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The Impact Study of Anti-Radiation Biomass Material on Partition Wall Absorption Performance

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ABSTRACT

With the increasing public concern over radiation exposure and its potential health risks, exploring practical solutions for mitigating radiation in various environments is essential. This study aims to raise awareness about radiation-related issues by investigating the impact of anti-radiation biomass material on the reflectivity performance of partition walls. By incorporating this biomaterial into partition walls, we examine how radiation absorption capabilities can be improved, enhancing overall radiation safety. The process entails combining the biomass material, Palm Oil Fuel Ash (POFA), cement, aluminum, and water in the proper ratios to create a composite material. The combined material is subsequently shaped into partition walls. The anti-radiation biomass partition wall's reflectivity performance was measured using the Naval Research Laboratory (NRL) Arch free space method, with frequencies between 1 GHz and 12 GHz utilised in this project. The study showed that the anti-radiation biomass partition wall containing 35% POFA demonstrated the best reflectivity performance.

Keywords: microwave absorber; palm oil fuel ash (POFA); reflectivity performance; partition wall.

1. INTRODUCTION

Nowadays, wireless communication technology significantly impacts the global economy, research, medical, social, and military sectors, where it has seen international expansions that are highly classified and opportunities that go beyond current technology [1]. As a result, new technology may contribute more to radiation production among users. The materials that attenuate the energy in an electromagnetic (EM) wave, such as radio frequency (RF) or microwave, are referred to as absorbers, used in various applications to destroy stray or unwanted radiation that could disrupt a system’s operation [2]. In general, many microwave absorbers have been broadly used in all countries for various purposes that match their suitability, including military, anechoic chambers, and building rooms [1].

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Installing a microwave absorber in the area where people spend the majority of their daily time—which is in buildings—can significantly minimise the amount of radiation exposure to human skin. The primary goal of this work is to develop an effective method—a microwave absorber—to absorb electromagnetic radiation. The microwave absorber will take the shape of mixed biomass material partition walls. The proposed partition wall size refers to the standard dimensions of modern partition walls available in the commercial market. Depending on the application, the applicable building codes, and design factors, the commercial thickness for partition walls may vary. Biomass materials such as Palm Oil Fuel Ash (POFA) are used in the creation of these partition walls mixed with cement, water, and aluminium at different ratios. The foremost issue of the research on electromagnetic wave fields (EMF) is health concerns. The high-frequency band of electromagnetic waves can raise the human body's temperature by 1 to 5 degrees Celsius [3]. Aside from that, the primary target organ for RF emissions is the brain, and epidemiological studies have shown an increased risk of brain and head tumors such as acoustic neuroma and glioma [4]. As a result, decreasing EM radiation is critical.

Biomass materials are gaining interest as an economical and environmentally friendly alternative to traditional microwave absorbers. Biomass materials refer to plant-based organic substances, including wood, straw, and grass. The waste from these materials had been trucked out and deposited or burned on the field, resulting in ash containing carbon [5]. Carbon is the most crucial ingredient when it comes to microwave absorption. As a semiconductor, carbon permits minimal current or charge to pass through it. This quality offers carbon an excellent absorption capacity, making it a desirable material for constructing absorbers. Certain biomass waste materials can be used as microwave absorbers because of their capacity to absorb and dissipate electromagnetic radiation in the microwave frequency range. These materials exhibit properties that make them suitable for applications such as microwave absorption coatings, electromagnetic shielding, and radar-absorbing materials.

Biomass material, such as POFA, is a byproduct produced when palm oil biomass burns in power plants. Recent research shows that POFA could absorb microwave radiation. The primary component of POFA is ash containing silicon dioxide (SiO2). A small volume of residual fat from the oil palm shell is one of the other components of POFA, along with aluminium oxide (AI2O3), iron III oxide (Fe2O3), calcium oxide (CaO), magnesium oxide (MgO), sodium oxide (Na2O), potassium oxide (K2O), and sulfur trioxide (SO3) [6-9]. The potential applications for POFA include construction materials [6–14], soil conditioners, renewable energy sources, and microwave absorbers [15–16]. POFA absorbs microwave radiation due to its high silica and alumina contents, which possess high dielectric constants and loss tangents [16]. The dielectric constant measures a material's ability to absorb electromagnetic radiation, whereas the loss factor measures its ability to dissipate it as heat. The loss factor-to-dielectric constant ratio strongly affects material heating. High-loss factor materials heat quickly in microwaves. [17].

