Measuring of Shielding Effectiveness of Electromagnetic Field of Polystyrene in the Frequency Range from 1 GHz to 9 GHz

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***Abstract** –* **This paper deals with measurement of the shielding effectiveness against the electromagnetic field. Shielding effectiveness against the electromagnetic field characterizes property of material to penetrate the electromagnetic field. Measuring of shielding effectiveness was performed in the frequency range from 1 GHz to 9 GHz with a step of 0.2 GHz. Measurement was performed in non-reflection chamber. Measured objects were the construction materials: Styrodur polystyrene with thickness of 50 mm, Styrodur polystyrene with thickness of 25 mm and their combination. The result of measurement is comparison of shielding effectiveness of shielding objects.**

***Keywords** –* **shielding effectiveness, electromagnetic field, reflection, polystyrene.**

I. INTRODUCTION

It should be noted that the sources of the electromagnetic field not only negatively affect the human body but 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 to electromagnetic radiation everytime and everywhere. The trend of number of sources of electromagnetic radiation will increase. As ordinary persons we can not perceive the electromagnetic radiation with our senses. 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 actual.

The opinions on this topic are different. On the one hand manufacturers of devices operating on the principle of electromagnetic field claiming that their pruducts are safe. And on the other stands the World Health Organization which says the 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 is more and more focused to resources of electromagnetic fields, their impact and the associated concept of electromagnetic compatibility.

Modern construction technologies are based on a multi-layer material. Examples consist of houses whose walls are made of bricks and polystyrene. Polystyrene is used for thermal insulation. This article is focused on measuring of the shielding effectiveness against the electromagnetic field of polystyrene.

II. SHIELDING EFFECTIVENESS

Quality shielding materials are determined by three coefficients, shielding coefficient K_S, absorption coefficient A and a reflection coefficient R. The shielding effectiveness SE is closely related to 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 [3], [4], [5]:

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

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 [5].

Shielding effectiveness SE is calculated using the formulas (2–4) if intensity of electric field and intensity of magnetic field are in basic units [7], [8].

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

Formula varies with determining of the shielding effectiveness SE according to the frequency range. According to [5], the shielding effectiveness is determined by the relation:

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

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

$$SE = 20\log\frac{|E_1|}{|E_2|} = 10\log\frac{P_1}{P_2} \ \text{[dB]} \qquad (4)$$

where E_1 and H_1 are the intensity of electric field and magnetic field at any point in the space where there are no shielding materials respectively. E_2 and H_2 are the intensity of electric field and magnetic field where the shielding materials are in the same place. 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. Then SE of the material was calculated at specific frequency using by (4) [5], [8], [9].

The main factors which determine the shielding effectiveness are the capability of shielding materials (the electric and magnetic conductivity and the permeability), the thickness and the frequency of the incident wave. If we know all these factors, the shielding effects of materials can be calculated by (5). If these factors are unknown, we can measure the intensity of electric field and magnetic field when there are shielding materials or not, and then SE could be calculated by (2). According to [7] the shielding effectiveness is the sum of the reflection R, multiple reflection B and absorption A of electromagnetic field derived as [10], [11], [12]:

$$SE = A + R + B \qquad (5)$$

$$SE = 15.4t\sqrt{f\mu\sigma} + 168.16 - 10\log\frac{\mu_R f}{\sigma_R} + 20\log\left(1 - e^{\frac{2t}{\delta}}\right)$$

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

$$SE = A + R \qquad (6)$$

$$SE = 8.69\frac{t}{\sqrt{\dfrac{2}{\omega\mu\sigma}}} + 20\log\left(\frac{1}{4}\sqrt{\frac{\sigma}{\omega\mu_r\varepsilon_0}}\right)$$

where μ is permeability which included permeability of the shielding material, ε_0 is electric permittivity of vacuum. The expression (6) is simplified expression of (5). Both terms are correct except of 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.

$$SE = \left|E_{1\log}\right| - \left|E_{2\log}\right| \qquad (7)$$

$$SE = \left|H_{1\log}\right| - \left|H_{2\log}\right| \ \text{[dB]} \qquad (8)$$

$$SE = \left|V_{1\log}\right| - \left|V_{2\log}\right| \ \text{[dB]} \qquad (9)$$

$$SE = P_{1\log} - P_{2\log} \ \text{[dB]} \qquad (10)$$

Formulas (7), (8), (9), (10) are used according to the available measuring equipment.

