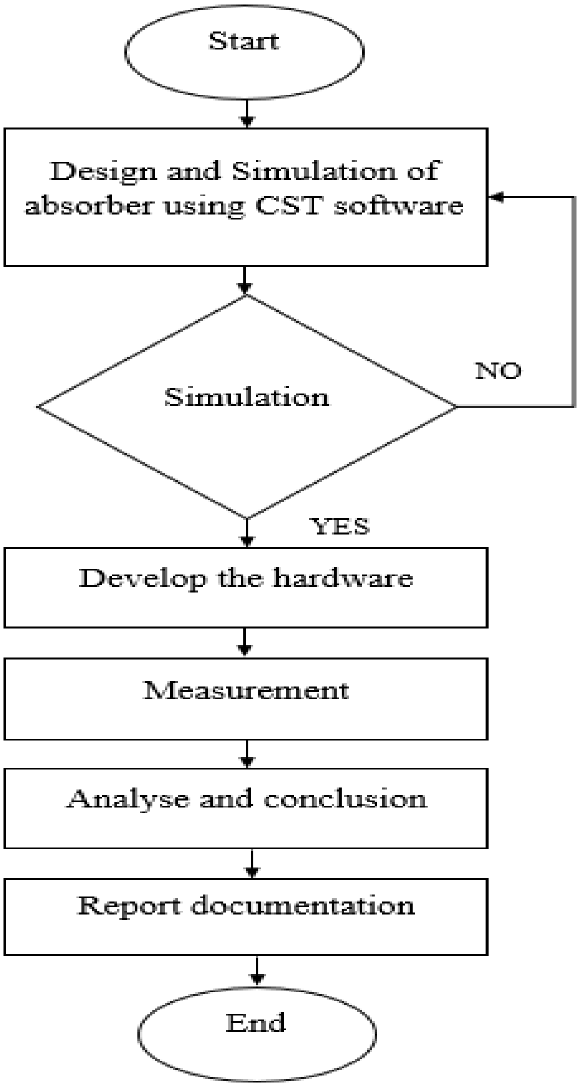


Figure 4: Flowchart of methodology

## *2.1 Absorber Design*

The unit structure of the pyramidal absorber is considered in this study. The pyramidal shape has an advantage in the electromagnetic cross-section due to the propagation of electromagnetic waves [10]. Furthermore, the hollow pyramidal absorber is lightweight and facilitates the installation process in anechoic chamber [15]. In designing an absorber, the pyramidal-shaped absorber must be larger than the longest wavelength in order to reflect the incident wave, and the height of the pyramid must be greater than the half-wavelength [16]. There are six designs of the absorber in this research, and there are two types of slotted design, which are a triangular and rectangular slot. The initial designs, Design 1, 2, and 3 are triangular slotted designs with different sizes and arrangements of slots. Next, Design 4, 5, and 6 which are rectangular slotted, also with different sizes and arrangement slots. Figures 5 and 6 showed the slotted pyramidal absorber design dimension. The selection size of hollow pyramidal absorber based on the commercial design by TDK Corporation, which is IS-030A2 model [17]. This commercial model pyramidal absorber required nine pyramids per absorber, as shown in Figure 7.

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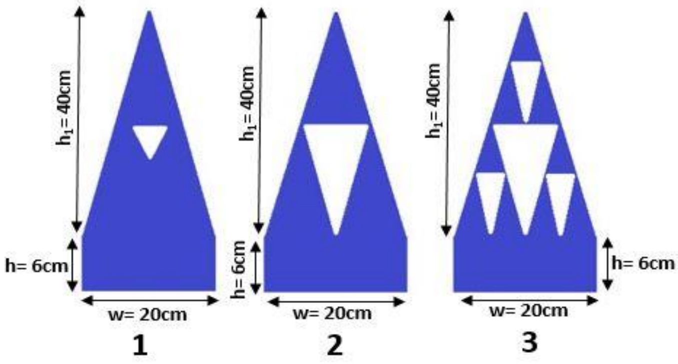


Figure 5: Design 1, 2, and 3 of triangular slotted.