2. METHODOLOGY

2.1 Development Process of Partition Walls

The proposed partition wall size, depicted in Figure 1, was created using the CST Studio Suite Software. The dimensions of the anti-radiation partition walls are 60 cm x 60 cm x 6 cm (length

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x width x height) - the measurements of the commercial partition wall used to create the partition walls.

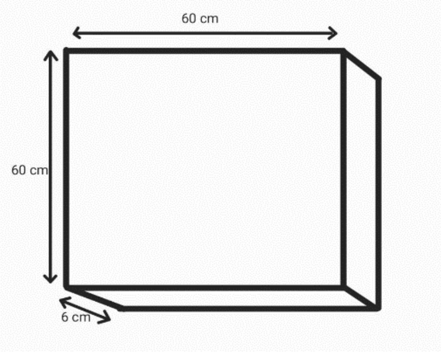

Figure 1: Measurement of Partition Wall

The fabrication process starts with raw material preparation, as shown in Figure 2. The mixed proportion of the partition wall is divided into three different percentages of POFA (25%, 35%, and 45%). Aluminium powder serves as the aerating agent, facilitating the liberation of hydrogen gas when it reacts with the calcium of the cement [18]. In the context of the partition wall, cement acts as the primary binding material that holds the other components together. The proportion for each prototype of the partition wall was prepared and shown in Table 1.

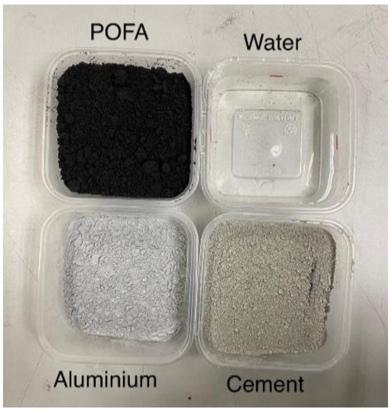

Figure 2: Biomass Material of Partition Wall

Table 1: Raw Material Proportion

Prototype	POFA (%)	Cement (%)	Aluminium (%)
A	25	75	0.5
B	35	65	0.5
C	45	55	0.5
D	25	75	3.0
E	35	65	3.0
F	45	55	3.0

Next, the biomass material is mixed and blended with other components, such as cement, aluminum, and water, in the appropriate ratios. The mixed material will be transferred into the

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desired mould with 60 cm width x 60 cm length x 6 cm thickness, as shown in Figure 3. Lastly, the moulded partition wall must undergo a curing and drying process for a few days to achieve the desired strength and stability of the wall structure before being tested under the Naval Research Laboratory (NRL) Arch.

