UDC 699.887:537.8:004.942

Ján Zbojovsky, Pavol Liptai, Marek Moravec

MODELLING AND CALCULATING THE SHIELDING EFFECTIVENESS OF BUILDING MATERIALS

Ян Збойовський, Павол Ліптай, Марек Моравець

РОЗРАХУНОК ЕФЕКТИВНОСТІ ЕКРАНІЗУВАННЯ БУДІВЕЛЬНИХ МАТЕРІАЛІВ НА ОСНОВІ МОДЕЛЮВАННЯ РОЗКЛАДУ ЕЛЕКТРОМАГНІТНОГО ПОЛЯ

Ян Збойовский, Павол Липтай, Марек Моравец

РАСЧЕТ ЭФФЕКТИВНОСТИ ЭКРАНИРОВАНИЯ СТРОИТЕЛЬНЫХ МАТЕРИАЛОВ НА ОСНОВЕ МОДЕЛИРОВАНИИ РАСПРЕДЕЛЕНИЯ ЭЛЕКТРОМАГНИТНОГО ПОЛЯ

This paper deals with modelling the penetration and absorption of high frequency electromagnetic field through the building material. It is focused on distribution of electromagnetic field in frequency range from 1.5 to 5.0 GHz, penetrating through the building material of different thickness. Nowadays in some domestic appliances and wide area exists a lot of electric and electronic devices, which are the sources of electromagnetic interference. To protect against electromagnetic interference in first case is important design concept of the devices, and some additional protection can be represented by construction works of rooms or building. For this reason, the article sets out to evaluate the shielding effectiveness and absorption of specific building materials in term of their harmful effect on the human body. Simulation of the penetration of HF electromagnetic field is created in the ANSYS HFSS.

Key words: *electromagnetic field, propagation, shielding, Ansys.*

Fig.: 4. Tabl.: 3. Bibl.: 7.

Розглянуто моделювання проникнення і поглинання високочастотного електромагнітного поля будівельними матеріалами. Основна увага зосереджена на поширенні електромагнітного поля, що проникає через будівельні матеріали з різними характеристиками в діапазоні частот від 1,5 до 5 ГГц. Нині є багато електричного і електронного обладнання, яке є джерелом електромагнітних завад. Щоб звести до мінімуму це втручання, дуже важливо правильно спроектувати конструкцію, причому додатковий захист можна забезпечити зо допомогою екранування окремих частин обладнання. З урахуванням вищевикладеного, проведено оцінювання ефективності екранування на певних будівельних матеріалах і їх комбінацій з метою підвищення ефективності екранування. Розрахунки проводилися у програмному комплексі ANSYS HFSS.

Ключові слова: *електромагнітне поле, поширення електромагнітного поля, екранування, ефективність екранування, Ansys.*

Рис.: 4. Табл.: 3. Бібл.: 7.

Рассмотрено моделирование проникания и поглощения высокочастотного электромагнитного поля строительными материалами. Основное внимание уделяется распределению электромагнитного поля, проникающего через строительные материалы разных свойств в частотном диапазоне од 1,5 до 5 ГГц. В настоящее время существует целый ряд электрического и электронного оборудования, которое является источником электромагнитных помех. Чтобы свести к минимуму помехи, при разработке этого оборудования очень важно правильно спроектировать конструкцию, причем дополнительную защиту можно обеспечить с помощью достаточного экранирования отдельных частей оборудования. С учетом вышеизложенного, проведена оценка эффективности экранирования определенных строительных материалов и их комбинаций с целью повышения его эффективности. Симуляции были произведены на программном комплексе ANSYS HFSS.

Ключевые слова: *электромагнитное поле, распространение волн, экранирование, эффективность экранирования, Ansys.*

Рис.: 4. Табл.: 3. Библ.: 7.

