Attenuation Measurements of Materials Used in Construction of Buildings

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Abstract— In the article research methodology and measuring position for determining attenuation of materials used for building structures have been described. The discussed research methodology is based on microwave measuring set on the basis of coaxial line guaranteeing large bandwidth of realized measurements. In the article selected samples of materials used for building structures have been characterized as well as attenuation results of those materials have been presented.

1. INTRODUCTION

Attenuation of walls, ceilings or other building barriers depends — among other things — on permittivity of material the wall is made of, frequency of incident radiation and wall thickness. In order to determine attenuation of electromagnetic waves by wall, each wall should be measured individually to define what level of electromagnetic field intensity is attenuated by such a barrier. In order to determine attenuation of materials used for building structures it is necessary to perform analytical calculations of electric field attenuation or make a direct measurement on a natural sample of a particular material. For analytical calculation of electromagnetic field attenuation by shielding material it is necessary to determine electric and magnetic values of material a particular structural material is made of. Parameters which define the above mentioned properties are respectively permittivity ε and magnetic permeability μ of tested material. Due to the fact that building materials, particularly those based on natural raw materials(concrete, brick, plaster), are characterized by seldom repeatable composition, the only method of estimating their electric and magnetic properties is conducting laboratory measurements with the use of natural samples [3, 4, 7, 8, 10–12, 14].

2. MICROWAVE MEASURING SET FOR ATTENUATION TESTS BASED ON COAXIAL LINE

For conducting attenuation tests of materials used for building structures a microwave measuring set has been designed. With the use of the above mentioned set we can make measurement and determine values of combined coefficients of dispersion matrices which next can be used for calculation of attenuation coefficients and absorption of particular shielding material. The measuring set in current configuration makes measurements within the frequency range from 50 MHz to 6 GHz possible. Band limitations for this set are caused by the set structure on the basis of coaxial line, possessed measuring equipment and measuring software [2, 5, 6, 9, 13].

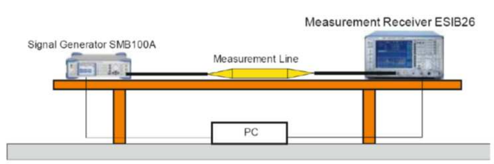

Figure 1: Block diagram of measuring position.

3. METHOD OF MEASURING ATTENUATION OF BUILDING MATERIALS

Measurement of attenuation of materials used for building structures was conducted with the use of measuring position which block diagram is presented in Figure 1. Measurements were divided in two stages. The first stage is reference measurement during which the signal level which directly crosses measuring line (without the placed tested material sample) is measured. The second stage is basic measurement in which the signal level crossing measuring line with the placed tested material sample inside is measured. Due to obtained results from the two measuring stages it is possible to calculate attenuation of the tested sample of material A using the dependence:

$$A = E_1 - E_2, \tag{1}$$

where: E_1 — signal level at the output of measuring line without the material sample placed inside for a particular frequency, E_2 — signal level at the output of measuring line with the material sample placed inside for a particular frequency [19–21].

Measuring methodology is based on measurement of signal level at the output of measuring line without sample and with sample placed in microwave set for measuring attenuation. Test signal is generated by microwave generator in a given frequency range. Received signal at the output of measuring line is measured with the use of measuring receiver. The designed program allows to perform basic preparation activities automatically, carry out measurements themselves and make appropriate diagrams presenting the obtained results. The application allows to introduce initial and final frequency of measuring range and define measuring step and level of test signal deriving from signal generator [15–18].

4. SELECTED MATERIALS USED FOR BUILDING STRUCTURES

During conducted tests the study subject were selected samples of building materials with different thickness. The first sample was red brick commonly used for structure of building walls with three various thicknesses: 7.1 mm, 8.0 mm, 17.8 mm. The look of particular samples from red brick has been shown in Figure 2. The second studied sample was clinker brick commonly used for structure of walls inside buildings, chimneys etc. with three various thicknesses: 8.4 mm, 9.2 mm, 16.5 mm. The look of particular samples from clinker brick has been shown in Figure 3. The third selected studied sample was concrete commonly used for structure of ceilings, main walls inside buildings etc. with two various thicknesses: 9.0 mm, 17.2 mm. The look of particular samples from concrete has been shown in Figure 4. Another studied sample was cellular concrete (suporex) commonly used for structure of walls inside buildings with two various thicknesses: 8.3 mm, 16.8 mm. The look of particular samples from suporex has been shown in Figure 5. The last selected sample was cardboard gypsum commonly used for structure of partition walls inside buildings etc. with three various thicknesses: 11.25 mm, 22.50 mm, 33.75 mm. The look of particular samples from cardboard gypsum has been shown in Figure 6.

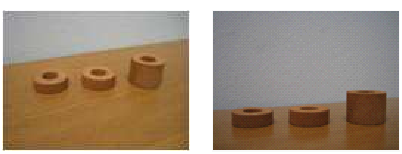

Figure 2: Look of samples — red brick

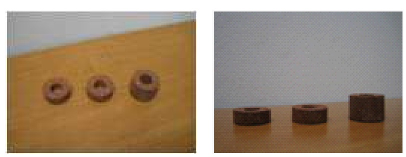

Figure 3: Look of samples — clinker brick

Figure 4: Look of samples — concrete.

Figure 5: Look of Samples — suporex.

Figure 6: Look of Samples — cardboard gypsum.