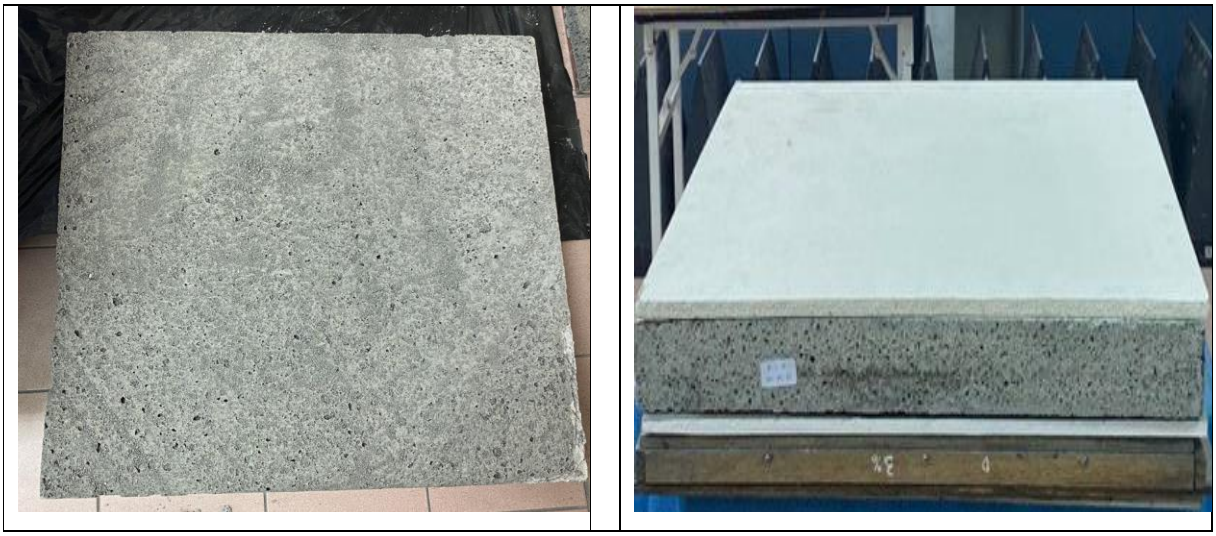

Figure 3: The Final Prototype of The Fabricated Partition Wall

2.2 Performance Analysis using NRL Arch Free Space Method

NRL Arch's free space method is to measure the performance of the microwave absorbers. NRL-free space is a standard method widely adopted across most industries to test the efficiency of anti-microwave materials and the reflectivity of microwave absorbers. This method has a simple measurement procedure: the microwave absorbers are placed on a table set in the arch centre, and the reflected signal is measured. NRL Arch consists of two horn antennas transmitting and receiving antennas on a semi-circular shape facing a metal plate. Both antennas are at a constant distance from the material under test. The transmit antenna connects to the signal generator.

In contrast, the receive antenna connects to the signal detector to measure the excess microwave energy after the reflection. Figure 4 shows the setup of the NRL Arch free space measurement method.

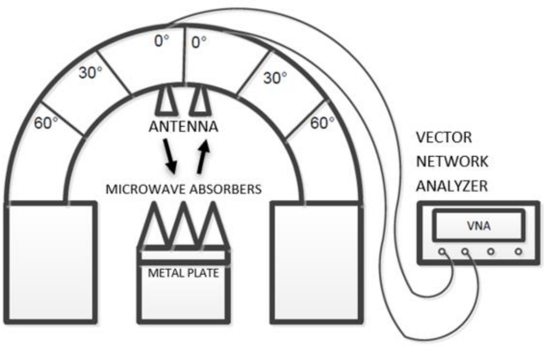

Figure 4: NRL Arch Free Space Setup [19]

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3. RESULTS AND DISCUSSION

The reflectivity performance of the anti-radiation biomass partition wall was measured for different percentages of POFA and Aluminium using the NRL Arch's free space method. Figure 5 shows the reflectivity performance of anti-radiation biomass partition wall containing POFA of 25%, 35%, and 45%, namely as prototypes A, B, and C mixed with 0.5% Aluminium (AL) from 1 to 12 GHz and Figure 6 shows the reflectivity performance by fraction four frequency bands; L-band (1-2 GHz), S-band (2-4 GHz), C-band (4-8 GHz), and X-band (8-12 GHz).

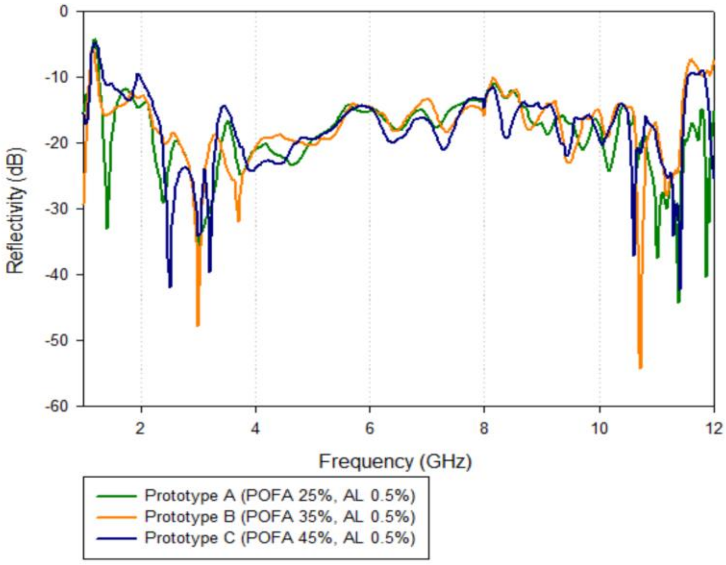

Figure 5: Reflectivity Performance of Anti-Radiation Biomass Partition Wall Prototypes A, B, and C.

