MEASURING OF DEPENDENCE OF SHIELDING EFFECTIVENESS OF WET MATERIALS ON THE FREQUENCY OF ELECTROMAGNETIC FIELD IN THE HIGH FREQUENCY RANGE

Marek PAVLÍK, Iraida KOLCUNOVÁ, Bystrík DOLNÍK, Juraj KURIMSKÝ, Alexander MÉSZÁROS, Dušan MEDVEĎ, Michal KOLCUN, Ján ZBOJOVSKÝ
Department of Electric Power Engineering, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Letná 9, 042 00 Košice, Slovak Republic, e-mail: marek.pavlik@tuke.sk, iraida.kolcunova@tuke.sk, bystrik.dolnik@tuke.sk, juraj.kurimsky@tuke.sk, alexander.meszaros@tuke.sk, dusan.medved@tuke.sk, michal.kolcun@tuke.sk, michal.kolcun@tuke.sk

ABSTRACT
This paper deals with measuring of shielding effectiveness of electromagnetic field. The measurements were focused on shielding effectiveness while gradually drying out building materials in the range of high frequencies from 1 GHz to 13 GHz. The measured object was fiber cement board facade Eterplan and exterior facade board Natura Pro. Thickness of the boards were 8 mm. The measurement should prove that the shielding effectiveness of electromagnetic field of the wet materials is higher than the dry materials.

Keywords: *shielding effectiveness, electromagnetic field, high frequencies*

1. INTRODUCTION

We are witnessing an increase of resources of electromagnetic radiation which in the past were not so great. Wireless on the one hand provides convenience and speed of communication but on the other hand brings some negatives that are in the world more and more discussed topic.

It should be noted that the sources of the electromagnetic field not only negatively affect the human body. A well-known example of the beneficial uses of source of electromagnetic radiation at higher frequencies is the thermal hyperthermia which is described in [1].

Wireless communication is not only represented in the IT sector, but also the constant development in the medical environment requires the use of this type of communication. In the medical field, there are many applications using wireless communication just for capturing and monitoring of the human body, the output data are collected from the human body.

The wireless communication provides long-term monitoring activities of the human body even under severe conditions [2].

We are exposed electromagnetic radiation everytime and everywhere. The trend of volume of sources of electromagnetic radiation will increase. As ordinary persons we can not with our senses perceive electromagnetic radiation. This mean that human is so benevolent to potential threats. That is why it is a topic of increasing sources of electromagnetic radiation and its impact on human body for the general public so current.

The opinions on this topic are different. On the one hand manufacturers of devices operating on the principle of electromagnetic field claiming that their funds are safe. And on the other stands the World Health Organization which say opposite. The time of use of such devices is relatively short. We can not say with certainty whether these devices cause health risks or not.

Wide professional community more and more focused to resources of electromagnetic fields, their impact and the associated concept of electromagnetic compatibility.

2. SHIELDING EFFECTIVENESS

Shielding of electromagnetic field can be defined as a ability of material to defend of the penetration of the electromagnetic field. Various types of equipment use shielding in various fields of our daily lives. This is mobile phones, mobile stations, wifi devices to provide internet through a variety of medical devices, communications networks, electronic devices and so on. This concept closely related with electromagnetic compatibility. Electromagnetic compatibility could be defined as the ability of devices to coexist in the same electromagnetic environment [1] [3] [5].

Quality shielding material are determined by three coefficients, K_S shielding coefficient, absorption coefficient A and a reflection coefficient R. The shielding effectiveness SE closely related with coefficient K_S, R, and A. Shielding coefficient K_S is determined by the intensity of electric field strength E, possibly based on the intensity of the magnetic field H by the relation:

$$K_S = \frac{E_2}{E_1}; K_S = \frac{H_2}{H_1} \tag{1}$$

where E_2 is intensity of electric field measured using the antenna placed in the prescribed configuration within the enclosure, E_1 is intensity of electric field measured using the antenna placed in the prescribed configuration in the absence of the enclosure, H_2 is intensity of magnetic field measured using the antenna placed in the prescribed configuration within the enclosure, H_1 is intensity of magnetic field measured using the antenna placed in the prescribed configuration in the absence of the enclosure

