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THE SHIELDING EFFECTIVENESS OF DIELECTRIC-CONDUCTIVE MATERIALS INVESTIGATED BY NUMERICAL ELECTROMAGNETIC TECHNIQUES

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Abstract. A special class of materials, dielectric-conductive structures, is investigated by numerical simulation and modeling. The properties of electromagnetic shielding applications are taken into account. The discussion reviews some of the basic problems encountered in developing numerical models to characterize the EMC using dielectric properties of materials and includes some practical details necessary for optimal results.

Key words: EMC (electromagnetic compatibility); electromagnetic modeling; dielectric measurements; electromagnetic wave.

1. Introduction

Electromagnetics is the scientific discipline that characterizes electric and magnetic sources and the fields that these sources produce in specified environments. Maxwell's equations provide the starting approach for the study of electromagnetic problems. Today, the continuing growth of computing resources is changing how we think about, formulate, solve, and interpret these problems. In electromagnetics as elsewhere, computational techniques are complementing the more traditional approaches of measurement and analysis to vastly broaden the breadth and depth of problems that are now quantifiable.

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Because of the high complexity of electromagnetic phenomena and of materials, we are using numerical techniques (FDTD – finite difference time domain) (Ursache *et al*., 2008) to simulate the fields. In this paper we investigate the interaction between a plane wave and a large sheet of dielectric material with conductive particles, at normal incidence for evaluating the shielding effectiveness (Steffan *et al*., 2010). The simulations for electromagnetic behavior of the material and the measurements of shielding effectiveness are made in the frequency range of 0...15.0 GHz using CST Microwave Studio, a software package dedicated to electromagnetic field analysis and design in high frequency. The CST Microwave Studio time domain solver calculates the development of fields through time at discrete locations and at discrete time samples. It calculates the transmission of energy between various ports and/or open space of the investigated material.

Composite materials are multiphase materials obtained by artificial combination of different components to gain properties that the individual materials cannot attain (Sudha *et al*., 2009). The structure under tests is a composite material and was made in nanocomposite form of extruded polysulfone with magnetite powder 10 nm sizes in the presence of oleic acid. Polysulfone has the highest service temperature of all melt-processable thermoplastics. The polysulfone pure is used as a dielectric in capacitors. The magnetite powder is in proportion of 1% and is used to increase conductivity of the composite material (Mathew *et al*., 2010).

2. Dielectric Measurements

The composite material was preliminary tested *via* dielectric spectroscopy. Dielectric analysis provides information about important dielectric parameters such as dielectric constant, dielectric loss, loss tangent and conductivity. Dielectric measurements were performed in the frequency range

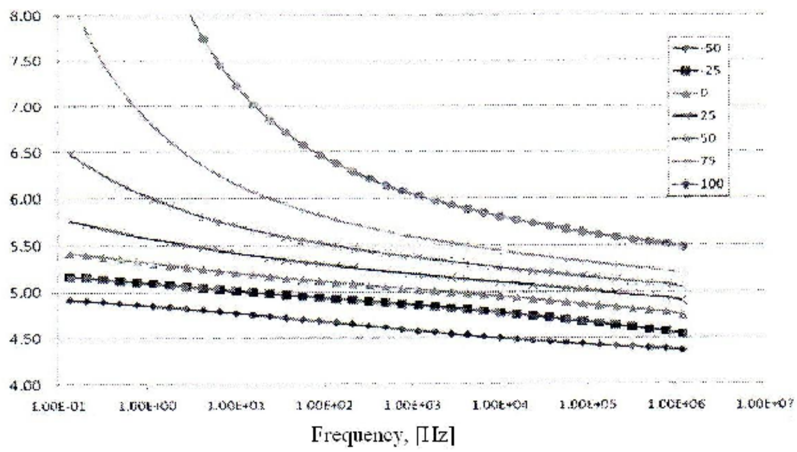

Fig. 1 – Dielectric permittivity (ε).

from 0.1 Hz to 3 GHz using a High Resolution Dielectric Alpha-Analyser (Novocontrol GmbH). Dielectric spectra (Fig.1 – dielectric permittivity and Fig. 2 – tangent of loss angle) were obtained at temperature of: –50°, –25°, 0°, 25°, 50°, 75°, 100°C. These characteristics are used in numerical simulations as input variables of the material (Koledintseva *et al.*, 2009).

