The shielding effectiveness of building material – brick filled with mineral wool

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***Abstract*— initially, people were exposed to radiation originating from Earth and the cosmos, a rapid increase in artificial sources of electromagnetic radiation began at the end of the 20th century. This paper deals with research in electromagnetic shielding field. Experiment in this paper is focused on measurement of shielding effectiveness. Measured object was brick filled with mineral wool. Measurements were made for filled bricks with a thickness of 30 cm, 38 cm, 44 cm and 50 cm. The measurement shows that the shielding effectiveness increases with the increasing thickness of the material.**

Keywords—protection to electromagnetic field, shielding effectiveness, electromagnetic radiation

I. Introduction

Currently it is possible to observe a high increase in the sources of electromagnetic radiation. In every place, where electrical equipment is used, their electrical circuits generate electric and magnetic fields, and also, last but not least, because of the boom of wireless technologies, it is currently impossible to avoid the effects of electromagnetic fields.

Initially, people were exposed to radiation originating from Earth and the cosmos, a rapid increase in artificial sources of electromagnetic radiation began at the end of the 20th century. With the development of wireless technologies there is a question of the impact of electromagnetic radiation on the human organism. The effect of electromagnetic fields on living organisms is the subject of extensive scientific studies to prove or disprove their connection in the changes of health condition, while these impacts are still not clearly confirmed, nor disproved.[1]

Considering that people are daily exposed to the effect of electromagnetic field even though it is located in the space of different buildings and so on, it is necessary to find out how the electromagnetic field passes, is absorbed, or reflected by various building objects and materials. This can be determined by measuring fields in laboratory conditions.

II. Effects of electromagnetic field

Basically, electromagnetic field effects are divided into two main groups - thermal and non-thermal. However, this division is only theoretically possible; in real practice, these two types of EM field effects are practically inseparable. Thermal effects of electromagnetic fields are already very well mapped and widely used in medicine for various therapeutic applications in oncology, cardiology, urology, surgery, physiotherapy, etc.

Thermal effects are dependent on the amount of absorbed energy and the depth of absorption. Here applies that the lower the working frequency, the waves penetrate more into the depth of the body. The problem occurs if the body is not able to transfer the amount of supplied heat to the surrounding environment, and there may occur thermal overload of some organs. The most sensitive organs to temperature rise are: eye lens, brain and testicles. For example, the eye lens is particularly sensitive to high-frequency radiation. Exposing it to a relatively small load may cause its cataract because it is hard for it to remove heat.[2][3][4]

Non-thermal effects are mostly determined by the instantaneous amplitude of high-frequency radiation. Repeated irradiation at relatively low intensities causes that their effect increases especially when is exposed to the impulse field. Overall total radiated power of this field is relatively small, but its immediate amplitude is large. Field susceptibility of individuals significantly differs. The effect of long-term electromagnetic irradiation with low power density is especially manifested in the state of the central nervous system. These changes cause physical weakness such as: exhaustion, indifference, and increased fatigue, and sleep disturbances, decrease of attention, memory impairment, headache, hypersensitivity, and reduced potency. They affect the structure of cellular content and electrical properties of the cell. They occur especially where the organism is irradiated by repeated or permanent low intensity of electromagnetic fields.[3][5][6]

III. Effect of electromagnetic field on living organisms

The effect of electromagnetic fields on the living organism is dealt with by the World Health Organization (WHO) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which determined that electrical devices must comply with certain limits to be used in practice without risk to human health. The human body is a set of cells whose sensitivity to ionizing radiation is different. To assess the effects of ionizing radiation on biological systems, the following terms were introduced: radiosensitivity and radioresistance. Radiosensitive (highly sensitive to ionizing radiation) cells include stem cells, sex cells, basal skin cells, etc. Radio-resistant (low-sensitive to ionizing radiation) include muscle cells, peripheral nerves, etc. From the point of view of health protection against radiation, we divide the biological effects of ionizing radiation into stochastic (random) and non-stochastic (deterministic). Stochastic effects – with increasing dose, the