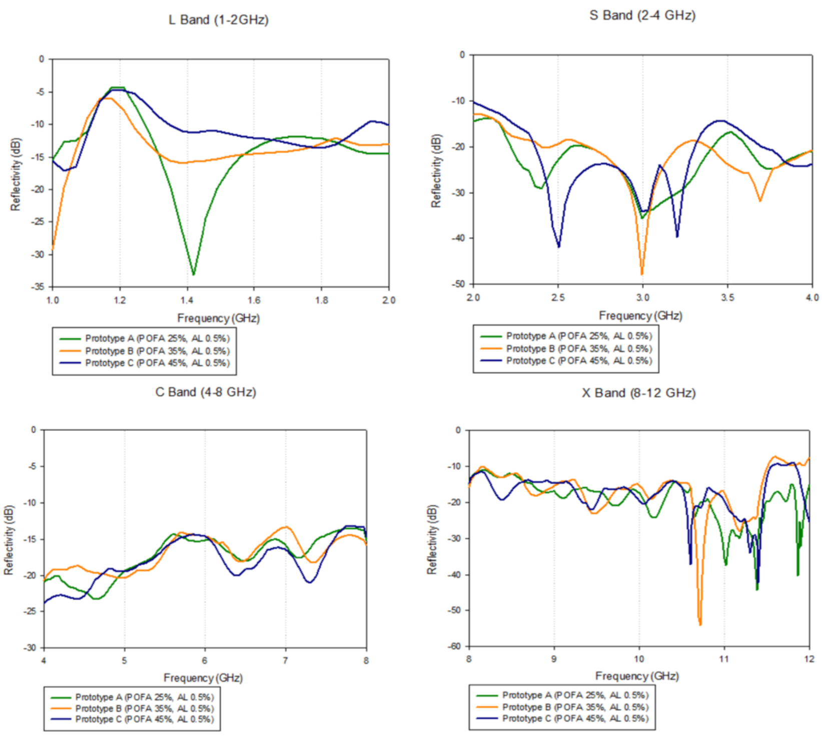

Figure 6: Reflectivity Performance Prototype A, B, and C in L Band, S Band, C Band, and X Band.

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The data analysis is in Table 2 from the graph obtained. The reflectivity performance of the anti-radiation biomass partition wall is also shown in the bar graph in Figure 7 and Figure 8.

Table 2: Maximum Reflectivity Performance Data of Prototypes A, B, and C.

Frequency	Reflectivity (dB)					
	Prototype A		Prototype B		Prototype C	
	Min	Max	Min	Max	Min	Max
L Band (1-2 GHz)	-4.2397	-33.0803	-5.9807	-29.2159	-4.7482	-17.1610
S Band (2-4 GHz)	-13.7887	-35.7194	-12.9078	-47.8784	-10.4291	-41.8976
C Band (4-8 GHz)	-13.5262	-23.3037	-13.3543	-20.5041	-13.1609	-23.7203
X Band (8-12 GHz)	-10.9514	-44.2286	-7.2479	-54.2510	-8.9218	-42.3019

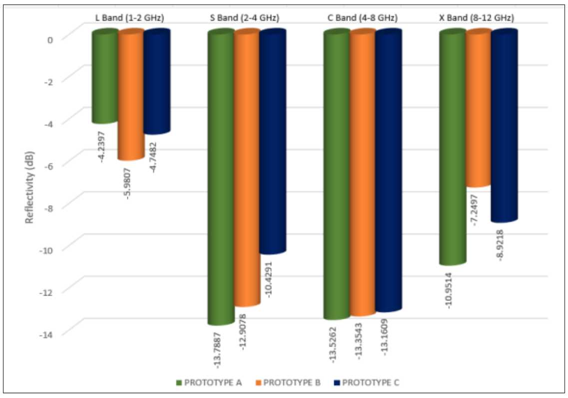

Figure 7: Bar Graph of Minimum Reflectivity Performance Data Prototype A, B and C.