III. EXPERIMENT

Block diagram for the purpose of measuring of shielding effectiveness *SE* of the electromagnetic field is shown in Fig. 1. This workplace consists of the analog signal generator Agilent N5181A, spectrum analyzer Agilent N9038A MXE EMI (Fig. 2), the receiving antenna and transmitting antenna of horn type (Fig. 4). Measured objects (Fig. 3) 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.

The measurement was performed with three samples. The first sample consisted of Styrodur polystyrene with thickness of 50 mm. The second sample consisted of two Styrodur polystyrene with thickness 2 mm x 25 mm. The third sample was formed by combining the first two samples.
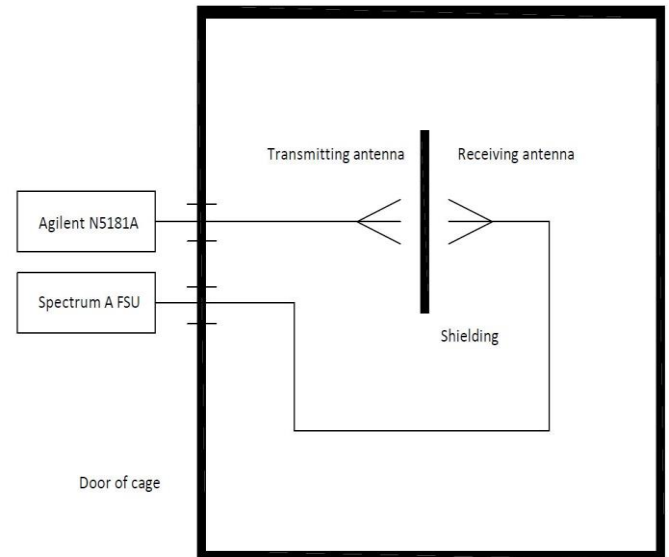

Fig. 1. The block diagram of measurement of shielding effectiveness.
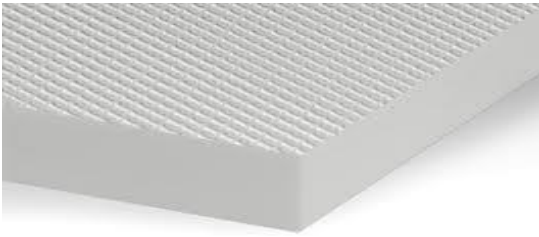

Fig. 2. View on the measuring instruments.

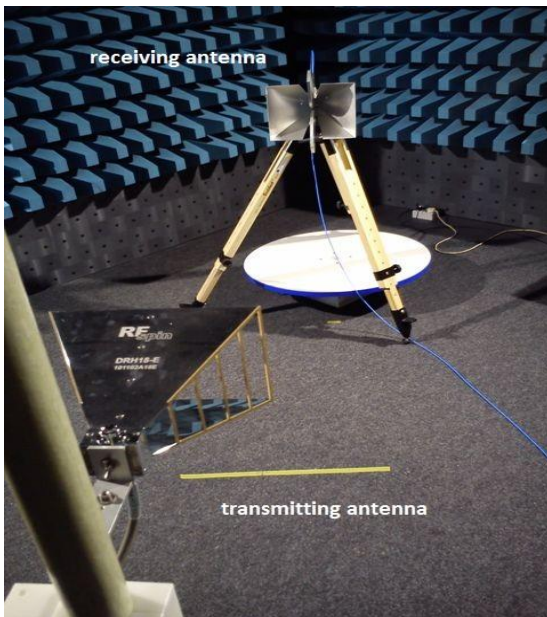Fig. 3. Polystyrene Styrodur – measured object.

Fig. 4. The antennas for purpose of experiment.

IV. RESULTS

Fig. 4, Fig. 5 and Fig. 6 represent the dependence of value of an electromagnetic field (EMF) with and without shielding in frequency range 1 GHz to 9 GHz for sample 1, 2 and 3. We can see from Fig. 7, Fig. 8 and Fig. 9 describe the dependence of shielding effectiveness against to electromagnetic field (*SE*) in frequency range from 1 GHz to 9 GHz for sample 1, 2 and 3. Shielding effectiveness was calculated by using formula (10).

