Journal of Materials Science Research and Reviews

5(1): 42-49, 2020; Article no.JMSRR.55558

An Initial Investigation on Microwaves Reflection and Transmission Coefficients of Oil Palm Empty Fruit Bunch Biocomposites Incorporated with Nickel Zinc Ferrite

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Authors' contributions

This work was carried out in collaboration between both authors. Author MIA managed the literature searches, designed the study, managed the analyses of the study and wrote the protocol. Author AAS wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Suraya Hani Bt Adnan, Universiti Tun Hussein Onn Malaysia, Malaysia.
Reviewers:
(1) Uzoma Paul Chinonso, Federal University of Technology, Nigeria.
(2) H. Y. He, Shaanxi University of Science and Technology, China.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55558

Short Communication

Received 12 January 2020
Accepted 19 March 2020
Published 26 March 2020

ABSTRACT

In this initial investigation, oil palm empty fruit bunch (OPEFB) biocomposites incorporated with nickel zinc ferrite (NZFO) were prepared via heat blending technique followed by a compression molding technique, the percentages of NZFO were varied from 2.5 to 12.5%. All microwave measurements were carried out by means of Vector Network Analyzer (VNA) in the frequency ranges between 8 and 12 GHz. The attenuation measurement software was developed to retrieve data from VNA through a Visual Engineering Environment platform. The simulated and measured results showed that the biocomposites with a higher percentage of NZFO would have higher values of reflection coefficient and lower values of the transmission coefficient. On the contrary, the biocomposites with a lower percentage of NZFO have lower values of reflection coefficient and higher values of the transmission coefficient. In conclusion, the percentage of NZFO has significantly influenced the values of microwaves reflection and transmission coefficients of the OPEFB biocomposites.

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Keywords: Microwave transmission; microwave reflection; oil palm empty fruit bunch; biocomposite; nickel zinc ferrite.

1. INTRODUCTION

In Malaysia, there are about 3.1 million hectares of oil palm trees that produce over 9 million tonnes of crude palm oil (CPO) annually. The oil production represents only 10% and the remaining 90% consists of lignocellulosic material of the total biomass produced by the industry [1]. Oil palm empty fruit bunch (OPEFB) fiber is one of the readily available, non-woody natural fibers in Malaysia. OPEFB fiber is a by-product from the oil palm industry [2]. Therefore, it is useful to find the application for these materials, which will inevitably lessen environmental problems related to the disposal of oil palm wastes and produce materials that could offer a favorable balance of quality, performance, and cost [3]. Biocomposite materials have emerged in a broad spectrum of area of the composite science. The biocomposite produced from OPEFB fiber is low density, low cost, comparable specific properties and most importantly they are environmentally friendly [4].

Nickel Zinc Ferrite (NZFO) is a ferromagnetic material which is a soft ferrite and the chemical formula of NZFO is $Ni_xZn_{1-x}Fe_2O_4$. Their properties were strongly dependent on their composition and microstructure [5]. NZFO is versatile technological material due to its high-resistivity and low eddy current losses. NZFO are important electronic ceramic materials which are used in electronic devices suited for high-frequency applications in the telecommunication field [6]. They are commercially used in high-quality filters, rod antenna of radio frequency circuits, recording heads, loading coils, microwave devices, and many other operating devices [7]. The potential applications of the OPEFB biocomposites incorporated with NZFO such as electromagnetic interference (EMI) shielding, electrodes and sensors, and microwave absorption [7]. The effects of NZFO on the application properties are enhance the structural properties of the outcomes as well as increase the ability to control the EMI properties, particularly when operating at the high-frequency range [5]. The aim of this initial investigation is to prepare OPEFB biocomposites incorporated with NZFO. The prepared biocomposites were comprehensively characterized through microwaves reflection and transmission measurements.

2. MATERIALS AND METHODS

2.1 Materials

The OPEFB fiber used has been procured from Sabutek Sdn. Bhd., Malaysia, whereas the powder of NZFO was prepared via a conventional solid-state method according to Ahmad et al. 2016 [7]. The distilled water was acquired from preparation laboratory, while acetone was obtained from Sigma-Aldrich.