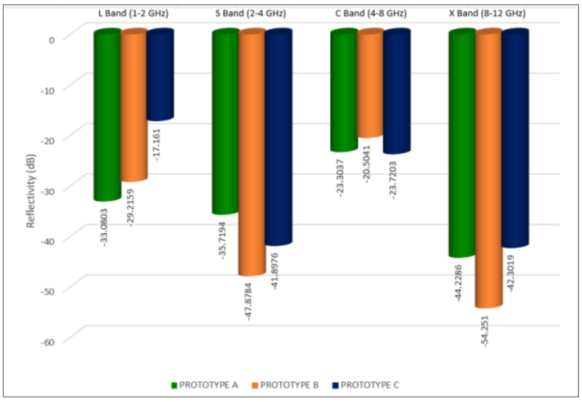

Figure 8 Bar:Graph of Maximum Reflectivity Performance Data Prototype A, B and C.

In general, efficient absorption occurs when the reflectivity is less than -15 dB. All prototypes (A, B and C) can act as microwave absorbers because the reflectivity value is more than -15 dB in the frequency range between 2 GHz to 12 GHz, as shown in Figure 5 and Figure 6. However, prototype B (POFA 35%, AL 0.5%) is the best prototype compared to prototype A and prototype C since the reflectivity of prototype B is nearly -15 dB.

It can be seen from Figure 7 that the minimum reflectivity -5.0897 dB is at L Band from prototype B (POFA 35%, AL 0.5%). Next, for S-band, C-band, and X-band, the minimum reflectivity is -13.7887 dB, -13.5262 dB, and -10.9514 dB from prototype A (POFA 25%, AL 0.5%). For Figure 8, prototype A (POFA 25%, AL 0.5%) performs best for the L-band, with a reflectivity of -33.0803 dB, and prototype C (POFA 45%, AL 0.5%) serves best with a reflectivity of -23.7203 dB. Lastly, S-band and X-band prototype B (POFA 35%, AL 0.5%) have the best performance with reflectivity of -47.8784 dB and -54.251 dB.

Figure 9 shows the reflectivity performance of anti-radiation biomass partition wall containing POFA of 25%, 35%, and 45%, namely as prototypes D, E, and F mixed with 3.0% Aluminium (AL) from 1 to 12 GHz and Figure 8 shows the reflectivity performance by fraction four frequency bands; L-band (1-2 GHz), S-band (2-4 GHz), C-band (4-8 GHz), and X-band (8-12 GHz).

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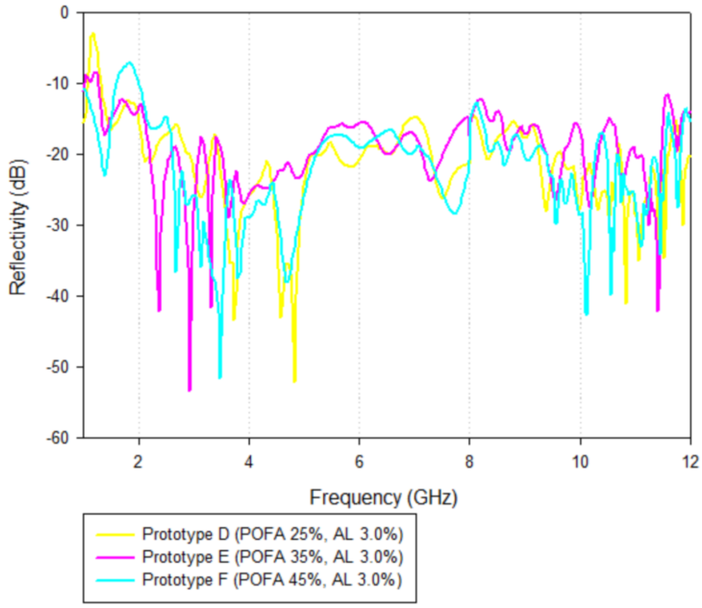

Figure 9: Reflectivity Performance of Anti-Radiation Biomass Partition Wall Prototype D, E, and F.

