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ABOUT A SIMULATION METHOD OF THE MAGNETODIELECTRICAL MATERIALS PROPERTIES IN RADIOFREQUENCY MAGNETIC FIELDS

M. Osaci[*]
Technical University of Timişoara, Hunedoara Engineering Faculty
Str. Revolutiei, no.5 Hunedoara, 2750, Romania

Abstract

This paper present the programming of the simulation method which permit to study the influence of the magnetically radio frequency fields on the magnetodielectrical materials properties.This method was published in Journal of Magnetism and Magnetic Materials 234 (2001) , p. 148 – 152.

The proposed method can be used to simulate the dependency of magnetic permeability on the frequency for different values of magnetic permeability on the frequency for different values of volume ratio magnetic particles in dielectrically matrix, knowing the magnetic particles properties on the different frequency.

The programs package, having a interactive graphical interface, can be ruled from Matlab 5.0 medium.

Keywords: Magnetodielectric material; Simulation; Effective complex magnetic permeability; Effective complex electric permittivity

1. The Simulation Method Introduced for Magnetodielectric Materials

We suggest another variant of simulation for the effective magnetodielectric properties of the composite media, characterized by complex magnetic permeability and complex electric permittivity, without resorting to the method of the finite element.

We consider a resonant cavity of parallelipipedic shape and having the dimensions l_x, l_y, and l_z. We divide this cavity into cubes of unitary dimensions. The number of cubes will then be $n = l_x l_y l_z$. We regard each unitary cube of the mixture as a small resonator, the effective magnitude $\overline{(\varepsilon\mu)}$ for the material filling the cavity, made up of magnetic powder P in a dielectric matrix M is the arithmetic mean of magnitudes effective $\overline{(\varepsilon\mu)}_i$, simulated for each unitary-dimensional cube, i.e.:

$$\overline{(\varepsilon\mu)} = \frac{\sum_{i=1}^{n} (\varepsilon\mu)_i}{n} \tag{1}$$

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[*] **Corresponding author:** ***E-mail:*** m.osaci@fih.utt.ro, ***Tel. 054/712538, Fax:054/713400***

We suppose each elementary cube filled randomly with material P or M, i.e. inside the cavity with elementary cubes the volume fraction of powder P is a random variable of lognormal distribution, so that the mean of this random variable all over the cavity be the volume fraction under consideration. The distribution density of the lognormal law of the powder volume fraction is [2], [3] :

$$F(f) = \frac{1}{\sqrt{2\pi} f\sigma} \exp\left[-\frac{\left(\ln \frac{f}{f_0^{\sigma+1}} \right)^2}{2\sigma^2} \right] \tag{2}$$

Through the simulation method for a lognormal random variable, we generate n random numbers lognormally distributed.

$$f_i = e^z = e^{\sigma \cdot u_i + \ln f_0^{\sigma+1}} \tag{3}$$

where u_i is random variables normally distributed, of mean 0 and variance 1.

2. The Algorithm of the Method

The algorithm of the simulation consists in the following steps:
1.The resonant cavity is divided into n elementary cubes;
2.We establish the value of the volume fraction of the powder over the entire material f;
3.We generate random numbers normally distributed, of mean 0 and variance 1 u_i;
5.We generate the random variables f_i, lognormally distributed, so that their statistic mean be equal to f; each f_i is the volume fraction for each elementary cube;
6.We simulate for each cube

$$\begin{aligned} (\varepsilon\mu)_i &= [f_i(\mu_P - 1) + 1] \cdot [f_i(\varepsilon_P - 1) + 1] \\ \varepsilon_i &= f_i(\varepsilon_P - 1) + 1 \\ \mu_i &= f_i(\mu_P - 1) + 1 \end{aligned} \tag{4}$$

$$\overline{(\varepsilon\mu)} = \frac{\sum_{i=1}^{n} (\varepsilon\mu)_i}{n}$$

7.We calculate the means

$$\bar{\varepsilon} = \frac{\sum_{i=1}^{n} \varepsilon_i}{n} \qquad \bar{\mu} = \frac{\sum_{i=1}^{n} \mu_i}{n} \tag{5}$$

8. We compare $\overline{(\varepsilon\mu)}$ with the product $\bar{\varepsilon} \cdot \bar{\mu}$. If the difference between the two magnitudes is smaller or equal to a previously established error, we retain the values, if not, the algorithm is repeated.

3. Programming the simulation method

The method can be used for the simulation of magnetodielectric material behavior under various work frequencies. It is necessary to know the structure of the mixture, the complex magnetic permeabilities and the complex electric permittivities of the components under different frequencies, in order to have a clear, overall image on the way the material will behave under different frequencies.