2.2 Preparation of OPEFB Biocomposites

The OPEFB fiber was soaked in hot distilled water (90°C) for 24 hours. The fiber was then filtered and washed with acetone, followed by drying it in an oven at 60°C. The whole process was repeated twice in order to remove the layer of wax and other impurities from the fiber [8,9]. Later, it was grinded by using a grinder machine, and the ground fiber was then sieved to the size of 250μm. The OPEFB biocomposites incorporated with NZFO were prepared through heat blending technique by using a Thermo Haake blending machine. The technique was carried out by setting the blending machine at a temperature of 70°C, rotor speed at 50 rpm and a duration of 10 minutes. The percentages of NZFO in the biocomposites varied from 2.5 to 12.5%. The biocomposites were then molded to sheet form via a compression molding technique by placing 10g of the sample into a mold with the dimensions of 165 × 165 × 1 mm^3. The technique was carried out by setting the molding machine at a temperature of 70°C. The biocomposites were initially preheated for 10 minutes, followed by pressing at a pressure of 110 kg/cm^2 for another 10 minutes at the same temperature. Lastly, the cooling procedure was done by pressing the biocomposites at a temperature of 20°C for 10 minutes.

2.3 Microwave Measurements of OPEFB Biocomposites

The microwave measurements were carried out by using a Vector Network Analyzer (VNA) and Visual Engineering Environment software was used for data acquisition. Before any measurements are conducted, the VNA first was calibrated by implementing a standard full two-port calibration technique since this method permits error correction over a wide frequency band. The VNA can be used for uncorrected measurements, or with one of several calibrations' choices, including short or open response calibrations and one or two-port vector calibrations. After successful calibration, the measurement of reflection and transmission coefficients for standard material such as air was carried out. The obtained results of measurement taken should be closed to the results of the theoretical standard, where reflection is equal to 0 and transmission is equal to 1 for air.

3. RESULTS AND DISCUSSION

Fig. 1 shows the simulated reflection coefficient of 2.5%, 5.0%, 7.5%, 10.0% and 12.5% of NZFO in the biocomposites. The simulation was done in order to get the idea of the pattern and sequence of the reflection coefficient of the samples prepared, by using conventional Finite Element Method (FEM). Based on the graph, it can be concluded that the sample with the lowest percentage of NZFO (2.5%) has the lowest value of reflection coefficient, followed by the samples with the content of 5.0%, 7.5% and 10.0% of NZFO. In comparison, the sample with the highest content of NZFO (12.5%) has the highest values of the reflection coefficient. The graph shows an increasing pattern at a frequency of 9.5 GHz to 12.0 GHz. However, there are fluctuations in reading in the frequency range of 8.0 GHz to 9.5 GHz. The simulation done is dependent on several factors such as the capacity of machine used (in this case; computer) and the number of mesh used during the simulation.

Fig. 2 shows the simulated transmission coefficient of 2.5%, 5.0%, 7.5%, 10.0% and 12.5% of NZFO in the biocomposites. The simulation was done in order to get the idea of the trend and sequence of the reflection coefficient of the samples prepared, by using conventional FEM. Based on the graph, it can be concluded that the sample with the highest percentage of NZFO (12.5%) has the lowest value of transmission coefficient, followed by the samples with content of 10.0%, 7.5% and 5.0% of NZFO; while the sample with the lowest content of NZFO (2.5%) has the highest values of transmission coefficient. The graph shows a decreasing pattern at a frequency of 9.0 GHz to 11.0 GHz. However, there are fluctuations in reading in the frequency range of 8.0 GHz to 9.0 GHz and 11.0 GHz to 12.0 GHz. The simulation done is dependent on several factors such as the capacity of machine used (in this case; computer) and the number of mesh used during the simulation.