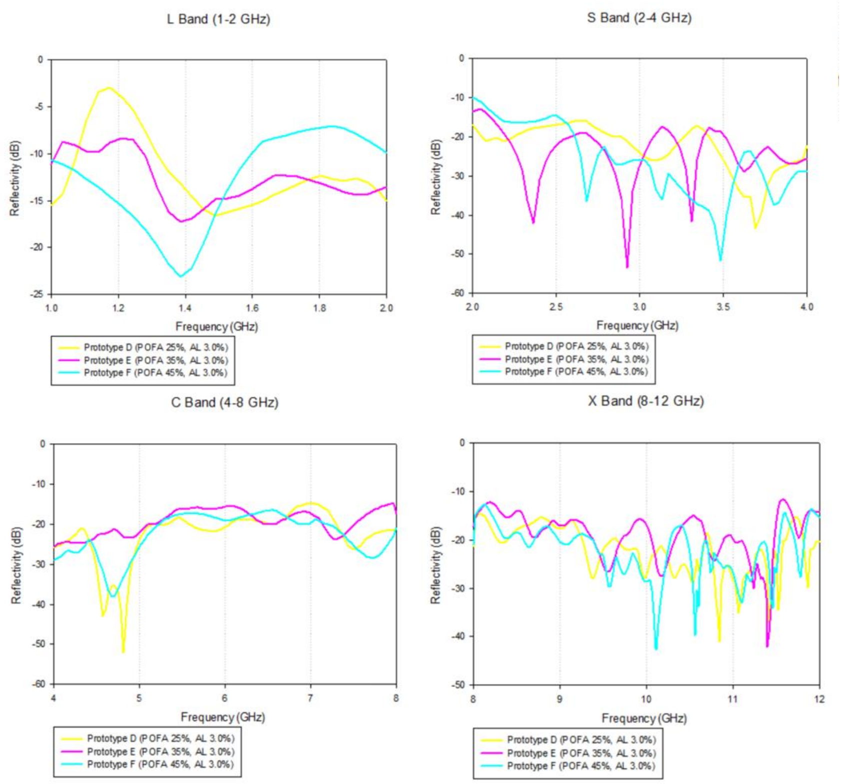

Figure 10: Reflectivity Performance Prototype D, E, and F in L Band, S Band, C Band, and X Band.

Table 3 shows the data analysis of the maximum and minimum reflectivity performance of anti-radiation partition walls and is shown in Figure 11 and Figure 12.

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Table 3: Maximum Reflectivity Performance Data of Prototypes D, E, and F.

Frequency	Reflectivity (dB)					
	Prototype D		Prototype E		Prototype F	
	Min	Max	Min	Max	Min	Max
L Band (1-2 GHz)	-2.9253	-16.5843	-8.3312	-17.2483	-7.0543	-23.0719
S Band (2-4 GHz)	-15.6690	-43.4308	-12.7556	-53.4282	-10.2356	-51.6002
C Band (4-8 GHz)	-14.7394	-52.2152	-14.7612	-25.4724	-16.4601	-37.9979
X Band (8-12 GHz)	-14.6614	-41.1052	-11.6058	-42.0967	-12.6121	-42.6189

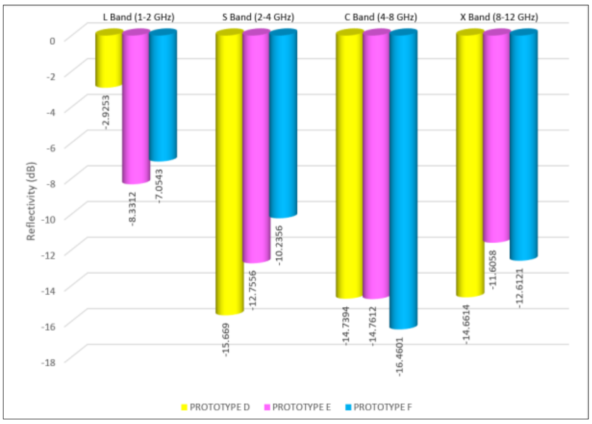

Figure 11: Bar Graph of Minimum Reflectivity Performance Data Prototype D, E and F.