Shielding effectiveness SE is calculated using the formula (2-4) if intensity of electric field and intensity of magnetic field is in basic unit.

$$SE = 20.\log\frac{1}{|K_S|} = 20.\log\frac{|H_1|}{|H_2|} = 20.\log\frac{|E_1|}{|E_2|}[dB] \tag{2}$$

Formula varies for determining of the shielding effectiveness SE according to the frequency range. According to [4], the shielding effectiveness is determined by the relationship:

$$SE = 20.\log\frac{|H_1|}{|H_2|} = 20.\log\frac{|V_1|}{|V_2|}[dB] \tag{3}$$

For the frequency range from 50 Hz to 20 MHz and for the frequency range from 20 MHz to 300 MHz and also the same applies to the frequency range 300 MHz to 100 GHz

$$SE = 20.\log\frac{|E_1|}{|E_2|} = 10.\log\frac{P_1}{P_2}[dB] \tag{4}$$

where H_2, E_2 is intensity of magnetic and intensity of electric field measured using the antenna placed in the prescribed configuration within the enclosure, H_1, E_1 is intensity of magnetic and intensity of electric field measured using the antenna placed in the prescribed configuration in the absence of the enclosure, V_2 is voltage reading within the enclosure, V_1 is voltage reading in the absence of the enclosure and P_2 is power detected within the enclosure, P_1 is power detected in absence of the enclosure.

According to [5] shielding effectiveness is the sum of the reflection R, multiple reflection B and absorption A of electromagnetic field derived as [6]:

$$SE = A + R + B \tag{5}$$

$$SE = 15{,}4t\sqrt{f.\mu.\sigma} + 168{,}16 - 10\log\frac{\mu_R.f}{\sigma_R} + 20\log\left(1 - e^{\frac{2t}{\delta}}\right)$$

where t is material thickness, σ is conductivity of shielding material, σ_R is the relative conductivity, μ_R is the relative permeability of shielding material, μ is the permeability of shielding material, f is frequency, δ is depth of penetration. For simplicity, it is possible to determine the shielding effectiveness SE also as (6) without multiple reflection B.

$$SE = A + R \tag{6}$$

$$SE = 8{,}69.\frac{t}{\sqrt{\frac{2}{\omega.\mu.\sigma}}} + 20.\log\left(\frac{1}{4}.\sqrt{\frac{\sigma}{\omega.\mu_r.\varepsilon_0}}\right)$$

where μ is permeability which is included permeability of the shielding material, ε_0 is permittivity of vacuum. The relationship (6) is simplified relationship of (5). Both terms are correct but from other literatures.

From equation (6) we can see, the relative permeability and relative conductivity affect shielding effectiveness SE [5].

Shielding effectiveness can be calculated according to the relations (7-10) if the value of the transmitted signal is set in logarithmic unit.

$$SE = |E_{1\log}|(dB) - |E_{2\log}|(dB) \tag{7}$$

$$SE = |H_{1\log}|(dB) - |H_{2\log}|(dB) \tag{8}$$

$$SE = |V_{1\log}|(dB) - |V_{2\log}|(dB) \tag{9}$$

$$SE = P_{1\log}(dB) - P_{2\log}(dB) \tag{10}$$

Formula (7), (8), (9), (10) is used according to the available measuring equipments.

3. WORKPLACE FOR THE PURPOSE OF MEASURING SHIELDING EFFECTIVENESS OF ELECTROMAGNETIC FIELD

Block diagram for the purpose of measuring of shielding effectiveness SE of the electromagnetic field is shown in Fig.1 and view to the workplace for the purpose of measuring of the shielding effectiveness in Fig.2 and Fig.3. This workplace consists of a pulse generator Agilent N5181A spectrum analyzer Agilent N9038A MXE EMI (Fig.2), the receiving antenna and transmitting antenna horn type (Fig.3). Measured objects were placed at a distance of 30 cm from the transmitting antenna. The whole measurement was carried out in an anechoic chamber at the Department of Electrical Power Engineering of FEI TU and there is no extraneous influence of electromagnetic field on the measurement.