Introduction. We can say that nowadays everyone is exposed to electric and magnetic fields generated from electricity transmission, telecommunication, broadcasting devices, aviation and from industrial area. The electromagnetic fields exposition has been continually increasing since the 20th century. Based on numerous scientific studies it is established, that exposition to electromagnetic field can affect the correct function of devices, and can cause harmful effects on biological organism. For example, one case from 1984. The fighter aircraft has crashed near Munich due to the interference of the electronic control system by electromagnetic waves. Therefore it is necessary to protect equipment's and biological organisms against the harmful effect. Electrical systems must be resistant against the activity of other systems and cannot adversely affect the normal operation of other systems and devices. Electromagnetic interference can cause severe problems, and this should be taken

© Збойовський Я., Ліптай П., Моравець М., 2016

into account during the design of new equipment. Shielding is commonly used to protect against the harmful effect of electromagnetic field.

Modeling of electromagnetic fields around electrical equipment and in each part of these devices are now an important part of the development and analysis which are important to the quality of equipment with regard to electromagnetic compatibility. These analyzes are performed by computing program. The simulation is performed in the program Ansys high frequency structural simulator. In this article is simulated and calculated the shielding effectiveness of field penetration through the glass and brick, and combinations with conductive surface. Frequency range is from 1.5 GHz to 5 GHz and simulations are created in HFSS (High frequency structural simulator). In the conclusion is described the comparison of shielding effectiveness for common frequencies using in telecommunication area.[1][2][3][4]

1. Equations of the electromagnetic field

The electromagnetic field is characterized as a physical field in which the electric and magnetic forces operate in the space.

It is described by Maxwell's equations:

$$\nabla \times \mathrm{H} = \mathrm{J} + \frac{\partial}{\partial t}\mathrm{D}; \tag{1}$$

$$\nabla \times \mathrm{E} = -\frac{\partial}{\partial t}\mathrm{B}; \tag{2}$$

$$\nabla \cdot \mathrm{B} = 0 \qquad \nabla \cdot \mathrm{D} = \rho. \tag{3}$$

And supplementary equations:

$$\mathrm{B} = \mu \mathrm{H} \qquad \mathrm{D} = \varepsilon \mathrm{E}; \tag{4}$$

$$\frac{1}{\mu_r\, \mu_0}\left(\frac{\partial^2 A}{\partial \mathrm{x}^2} + \frac{\partial^2 A}{\partial \mathrm{y}^2} + \frac{\partial^2 A}{\partial \mathrm{z}^2}\right) = -J_z + \mathrm{j}\,\omega\,\gamma\, A. \tag{5}$$

The electromagnetic compatibility (EMC) is divided to EMC of biological systems and EMC of technical systems. The EMC of biological systems dealt with effects of electromagnetic field on human organism and they have been published in many research works. The EMC of technical systems deals with the interaction and coexistence of technical equipment, especially electrical and electronic devices and equipment. [3], [4]

As it was mentioned above, one of the basic ways to protect against harmful effect and interference between equipment's is shielding. [5], [6]

Shielding effectiveness can be expressed by:

$$SE = |E_1| - |E_2 \tag{6}$$

$$SE = |H_1| - |H_2 \tag{7}$$

Where E_1, H_1 represents the magnitude of electric and magnetic field impinging on a shielding material (barrier) and E_2, H_2 represents the magnitude of electric and magnetic field at some specific point of shielded area. [7] These equations is for case, if the value of the transmitted signal is set in logarithmic unit.

2. Modelling the propagation of electromagnetic waves and calculation of shielding effectiveness

The electromagnetic field simulations depending on frequency are realized in the program HFSS (High Frequency Structure Simulator). HFSS is a high-performance full-wave electromagnetic field simulator for arbitrary 3D volumetric passive device modeling and uses a numerical technique called the Finite Element Method (FEM), Integral Equation (IE) or Physical Optics (PO) solution techniques.

A model is represented by waveguide with input and output ports, in the center of which the shielding material is located. The input power is 1W and frequency range is set from 1.5

to 5 GHz, with step 0.01 GHz. Convergence was created to 6 steps. On the following picture the waveguide model is shown. The surrounding area is air.