We can affect overall shielding effectiveness by combination of shielding materials. Shielding effectiveness against to electromagnetic field is from 1,5 dB to 3 dB for sample 1. Shielding effectiveness of electromagnetic field is from 0,5 dB to 2,5 dB for sample 2. Shielding effectiveness against to electromagnetic field is from 0,2 dB to 2 dB for sample 3. We can see from these results, that by combination of two materials the shielding effectiveness not increased. It is because between the materials is formed multi reflection. These multi reflections cause the reflecting waves reaching the receiving antenna. The reflecting waves are not reflected as in the case of a single material. The value of the electromagnetic field behind the shielding for two materials is higher than with the only one. Therefore, shielding effectiveness is lower.
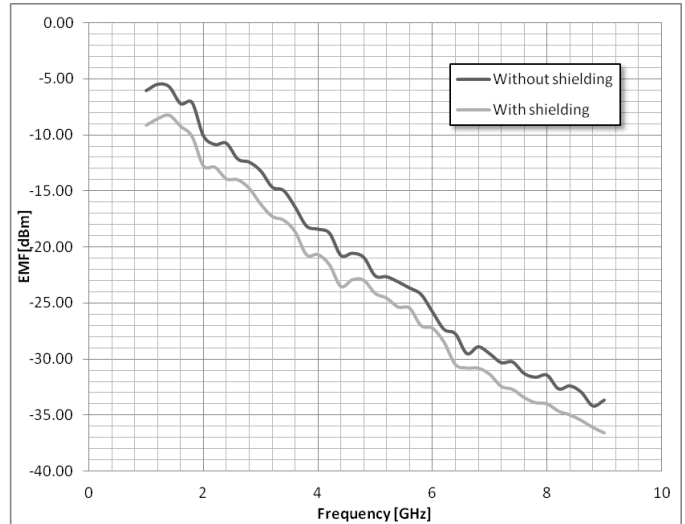

Fig. 5. Dependence of value of an electromagnetic field with and without shielding in frequency range of 1 GHz to 9 GHz for sample 1.
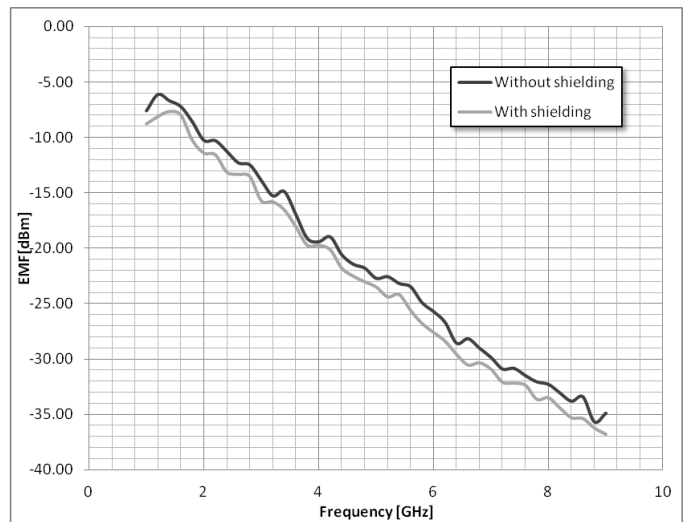

Fig. 6. Dependence of value of an electromagnetic field with and without shielding in frequency range of 1 GHz to 9 GHz for sample 2.
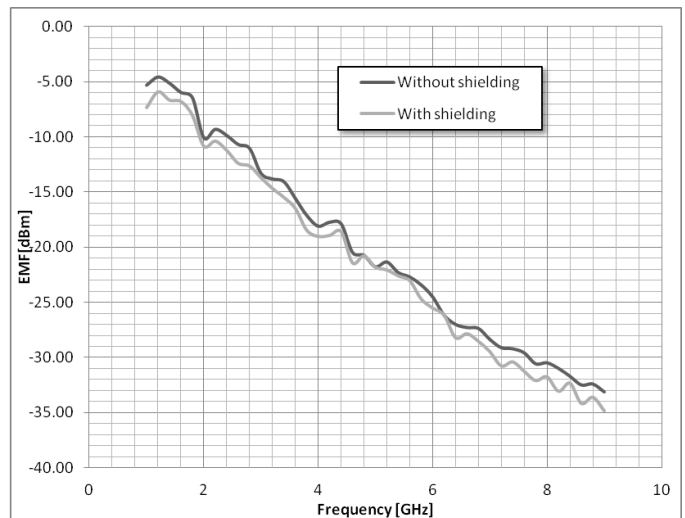

