

Electromagnetic shielding proprieties evaluation of buildings situated near radio frequency transmitters

Valeriu David¹, Alexandru Salceanu¹, Emil Vremera¹, Ionut Nica¹

¹ Technical University of Iasi, Faculty of Electrical Engineering, Bd. D. Mangeron, 53, Iasi, Romania, phone +40 232 278680, fax+40 232 237627, e-mail valdavid@ee.tuiasi.ro

Abstract-In this paper we present the results of the radio-frequency electromagnetic field measurements both indoor and outdoor of some buildings situated near broadcastings towers. The aim of our measurements is the evaluation of the electromagnetic shielding proprieties of the buildings in view of the characterization of the electromagnetic field propagation through buildings' walls and to estimate the electromagnetic environment in these specific areas.

I. Introduction

The electromagnetic shielding of some special buildings as hospitals, control rooms of radars or radio transmitters, offices or just houses near the sources of electromagnetic fields or even the residential buildings is an up to date theme [1].

Thus, there are preoccupations both in the intrinsic determination and control of the shielding and attenuation proprieties at the buildings' level (complex and big structures) [2], [3] or even in finding or development of new construction materials having good absorption proprieties for the electromagnetic waves [4], [5].

Because of the complexity and non-uniformity of the building structures (windows, doors, walls, etc.), it is very difficult to estimate their shielding characteristics.

This paper presents the levels of the electromagnetic environment outside and inside of three houses and two large buildings situated near the radio and TV broadcastings systems. It was considered the estimation of the shielding and attenuation proprieties of these buildings situated around of the radio frequency high fields transmitters.

II. Instrumentation and procedure

The instrumentation used in these measurements is represented by: a near-field probe set, model 7405, ETS, EMECO; an IFR 2398 Spectrum Analyser, frequency range 9 kHz ÷ 2.7 GHz, measurement range between - 105 dBm and +20 dBm.

The value of the electric field expressed in dB μ V/m is:

$$E = U + PF \quad (1)$$

where U is the voltage developed by the probe expressed in dB μ V and PF is the probe performance factor, expressed in dB.

For 50 Ω input impedance, the voltage U expressed in dB μ V is:

$$U = P + 107 \quad (2)$$

where P is the power in dBm, displayed by Spectrum Analyser connected to the electric field probe.

Thus, the values of the electric field expressed dB μ V/m and then in V/m are:

$$E[\text{dB}\mu\text{V}/\text{m}] = P[\text{dBm}] + 107 + PF[\text{dB}] \quad (3)$$

$$E[\text{V}/\text{m}] = 10^{-6} \cdot 10^{\frac{E[\text{dB}\mu\text{V}/\text{m}]}{20}} \quad (4)$$

Near the radio frequency transmitters and thus outside and inside of the buildings, the electric and magnetic field vectors are very complex, with great spatial and temporal variability.

In order to obtain a lot of information in a short measurement time, we acted in the following manner: the field sensor was rotated, and the maximum values of the E field vectors for each frequency were memorised by the spectrum analyser (trace "max hold"). We also determined the average values of the electric fields by setting the spectrum analyser in the trace "average" mode.

The measurement time in each of these two situations was about 1 minute.

For the electric fields measurements, we considered some buildings situated near a medium wave transmitter, respectively some buildings situated near a broadcasting tower for FM radio and television

transmitters.

Thus, we measured the radio frequency electric fields generated by these intentional electric field sources represented by the radio stations both inside and outside the buildings and we have determined the field attenuation through the buildings' walls.

In this manner, it was not necessary to use our own transmitter antenna for generate the radio frequency fields. Moreover, by these "in situ" field measurements, we characterise the electromagnetic environment in these specific areas [6].

III. Measurement results

We made the electric fields measurements and we determined the field attenuation for some buildings situated near a broadcasting tower, respectively some buildings situated near a medium wave transmitter.

A. Buildings situated near the FM radio and television transmitters

The considered emission station is RF transmitters Petraria – Bucium, situated about at 10 km distance from Iasi, having a lot of broadcasting radio and television antennas. In its proximity there are: a tourism place, a major road and some residential and holiday houses.

The field measurements were made for three residential houses: House 1, situated at about 400 meters distance from the transmitter; House 2 and House 3 situated at about 250 meters distance from the transmitters.

Table 1 presents the maximum values of the electric field in two measurement points: one point situated outside the House 1 and the other point in a room inside this house. The first point is situated between broadcasting tower and this house, at about 400 m distance from the tower and 3 meters distance from the house. The attenuations of the buildings' walls for the electromagnetic fields generated by these local stations were determined by subtracting the values of the electric fields outdoor and indoor, expressed in dB.

The average values of the electric fields and the building's walls attenuations are shown in Table 2. In all tables will be presented also the values of electric fields in V/m determined with (4), truncated at two decimals.