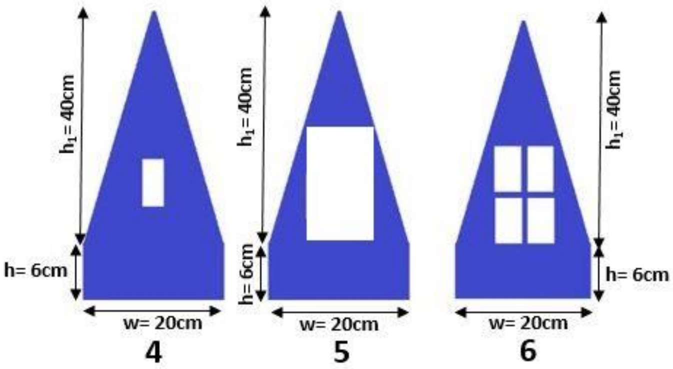


Figure 6: Design 4, 5, and 6 of rectangular slotted.

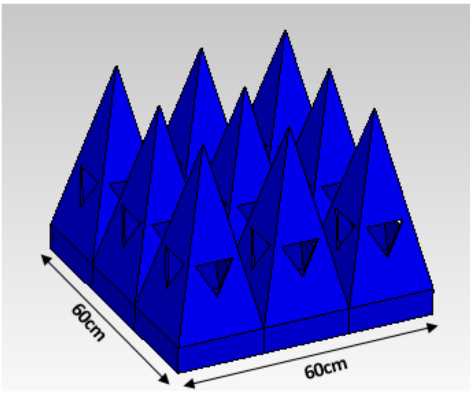


Figure 7: A set of the pyramidal absorber.

Figure 5 showed the inverted triangular slotted on the hollow pyramidal absorber, namely Design 1, 2, and 3. These designs have a different size and arrangement of slots. Design 1 is a single inverted triangular slot with a small size, and Design 2 is also a single inverted triangular slot but with a bigger size than Design 1. Design 3 has a combination size and different arrangement of inverted triangular slotted. The pattern of inverted triangular slotted was designed by referring to the Sierpinski triangle. Figure 6 shows the rectangular slot absorber

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with three different designs. Design 4 has a single slot with a small area of rectangular, and Design 5 has a bigger area than Design 4. Multiple rectangular slotted is shown in Design 6 with four multiple slots. Rectangular design on pyramidal absorber based on basic slotted antenna design.

### *2.2 Material of the absorber*

The current construction of commercial microwave absorber is using chemical materials such as polyurethane and polystyrene [7]. In this project, we are constructing the pyramidal absorber with cardboard and coated by Powdered Activated Carbon (PAC). These materials are economical and eco-green. Carbon has a lightweight property, which is why it is used as an EM absorbent material [14].

### *2.3 Far-field measurement*

The measurement setup is as shown in Figure 8. According to the literature review, some of the researchers used the arch measurement method to investigate the absorptivity of pyramidal absorbers [10,19,20]. Two antennas were placed at the arch and the pyramidal absorbers are placed under the antenna. One of the two horn antennas acts as a transmitter, and the other one is a receiver. The transmitter antenna transmitted microwave energy and reached the absorber. The microwave energy was partially absorbed, and the rest was reflected in the receiver antenna. Both antennas were connected with Vector Network Analysis (VNA) to measure the S12 parameter, which is the reflected microwave energy. A metal plate was placed under a pyramidal absorber to ensure the accuracy of the measurement result. The distance from the absorber to an antenna is a far-field region and must be much greater than the size of the antenna and the wavelength. The far-field region is represented by the following Equation (2):

