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A comparative study of electromagnetic shielding efficiency of composites conducting polymers in near and far-fields

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Abstract
The present article is a theoretical contribution to the comparative study of a single layer electromagnetic shielding efficiency of high density polyethylene/trioxide of vanadium (HDPE/V_2O_3) and low density polyethylene/trioxide of vanadium (LDPE/V_2O_3) conductive polymers composites in near and far field. This study was realized over a wide range of frequency (50MHz-50GHz). To this effect, the volume fraction of the conductive inclusions is fixed. This volume fraction leads an electrical conductivity which verifies the condition of a good conductor ($\sigma/\omega\varepsilon_0 >> 1$).The thickness of the shield was chosen superior to the depth of penetration of the electromagnetic wave. In these conditions the multi- reflections are neglected.

*Keywords:*Conducting polymer composites, electromagnetic shielding, attenuation due to the absorption, global efficiency, attenuation due to the refletion.

Introduction
Due to their low specific mass, easiness of synthesis, the possibility to modulate easily the electronic properties from insulating to conducting materials through chemical process, low cost and processability, conducting polymers composites are attractive materials for use in many fields of engineering such as solar cellule, antistatic media, light-emitting diode (LED), thermal fuses, shielding for electromagnetic interference of electronic devices [1-5].The development of digital communication technologies in modern industry has led to the use of high performance electrical apparatus and the use of them has been causing electromagnetic environmental pollution called electromagnetic shielding [6-11].
Electromagnetic interferences have become an important problem due to the proliferation military, commercial and scientific electrical devices. The problem of protection against electromagnetic radiation has a very important technical aspect concerning a reduction in the level of reciprocal interference of electronic instruments [12,13]. Furthermore, an even more important element of protection against electromagnetic radiation is the social aspect: the health protection of persons present in vicinity equipment emitting EMR with an appropriate power and frequency, and exposed to its prolonged effects [1, 14-18]. Conducting polymers composites like polyaniline-polyurethane (PAni/PU), polypropylene filled with copper particles (PP/Cu) and polyethylene high and low density filled with trioxide of vanadium inclusions conducting are very promising for applications in electromagnetic interference shielding [19-23].
The present work is a theoretical contribution to the comparative study of electromagnetic shielding efficiency of polyethylene high and low density filled with trioxide of vanadium conducting inclusions (HDPE/V_2O_3) and (LDPE/V_2O_3) in near and far field.

1. Theoretical background
When an electromagnetic wave arrives to the surface of a shield material, three physical phenomena can occur: reflection, absorption and transmission of the incidental electromagnetic wave (figure 1).
Reflection is often the primary mechanism of shielding. To shield by reflection, the material must have mobile charge carriers. The second important mechanism is the absorption it depend on the thickness of the shield. For absorption of the radiation by the shield, the shielding materials have electrical or magnetic dipoles which

interact with the electromagnetic wave [3,4,8,9,11]. The last mechanism is the multiple-reflections; it represents the internal reflection within the shielding material.

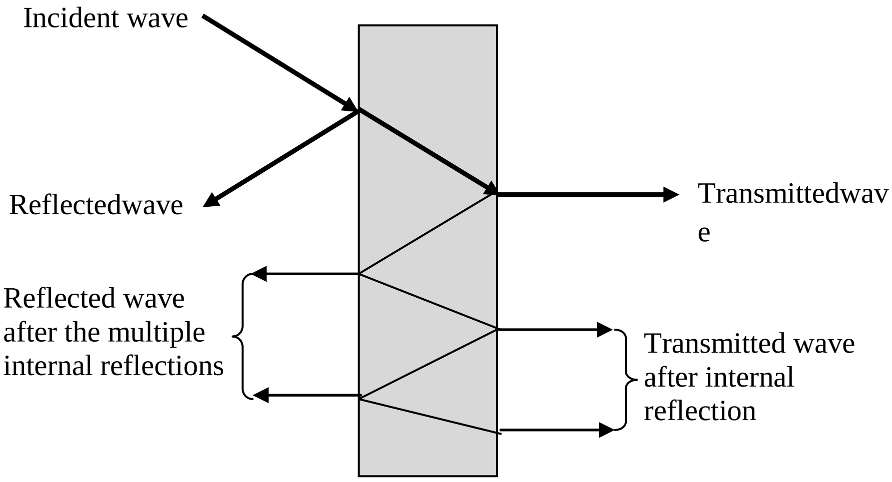

Figure1: Schematic showing electromagnetic shielding.