Table 1: The values of electric fields outside and inside of the House 1, obtained in the "Max hold" trace mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB μ V/m]
	E [dB μ V/m]	E [V/m]	E [dB μ V/m]	E [V/m]	
96,3 MHz	124,47	1,67	119,12	0,9	5,35
99,24 MHz	118,29	0,82	108,27	0,26	10,02
101,13 MHz	126,14	2,03	120,43	1,05	5,71
103,11 MHz	129,83	3,1	121,49	1,19	8,34
198,96 MHz	135,92	6,25	131,07	3,58	4,84
205,44 MHz	127,78	2,45	120,65	1,08	7,13

Table 2: The values of electric fields outside and inside the House 1, obtained in the "Average" trace mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB μ V/m]
	E [dB μ V/m]	E [V/m]	E [dB μ V/m]	E [V/m]	
96,3 MHz	120,34	1,04	117,29	0,73	3,05
99,24 MHz	110,45	0,33	106	0,2	4,45
101,13 MHz	123,58	1,51	118,49	0,84	5,09
103,11 MHz	125,06	1,91	118	0,8	7,6
198,96 MHz	130,6	3,39	124,3	1,64	6,3
205,44 MHz	122,87	1,4	117,7	0,77	5,17

Thus, for House 1, a brick house, the attenuation of the electromagnetic fields can be considered as poor, less 10 dB.

The next two houses investigated, House 2 and House 3, are situated one in immediately neighbourhood of the other, at a few meters distances.

Figure 1 shows the maximum electric field values, trace “max-hold”, in 90 MHz ÷ 105 MHz frequency range, for the measurements made in a point between broadcasting tower and these houses, at about 250 meters distance from the tower and 3 meters distance from the considered rooms in House 2 and House 3.

Figure 2 shows the maximum electric field values, trace “max-hold”, in the centre of the considered room in House 2, which has the walls made from cellular expanded concrete.

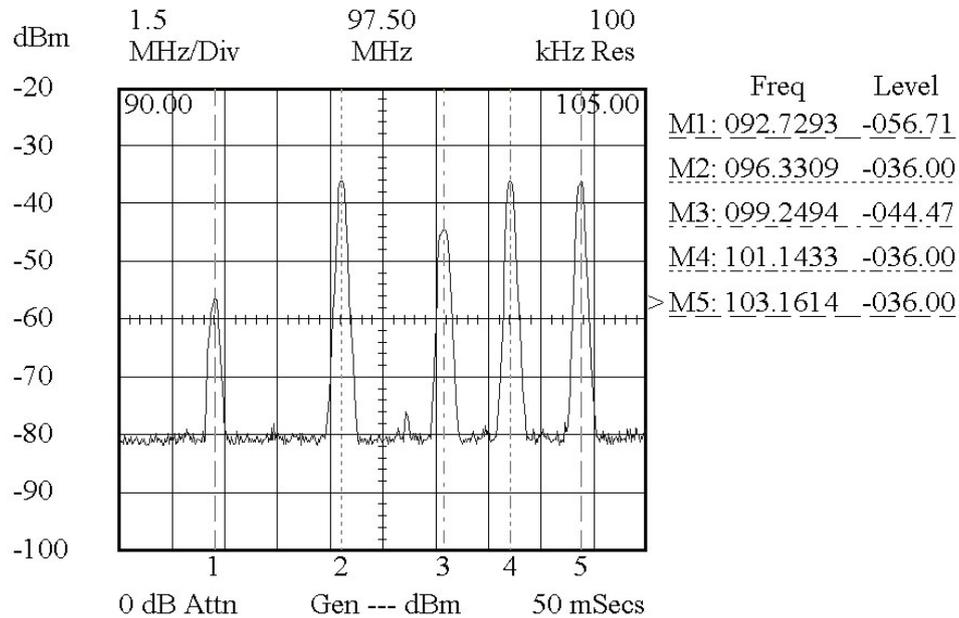


Figure 1. The maximum E values in 90 MHz ÷ 105 MHz frequency range, obtained outside the House 2 and House 3

