

Electromagnetic Shielding Effectiveness of Gypsum-Magnetite Composite at X-Band Frequency

Mohamad Ashry Jusoh^{1,*}, You Kok Yeow², Rodziah Nazlan¹, and Fahmiruddin Esa³

Abstract—Rapid development of the electronic industry has increased the frequency of communication devices which lead to higher intensity of electromagnetic (EM) wave production. Too much exposure of EM wave can cause harm to health besides imposing disturbances in performances of other electronic devices. Hence, this research studies the structural and electromagnetic properties of materials that can act as electromagnetic shielding material at x-band frequency. Different compositions of magnetite powder/ Fe_3O_4 (0, 10, 20 and 100 wt.%) were prepared to be dispersed in gypsum powders to form gypsum-magnetite composites. The structural properties of composites were characterized using Scanning Electron Microscopy (SEM) to observe homogeneity of the composites. The X-Ray Diffraction (XRD) was used to determine phase composition of the gypsum-magnetite composites. Scattering parameters of reflection coefficient, S_{11} , and transmission coefficient, S_{21} , were measured using Vector Network Analyzer (VNA). These parameters will be used to calculate the shielding effectiveness (SE) of gypsum-magnetite composite at x-band frequency. The results show that the total SE of the gypsum-magnetite composites were increased by adding magnetite powders.

1. INTRODUCTION

The rapid development of communication technology has increased electromagnetic (EM) wave in our daily life. Instead of bringing great convenience into our lives, electromagnetic wave also causes electromagnetic pollution and radiation which give negative impact on commercial, industrial, and military systems [1]. Uncontrolled development of microwave electronic devices will create severe electromagnetic pollution that degrades the electronic devices' performance and negatively affects human health [2]. Some devices that are capable of creating electromagnetic interference (EMI) and lead to the interruption of those applications are digital computers, calculators, printers, modems, electronic typewriters, cellular phones, AC motors, and others [3].

To overcome these problems, attaching electromagnetic wave absorbers to the walls of buildings, bridges, and structures providing substantial reflection and scattering of electromagnetic waves is a viable option. Furthermore, the increasing electromagnetic interference problems had introduced electromagnetic interference (EMI) shielding materials that had been widely used in the electric, aerospace, and military applications [4].

The frequency range of communication devices has increased rapidly to enhance better data transfer rates in the electronic industry. EM radiations can cause a wide range of destruction, from a simple degradation to the complete loss of data apart from giving bad effects to human health too. Hence, the EM shielding and microwave absorbers in this range of frequency have increased in demand. The metallic walls are used to build a shielding room for the protection of sensitive environment. However,

Received 14 May 2019, Accepted 12 July 2019, Scheduled 23 July 2019

* Corresponding author: Mohamad Ashry Jusoh (ashry@ump.edu.my).

¹ Faculty of Industrial Sciences & Technology, Universiti Malaysia Pahang, Gambang Kuantan, Pahang 26300, Malaysia. ² Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Skudai, Johor 81310, Malaysia. ³ Faculty of Applied Science and Technology, Universiti Tun Hussein Onn Malaysia, Parit Raja, Johor 86400, Malaysia.

it is impossible to install these heavy structures over existing walls as the environment becomes quite uncomfortable if magnetic structures are used. Therefore, this study is carried out to add magnetic material into gypsum plaster, which seems to be rational in order to reduce the EMI at X-band (8.2–12.4 GHz).

2. EXPERIMENTAL

2.1. Materials

The following materials were used in this study: Gypsum powder ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, MW = 172.17 g/mol), iron (II) oxide powder (Fe_3O_4 , MW = 231.54 g/mol), purchased from R&M Chemical and deionized water.

2.2. Sample Preparation

Gypsum and Fe_3O_4 powder were mixed and grinded for 3 hours using a mortar and pestle. The weight percent (wt.%) of gypsum- Fe_3O_4 composite is described in Table 1. Water was added to the composite in mortar mixer at a volume fraction of 0.3. The mixture was mixed using mini-mechanical vortex to disperse magnetic filler in order to get a homogeneous composite sample and poured into x-band mold ($22.86 \text{ mm} \times 10.16 \text{ mm} \times 3 \text{ mm}$) for characterization.