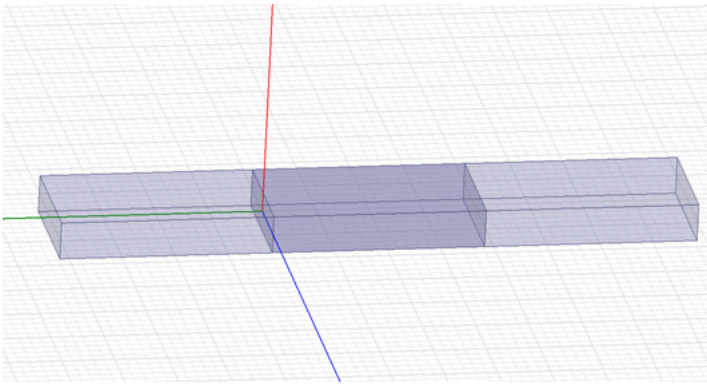

Fig. 1. Model of waveguide

Table 1

Material properties

Material	Relative permitivity	Relative permeability
Air	1.0006	1.0000004
Glass	5.5	1
Brick	4.01	1

Next picture represents the propagation of electromagnetic wave through the glass with thickness 0.5 cm.

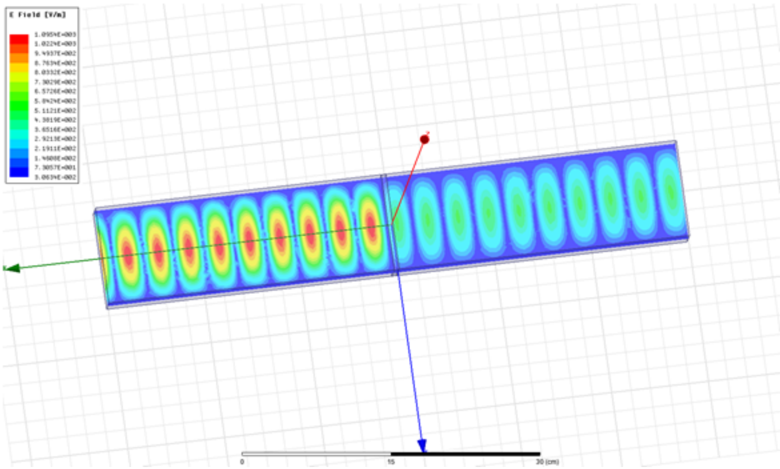

Fig. 2. The electromagnetic wave propagation for glass (thickness 0.5cm)

The average value of shielding effectiveness for glass is 0.0002 dB.

On the following picture (Fig. 3) is shown the propagation of electromagnetic wave through the glass and conductive surface with resistance 50 ohm.

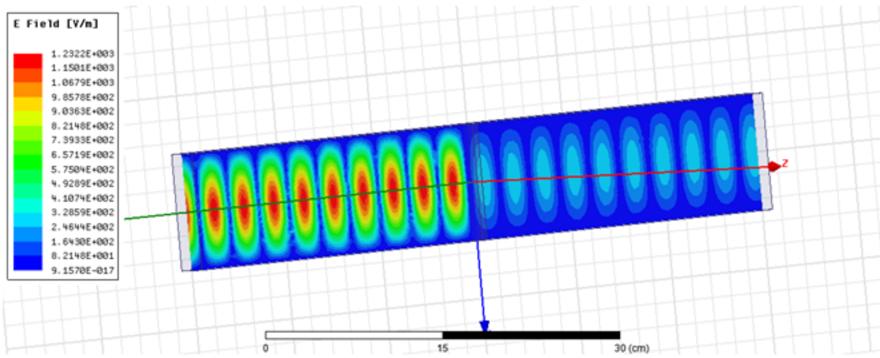

Fig. 3. The electromagnetic wave propagation for glass (thickness 0.5cm) and conductive surface

The average value of shielding effectiveness in that case is 3.4175 dB.

The propagation of electromagnetic wave through the brick and conductive surface with resistance 50 ohm is shown on the last picture.