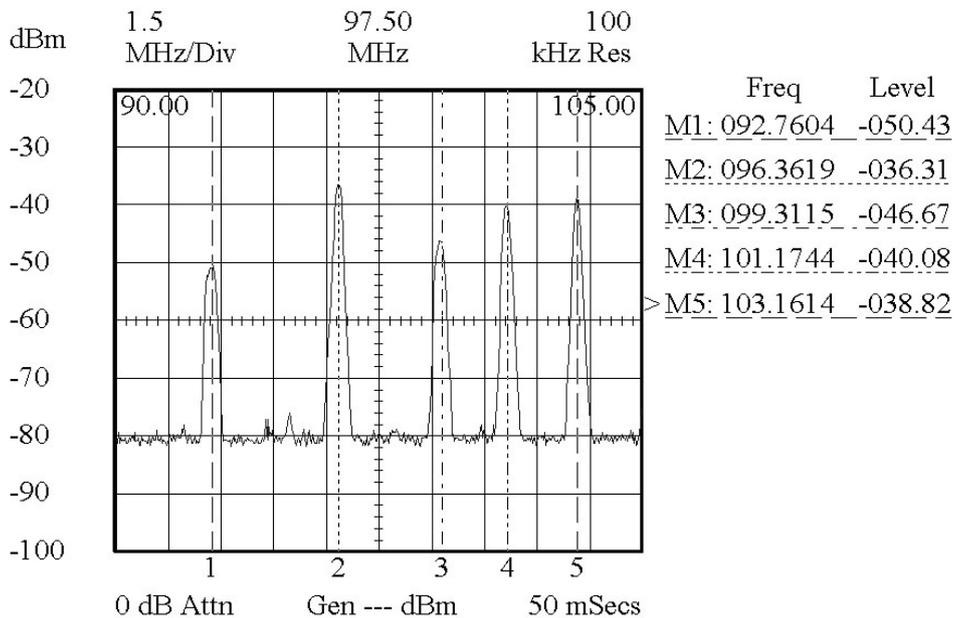


Figure 2. The maximum E values in 90 MHz ÷ 105 MHz frequency range, obtained inside the House 2

Table 3 and Table 4 present the maximum, respectively average values of the electric field, in two measurement points: one point situated outside the House 2 and the other point in the centre of a room inside this house.

Table 3: The values of electric fields outside and inside of the House 2, obtained in the “Max hold” trace mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB μ V/m]
	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	
96,3 MHz	128	2,51	127,69	2,42	0,31
99,24 MHz	118,53	0,84	116,33	0,66	2,2
101,13 MHz	127	2,24	122,92	1,4	4,08
103,11 MHz	127	2,24	124,18	1,62	2,82
198,96 MHz	138	7,94	130,74	3,44	7,26
205,44 MHz	131,8	3,89	121	1,12	10,8

Table 4: The values of electric fields outside and inside the House 2, obtained in the “Average” trace mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB μ V/m]
	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	
96,3 MHz	124,24	1,63	121,78	1,23	2,46
99,24 MHz	115	0,56	109	0,28	6
101,13 MHz	123	1,41	120	1	3
103,11 MHz	124	1,58	119	0,89	5
198,96 MHz	129,78	3,03	124	1,58	5,78
205,44 MHz	125	1,78	118	0,79	7

For House 3 were made measurements in two rooms: Room 1, which is situated at the first floor of the house; Room 2, situated at the ground floor. Room 1 has the walls made from panel tip sandwich (wooden, mineral cotton, gypsum wall board) and Room 2 has the walls made from brick. The measurement results for these two rooms are presented in Table 5, Table 6, Table 7 and Table 8.

Table 5: The values of electric fields outside and inside the House 3 (Room 1), in “Max hold” mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB μ V/m]
	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	
96,3 MHz	128	2,51	126,03	2	1,97
99,24 MHz	118,53	0,84	117,2	0,72	1,33
101,13 MHz	127	2,24	124	1,58	3
103,11 MHz	127	2,24	126,47	2,11	0,53
198,96 MHz	138	7,94	136	6,31	2
205,44 MHz	131,8	3,89	126	2	5,8

Table 6: The values of electric fields outside and inside the House 3 (Room 1), in “Average” mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB μ V/m]
	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	
96,3 MHz	124,24	1,63	123	1,41	1,24
99,24 MHz	115	0,56	114,89	0,56	0,11
101,13 MHz	123	1,41	115,45	0,59	7,55
103,11 MHz	124	1,58	122	1,26	2
198,96 MHz	129,78	3,03	129	2,82	0,78
205,44 MHz	125	1,78	119	0,89	6

Table 7: The values of electric fields outside and inside of the House 3 (Room 2), in “Max hold” mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB μ V/m]
	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	<i>E</i> [dB μ V/m]	<i>E</i> [V/m]	
96,3 MHz	128	2,51	122,8	1,38	5,2
99,24 MHz	118,53	0,84	109,77	0,31	8,76
101,13 MHz	127	2,24	120,76	1,09	6,24
103,11 MHz	127	2,24	122,72	1,37	4,28
198,96 MHz	138	7,94	128,95	2,8	9,05
205,44 MHz	131,8	3,89	119,19	0,91	12,61

Table 8: The values of electric fields outside and inside the House 3 (Room 2), obtained in the “Average” trace mode