Fig. 3 shows the measured reflection coefficient of 2.5%, 5.0%, 7.5%, 10.0% and 12.5% of NZFO in the biocomposites. Based on the graph, it can be concluded that the reflection coefficient of the biocomposites have an increasing pattern against the frequency used during the measurement, which is in the range of 9.0 GHz to 12.0 GHz. The reflection coefficient also

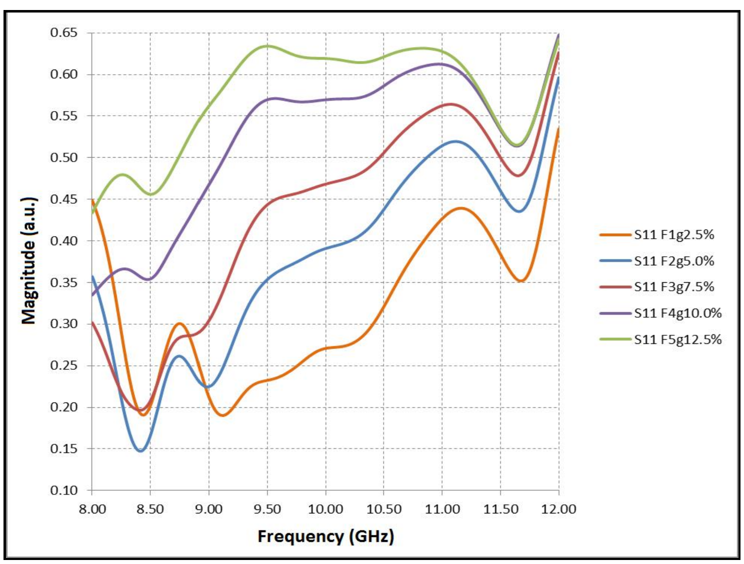

Fig. 1. The graph of the simulated reflection coefficient of a different percentage of NZFO in biocomposites

shows an almost similar pattern for all the samples measured. At the frequency range of 8.0 GHz to 9.0 GHz, there are fluctuations in the reading of the value of the transmission coefficient as the decreasing pattern showed. The fluctuations may occur due to contamination in the samples, the presence of an air gap in the rectangular waveguide or the calibration of the VNA was not performed properly.

The simulation shows a visually clear sequence of the value of reflection coefficient of the samples against the frequency, which is the sample with the highest content of NZFO has the highest value of reflection coefficient and vice versa. The measurement done shows that the sample with the highest content of NZFO (12.5%), has the highest value of reflection coefficient across the frequency range of 8.0 GHz to 12.0 GHz. The trend of the reflection coefficient of the other samples in relation to the samples with the percentages of 10.0%, 7.5%, 5.0% and 2.5% also agreed with the pattern shown on the simulation that have been done. The pattern of the reflection coefficient should show smooth curves across the frequency range of 8.0 GHz to 12.0 GHz; however, there are a few deflections in the pattern of the samples. This result may be due to the contamination of the sample during the preparation process.

Fig. 4 shows the measured transmission coefficient of 2.5%, 5.0%, 7.5% and 12.5% of NZFO in the biocomposites. Based on the graph, it can be concluded that the transmission coefficient of the biocomposites have a decreasing pattern against the frequency used during the measurement, which is in the range of 8.0 GHz to 11.5 GHz. At the frequency range of 11.5 GHz to 12.0 GHz, there are fluctuations in the reading of the value of the transmission coefficient. The fluctuations may occur due to contamination in the samples, the presence of an air gap in the rectangular waveguide or the calibration of the VNA was not performed properly.