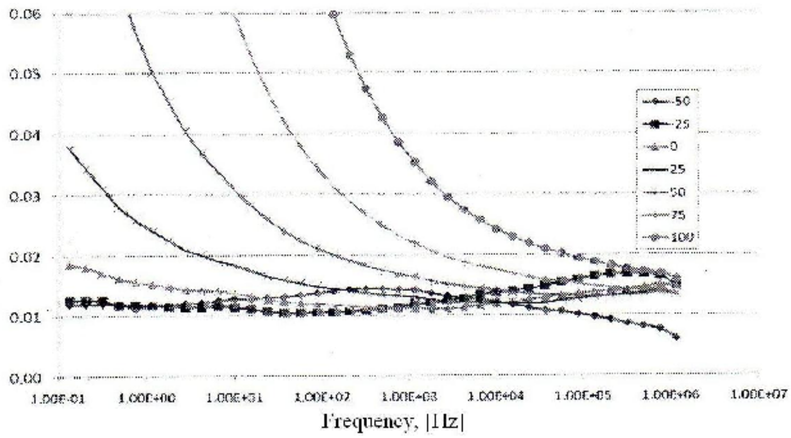

Fig. 2 – Tangent of loss angle.

3. Electromagnetic Simulations

Electromagnetic simulations that prove the electromagnetic performances of the material have been performed. The software used for simulations was CST Microwave Studio.

Electromagnetic simulation results show the *S*-parameters for the structure. The typical macroscopic parameters that define the reflectance, transmittance and absorption are defined relative to the electromagnetic power and are related to the *S*-parameters like in eqs. (Ciobanu *et al.*, 2008)

$$R = |S_{11}|^2 , \tag{1}$$

$$T = |S_{21}|^2 , \tag{2}$$

$$A = 1 - R - T = 1 - |S_{11}|^2 - |S_{21}|^2 . \tag{3}$$

The simulations were made in 0…15 GHz range with input conditions obtained in dielectric measurements. An input wave port is placed at some space from the structure. In order to simplify the computation in both time/memory consumption the losses inside the material where added only if they impact on the structure performance. In this case the second (exit) wave port is added. In the lossless case only eqs. (1) and (2) are used, the absorption being annulled in this case.

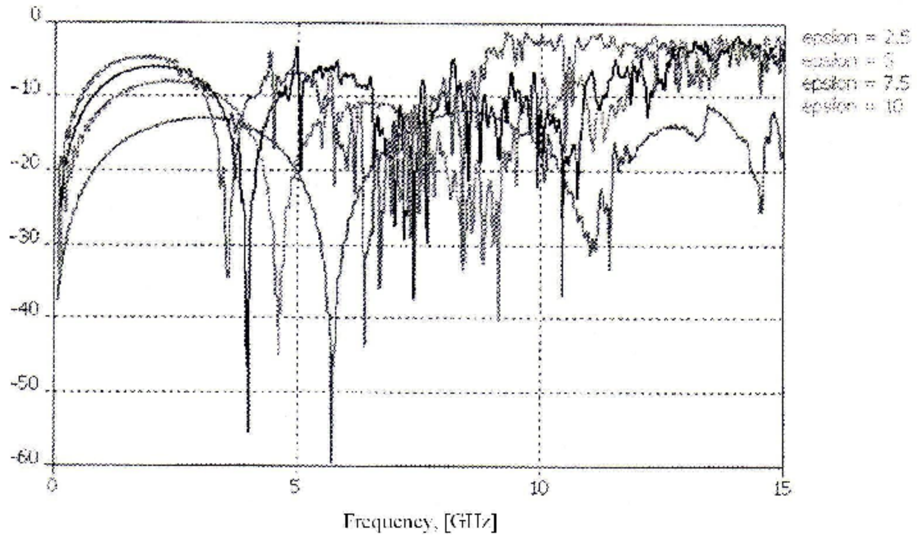

Fig. 3 – Reflectance *vs*. dielectric permittivity (ε).

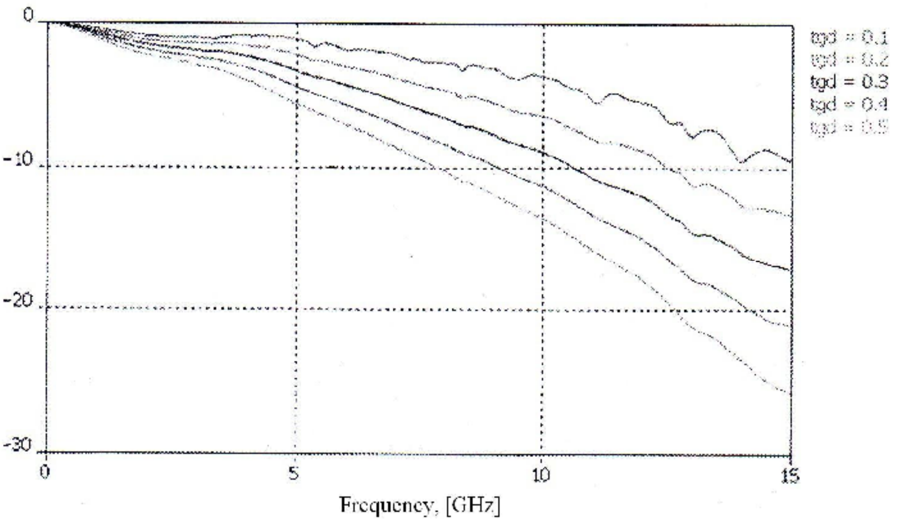

Fig. 4 – Transmission *vs.* losses.