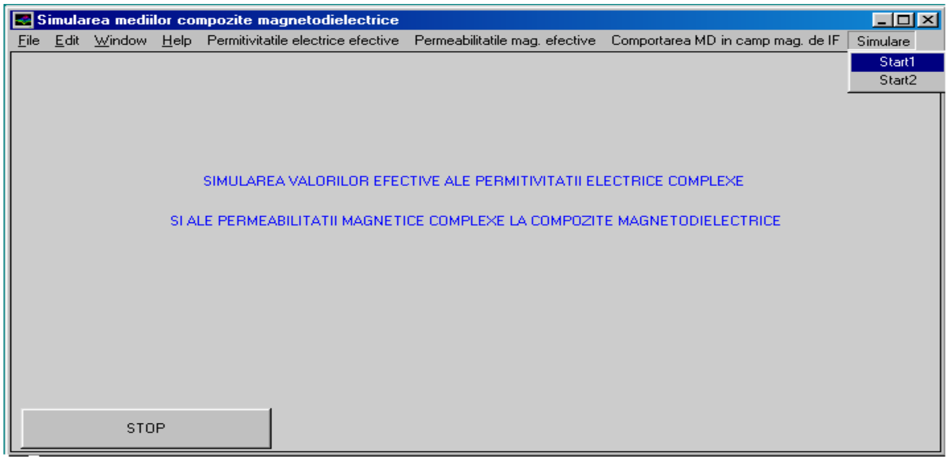
For instance, suppose we want to study by simulation a magnetic-dielectric made up of magnetic powders for which we know the variation of the complex magnetic permeability according to frequency (table1) and an organic material for which, for the sake of simplicity $\varepsilon_M = \mu_M = 1$.

Table 1

f(MHz)	μ'	μ''
6	1.5562	0.0009
8	1.5638	0.0013
10	1.5438	0.0005
12	1.5622	0.0015
14	1.5765	0.0016
16	1.5739	0.0021
18	1.5864	0.0021
20	1.5721	0.0020
22	1.5847	0.0026
24	1.5962	0.0040
26	1.5968	0.0047
28	1.6086	0.0044
30	1.6191	0.0047
32	1.7178	0.0043
34	1.6527	0.0040

By simulation we can find out the way in which the components of complex permeability and the tangent of the angle depend on losses of frequency and on the volume fraction of the powder in the mixture.

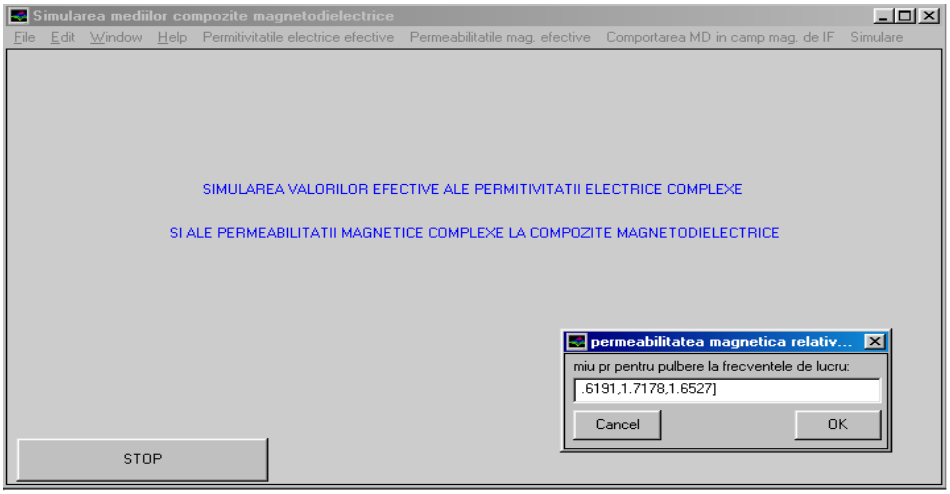
The programs package, having a interactive graphical interface, can be ruled from Matlab 5.0 medium. For the data given in table 1, the results of the simulation are given in a graphical form in fig.1, 2, 3, 4, and 5.



SIMULAREA VALORILOR EFECTIVE ALE PERMITIVITATII ELECTRICE COMPLEXE

SI ALE PERMEABILITATII MAGNETICE COMPLEXE LA COMPOZITE MAGNETODIELECTRICE

Fig. 1 Principal form



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.6191,1.7178,1.6527]