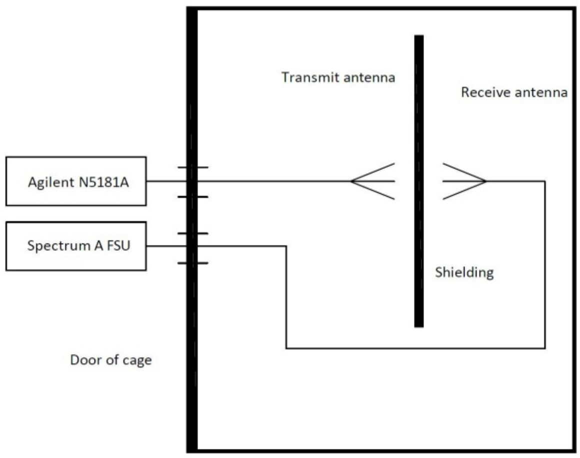

Fig. 1 The block diagram of measurement of shielding effectiveness

Fig. 2 View of the measuring instruments

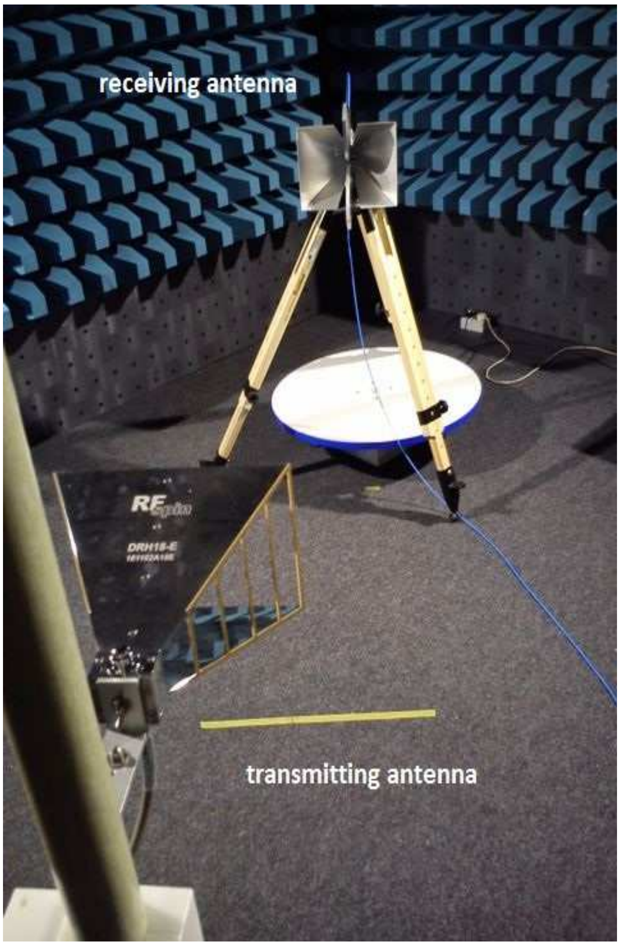

Fig. 3 The measuring antennas

Measured objects were fiber cement board facade Eterplan and exterior facade board Natura Pro. Thickness of the plates was 8 mm. Boards size were 0.7 x 0.7 m. Shielding effectiveness was measured in the frequency range from 1 GHz to 13 GHz in steps of 1 GHz. The first step was measured electromagnetic fields dry plates in frequency from 1 GHz up to 13 GHz in steps of 1 GHz. After this measurement the plates was sprayed volume of water corresponding with the rainfall 0.15 mm. The measurement was done at all frequencies with a time interval of 3 minutes after spraying. The time interval was chosen so that the dependence of the electromagnetic field was better measurable. The measurement was continued for 70 minutes, where board was dry. Shielding effectiveness was zero.

4. RESULTS

The change of the shielding effectiveness of electromagnetic field was calculated by equation (9). In Fig. 4 to 7 shows change of the shielding effectiveness in dependency on time. Shielding effectiveness of electromagnetic field was change over time. The characteristics are decreasing. It is for reason, that the shielding effectiveness of the wet board is better like dry board. Shielding effectiveness decreases with a time.