Table 1. Weight percent of the composite.

wt% gypsum	wt% Fe_3O_4
100	0
90	10
80	20
0	100

The gypsum-magnetite composites were characterized by x-ray diffraction method using Rigaku Miniflex to obtain a phase composition of composites. The scan ranges were recorded at 20 to 80° at a scan rate of $1^\circ/\text{min}$. The morphology of gypsum-magnetite composites were observed using Scanning Electron Microscope (SEM). The scattering parameters of reflection, S_{11} , and transmission, S_{21} , were measured using Keysight E5071C Vector Network Analyzer at x-band frequency (8.2 GHz to 12.4 GHz) as shown in Fig. 1. The total shielding effectiveness, SE_{Total} , were obtained from shielding effectiveness



Figure 1. Measurement setup.

due to reflection, SE_R , and absorption, SE_A , as expressed in Eq. (1) [5, 6].

$$SE_{\text{Total}} = SE_R + SE_A \quad (1)$$

$$SE_R = 10 \log \left(\frac{1}{1 - R} \right) = 10 \log \left(\frac{1}{1 - |S_{11}|^2} \right) \quad (2)$$

$$SE_A = 10 \log \left(\frac{1 - R}{T} \right) = 10 \log \left(\frac{1 - |S_{11}|^2}{|S_{21}|^2} \right) \quad (3)$$

where R and T are the reflection and transmission coefficients, respectively.

3. RESULTS AND DISCUSSION

3.1. XRD Analysis

Figure 2 shows the XRD patterns of the gypsum-magnetite composites, pure Fe_3O_4 , and pure gypsum. The XRD analysis was conducted to prove that there were no contaminants in the sample used. Moreover, Fig. 2(b) shows the XRD analysis of Fe_3O_4 . The Fe_3O_4 compound was found at the peak (220), (311), (400), (422), (511), and (440). As 20 wt.% of magnetite fillers have been dispersed in gypsum, there were a few peaks of Fe_3O_4 that had disappeared.

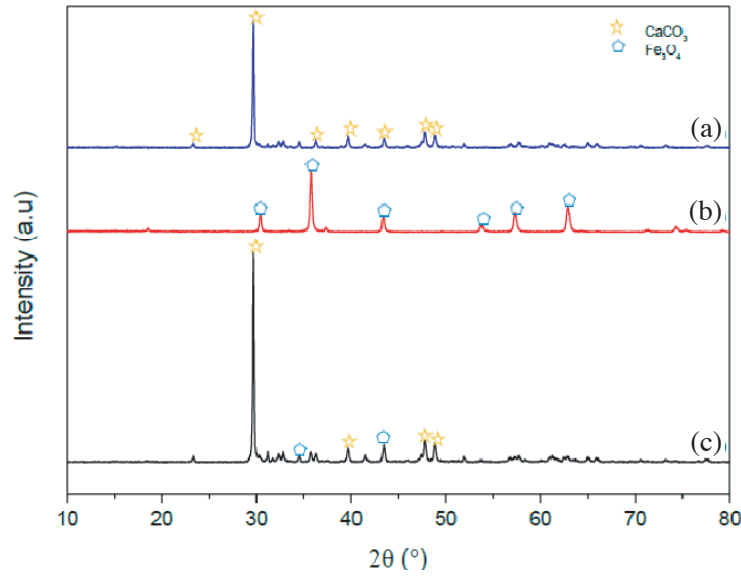


Figure 2. X-ray diffraction pattern of (a) pure gypsum, (b) pure Fe_3O_4 and (c) 80 wt.% gypsum-20 wt.% Fe_3O_4 .

3.2. SEM Analysis

SEM images of the pure gypsum, magnetite Fe_3O_4 , and gypsum-magnetite composites at 20 wt.% fillers at $\times 2500$ and $\times 5000$ magnifications are shown in Fig. 3. These images were taken after 3 hours of grinding using agate mortar. Gypsum particles also have various sizes but mostly were less than $20 \mu\text{m}$. The surface of Fe_3O_4 was rough and seemed to be powdery. The 20 wt.% of magnetite fillers were randomly dispersed in the gypsum powder.

3.3. Electromagnetic Shielding Effectiveness

The shielding effectiveness (SE) of gypsum-magnetite was measured at x-band frequency. Figs. 4 to 6 show the SE due to reflection (SE_R), absorption (SE_A), and total SE (SE_{total}), respectively. As the