5. MEASUREMENT RESULTS

To present measuring possibilities of the described measuring method in Section 3 attenuation measurements of samples of building materials used for building structures within the frequency range from 10 kHz to 6000 MHz were conducted. The purpose of the presented and discussed below measurement results is to show the reader the method how to make the parameter analysis of building materials based on measurement results carried out in accordance with research methodologies described in the following study. In Figures from 7 to 11 measured attenuation values of particular samples characterized in Section 4 have been presented.

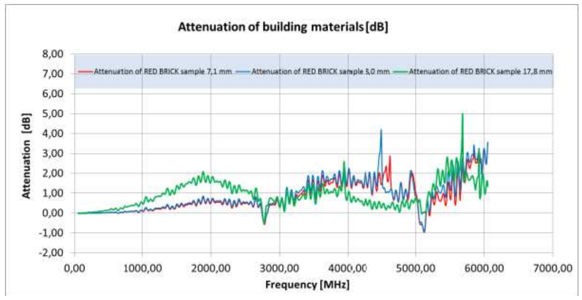

Figure 7: Diagrams of attenuation of red brick samples in frequency function.

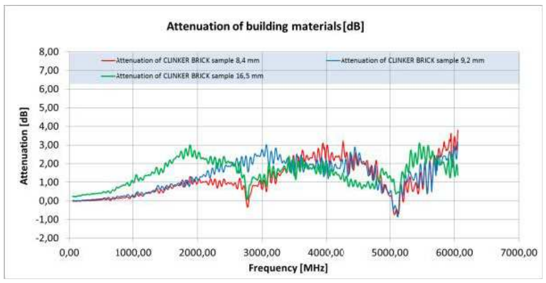

Figure 8: Diagrams of attenuation of clinker brick samples in frequency function.

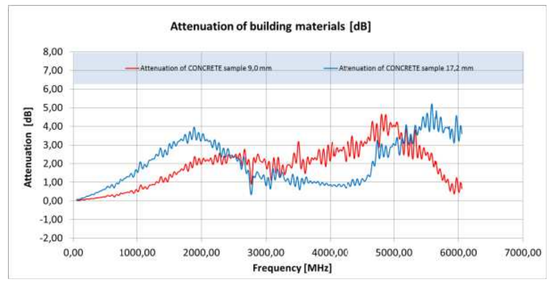

Figure 9: Diagrams of attenuation of concrete samples in frequency function.

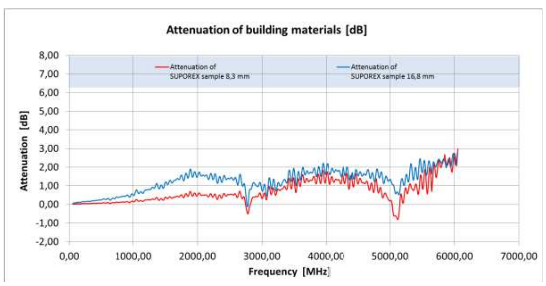

Figure 10: Diagrams of attenuation of cellular concrete (suporex) samples in frequency function.

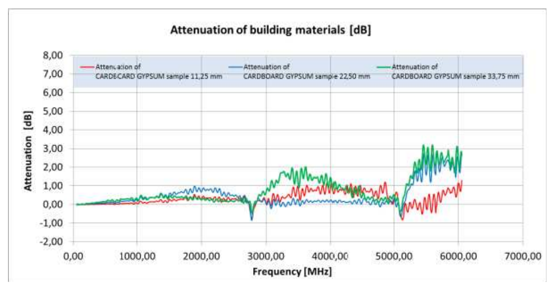

Figure 11: Diagrams of attenuation of cardboard gypsum samples in frequency function.

On the basis of the received results for selected samples of materials used for building structures it is clearly seen that the attenuation value practically does not depend on such little changes of material thickness. The obtained data show that within low frequencies (up to 1000 MHz) attenuation of selected material samples is characterized by low values and is lower than 1 dB. Increase of attenuation along with increase of test frequency can be seen. Within high frequencies (from 1 GHz to 6 GHz) such materials as red brick, clinker brick and concrete are characterized by high values of shielding efficiency and are higher than 3 dB. For samples made of suporex and cardboard gypsum it can be clearly seen that the attenuation value in the whole examined frequency range has low values (below 2 dB). So those materials are transparent for electromagnetic waves within that frequency range. It can be easily noticed that the sample made of concrete is characterized by the largest attenuation in the whole examined frequency range [1].

6. CONCLUSIONS

The whole gamut of building materials with various physical and electromagnetic properties is currently used. For electromagnetic field building materials mainly acquire significance during occurrence of the phenomenon of shielding and EM wave absorption. The used materials have diametrically opposed properties of reaction to EM field. Starting from metal (mainly aluminium) or metalized facades which have prevailing shielding properties and ending on traditional, based on mineral raw products (concrete, brick, plaster) with parameters directed towards field energy absorption. While materials like metal, glass, plastic have quite solid parameters during changes of weather conditions, walls (facades) made of concrete, brick, plaster or gypsum are especially very susceptible to changes of humidity of surroundings. It causes that real attenuation of such materials can be determined only by measurements in natural or laboratory conditions with the use of natural samples. It is practically impossible to test all used materials due to their broad assortment gamut and seldom repeatable composition. Because of that there is no possibility of accurate determination of attenuation value of a particular wall (facade) or a simple, quick and direct method of making its measurement. So in the article attention was focused on a few selected kinds of materials used for building structure.

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