The plane wave shielding theory defines the shielding efficiency SE (dB)[1,25-31] as

$$SE(dB) = SE_A(dB) + SE_R(dB) + SE_M(dB) \tag{1}$$

Where SE_A is the absorption loss, $SE_R$is the reflection loss and SE_M is a term which takes into account the loss caused by multiple reflections inside the shield.

2. Results and discussion

In this work, we have examined the effect of frequency source on the electromagnetic shielding in near and far field. This study was realized over a wide range of frequency (50 MHz-50 GHz). To this effect, the volume fraction of the conductive inclusions of trioxide of vanadium is fixed to 34.4% in the case of (HDPE/V_2O_3) composite conducting polymer and to 42.4% in the case of (LDPE/V_2O_3). This volume fraction leads, respectively, an electrical conductivity of 25.84 s/cm and 5.52 s/cm which verifies the condition of a good conductor ($\sigma/\omega\varepsilon_0$>>1) [24-27]. The thickness of the shield ($d=3.10^{-3}$ m) was chosen superior to the skin depth δ. In these conditions, the loss due to the multiple reflections is neglected. The electromagnetic interference shielding efficiency se can be expressed as summation of the initial reflection loss (R) and absorption loss (A).
Attenuation due to the absorption
In near and far field, the attenuation due to the absorption is given by[28]:

$$SE_A = 20\log\left(e^{\frac{d}{\delta}}\right) \tag{2}$$

Attenuation due to the reflection

$$SE_R = 10\log\left(\frac{C^2\sigma}{16\omega\varepsilon(Kr)^2}\right) \text{ near field} \tag{3}$$

$$SE_R = 10\log\left(\frac{\sigma}{16\omega\varepsilon}\right) \text{far field} \tag{4}$$

Global efficiency

$$SE = 20\log\left(e^{\frac{d}{\delta}}\right) + 10\log\left(\frac{C^2}{16\omega\varepsilon(Kr)^2}\right) \text{ near field} \tag{5}$$

$$SE = 20\log\left(e^{\frac{d}{\delta}}\right) + 10\log\left(\frac{\sigma}{16\omega\varepsilon}\right) \qquad \text{far field} \tag{6}$$

Where
$\delta = (2/\omega\mu\sigma)^{0.5}$ is the skin depth
$\omega=2\pi f$: angular frequency
$C=2.99\ 10^{8}$ (m/s): velocity of light
d: thickness of the shield
r: source to shield distance
$Z_0=377\Omega$: free-space wave impedance
$K=(2\pi/\lambda)$: module of wave vector
$\varepsilon=\varepsilon_r\varepsilon_0$: electrical permittivity
ε_r: relative permittivity
$\varepsilon_0 =8.854\ 10^{-12}$(F/m) permittivity of free space

2.1. Case of (HDPE/V_2O_3) composite conducting polymer
Figures (2a), (2b) and (2c) show evolutions of the absorption, reflection and overall efficiency of the electromagnetic shielding in the frequency range 50MHz-50GHz for an (HDPE/ V_2O_3) screen in near and far - field regions. These data confirm that magnitudes of overall efficiency due to the absorption increases in the range 18.54:586.51dB and unlike the reflection which decreases when the source frequency increases from 50MHz to 50GHz. This is explained by the fact that when an electromagnetic wave penetrates a material medium, a part of its energy is transferred to the matter in a form of Foucault current. As a consequence, the heat of the screen creates decay in magnitudes of electromagnetic fields. However, we can underline in this study that the attenuation of the reflection from 89 dB to 1 dB is more important in near-field than the one in far-field. The reflection being related to the index variation in the vicinity of an interface; i.e., it depends on impedances of the surface material and of the incident field defined by the ratio, E/H. In addition, the evolution of the overall efficiency in a dependence frequency specified below is clearly distinguished between the near-field and the far-field. The synthesis reported to these results is that the screen is more efficiency in near-field than in far-field. Furthermore, in the two regions, the overall efficiency of the attenuation is more important than in the reflection. In low frequencies, and near-field, a screen shield in HDPE/V_2O_3 is more efficient, because it absorbs an electromagnetic radiation in a high proportion compared to the reflection.

