Measurements of Wall Attenuation in Closed Spaces inside a Building

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Abstract— Within this article the issue of measuring wall attenuation in closed spaces inside a building has been discussed. Measuring methodology and measurement results obtained while determining wall attenuation as well as other structural components in closed spaces inside a building have been presented.

1. INTRODUCTION

In order to measure values of wall attenuation in closed spaces a measuring set is required which includes transmitter of measuring signal and meter of electromagnetic field intensity. Particular parts of the measuring set might also include software which activated on an operating computer makes automation of measuring process possible [20, 21]. Within this article the principle of operation of measuring set without using operating software has been presented.

The suggested measuring method is a basic comparative method [17, 18]. On the basis of obtained measurement results it is possible to determine attenuation of elements inside a building such as walls, ceilings and other building structural components. For the discussed measuring method a few following principles should be met:

- transmitting and receiving antenna must be remote from a tested obstacle within the distance meeting the principles of far zone, i.e., wave incident on obstacle should have the nature of plane wave,
- in order to make measurements properly, antennas should be characterized with the same radiation characteristics [1–3].

Measurement of wall attenuation in closed spaces comes down to performance of two measurements of signal level at the receiver input for particular frequency. The first measurement is made as so called reference measurement. With a determined value of signal level generated by transmitter of measuring signal the level of electromagnetic field intensity is measured in the place of installation of receiving antenna of meter of electromagnetic field intensity [15, 16]. During standardization measurement transmitting antenna of measuring signal transmitter and receiving antenna of electromagnetic field intensity meter are placed close to one another in direct visibility. Measurements can be made at discrete frequencies or in a given band with determined step. Measured values of electromagnetic field intensity corresponding with particular measuring frequencies ought to be remembered [4–8].

2. MEASURING POSITION

Block diagram of measuring position for wall attenuation in closed spaces has been shown in Figs. 1 and 2. The position includes measuring signal transmitter and electromagnetic field intensity meter.

The suggested above measuring position for measuring wall attenuation in closed spaces consists of the following elements: signal generator, transmitting antennas, receiving antennas, measuring receiver, HF paths, power amplifier possible to use in transmitting path [9–12].

Measurements being reference measurement were made within the frequency range from 200 MHz to 6 GHz for four distances between measuring antennas (1 m, 2 m, 4 m, 6 m).

It can be easily noticed that along with moving away of measuring antennas from each other the nature of received courses more and more differs from linear (Fig. 3). Levels of received signal decrease along with moving away of measuring antennas from each other. Obtained reference courses along with results of basic measurements will serve to determine wall attenuation in closed spaces inside a building [13, 14, 19].

At a stage of conducting basic measurements, measurements of signal levels received by measuring antennas have been made in the configuration in which between measuring antennas there was a wall for which attenuation was determined. Measurements were conducted in accordance

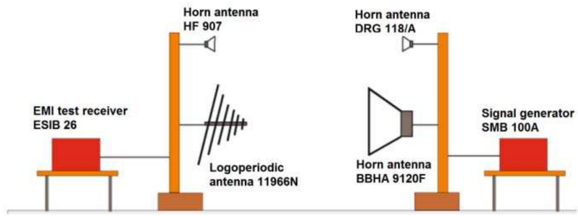

Figure 1: Block diagram of measuring position for wall attenuation in closed spaces in the configuration for reference measurement.

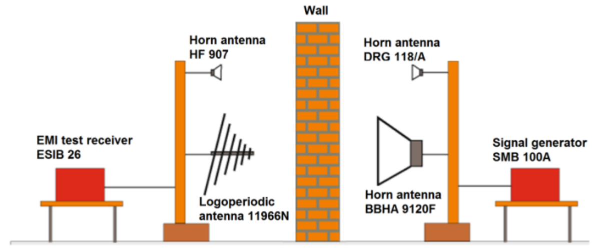

Figure 2: Block diagram of measuring position for wall attenuation in closed spaces in the configuration for basic measurement.

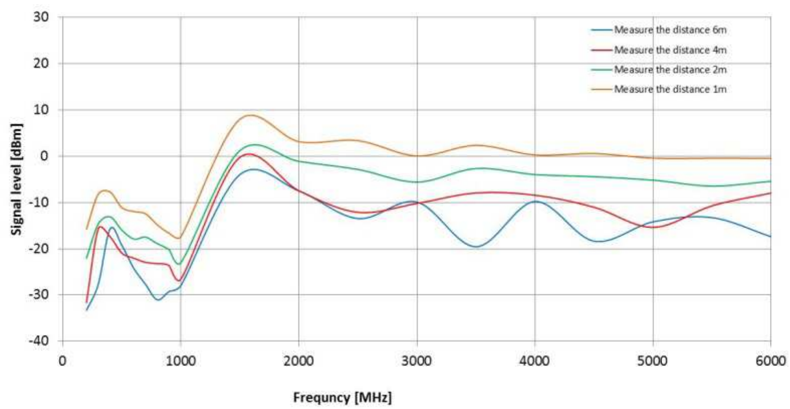

Figure 3: Diagrams of signal levels received by measuring antennas in the configuration of direct visibility of antennas for four distances between measuring antennas (1 m, 2 m, 4 m, 6 m).