The simulation shows that the sample with the highest content of NZFO has the lowest value of transmission coefficient and vice versa. The measured value of transmission coefficient shows that the value is in sequences at a frequency range of 8.0 GHz to 12.0 GHz, which are, the sample with the highest content of NZFO has the lowest value of transmission coefficient and vice versa. The sample with the highest content of NZFO (12.5%) has the lowest value of transmission coefficient, followed by the samples with the content of 10.0%, 7.5% and 5.0% of NZFO; while the sample with the lowest content of NZFO (2.5%) has the highest value of transmission coefficient. It can be concluded that the measurements at a frequency range of 8.0 GHz to 12.0 GHz agree with the simulation that has been carried out before. The pattern of the reflection coefficient should show smooth curves across the frequency range of 8.0 GHz to 12.0 GHz. However, there are a few deflections in the

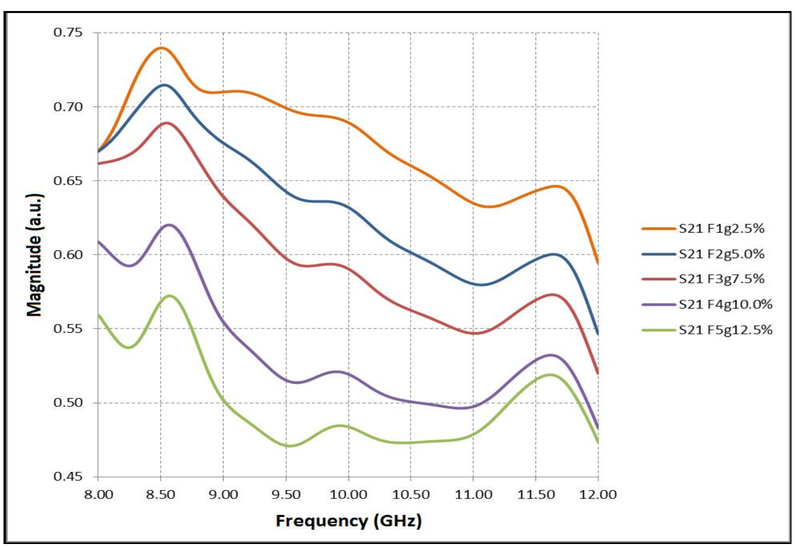

Fig. 2. The graph of the simulated transmission coefficient of a different percentage of NZFO in biocomposites

pattern of the samples. This result may be due to the contamination of the sample during the preparation process.

Fig. 5 shows the comparison of measured values and simulated values of reflection coefficient of the biocomposites with content of (a) 2.5%, (b) 5.0%, (c) 7.5%, (d) 10.0% and (e) 12.5% of NZFO. Based on the graph, the simulated values of the reflection coefficient of the biocomposites with the content of 2.5%, 5.0%, 7.5%, 10.0% and 12.5% NZFO display that the values of reflection coefficient increase as the frequency increases. The measured values agree with the simulated values as it also shows an increasing pattern.

Fig. 6 shows the comparison of measured values and simulated values of transmission coefficient of the biocomposites with content of (a) 2.5%, (b) 5.0%, (c) 7.5%, (d) 10.0% and (e) 12.5% of NZFO. Based on the graph, the simulated values of the transmission coefficient of the

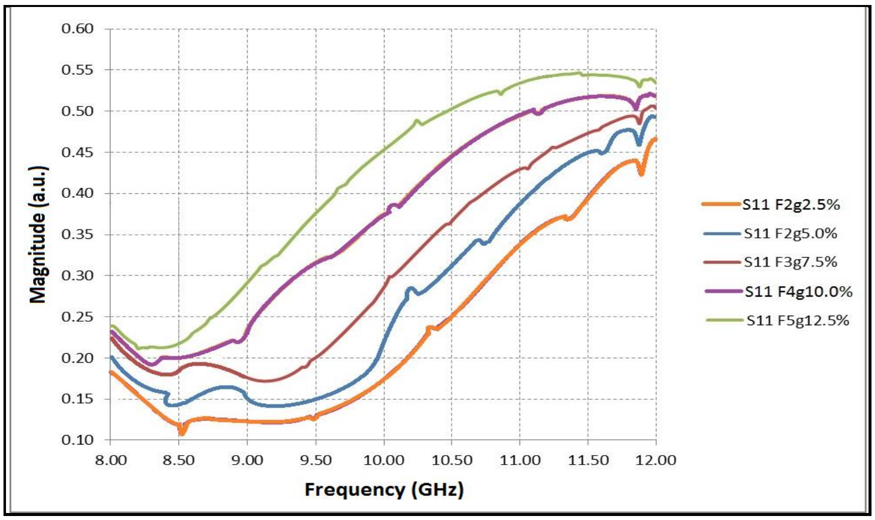

Fig. 3. The graph of the measured reflection coefficient of a different percentage of NZFO in biocomposites