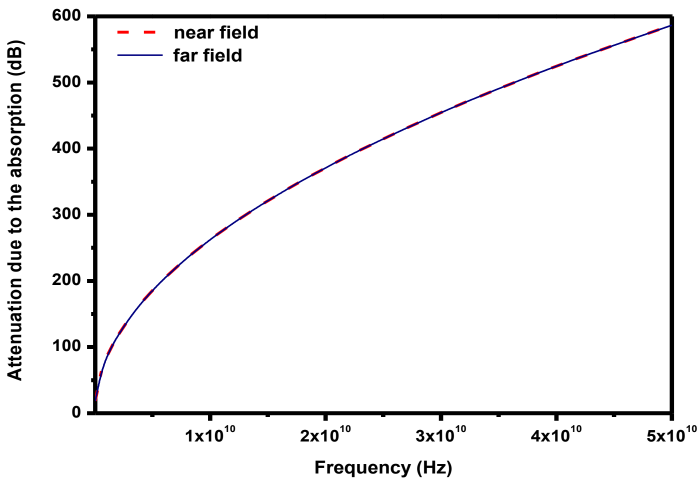

Figure 2a: Variation of attenuation due to the absorption as a function of frequency for (HDPE/V_2O_3) conducting polymer composite in near and far field.

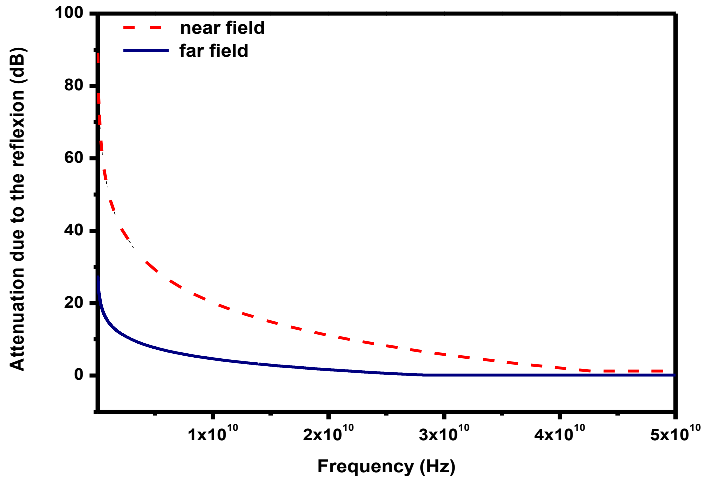

Figure 2b: Variation of attenuation due to the reflexion as a function of frequency for ($HDPE/V_2O_3$) conducting polymer composite in near and far field

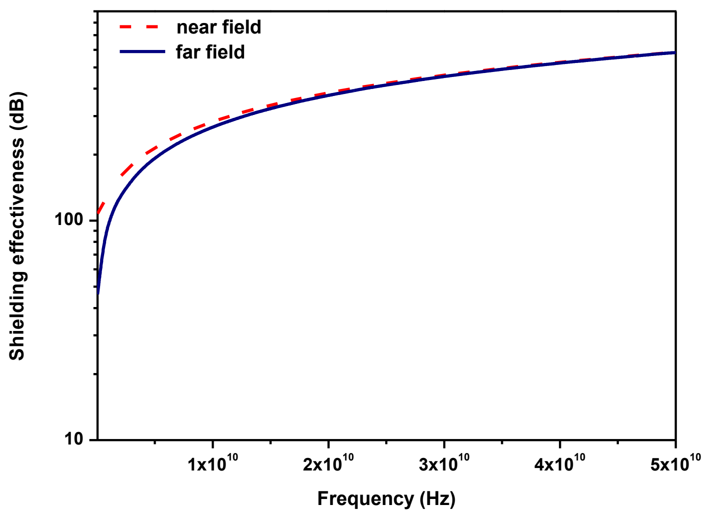

Figure 2c: Variation of electromagnetic shielding efficiency as a function of frequency for ($HDPE/V_2O_3$) conducting polymer composite in near and far field.