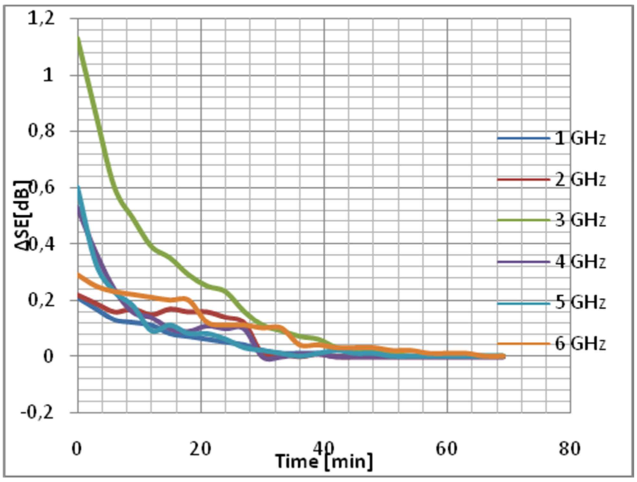

Fig. 4 Dependence of change shielding effectiveness of electromagnetic field on the time from 1 GHz to 6 GHz for Eterplan

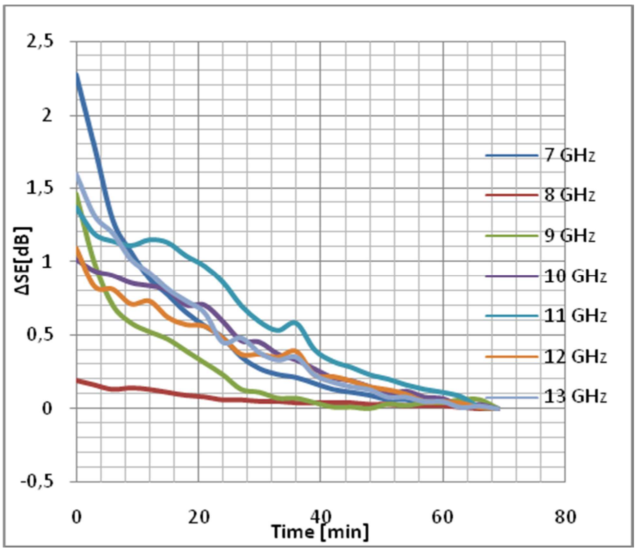

Fig. 5 Dependence of change shielding effectiveness of electromagnetic field on the time from 7 GHz to 13 GHz for Eterplan

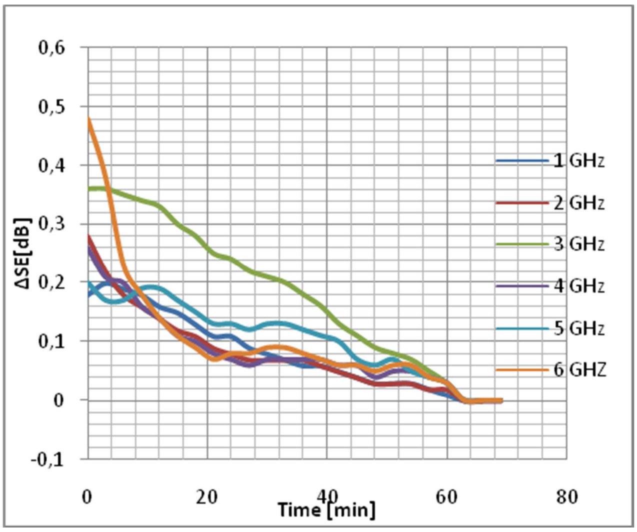

Fig. 6 Dependence of change of shielding effectiveness of electromagnetic field on the time from 1 GHz to 6 GHz for Natura Pro