$$Far\ Field\ Region\ (R) > \frac{2D^2}{\lambda} \tag{2}$$

Where $D$ = Maximum linear dimension of the antenna

$\lambda$ = wavelength of the wave

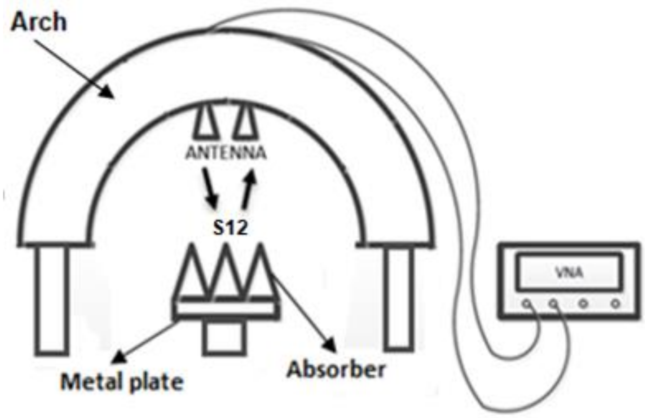


Figure 8: Arch measurement method setup

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## 3. RESULT AND DISCUSSION

This section discusses the results of absorption performance between rectangular and triangular slotted absorbers by using the arch measurement method. The absorber is studied for the absorption performance tested at a range of a frequency 1 - 12GHz. The measurement result with the comparison of all slotted designs is given in Figure 9. Based on the measurement spectrum, four frequency bands were observed at 1 – 2 GHz (L), 2 – 4 GHz (S), 4 – 8 GHz (C), and 8 -12 GHz (X), as shown in Figure 10.

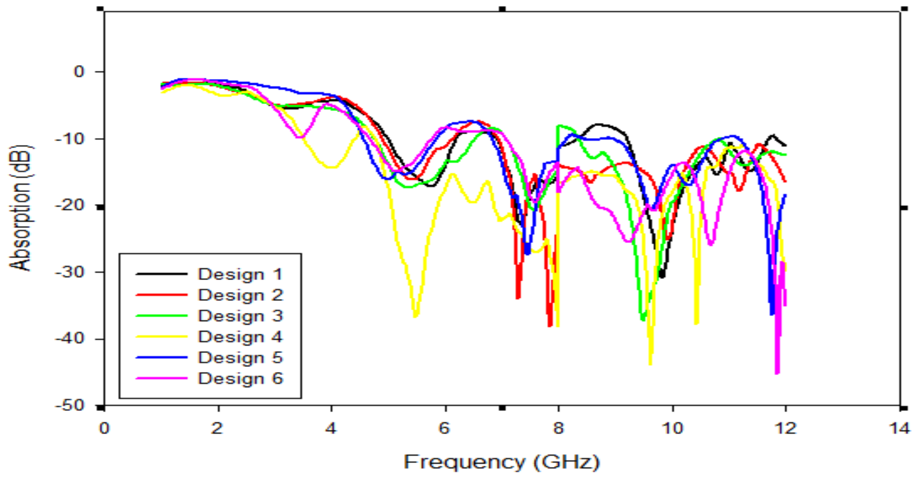


Figure 9: Absorption performance comparison for all slotted design.