Typical results (Koledintseva *et al*., 2009) are those from Figs. 3 and 4. Fig. 3 shows the S_{11} parameter, defining the electromagnetic reflective properties of the material. In Fig. 4, S_{21}, the electromagnetic transmission through the structure, is represented.

4. Conclusions

The evaluation of the electromagnetic properties of a composite material – polysulfone with magnetite powder 1%, was made *via* numerical simulations and modelations. The input variables (dielectric characteristics) were obtained with dielectric spectroscopy. The obtained results show that the shielding effectiveness depends on dielectric properties. The transmittance is influenced mainly by the losses in the dielectric, that means that the growing percent of metallic insertions, like magnetite powder, provide better results. We obtained a good enough attenuation ranging from 10…25 dB in the 1.2…2.8 GHz bandwidth (which cover GSM band, wireless communications and power line transmitters) which means that these kind of materials can be used as composite structures in shields for limiting electromagnetic pollution.

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REFERENCES

Ciobanu R., Damian R., Schreiner C., *Effects of Inhomogeneous Microwave Energy Dissipation on the Electromechanical Performance of the Auxetic Chiral Structures.* Sec. Internat. Conf. in Auxetics, Bristol, UK, September 14-17, 2008.

Koledintseva M.Y., Drewniak J., DuBroff R., *Modeling of Shielding Composite Materials and Structures for Microwave Frequencies*. Progr. in Electromag. Res. B, **15**, 197-215 (2009).

Koledintseva, M., Drewniak J., Zhang Y.J., Lenn J., Thoms M., *Modeling of Ferrite-Based Materials for Shielding Enclosures*. J. Magn. Magn. Mater., **321**, 730-733 (2009).

Mathew K.T., Kalappura U. ., Augustine R., Laheurte J.-M., Lakshmi K., *Enhanced EMI Shielding Efficiency Using Carbon, Graphite, and Polyaniline Blends*. Microwave a. Opt. Technol. Lett., **52**, 393-397 (2010).

Steffan P., Vrba R., Drinovsky J., *A New Measuring Method Suitable for Measuring Shielding Efficiency of Composite Materials with Carbon Fibers*. Fifth Internat. Conf. on Syst., Nice, France, August 22-27, 2010, 186-189.

Sudha J.D., Sivakala S., Prasanth R., Reena V.L., Radhakrishnan Nair P., *Enhanced Development of Electromagnetic Shielding Materials from the Conductive Blends of Polyaniline and Polyaniline-Clay Nanocomposite-EVA: Preparation and Properties*. Compos. Sci. a. Technol., **69**, *3-4*, 358-364 (2009).

Ursache S, Brânzilă M., Brătescu C., Burlacu R, *FDTD Implementations for Electromagnetic Shields*. J16th IMEKO TC4 Symp., 13th Workshop on ADC Modeling and Testing, Florence, Italy, Sept. 22-24, 2008.

EFICACITATEA DE ECRANARE A MATERIALELOR DIELECTRIC-CONDUCTIVE, INVESTIGATĂ PRIN TEHNICI NUMERICE ÎN DOMENIUL ELECTROMAGNETIC

(Rezumat)

Se prezintă caracteristicile dielectrice şi proprietăţile de ecranare ale unui material compozit, o structură dielectric conductivă obţinută în formă extrudată din polisulfonă cu pulbere de magnetită în proporţie de 1%. Adăugarea magnetitei s-a făcut pentru a creşte conductivitatea materialului. S-au făcut măsurători ale parametrilor de material utilizând tehnica spectroscopiei dielectrice obţinându-se permitivitatea şi tangenta unghiului de pierderi, aceste caracteristici fiind necesare ca parametri iniţiali în modelările şi simulările numerice. S-au stabilit, în urma calculelor numerice, proprietăţile electromagnetice care sunt dependente de parametrii de material. S-au observat rezultate bune în domeniul de frecvenţe de interes (1,2...2,8 GHz) obţinându-se o eficacitate de ecranare de 10...25 dB, ceea ce denotă bune proprietăţi electromagnetice ale materialului putând fi utilizat în realizarea ecranelor de protecţie împotriva radiaţiilor electromagnetice.