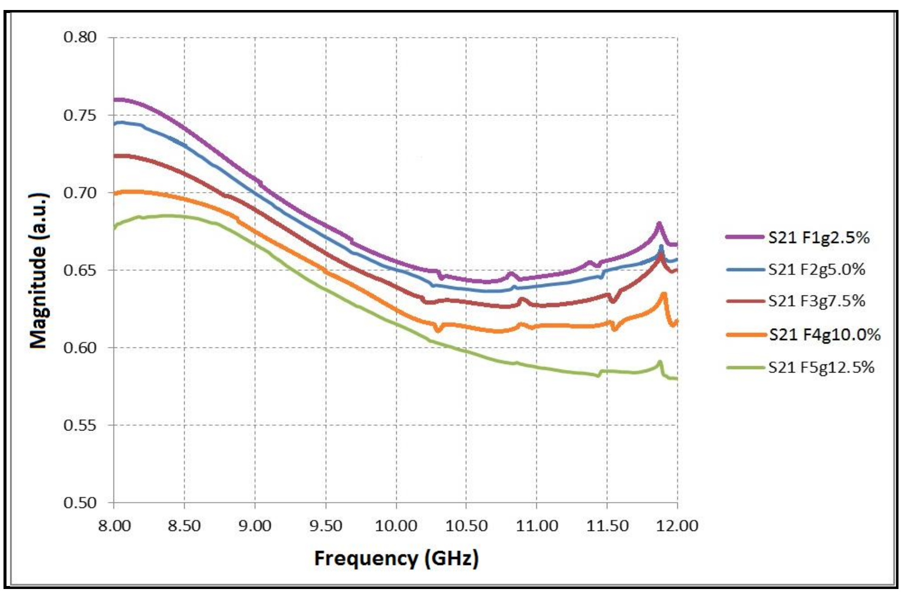

Fig. 4. The graph of the measured transmission coefficient of a different percentage of NZFO in biocomposites