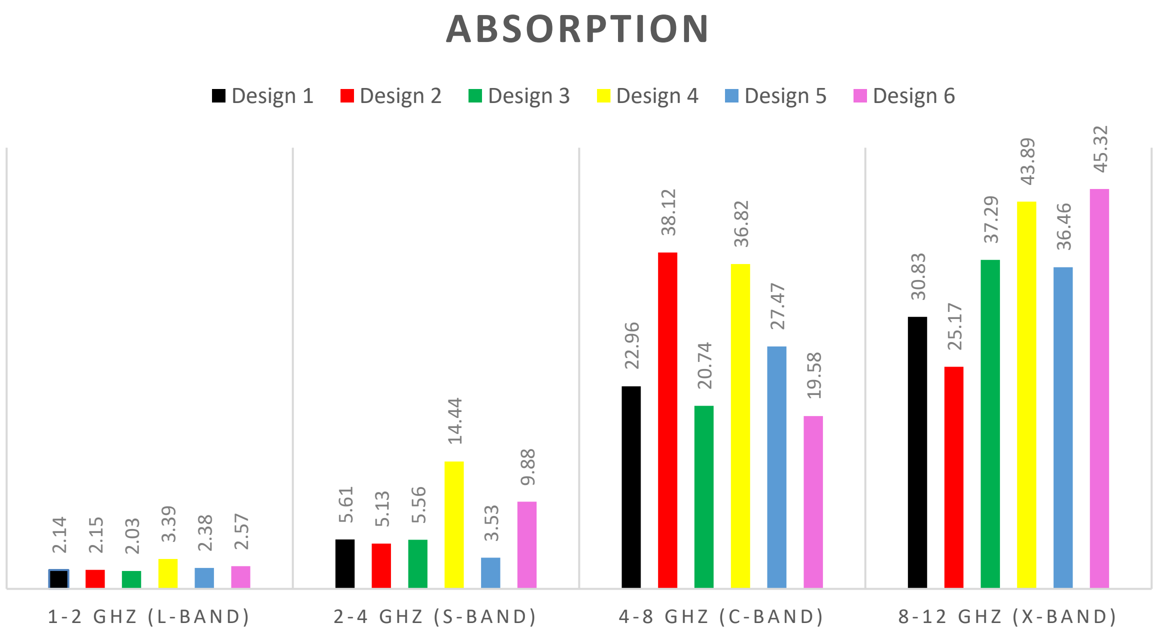


Figure 10: Absorption performance data

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### *3.1 Size of the slot (Design 1, 2, 4, and 5)*

The absorption performance results of Design 1, 2, 4, and 5 with different sizes of the slot are given in Figure 10. Design 1, with the smallest triangular slot size compared to Design 2, shows good absorption performance at C-band frequency. Design 2 is a larger size triangular slot than Design 1 and has a high absorption rate at the X-band frequency. Both Design 1 and 2 have a slightly different absorption performance at the rest frequency band. Comparing the size of the rectangular slot for Design 4 and 5 reveals that the improved absorption efficiency of the small rectangular slot Design 4 is higher than the wide rectangular slot Design 5 at all frequency bands. Through the data analysis between the size of the slot, the result shows hollow pyramidal absorber with small slot size has a high absorption performance at high frequency band, which is X-band frequency. The slot size formed on the basis of wavelength affects the absorption efficiency of the hollow pyramidal absorber.

### *3.2 Single slot and slot array (Design 3 and 6)*

The slot array on the pyramid microwave absorber influences absorption performance at a certain frequency. As we can see in Figure 10, Design 3 and 4 that represent triangular and rectangular slot array is more efficient in high frequency, which is 8 – 12 GHz compared to their single slot. The triangular slot array on the L-band, S-band, and C-bands is inefficient because its absorption efficiency is lower compared to the single triangular slot, same as the rectangular slot of Design 6. The slot arrays are often used by antennas to improve efficiency. Therefore, the implementation of the slot array on the pyramidal microwave absorber can enhance their absorption performance.

### *3.3 Triangular and Rectangular shape of the slot*

Through the analysis of data between the shape of small triangular of Design 1 and rectangular slot of Design 4, the results show that Design 4 obtained higher absorption performance than Design 1 at all frequency bands due to the incidence wave passes through the different slot wavelength.  The shape of large triangular of Design 2 and Design 5 have been compared and analyzed for their significant absorption performance. The results indicated that the absorption performance obtained by Design 2 has a higher absorption performance than Design 5 at S-band and C-band, while Design 5 has better absorption performance than Design 2 at L-band and X-band frequency. Thus, both designs show good performance at certain frequency bands. Based on the analysis of slot arrays, rectangular slot array Design 6 has better absorption performance than triangular slot array Design 3 at L-band, S-band, and X-band frequency. At the C-band frequency, both designs have a slightly different absorption performance. This study indicated that the size, array, and shape of the slot have the potential to improve the absorption performance at the desired frequency band.

## 4. CONCLUSION

In conclusion, there are different absorption performance of rectangular and triangular slotted pyramidal absorber. The size of a triangular slot has a significant effect on absorption performance at high frequency C-band and X-band. The rectangular slot is appropriate with a small size because it has better absorption performance compared to the bigger size. A slot array on a pyramidal absorber has the potential to improve the absorption performance, especially at X-band frequency. The triangular and rectangular shapes formed as a slot on the pyramidal

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absorber will greatly boost absorption efficiency at certain frequencies. Further studies on slot array, slot size, and slot shape are required to enhance the microwave absorber absorption performance.

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