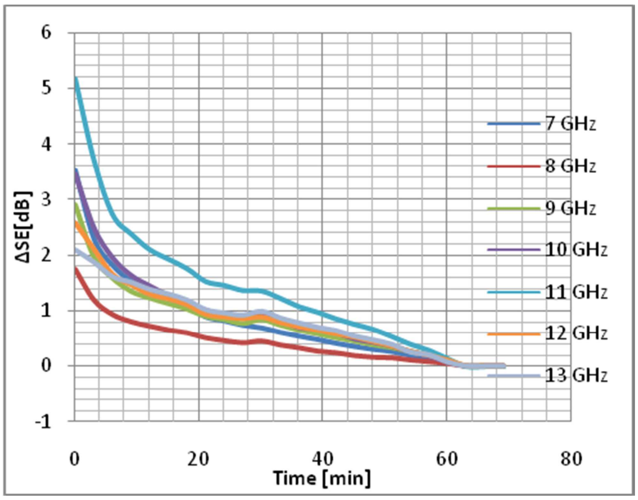

Fig. 7 Dependence of change of shielding effectiveness electromagnetic field on the time from 7 GHz to 13 GHz for Natura Pro

In Fig.8 we can see shielding effectiveness for Eterplan board and Natura Pro board in dependence of frequency. The measurement was done immediately after sprayed.

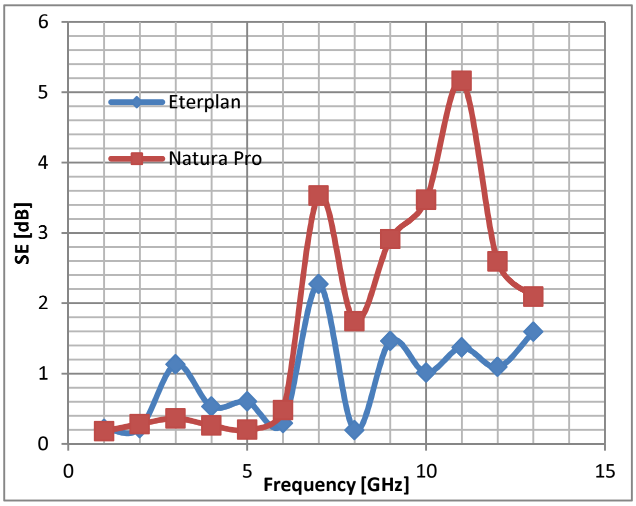

Fig. 8 Dependence of shielding effectiveness of electromagnetic field on the frequency from 1 GHz to 13 GHz for Eterplan and Natura Pro

5. CONCLUSIONS

This paper was focused on the measurement of shielding effectiveness of electromagnetic field. Measured object was fiber cement board facade Eterplan and exterior facade board Natura Pro. Shielding effectiveness was measured in the frequency range from 1 GHz to 13 GHz in steps of 1 GHz. Measured object´s were sprayed by water. Shielding effectiveness was measured at the gradual drying out.

The results show shielding effectiveness decreases with gradual drying out. According to results Natura Pro board shade better than Eterplan board. Both boards shadow similarly in the range frequency from 1 GHz to 6 GHz. The Natura Pro board shadow better than Eterplan board in the range from 7 GHz to 13 GHz.

ACKNOWLEDGMENT

This publication 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 .

We support research activities in Slovakia / Project is cofinanced from EU funds.

REFERENCES

[1] HABASH, R. W. – KREWSKI, D. – BANSAL, R. – ALHAFID, H. T.: Principles, Aplications, Risk and Benefits of Therapeutic Hyperthermia, Frontiers in Bioscience (Elite Edition), 3 (2011), pp. 1169-1181.

[2] PLAWIAK-MOWNA, A. – KRAWCZYK, A.: Wireless Body Sensor Network-Fundamental Concepts and Aplication, Przeglad Electrotechniczny, 12b/2012, 2012, pp. 267-268.

[3] RUSIECKI, A.: Calculation and measurements of shielding effectiveness of slotted enclosure with built-in conductive stirrer, Przegland Elektrotechniczny, ISSN 0033-2097, R. 88 NR 10b/2012, pp. 328-329.

[4] IEEE Standart, Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures, EMC Society, New York 2006, p. 39.

[5] PAN, Z. – ZHANG, H. et al.: Advances of Studies on Electromagnetism Shielding Fabric, Science & Technology Review, 27 (2009), 24, pp. 86-91.