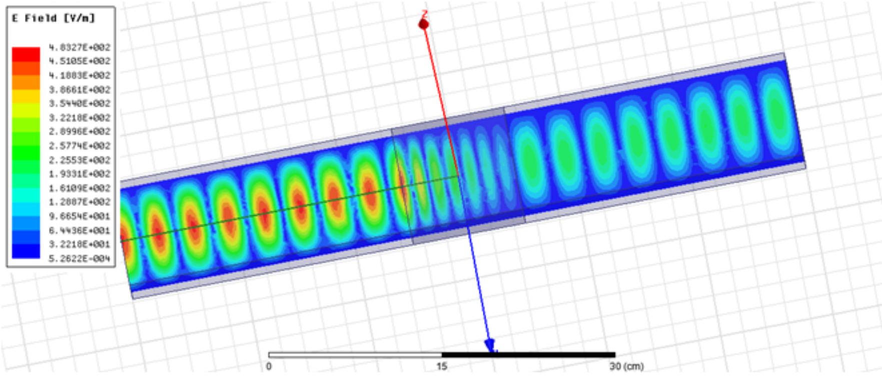

Fig. 4 The electromagnetic wave propagation for brick (thickness 10cm)

The average value of shielding effectiveness for brick with thickness 10 cm is 0.0233 dB.

Generaly, shielding effectiveness of building materials is very low. If we want to increase the shielding effectiveness it is appropriate to combine the materials.The following tables shows the frequencies, for which is the shielding effectiveness calculated, calculated shielding effectiveness and average value of shielding effectiveness.

Table 2

Frequencies for comparing of the shielding effectiveness

Frequency [GHz]	Utilization
1.8	Mobile network (2G)
2.1	Mobile network (3G)
2.4	WiFi
2.6	Mobile network (4G LTE)
5	WiFi

Table 3

Calculated shielding effectiveness

Frequency [GHz]	Shielding material	Shielding effectiveness [dB]
1,8	Glass 0.5 cm	0,000011
	Glass – conductive surface 50 ohm	0,2870721
	Brick thickness 10 cm	0,000899
2,1	Glass 0.5 cm	0,000042
	Glass – conductive surface 50 ohm	0,5343802
	Brick thickness 10 cm	0,000176
2,4	Glass 0.5 cm	0,000299
	Glass – conductive surface 50 ohm	0,8451156
	Brick thickness 10 cm	0,002037
2,6	Glass 0.5 cm	0,0000264
	Glass – conductive surface 50 ohm	1,10207195
	Brick thickness 10 cm	0,003566
5	Glass 0.5 cm	0,0001325
	Glass – conductive surface 50 ohm	11,0739871
	Brick thickness10 cm	0,112538

Conclusion. This paper was aimed to determinate the shielding effectiveness of glass, brick and combinations of some materials. This was achieved by simulation of electromagnetic field in computational software Ansys HFSS. Frequency range was from 1.5 to 5 GHz with step 0.01. The average value of shielding effectiveness for glass with thickness 0.5 cm was 0.0003dB. It means that glass shield the electromagnetic field minimally. For combinations glass + conductive surface with 50 ohm it was 3.4175dB. The average value of shielding effectiveness for brick with thickness 10 cm is 0.0233 dB. Then the shielding effectiveness for frequencies using in telecommunications was compared. The best value of shielding effectiveness achieved combination glass + conductive surface for frequency 5 GHz and it was 11.0739871 dB.

In this article there were shown the simulations of the electromagnetic field distribution and calculated shielding effectiveness some building materials with different thickness and with conductive surface.

In the future it will be interest to investigate the shielding of electromagnetic field, with wider frequency range, and with various building and other materials which can be used as an appropriate shielding material for various equipment's.

Acknowledgement. This work is the result of the project implementation: Protection of the population of the Slovak Republic from the effects of electromagnetic fields, ITMS: 26220220145, Activity 2.1 supported by the Research & Development Operational Programme funded by the ERDF.