Figure 4: View of measuring position while performing reference measurements.

with the above described methodology. Measurements being basic measurements were carried out within the frequency range from 200 MHz to 6 GHz for five scenarios of antenna arrangement:

a) reinforced concrete wall between corridor and room in which there is anechoic chamber, the distance between measuring antennas was 1 m, (Fig. 9),
b) gypsum-cardboard wall between corridor and lecturer's room, the distance between measuring antennas was 1 m, (Fig. 6),
c) gypsum-cardboard and wooden wardrobe wall between lecturer's room and other lecturer's room, the distance between measuring antennas was 2 m (Fig. 10),
d) wooden door between corridor and lecturer's room, the distance between measuring antennas was 1 m, (Fig. 3),
e) reinforced concrete ceiling between corridor on the ground floor and corridor on the first floor, the distance between measuring antennas was 4 m (Fig. 12).

3. MEASUREMENT RESULTS OF WALL ATTENUATION IN CLOSED SPACES INSIDE A BUILDING

To obtain wall attenuation it is necessary to use energy balance equation of radio link:

$$P_{odbmin}[\mathrm{dBm}] = P_{nad}[\mathrm{dBW}] + G_{nad}[\mathrm{dB}] - L_{prop}[\mathrm{dBm}] + G_{odb}[\mathrm{dB}] \tag{1}$$

After transformations we receive attenuation dependence:

$$L_{prop}[\mathrm{dBm}] = P_{nad}[\mathrm{dBW}] - P_{odbmin}[\mathrm{dBm}] + G_{nad}[\mathrm{dB}] + G_{odb}[\mathrm{dB}] \tag{2}$$

where:

P_{odbmin}[dBm] — minimal signal power received at the output of receiving antenna, expressed towards one watt, necessary for correct reception of radio signal,

p_{nad}[dBW] — power of signal transmitted at the input of transmitting antenna expressed towards one watt,

G_{nad}[dB] — gain of transmitting antenna,

L_{prop}[dBm] — attenuation of radio wave in propagation environment,

G_{odb}[dB] — gain of receiving antenna.

On the basis of reference and basic measurements we can determine attenuation of a selected wall in closed space according to the dependence:

$$L_{wall}[\mathrm{dB}] = P_1[\mathrm{dBm}] - P_2[\mathrm{dBm}] \tag{3}$$

where:

P_1[dBm] — level of signal received by measuring antennas in reference measurement,

P_2[dBm] — level of signal received by measuring antennas in basic measurement,

P_2[dBm] — wall attenuation.

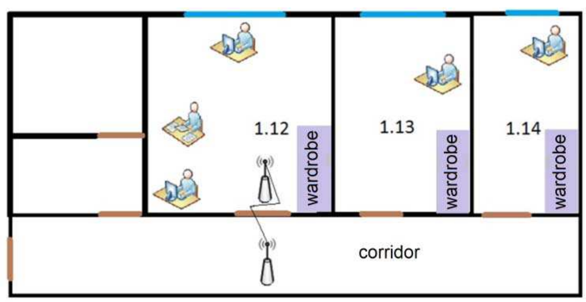

Figure 5: Section of building with the marked first measuring position. Measurement of attenuation between room 1.12 and corridor through closed door.

Figure 6: View of measuring position while performing basic measurements.

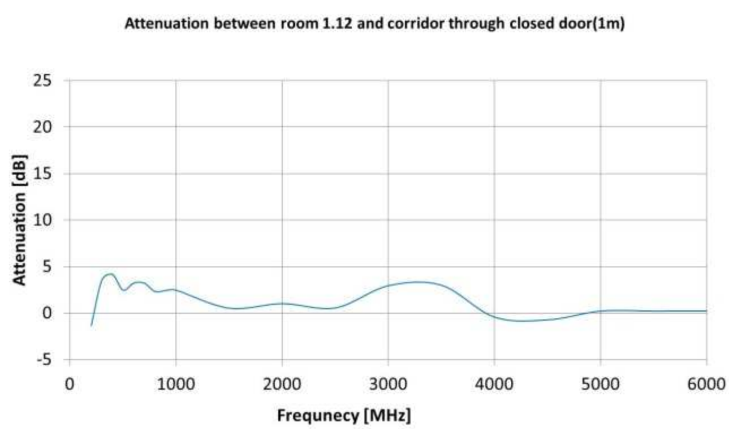

Figure 7: Attenuation received as a result of measurement through door between room 1.12 and corridor.