[6] WANG, X. – LIU, Z.: Influence of fabric density on shielding effectiveness of electromagnetic shielding fabric, Przegland Elektrotechniczny, ISSN 0033-2097, R. 88 NR 11a/2012, pp. 236-238.

Received September 03, 2013, accepted September 25, 2013

BIOGRAPHIES

Marek Pavlík was born on 24.10.1985 and he is a Ph.D. student at the Department of Electric Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. He received a master degree in electric power engineering. His scientific research is mainly focused on research of reflection , penetration and absorption of electromagnetic waves in layered materials.

Iraida Kolcunová was born in Kotlas, Russia, in 1955. She graduated from the Department of High Voltage Engineering, the Faculty of Power Engineering at the Moscow Power Engineering Institute in 1979. She received the PhD degree from Slovak Technical University in Bratislava in 1993. She became a Professor of Electric Power Engineering at the Faculty of Electrical Engineering and Informatics at the Technical University of Kosice in 2009. Since 1979 she has been working at the Technical University, first as a research worker in High Voltage Laboratory, then as a teacher at the Department of High Voltage Engineering. She deals with degradation of insulating materials and measuring of partial discharges in high voltage equipment. She is lecturing on Diagnostics of High Voltage Equipments and High Voltage Engineering.

Michal Kolcun was born in 1954 in Ruska Vola nad Popradom. In 1979 he graduated at the Faculty of Electric Power Engineering of the Moscow Power Engineering Institute. In 1989 he defended his PhD on the same institute in Moscow. In 1993 he habilitated to associated professor at the department of Electric Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. In 2000 he inaugurate to professor, in the field of Power Engineering and Energetics, at the Faculty of Electrical Engineering and Informatics at Technical University in Košice. Since 2006 he is honorary professor at ÓBUDA University in Budapest, Hungary. Since June, 2012 he is Doctor Honoris Causa from Politechnika Czestochowa, Poland. Since 1979 he is working at the Department of Electric Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. His scientific research is focusing on a power system control and computer application in electric power engineering. In addition, he also gives lectures in multiple foreign universities in Moscow, Sankt Peterburg, Czestochowa, Zelona Gorza, Budapest, Riga, Tallinn, Varna, Prague, Ostrava and Barcelona.

Bystrík Dolník was born in Handlová (Slovak Republic) in 1967. He received the Ing (MSc) in electrical engineering and Dr in electrical engineering and high voltage technique from Faculty of Electrical Engineering, Technical University in Košice in 1991, and 1996 respectively. Until 2005 he worked as a Senior Scientist, currently as a teaching professional at the Department of Electrical Power Engineering, Faculty of electrical engineering and informatics, Technical University of Košice. The major fields of his research and educational activities are overvoltage, overvoltage protection, computer aided simulation, accelerated ageing tests and electromagnetic compatibility.

Juraj Kurimský was born in Prešov, Slovakia in 1967. He received the the M.Sc. degree from the Technical University of Košice, Slovakia in 1990 and the Ph.D. degree from the Technical University of Košice in 2003. Since 1991 he has been working as a senior scientist at Department of Power Engineering, Technical University of Košice, Slovakia. His major fields of interests are research of partial discharge phenomena and diagnostics of high voltage equipments.

Alexander Mészáros was born in Rožňava. He received the Ing and PhD in electrical engineering from Faculty of Electrical Engineering, Technical University in Košice in 1983 and 2002. He is an associate professor at the Department of Electric Power Engineeringt at Technical University in Košice. His main specialization is economy in electric power engineering and power system control.

Dušan Medveď is an assistant professor at the Department of Electric Power Engineeringt at Technical University in Košice. His main specialization is electro-heat processes and optimization of heating equipment. Nowadays, he deals with the computer modelling of thermal and electromagnetic fields using numerical methods and with the computer modelling of electrical system elements

Ján Zbojovský is a Ph.D. student at the Department of Electric Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. He received a master degree in electric power engineering. His scientific research is mainly focused on modelling the distribution of electromagnetic field in inhomogeneous material environment.