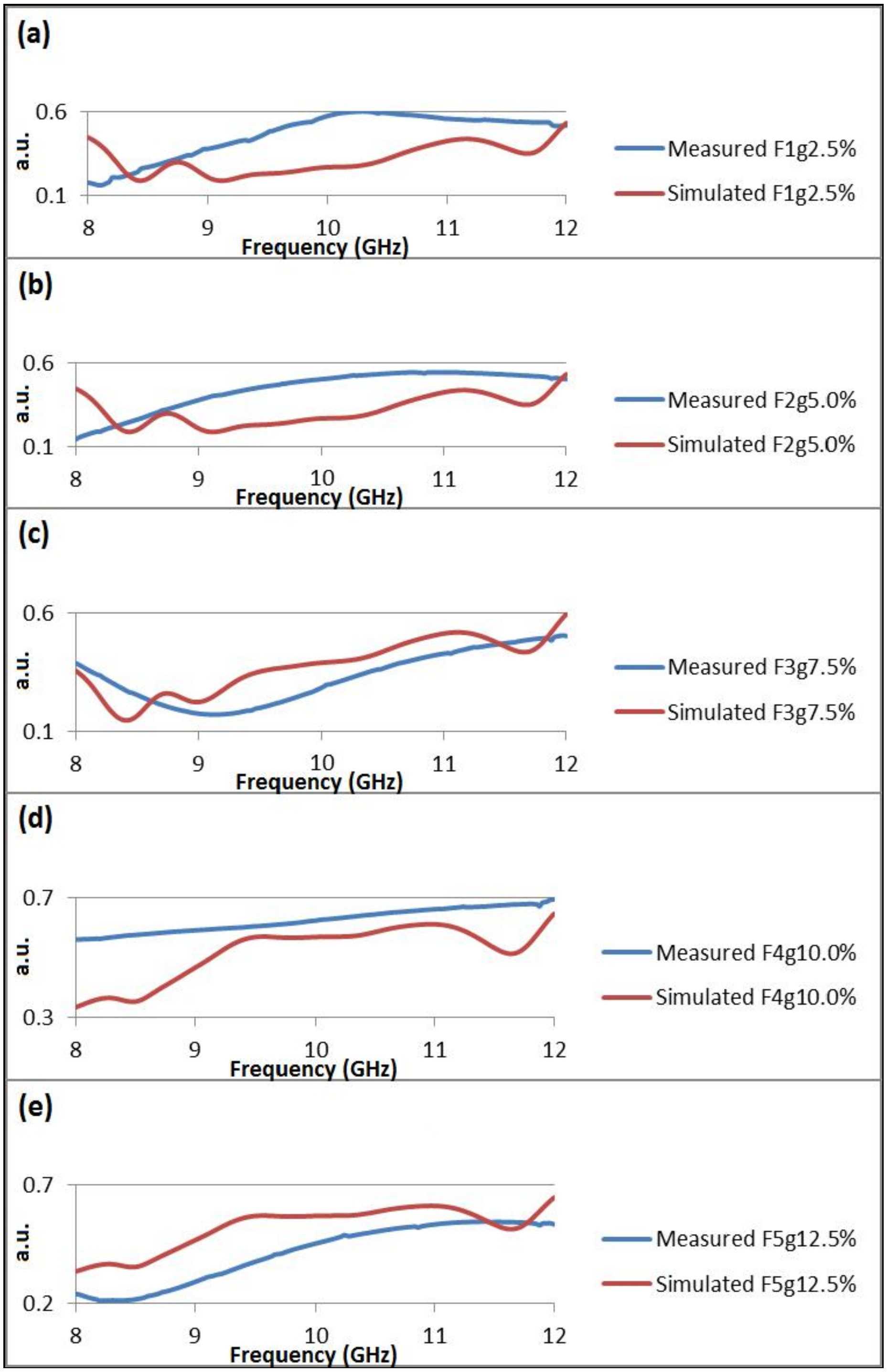

Fig. 5. The graph of the comparison of measured values and simulated values of reflection coefficient of the biocomposites with content of (a) 2.5%, (b) 5.0%, (c) 7.5%, (d) 10.0% and (e) 12.5% of NZFO

biocomposites with the content of 2.5%, 5.0%, 7.5%, 10.0% and 12.5% NZFO display that the values of transmission coefficient decrease as the frequency increases. The measured values agree with the simulated values as it shows a decreasing pattern.