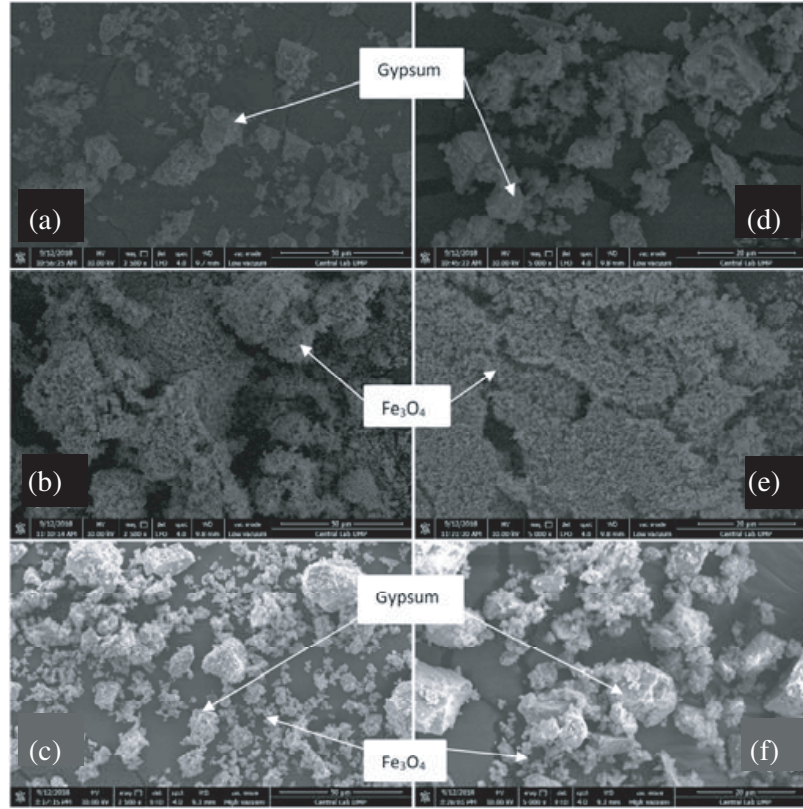


Figure 3. SEM morphology of (a) Gypsum, (b) Magnetite Fe_3O_4 , (c) Gypsum-magnetite composite.

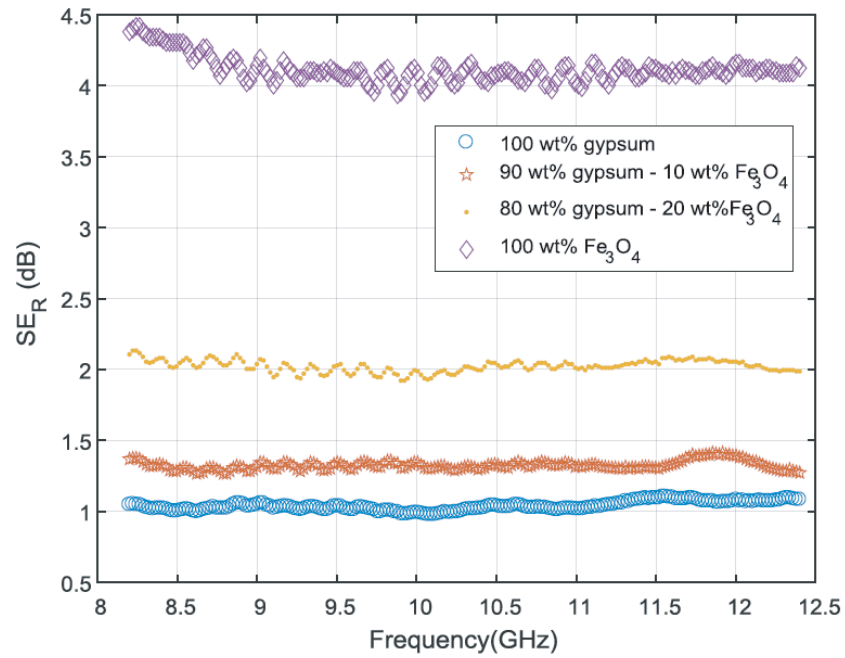


Figure 4. Shielding effectiveness due to reflection of gypsum, magnetite and gypsum-magnetite composite.

magnetite's composition increased, the total SE should also be increased [7]. It can be clearly seen that the total SE increases as the composition of magnetite fillers increases for 0, 10, and 20 wt.% of fillers. SE_A of 10 and 20 wt.% of magnetite show a small variation, but there was high variation for SE_R as can be observed in Figs. 4 and 5.

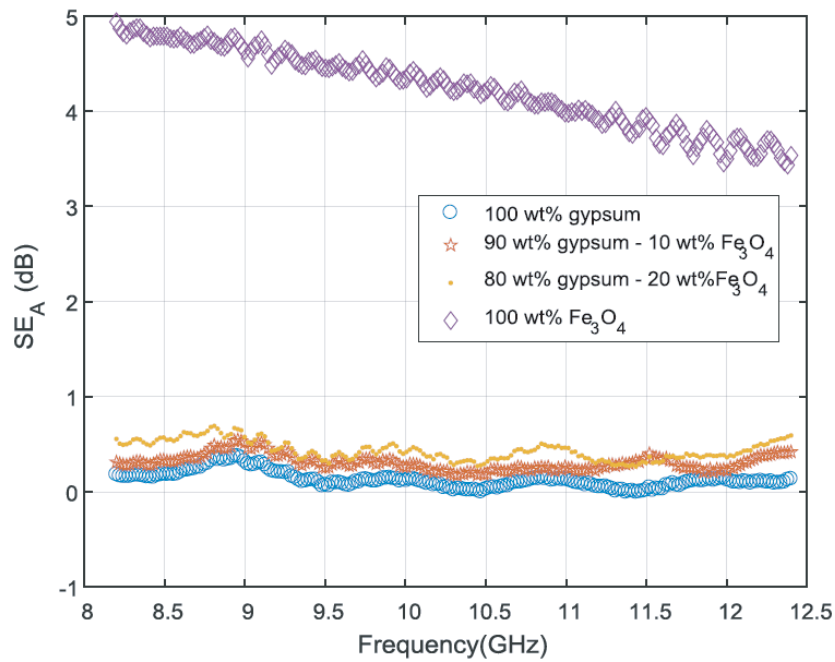


Figure 5. Shielding effectiveness due to absorption of gypsum, magnetite and gypsum-magnetite composite.