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probability of damage and increase in later forms of damage rises. Damage is caused by changes in genetic information of the cell, while the relationship of dose and effect is linear. Deterministic effects - are conditioned to cellular loss and concerning a large number of cells. At the cellular level, the moment of stochastic patterns (randomness, statistical probability) is also applied to these effects. Acute illness of radiation occurs after a one-off irradiation of the whole body or its significant part with a high dose. Acute local damage - the most common type of local damage is acute skin damage. Fertility disorders - arising from local irradiation due to irradiation of higher dose. Malignant tumours - are among the most serious stochastic effects of ionizing radiation. They occur as a consequence of mutations that pass into the loss of control over cell division. Genetic damage is a consequence of the effect of ionizing radiation on the exposed human that will be clinically manifested in its progeny. The effects of electromagnetic fields on the human organism can be divided into two categories: thermal and non-thermal effects. Thermal effects occur when the amount of absorbed energy in the biological organism causes an increase in temperature that exceeds the thermoregulatory capabilities of the organism. Firstly, it depends on the frequency, where applies that the thermal effects on the biological organism increases with rising frequency, as well as the content of the water in the tissue. At a current density of 10 mW/cm^{-2}, a non-specific thermal effect, called hyperthermia, is beginning to occur. The most sensitive organs for increasing the temperature are eyes, ears, brain and testicles. Ear warming may observed during long time phone calls. The temperature of ear lobes is increased by 1°C when call duration takes about 15 to 20 minutes. Consequences of long time phone calls lead to the occurrence of ear tumour or ringing in the ears. Warming of eyes is also very serious, because for the eye lens is difficult to remove heat, relatively low load by high-frequency radiation may cause its cataract. The effect of electromagnetic field on the eyes is manifested by tearing, eye fatigue, and reduced sensitivity to color perception. Non-thermal effects are associated with the long-lasting effects of weak fields and occur when the power density is less than 10 mW/cm^{-2}. Their effect increases with repeated irradiation of low intensities, especially in the exposure to impulse field, where the overall emitted energy is small but the instantaneous amplitude is large. Long-term irradiation by electromagnetic fields with low power density will be mainly manifested on the state of the central nervous system. It is manifested by feeling of weakness, exhaustion, headaches, increased fatigue, sleep disturbances, decreased concentration, etc. However, after a short interruption of the stay in the electromagnetic field, regeneration occurs.[1][3][6][7][8]

IV. Electromagnetic field protection

Electromagnetic field causes invisible threats to our health. Prolonged exposure to electromagnetic radiation causes physiological change in human. It is therefore important to focus on the protection of human against exposure of electromagnetic radiation. People work and live in buildings that constitute the shielding against electromagnetic fields. The electromagnetic field penetrates through the wall of the building from the outside. Therefore, the experiment was focused on building materials.[4][9][10][11]

Shielding effectiveness indicates the capability of a given material to operate as protection against external electromagnetic fields and as barrier preventing internal fields from damaging other devices. Its elements consist of simply the addition of the absorption loss, reflection loss, and re-reflection correction factor:

$$SE = A + R + B \tag{1}$$

where *SE* is shielding effectiveness, *R* is reflection of electromagnetic field, *B* is multiple reflections and *A* is absorption of electromagnetic field.

According to [12][13][14][15] for the frequency range from 300 MHz to 100 GHz is *SE* defined as:

$$SE = 20\log\frac{|E_1|}{|E_2|} = 10\log\frac{P_1}{P_2} \tag{2}$$

where E_1 is intensity of electric field at any point in the space where there are no shielding materials respectively. E_2 is intensity of electric field where the shielding material is in the same place. P_2 is power detected within the enclosure, P_1 is power detected in absence of the enclosure.

Measurement apparatus were set in logarithmic value. Shielding effectiveness we can calculation as:

$$SE = P_{1\log} - P_{2\log}\ [\mathrm{dB}] \tag{3}$$

where P_{2log} is power (in logarithmic value) detected within the enclosure, P_{1log} is power (in logarithmic value) detected in absence of the enclosure.

V. Workplace calibration

The experiment was focused on measuring of shielding effectiveness of electromagnetic field. The workplace for purpose of measuring of shielding effectiveness of electromagnetic field is shown on Fig. 1 - block scheme of the workplace. The measuring instruments were placed out of the chamber to prevent them from being influenced. Inside of chamber was placed receiving antenna and transmitting antenna horn type.

The shielding material was the brick filled with mineral wool - Fig. 2. Measurements were made for filled bricks with a thickness of 30 cm, 38 cm, 44 cm and 50 cm. In our previously experiments we can see dependence shielding effectiveness on thickness material. The shielding effectiveness has risen with the thickness of the material in frequency range from 1 GHz to 9 GHz. Even in this experiment applies that the thicker the brick, the higher the shielding efficiency. The gaps filled with mineral wool were equally large, but their number was adjusted to the thickness of given brick.

Measured object was placed at a distance of 0.3 m from the transmitting antenna.

