The Survey of Electromagnetic Environment near RF Transmitters

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***Abstract*-**In this paper we present the results of electromagnetic field measurements near two RF transmitters: one in the medium wave domain and one in FM radio and television frequency range. The RF transmitters are situated at about 15 km distance from the town, but near them there are: tourist places; main roads; houses, where the public may be present. Using both a set of near field E & H probes and the adjustable dipole antennas, comparative measurements were made. Beside the instantaneous values of the fields, the maximum and average values for 1 minute observation period were determined.

I. Introduction

The survey of the electromagnetic environment is necessary in electromagnetic compatibility ("in situ" measurements of electromagnetic interference) and in biological compatibility. The measurements of fields in residential and tourist places, public streets situated near the RF transmitters are important for: estimating EMI on automobiles [1]; EMI to implantable pacemakers and defibrillators [2]; the estimation of the biological and health effects of the electromagnetic fields [3], [4], [5]. The difficulties encountered in these measurements are caused by the complexity of the fields (great spatial and temporal variability) and, moreover, the estimation of biological effects is a very complex problem. Thus, the maximum recommended levels are not the same for different organisations, because different criteria are used in the effects estimation. For example, the limits recommended by the International Commission on Non Ionising Radiation Protection - ICNIRP are shown in Table 1 [6].

TABLE I. ICNIRP reference levels for general public exposure

Frequency	RMS values			
	E	H	B	P
Hz	V/m	A/m	mT	W/m^2
up to 1 Hz	-	$3,2 * 10^4$	$4* 10^4$	-
0,025 - 8 Hz	10000	$3,2 * 10^4/f^2$	$4 * 10^4/f^2$	-
8-25 Hz	10000	4000/f	5000/f	-
0,025-0,8 kHz	250/f	4/f	5/f	-
0,8-3 kHz	250/f	5	6,25	-
3-150 kHz	87	5	6,25	-
0,15-1 MHz	87	0,73/f	0,92/f	-
1-10 MHz	$87/\sqrt{f}$	0,73/f	0,92/f	-
10-400 MHz	28	0,073	0,092	2
0,4-2 GHz	$1,375*\sqrt{f}$	$0,0037*\sqrt{f}$	$0,0046 *\sqrt{f}$	f/200
2-300 GHz	61	0,16	0,20	10

We are interested in the electromagnetic characterisation of the populated areas around the RF transmitters. In these areas we measured both electric fields, and magnetic fields in a broad frequency range (9 kHz ÷ 2,7 GHz). Although the measurement points are in far field region from the source, for a good characterisation of the electromagnetic fields, far field and also near field sensors were used.

II. Instrumentation and Methodology

The instrumentation used in measurements is represented by: a near-field probe set, model 7405; adjustable dipole antennas, model 3121C, ETS, EMECO; an IFR 2398 Spectrum Analyser. For H measurements two probes (901 - 6 cm loop probe and 902 - 3 cm loop probe) were used. For E measurements, beside two near field probes (904 - E - field ball probe and 905 - E - field stub probe), the set of adjustable dipole antennas was utilised.

Owing to fields complexity, the three orthogonal components of the E and H fields (E_x, E_y, E_z, H_x, H_y, H_z) must be measured and the root mean square (r.m.s.) value of the resultant magnetic and electric fields can be determined with the relation:

$$E = \sqrt{E_x^2 + E_y^2 + E_z^2} \qquad (1)$$

where E is the is the r.m.s. value of the electric field and E_x, E_y, E_z are the rms values of the orthogonal components.

Moreover, to estimate the conformity with reference levels (e.g. Table 1), the average time must be of about 6 minutes.

When the electromagnetic field consists of many frequencies (e.g. there is many frequency bands - emitters or generally the fields have many harmonics), the normalised indices, such as the relative exposure RE, are used [7]:

$$RE = \frac{E_{f_1}^2}{E_{\lim\, f_1}^2} + \frac{E_{f_2}^2}{E_{\lim\, f_2}^2} + \ldots + \frac{E_{f_n}^2}{E_{\lim\, f_n}^2} \qquad (2)$$

where the r.m.s. values of the electric fields squared for all frequencies are at numerators and at denominators the corresponding exposure limits (r.m.s. values squared).

The normalised indices are calculated for E^2, H^2, S (power density) conforming (2), or sometimes in linear mode (E, H - r.m.s. values only) and the results (e.g. the relative exposure - RE) should not exceed unity.

With a view to obtain a lot of information in a short measurement time, we did as follows:

The field sensors were rotated, and the maximum value of the H or E field vectors was memorised by the spectrum analyser (trace "max hold"). We also determined the average values of the H or E fields by setting the spectrum analyser in a trace "average" mode. The measurement time in each of the two situations was of about 1 minute.