2.2. Case of ($LDPE/V_2O_3$) composite conducting polymer

Figures (3a), (3b) and (3c) show respectively the variation of attenuation due to the absorption, attenuation due to the reflection and electromagnetic shielding efficiency as a function of frequency for ($LDPE/V_2O_3$) screen in near and far field regions over a wide range of frequency (50MHz-50Ghz). From these figures, we can see an increase of the attenuation due to the absorption, the electromagnetic shielding efficiency and a decrease of the attenuation due to the reflection. This is explained by the fact that when an electromagnetic wave penetrates a material medium, a part of its energy is transferred to the matter in a form of Foucault 'current. As a consequence, the heat of the screen creates decay in magnitudes of electromagnetic fields. The heat of the shield creates decay in magnitudes of electromagnetic fields. However, we can underline in this study that the attenuation of the reflection from 83.20 dB to 0.22 dB is more important in near –field than the one in far-field.

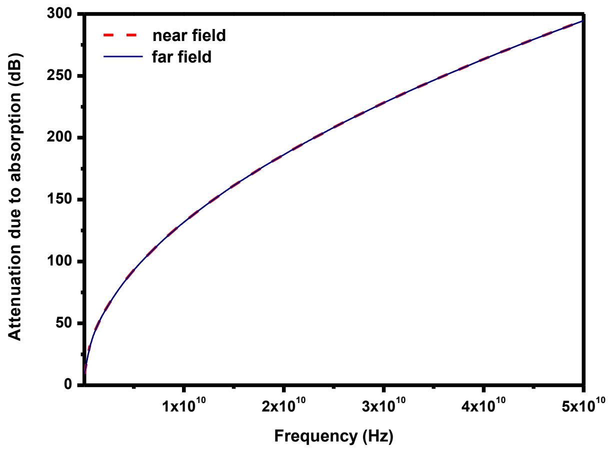

Figure 3a: Variation of attenuation due to the absorption as a function of frequency for ($LDPE/V_2O_3$) conducting polymer composite in near and far field.

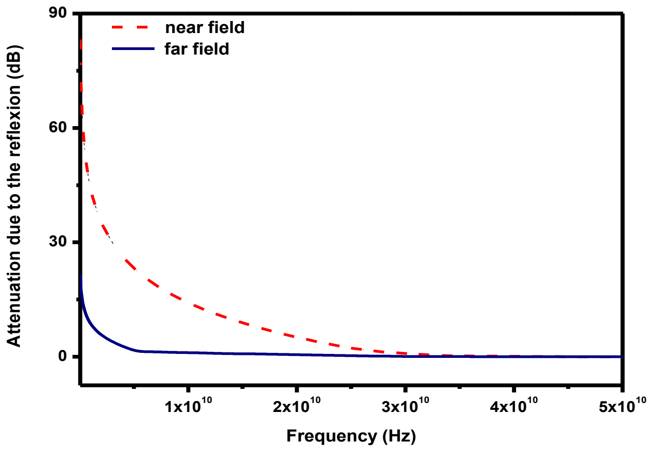

Figure 3b: Variation of attenuation due to the reflexion as a function of frequency for ($LDPE/V_2O_3$) conducting polymer composite in near and far field.

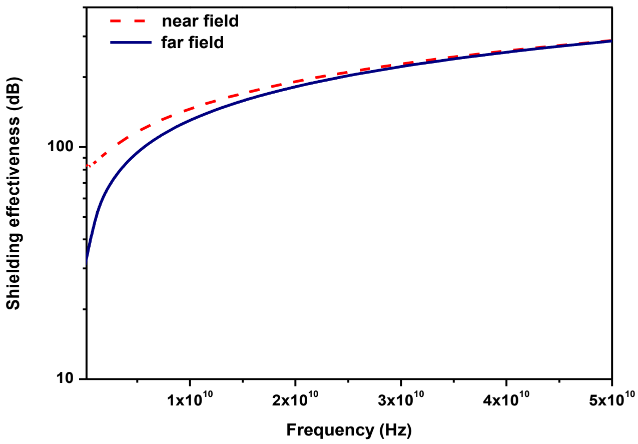

Figure 3c: Variation of electromagnetic shielding efficiency as a function of frequency for ($LDPE/V_2O_3$) conducting polymer composite in near and far field.

Conclusion

In the present work, we have down a comparative study between electromagnetic shielding based on the conductor polymers composites in near-field and far-field. This study allows us to make the effect frequency on the shielding electromagnetic efficiency of a screen based on the composite polymers (HDPE/V_2O_3) and (LDPE/V_2O_3). The obtained results reveal that for the above screens the attenuation due to the absorption is important for high frequency waves. The attenuation due to the reflection depends on the frequency of the electromagnetic source, i.e., it is more important in near-field than in far-field. In the latter regions far-field), the contribution of the overall efficiency of the attenuation due to the absorption is more substantial than the one of the reflection. The tow screens investigated absorb all the electromagnetic radiation; the reflected one is weak. In high frequencies the discrepancy between the overall efficiency becomes weak in near and far-fields.