Fig. 2 Introduction μ′ = f(f) for magnetic particles

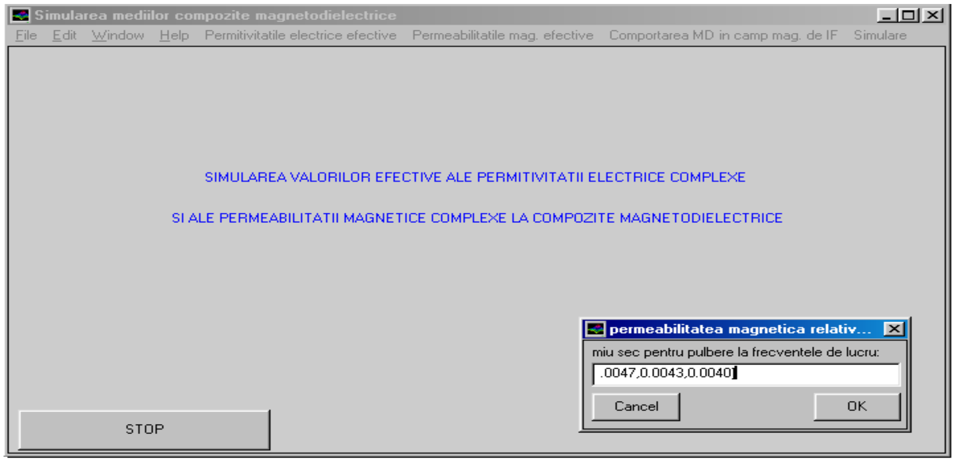

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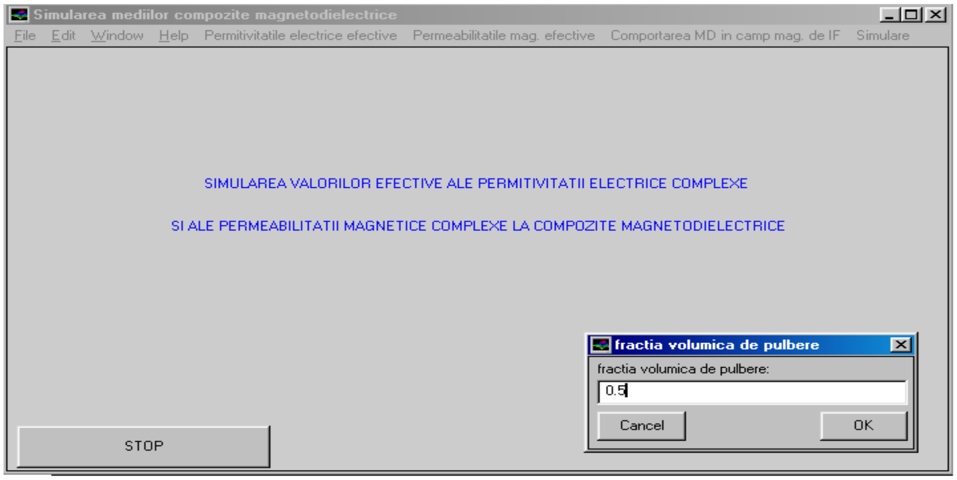
Fig. 3 Introduction μ″ =f(f) for magnetic particles



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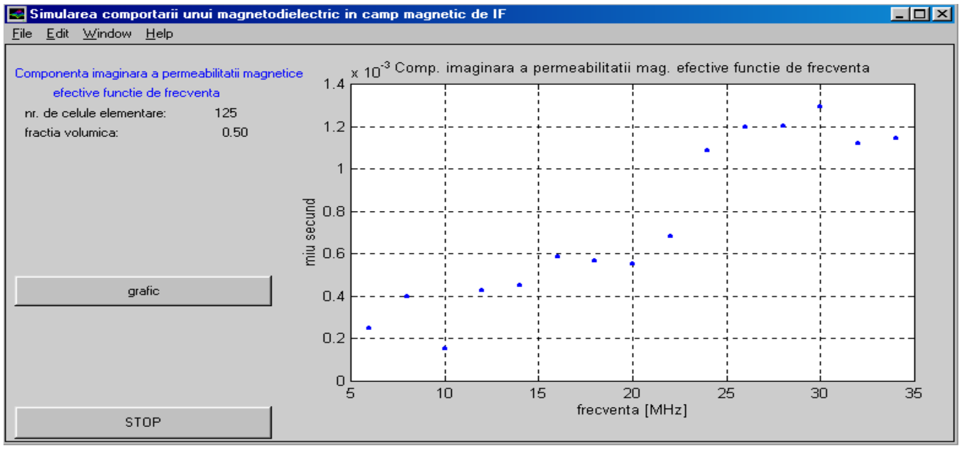
fractia volumica de pulbere:

0.5

Fig. 4 Introduction value for volume fraction


Simularea comportarii unui magnetodielectric in camp magnetic de IF

Componenta imaginara a permeabilitatii magnetice efective functie de frecventa

nr. de celule elementare: 125

fractia volumica: 0.50

Fig.5 μ'' =f(f) for magnetodielectric

4. Conclusion

The method of simulating the magnetodielectric composite media present here is less complicated than the Leinders method [1], using an algorithm easier to programming. It can be, also, successfully used for the simulation of behavior magnetodielectric materials under various work frequencies.

References

[1]H. Leinders,A.Enders,J.Phys.I.France,5(1995),555- 564

[2]I.Sacuiu, D.Zorilescu,The Random Numbers, Applications in Economy, Industry and in the Study Natural Phenomenon, Academy Publishing, Buc., 1978

[3]I. Mihoc, Calculus of probability and mathematical statistics, Cluj-Napoca, 1994