Fig. 7. Dependence of value of an electromagnetic field with and without shielding in frequency range of 1 GHz to 9 GHz for sample 3.
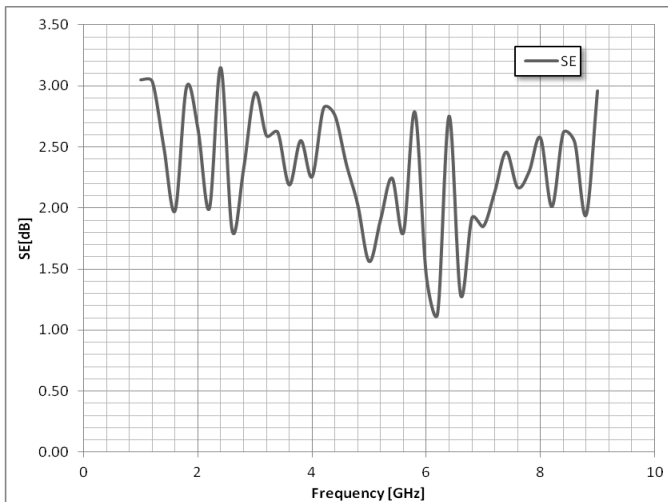
Fig. 8. Dependence of shielding effectiveness SE of electromagnetic field in frequency range of 1 GHz to 9 GHz for sample 1.
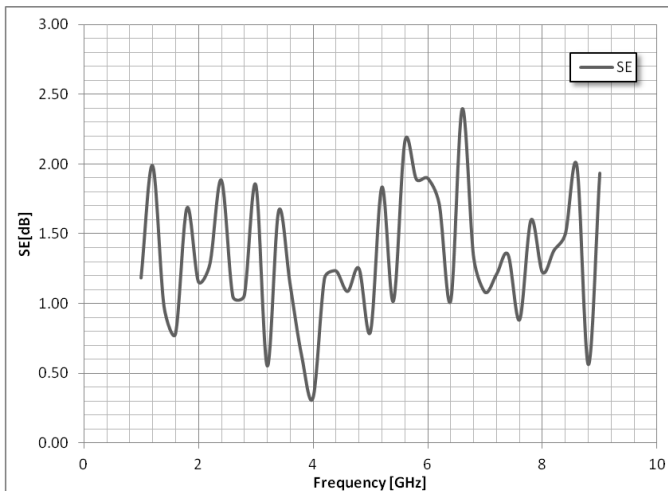

Fig. 9. Dependence of shielding effectiveness SE of electromagnetic field in frequency range of 1 GHz to 9 GHz for sample 2.
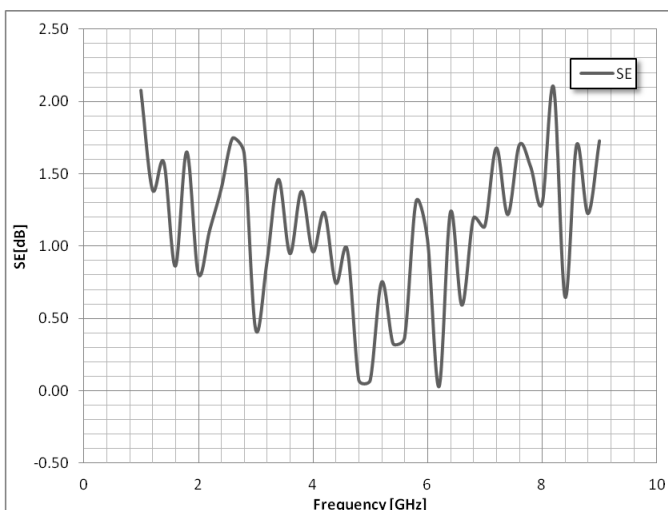

Fig. 10. Dependence of shielding effectiveness SE of electromagnetic field in frequency range of 1 GHz to 9 GHz for sample 3.

V. CONCLUSION

This article was aimed to measuring of shielding effectiveness against to electromagnetic field. The measurements were focused on measuring of shielding effectiveness in the range of higher frequencies from 1 GHz to 9 GHz by step of 0.2 GHz. The measured object was polystyrene with different thicknesses. Size of shielding was 2 m x 2 m. It should be noted that with increasing frequency the shielding effectiveness oscillates between maximum and minimum values.

It must also be noted that the results of the experiment show that between the materials is formed multi reflection. These multi reflections cause the reflecting waves reaching the receiver antenna. These reflecting waves are not reflected as in the case of a single material. Therefore, the value of the electromagnetic field behind the shielding for two materials is higher than with the only one. Therefore, the shielding effectiveness is lower.

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