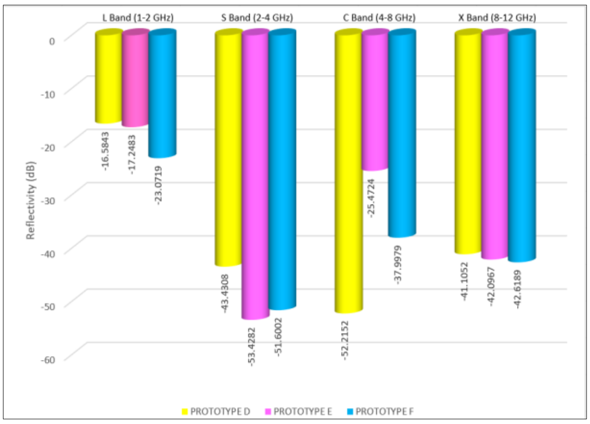

Figure 12: Bar Graph of Maximum Reflectivity Performance Data Prototype D, E and F.

Overall, it can be affirmed that all prototypes (D, E and F) are also able to act as microwave absorbers, given that their reflectivity value exceeds -15 dB in the frequency range between 2 GHz to 12 GHz, as shown in Figures 9 and 10. Moreover, prototype E (POFA 35%, AL 3.0%) is the best prototype compared to prototype D and prototype F since the reflectivity of prototype E is nearly -15 dB.

Figure 11 shows the best minimum reflectivity in the L and C bands from prototype E (POFA 35%, AL 3.0%), which is -8.3312 dB and -14.7612 dB. While for S and X bands, prototype D (POFA 25%, AL 3.0%) has the best minimum reflectivity, which is -15.6690 dB and -14.6614 dB. For Figure 12, prototype F (POFA 45%, AL 3.0%) performs best for the L-band, with a reflectivity of -23.0719 dB and an X-band with a reflectivity of -42.6189 dB. Meanwhile, prototype E (POFA 35%, AL 3.0%) shows minimum reflectivity in the S-band with a value of -53.4282 dB. Lastly, C-band prototype D (POFA 25%, AL 3.0%) performs best with the reflectivity of -52.2152 dB.

Table 4: The measurement of Dielectric Properties

	Loss Tangent, $tan\ \delta = {\varepsilon''}/{\varepsilon'}$	
	Aluminium 0.5%	Aluminium 3.0%
Prototype A and D (POFA 25%)	0.2430	0.1911
Prototype B and E (POFA 35%)	0.3380	0.3759
Prototype C and F (POFA 45%)	0.3031	0.2959

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The loss tangent value for each prototype utilised in this experiment is shown in Table 4. According to the measurements, the prototype with a POFA concentration of 35% exhibited the highest loss tangent. In a microwave absorber, the connection between the loss tangent and the reflectivity is inversely proportional. A high loss tangent value of the material indicates that it is good at absorbing microwave energy, resulting in low reflectivity. On the other hand, a low-loss tangent indicates that the material is less effective in absorbing microwave energy, which results in a higher reflectivity [20-22]. Therefore, to create successful microwave absorbers, choosing a material with a proper loss tangent is essential. The presence of aluminium contributes to increased porosity in the prototype, which is necessary because porosity is one of the factors that determines the absorption rate [23].

4. CONCLUSION

The reflectivity performance of the anti-radiation biomass partition wall in the frequency range of 1 GHz to 12 GHz has been analyzed and discussed. The anti-radiation biomass partition wall containing 35% POFA with 0.5% aluminium (prototype B) produced the best reflectivity performance result, with -47.8784 dB at a frequency of 2.995 GHz and -54.2510 dB at a frequency of 10.72 GHz. Another prototype, containing 35% POFA but with different percentages of aluminium 3.0% (prototype E), produced the highest reflectivity performance result, with -53.4282 dB at a frequency of 2.995 GHz. The observation shows that using 35% POFA in the anti-radiation biomass partition wall yields the most favorable reflectivity performance, and different ratios of aluminium affect the reflectivity performance because of the porosity.

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CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this paper.

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