This work was supported by project VEGA SR No.1/0132/15 and APVV 0432-12.

This work was supported by project: Convergence, Regional Competitiveness and Employment ITMS: 26210120002, 26230120002.

References

1. IEEE Guide--Adoption of IEC/TR 61000-3-7:2008, „Electromagnetic compatibility (EMC)--Limits--Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems“ IEEE Std 1453.1-2012 (Adoption of IEC/TR 61000-3-7:2008), 78 p., 2012, E-ISBN: 978-0-7381-7285-9J.

2. P. Vecchia, et al. "Exposure to high frequency electromagnetic fields, biological effects and health consequences (100kHz to 300GHz)", INCIRP 16/2009.

3. R YOSHINO, Y., SHOTA, I., MICHIHIKO, K., MASAO, T., Assessment of human exposure to electromagnetic field from an intra-body communication device using intermediate-frequency electric field, International Symposium on Electromagnetic Compatibility (EMC EUROPE), 2012, 17-21.9.2012, Rome, s. 1-4.

4. B. Dolník, Electromagnetic compatibility. (Elektromagnetická kompatibilita). TU of Košice, dec. 2013, monography.

5. Vaimann, T.; Belahcen, A.; Kallaste, A. (2014). Changing of magnetic flux density distribution in a squirrel-cage induction motor with broken rotor bars. Electronics and Electrical Engineering, 20 (7), pp. 11–14.

6. M.S. Zhdanova, I.M.Varentsov, et al.: "Methods for modelling electromagnetic fields – Results from COMMEMI—the international project on the comparison of modelling methods for electromagnetic induction" Journal of Applied Geophysics, 1997, 133–271 s.

7. M. Pavlik, M. Lison, P. Kurimsky, Measuring of electromagnetic field shielding in the frequency range from 1 GHz to 9 GHz for windows in: Elektroenergetika 2015. - Košice : TU, 2015, s. 560-563.

Ján Zbojovský – Doctor of Technical Sciences, Research Fellow, Technical University of Kosice (Letna 9 Str., 04200 Kosice, Slovakia).
Ян Збойовський – доктор технічних наук, науковий співробітник, Технічний університет Кошице (Letna 9 Str., 04200 Kosice, Slovakia).
Ян Збойовский – доктор технических наук, научный сотрудник, Технический университет Кошице (Letna 9 Str., 04200 Kosice, Slovakia).
E-mail: jan.zbojovsky@tuke.sk
ORCID: orcid.org/0000-0003-4383-3996
Scopus Author ID: 56119728300
ResearcherID: R-3952-2016

Pavol Liptai – Doctor of Technical Sciences, Assistant Professor, Technical University of Kosice (Letna 9 Str., 04200 Kosice, Slovakia).

Павол Ліптай – доктор технічних наук, доцент, Технічний університет Кошице (Letna 9 Str., 04200 Kosice, Slovakia).
Павол Липтай – доктор технических наук, доцент, Технический университет Кошице (Letna 9 Str., 04200 Kosice, Slovakia).
E-mail: pavol.liptai@tuke.sk
ORCID: orcid.org/0000-0001-8197-6627
Scopus Author ID: 56006964600
ResearcherID: P-2766-2016

Marek Moravec – Doctor of Technical Sciences, Assistant Professor, Technical University of Kosice (Letna 9 Str., 04200 Kosice, Slovakia).
Марек Моравець – доктор технічних наук, доцент, Технічний університет Кошице (Letna 9 Str., 04200 Kosice, Slovakia).
Марек Моравец – доктор технических наук, доцент, Технический университет Кошице (Letna 9 Str., 04200 Kosice, Slovakia).
E-mail: marek.moravec@tuke.sk
ORCID: orcid.org/0000-0001-8878-3457
Scopus Author ID: 55971454800

Zbojovsky, J., Liptai, P., Moravec, M. (2016). Modelling and calculating the shielding effectiveness of building materials. *Technical sciences and technologies*, no. 4 (6), pp. 205-210.