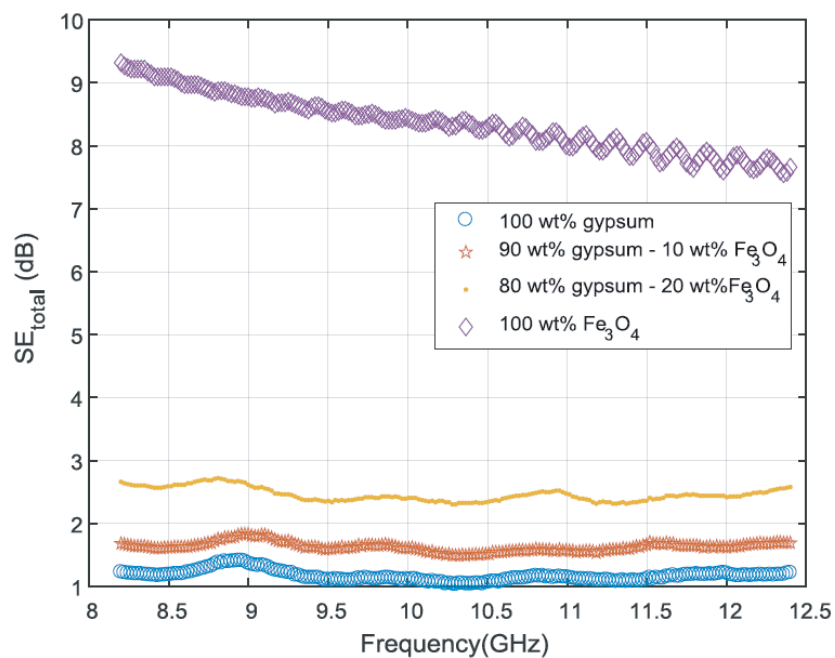


Figure 6. Total shielding effectiveness of gypsum, magnetite and gypsum-magnetite composite.

4. CONCLUSIONS

Gypsum-magnetite composites with different magnetite contents were fabricated, and their electromagnetic shielding effectiveness was studied in the frequency of 8.2–12.4 GHz (X-band). The results show that the total SE of the gypsum-magnetite composites was increased by adding magnetite powders. It is due to the absorption and reflection of wave by magnetic powder.

ACKNOWLEDGMENT

This research is funded by the Ministry of Education Malaysia from Ministry of Higher Education Malaysia (MOHE) under grant RDU 190125.

REFERENCES

1. Liu, Y., et al., “Electromagnetic interference shielding and absorption properties of Ti_3SiC_2 /nano Cu/epoxy resin coating,” *Journal of Alloys and Compounds*, Vol. 740, 68–76, 2018.
2. Chan, Y. L., F. Esa, K. Y. You, M. S. S, M. Z. H. Mayzan, and M. A. Jusoh, “Electromagnetic properties of magnetite/epoxy resin composites at X-band frequency,” *2017 Progress In Electromagnetics Research Symposium — Fall (PIERS — FALL)*, Singapore, Singapore, Nov. 19–22, 2017.
3. Ahmad, S. H., et al., “Magnetic and microwave absorbing properties of magnetite-thermoplastic natural rubber nanocomposites,” *Journal of Magnetism and Magnetic Materials*, Vol. 322, No. 21, 3401–3409, 2010.
4. Hu, T., et al., “Electromagnetic interference shielding properties of carbonyl iron powder-carbon fiber felt/epoxy resin composites with different layer angle,” *Materials Letters*, Vol. 142, 242–245, 2015.
5. Al-Saleh, M. H., “Influence of conductive network structure on the EMI shielding and electrical percolation of carbon nanotube/polymer nanocomposites,” *Synthetic Metals*, Vol. 205, 78–84, 2015.
6. Liu, X., et al., “Fabrication and electromagnetic interference shielding effectiveness of carbon nanotube reinforced carbon fiber/pyrolytic carbon composites,” *Carbon*, Vol. 68, 501–510, 2014.
7. Liu, X., et al., “Electromagnetic interference shielding effectiveness of titanium carbide sheets,” *Materials Letters*, Vol. 205, 261–263, 2017.