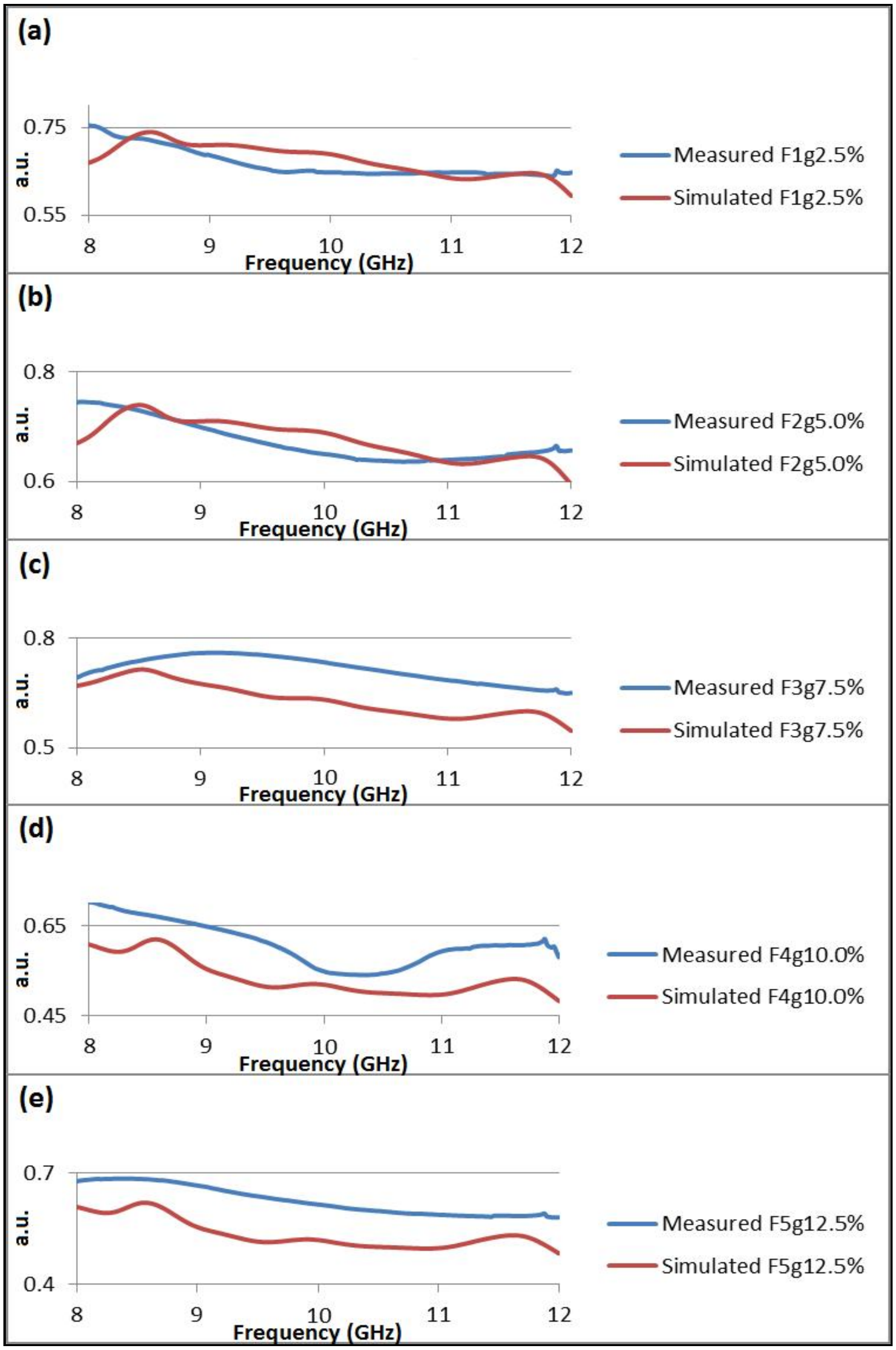

Fig. 6. The graph of the comparison of measured values and simulated values of transmission coefficient of the biocomposites with content of (a) 2.5%, (b) 5.0%, (c) 7.5%, (d) 10.0% and (e) 12.5% of NZFO

4. CONCLUSION

Based on the initial investigation conducted, the reflection and transmission coefficients of the OPEFB biocomposites are dependent on the percentage of NZFO. The different percentage of NZFO give out a distinct value of reflection and transmission coefficients. The biocomposite with the lowest percentage of NZFO (2.5%) indicates the lowest measured value of reflection coefficient. In contrast, the sample with the highest percentage of NZFO (12.5%) indicates the highest reflection coefficient value. The biocomposite with the lowest percentage of NZFO (2.5%) indicates the highest measured value of the transmission coefficient. In contrast, the sample with the highest percentage of NZFO (12.5%) indicates the lowest transmission coefficient value. It could be concluded that the values of microwaves reflection and transmission coefficients of the OPEFB biocomposites were significantly influenced by the percentage of NZFO.

ACKNOWLEDGEMENT

The authors would like to thank the Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia for encouraging us to write this paper.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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