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References

1. Al-Saleh M. H., Sundararaj U., *Carbon 47* (2009) 1738-1746.
2. Morari C., Balan I., Pintea J., Chitanu E., Iordache I., *Prog. Electro.Res. M*, 21 (2011) 93-104.
3. Chung D. D. L., *J. Mat. Eng. And Perfor*., 9 (2000) 350-354.
4. Liu Z., Bai G., Huang Y., Ma Y., Du F., Li F., Guo T., Chen Y., *Carbon 45* (2007) 821-827.
5. Xu H. P., Wu Y. H., Yang D. D., Wang J. R., Xie H. Q., *Rev. Adv. Mater. Sci*., 27 (2011) 173-183.
6. Franek J., Kollar M., Makoviny I., *J. Elect. Eng.*, 62 (2011) 25-30.
7. Schuh S., Albach M., *Elect. Pow. Qual. and Util. J.*, 11 (2005) 57-63.
8. Chung D. D. L., *carbon 39*, (2001), 279-285.
9. Schütze O., Jourdan L., Legrand T., Talbi E., Wojkiewicz J. L., *Polym. Adv. Tech*., 19 (2008) 762-769.
10. Koledinstseva M. Y., Drewniak J., DuBroff R., Rozanov K., Archambeault B., *Prog. Elect. Res. B*, 15 (2009) 197-215.
11. Jourdan L., Schütze O., Legrand T., Talbi E., Wojkiewicz J. L., *Mat., Manuf. Proc.*, 24 (2009) 350-357.
12. Lee C. Y., Kim H. M., Park J. W., Gal Y. S., Jin J. I., Joo J., *Synth. Met.*, 117 (2001) 109-113.
13. Angelopoulos M., *IBM J. Res*. Dev, 45 (2001) 57.
14. Chang Tsai H., *Math. Sci.& Tech.*, 51(1) (2006) 1-19.
15. Mathew K.T., Praveen Kumar A.V., John H., *IEEE.*
16. Ko J.M., Park D. Y., Myung N.V., Chung J.S., Nobe K., *Synt. Met.*, 128 (2002) 47-50.
17. Goyal R. K., KadamA., *Adv. Mat. Lett.*, 1 (2) (2010) 143-147.
18. Panwar V., Park J., Ho Park S., Kumar S., Mehra R. M., *J. Appl. Poly.Sci.*, 115 (2010) 1306-1314.
19. MacDiarmid A. G., Angew N. *Chem. Int. Ed. 40* (2001), 2581-2590.
20. Khairullin I. I., Khabibullaev P. K., Sokolov V. Y., Zakhidov A. A., *Tr. J. Physics 23* (1999) 1107-1126.
21. Bogush V., *J. Optoelec. and Adv. Mat.*, 7 (2005) 1635-1642.
22. Perumalraj R., Dasaradan B. S., *Fib. & Text.in East.Euro.*, 18 (2010) 74-80.
23. Sachdev V. K., Srivastava N. K., Kumar K., Mehra R. M., *Mat. Sci. Poland*, 23 (2005) 269-276.
24. Hamouni M., KhaldiS., *Rev. des Comp. et des Mat Av.*, 15 (2005) 157-172.
25. Hamouni M., Khaldi S., *Rev. des Comp. et des Mat Av*, 19 (2009) 201-213.
26. Hamouni M., Khaldi S., *Mat. & Tech.*, 97 (2009), 173-180.
27. Ranata B., Elias S., TahirS., *J. Fib Bioeng. & Infor.*, 2 (2010) 237-245.
28. Pande S., Singh B. P., Athur R. B., Dhami T. L., Saini P., Dhawan S. K., *Nanosc. Res. Lett.*, 4 (2009) 327-334.
29. Reda S.M., Sheikha M. A. G., *Amr. J. Nanotech.*, 4 (1) (2013) 16-22.
30. Parveen S., Veena C., *J. Appl. Polym. Sci.*, 129 (2013) 2832–2839.
31. Subhankar M., Kunal S., Pulak D., Mrinal S., *J. Saf. Engin.*, (2) (2013) 11-19.