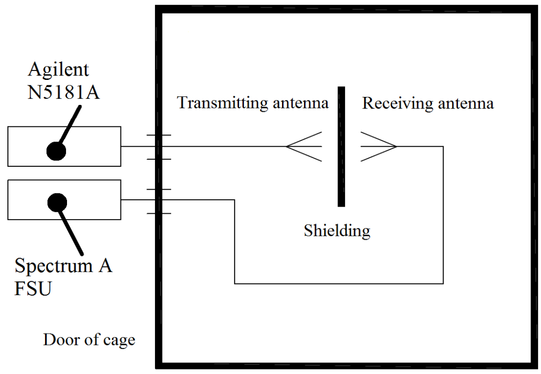

Fig. 1. Workplace for electromagnetic shielding measurements

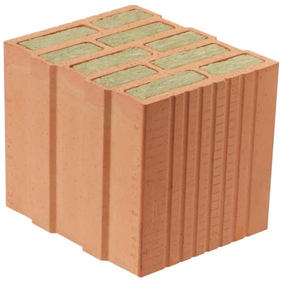

Fig. 2. Measured object

Calibration of the measuring station was based on the radio communication equation, which is defined as follows:

$$P_P = P_V - L_0 + G_V + G_P \tag{4}$$

where P_P is the received power, P_V is the transmitted power, L_0 is the free-space path loss, G_V is the gain of the transmitted antenna, and G_P is the gain of the receiving antenna. The parameter of the gain of antenna was described in the previous chapter and the free-space path loss L_0 is given as:

$$L_0 = 20\log\left(\frac{4\pi R}{\lambda}\right) \tag{5}$$

where R is the distance of the antenna, λ is the wavelength.

VI. Results of Electromagnetic Shielding Measurements

Measurements were made for filled bricks with a thickness of 30 cm, 38 cm, 44 cm and 50 cm. In our previously experiments [14] we can see dependence shielding effectiveness on thickness material. The shielding effectiveness has risen with the thickness of the material in frequency range from 1 GHz to 9 GHz.

The shielding effectiveness was measured for brick filled with mineral wool. The measurements were made for four thicknesses of bricks - 30, 38, 44 and 55 cm. The calibration at the 1 GHz frequency was performed before the measurement itself, according to chap. 5. The measurements were in the frequency range from 1 GHz to 9 GHz in a 0.1 GHz step. Measurements were repeated five times, and then averaged. The measurement results can be seen in Fig. 3. The results show that increasing frequency also increases the efficiency of shielding. This applies to all thicknesses of the measured samples. The results further show that the increase in shielding efficiency is faster to 6 GHz. From the frequency of 6 GHz to 9 GHz, the increase is slower. The smallest increase (in the frequency range from 6 GHz to 9 GHz) is with the thinnest sample. At a 30 cm sample thickness (TMV-30), the shielding efficiency is from 0.5 to 17 dB. At a thickness of 38 cm (TMV-38), the shielding efficiency is from 0.5 to 18.5 dB. The thickness of the 44 cm sample (TMV-44) is shielding efficiency from 0.5 to 24 dB. With a 50 cm sample thickness (TMV-50), shielding efficiency is from 0.5 to 31 dB. Measurement errors should be considered for this measurement. This error is 0.5 dB. The measurement error can have a significant impact on the measurement results, especially at lower frequencies.

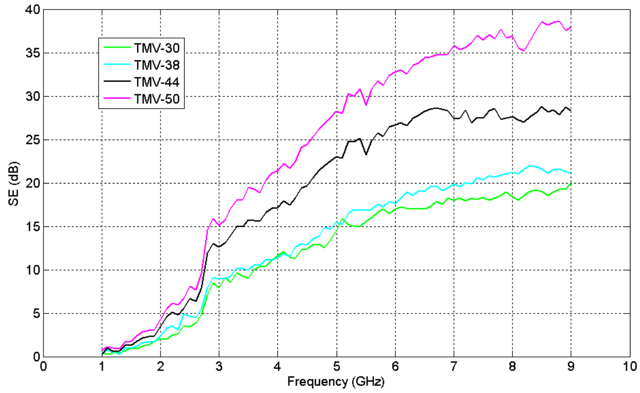

Fig. 3. Shielding effectivenes in frequency range from 1 GHz to 9 GHz

VII. Conclusion

This paper was aimed at detecting the shielding ability of bricks filled with mineral wool. Shading capability is defined by the effectiveness of shielding. The shielding efficiency can be determined from two measurements - shielded one and unshielded one. Then, the shield efficiency value can be calculated according to relation (2) or (3). This depends on the set values on the measuring instruments.

The results from the measurement show the shielding ability of brick filled with mineral wool. Shading capability increases with the thickness of the material. The thickness of material also directly affects the value of the absorption coefficient *A*, which is the *SE* component. Therefore, it is possible to assume that with increasing material thickness, this component will predominate in the total SE value. Throughout the measured range (from 1 GHz to 9 GHz), the SE value increased for all material thicknesses. In the range of 6 GHz to 9 GHz, this increase was slower. It can be assumed that at higher frequencies the *SE* would be stable.

Mineral wool has a good shielding ability even against acoustic waves. It is therefore possible to achieve a combination of brick and mineral wool material which can partially shield both electromagnetic and acoustic waves. A better combination of the material with which the brick is filled can also achieve better shielding capability against electromagnetic and acoustic waves. However, it is necessary to seek a compromise. In the case of mobile waves, it is desirable that this electromagnetic field penetrates the walls of the buildings [16] [17] [18] [19].

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