Frequency [Mz]	Field outside		Field inside		Attenuation [dB]
	E [dB μ V/m]	E [V/m]	E [dB μ V/m]	E [V/m]	
96,3 MHz	124,24	1,63	116,52	0,67	7,72
99,24 MHz	115	0,56	103,92	0,16	11,08
101,13 MHz	123	1,41	115,25	0,58	7,75
103,11 MHz	124	1,58	118,36	0,83	5,64
198,96 MHz	129,78	3,03	123,03	1,42	6,75
205,44 MHz	125	1,78	116,55	0,67	8,45

For House 1, House 2 and House 3 - Room1 was made a single measurement in the centre of each room, for House 3 - Room 2 were made measurements in many points and were determined the mean values of the electric fields inside the room. In this mode the attenuation values for House 3 - Room 2 obtained with the trace in “Max hold” mode (see Table7) is closer to those obtained in the trace “Average” mode (see Table 8), compared with the case of House 1 (see Table 1 and Table 2). Both these rooms have the walls made from the same material, explicitly brick.

B. Buildings situated near a medium wave transmitter

This medium wave transmitter is situated at about 15 km distance from Iasi in opposite direction with the first transmitter considered (radio and TV broadcastings systems). The emission frequency of the transmitter is 1053 kHz, and its power is 500 kW.

The field measurements were made outside and inside of two large buildings: Building 1, situated at about 600 meters distance from the transmitter; Building 2 situated at about 800 meters distance from the transmitters. In both situations were made measurements in many points and were determined the mean values and the standard deviations of electric field outside and inside the buildings.

The results is summarised in Table 9 and Table 10.

Table 9: The mean values and the standard deviations of the electric fields outside and inside of the Building 1

Trace mode	Field outside			Field inside			Mean value of attenuation [dB]
	Mean value of E	Mean value of E	Standard deviation of E	Mean value of E	Mean value of E	Standard deviation of E	
	[dB μ V/m]	[V/m]	[V/m]	[dB μ V/m]	[V/m]	[V/m]	
Max hold	145,72	19,32	7,6	136,55	6,72	2,84	9,17
Average	139,77	9,74	4,84	128,37	2,62	0,35	11,4

Table 10: The mean values and the standard deviations of electric the fields outside and inside of the Building 2

Trace mode	Field outside			Field inside			Mean value of attenuation [dB]
	Mean value of E	Mean value of E	Standard deviation of E	Mean value of E	Mean value of E	Standard deviation of E	
	[dB μ V/m]	[V/m]	[V/m]	[dB μ V/m]	[V/m]	[V/m]	
Max hold	135,5	5,94	2,39	122,34	1,31	0,57	13,16
Average	129,86	3,11	1,03	117,42	0,74	0,37	12,44

For Building 1, which has the walls partial covered with metallic plate, the mean values of the attenuation are about 10 dB.

The Building 2 has all the walls covered with metallic plate, but it has large windows and thus the attenuation of the field is only a few dB greater than the one of the Building 1.

The electric field has significant spatial variability both outside and inside of the buildings. Thus, it is necessary to make a great number of measurements and a statistical data processing. In these conditions, the mean values of attenuation obtained with spectrum analyser in “Max hold trace” and “Average trace” are about the same (e.g. 13,16 dB and 12,44 dB for the Building 2, according to Table 10).

IV. Conclusions

We carried out the electric fields measurements in order to characterise electromagnetic fields propagation through the walls of some buildings situated near broadcasting towers.

The levels of the electric field outside and inside the considered buildings from these special areas are below the reference levels for general public exposure (the maximum levels for public access, namely 87 V/m for 1 MHz and 28 V/m in 10 MHz ÷ 400 MHz), recommended by International Commission on Non Ionizing Radiation Protection - ICNIRP, but they are about 10 ÷ 100 times greater than those measured in the city, situated at about 10÷15 km distance.

The electromagnetic attenuations of the houses considered near the FM radio and television transmitters are poor, ranging from 1-7 dB, in the case of the walls tip sandwich panel made from wooden - mineral cotton - gypsum wall board, to 6-12 dB, in the case of the walls made from brick.

The electromagnetic attenuations of the commercial buildings considered near the medium wave transmitter are moderate (above 10 dB). These commercial buildings are partially covered with metallic plate.

Because the great spatial and temporal variability of the electric fields it is necessary to made many measurements both outside and inside the buildings. Thus, by a statistical data processing, in the case of the buildings situated near the medium wave transmitter, we obtained a good correlation between the values of attenuations determined in “Max hold” and “Average” modes.

The attenuation of the electromagnetic field inside of the buildings depends on the electric field frequency, the materials of the walls, the configuration of these complex structures (windows, doors, geometry of the rooms, etc.). The knowledge and the control of the electromagnetic shielding proprieties are very important, particularly in the case of the special buildings. Thus, in view of decreasing the electromagnetic threat, the development of new materials and determination of an adequate topology of the buildings must be considered.

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