In Fig. 4, arrangement of measuring antennas while conducting measurement according to the scenario from Fig. 3 is presented. In that configuration a wave propagates mainly through door. In Fig. 5, juxtaposition of measurement results and attenuation results for the configuration from Fig. 3 obtained with the use of selected analytical models is shown.

In next figures measurement results for particular scenarios have been presented respectively.

As it can be noticed from the above presented attenuation results of selected walls in closed spaces, diagrams differ from each other in attenuation values. The wooden door fixed in gypsum-cardboard wall is characterized by the least attenuation. The attenuation value of the discussed door is about 2 dB in the entire frequency band from 200 MHz to 6000 MHz. Walls made of gypsum-cardboard are characterized by larger attenuation. The attenuation value of such walls fluctuates within the range from 5 dB to 10 dB depending on measuring frequency. Reinforced concrete walls have the biggest attenuation. Their attenuation, depending on measuring frequency, ranges from about 10 dB to even 40 dB in case of the ceiling between the floors of the building.

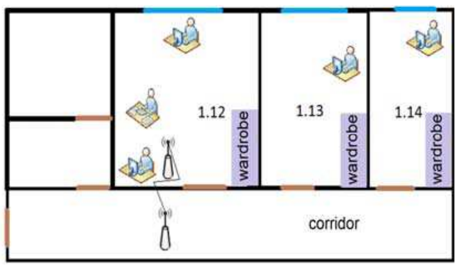

Figure 8: Section of building with the marked first measuring position. Measurement of attenuation between room

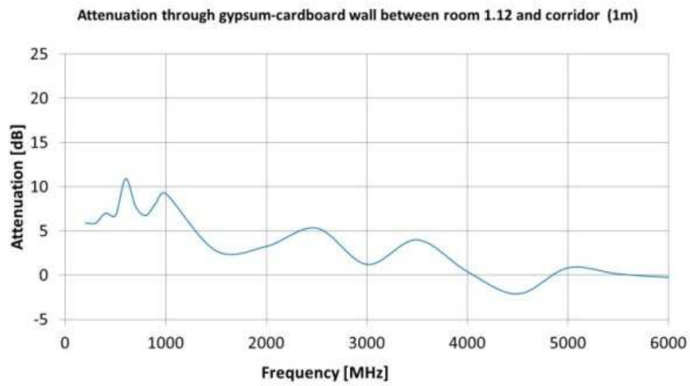

Figure 9: Attenuation received as a result of measurement through gypsum-cardboard wall between room 1.12 and corridor.

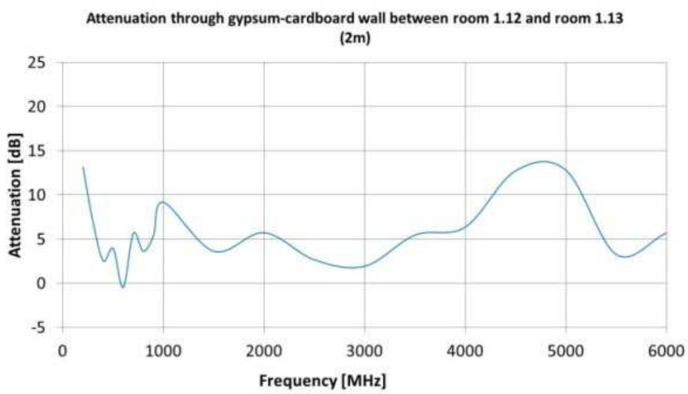

Figure 10: Attenuation received as a result of measurement through gypsum-cardboard wall between room 1.12 and room 1.13.

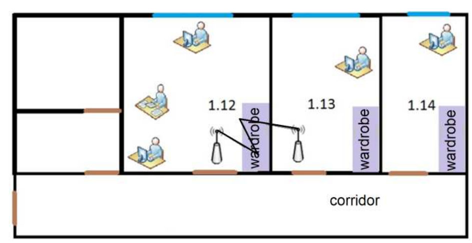

Figure 11: Section of building with the marked first measuring position. Measurement of attenuation between room 1.12 and room 1.13.

4. CONCLUSIONS

Measurement of wall attenuation and structural components in an already existing building is quite problematic. The main encountered problem is a possibility of providing the same measuring conditions while performing reference measurements like those occurring during basic measurement. Unfortunately while conducting measurements in closed space a problem of multipath and other phenomena accompanying wave propagation appears. It results in the fact that in specific situations for particular frequencies we can obtain a negative value of attenuation, i.e., reinforcement. It is an obvious influence of surroundings occurring around measuring equipment. Having measurement results we can also attempt to make an analysis and selection of most suitable propagation model for field prediction in a building.

ACKNOWLEDGMENT

The project is financed from the NCBiR means within Agreement No. 0024/R/ID2/2012/02 in the years 2012–2015.

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