The measurements were made near two RF transmitters. One of them (medium wave emitter) is situated at about 15 km from the town. The output power of this medium frequency transmitter is of 500 kW and the frequency is 1053 kHz. In its proximity are main roads, some houses and institutions. The other emission station has a lot of broadcasting antennas (radio and television). Some output powers and frequencies of these emitters are: 10 kW at 101,1 MHz, 10 kW at 103,12 MHz for the radio broadcastings and 100 W at 175,5 MHz, 12 kW at 199,25 MHz for television broadcastings. The latter emission station is situated at the top of the hill, at about 10 km distance from the town in the opposite direction of the former. In its proximity are: a tourist place, a main road and some houses.

III. Results

A. Medium wave transmitter

The emission frequency of the transmitter is 1053 kHz, and its power is 500 kW.

TABLE 2. The maximum and average electric field values for f = 1053 kHz

Probe used	Maximum field (E)		Average field (E)	
904 E	149 dBμV/m	28 V/m	145 dBμV/m	18 V/m
905 E	159 dBμV/m	89 V/m	156 dBμV/m	63 V/m
901 H	142 dBμV/m **90,48 dBμA/m**	13 V/m **34 mA/m**	140 dBμV/m **88,48 dBμA/m**	10 V/m **27 mA/m**
902 H	139 dBμV/m **87,48 dBμA/m**	9 V/m **24 mA/m**	135 dBμV/m **83,48 dBμA/m**	6 V/m **16 mA/m**

The field measurements were made at about 400 m distance from the transmitter, by using some near field probes: two for E field and two for H field. Table2 presents the maximum and average electric

field values for 1 minute measurement time. In the case of magnetic field sensors, the equivalent E value of the field (H multiplied by 377) and H, the measured quantity expressed in dBμA/m and mA/m are given in Table 2. There is a great difference between the indications of the two electric field probes (904 E and 905 E). Thus, we proposed to measure successive the three components (E_x, E_y, E_z) of the field with the two probes and to calculate and compare the resultant fields. The differences between the indications of the magnetic field probes (901 H and 902 H) are small. Moreover, the fields have a complex configuration, although the measurement point is in far field zone ($400 >> \frac{\lambda}{2\pi} = \frac{3 \cdot 10^8}{2 \cdot 3{,}14 \cdot 1053 \cdot 10^3} = 45$), and for a good characterisation of the field many measurements must be made.

B. FM radio and television transmitters

The measurements were made in a tourist place, nearby the broadcasting antennas.

Electric field "E" measurements

First we visualised the whole spectrum (9 kHz ÷ 2,7 GHz) by setting the spectrum analyser in "full span" mode. The maximum and average values of E field for one-minute measurement time obtained by using 904 E Field Ball Probe in this frequency range are shown in Table 3.

TABLE 3. The maximum and average values of electric fields in 9 kHz÷2,7 GHz frequency range

Frequency	Maximum values		Average values	
72 MHz	131 dBμV/m	3,55 V/m	124 dBμV/m	1.58 V/m
105 MHz	135 dBμV/m	5,62 V/m	131 dBμV/m	3,55 V/m
154 MHz	111 dBμV/m	0,355 V/m	89 dBμV/m	0,028 V/m
182 MHz	110 dBμV/m	0,316 V/m	103 dBμV/m	0,141 V/m
198 MHz	130 dBμV/m	3,162 V/m	127 dBμV/m	2,239 V/m
341 MHz	107 dBμV/m	0,224 V/m	98 dBμV/m	0,079 V/m
429 MHz	103 dBμV/m	0,141 V/m	-	-
462 MHz	102 dBμV/m	0,126 V/m	95 dBμV/m	0,056 V/m
930 MHz	83 dBμV/m	0,014 V/m	76 dBμV/m	0,006 V/m

After a general view on the emission spectrum ("full span"), we selected a frequency range where are included the main emissions and where the performance factors of the probe are well defined (100 kHz ÷ 500 MHz). Figure 1 shows the maximum electric field values (trace "max hold") in 100 kHz÷500 MHz frequency range. They were measured E with the 904 E Field Ball Probe. Table 4 presents the maximum values and the average values of the electric field, obtained with the 904 E field probe in 100 kHz÷500 MHz frequency range.

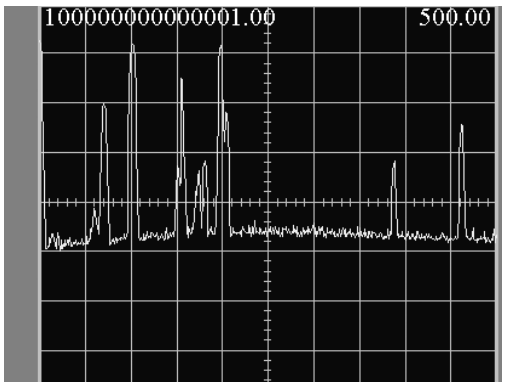

Fig. 1. The maximum E values in 100 kHz ÷ 500 MHz frequency range, obtained with the 904 E field probe

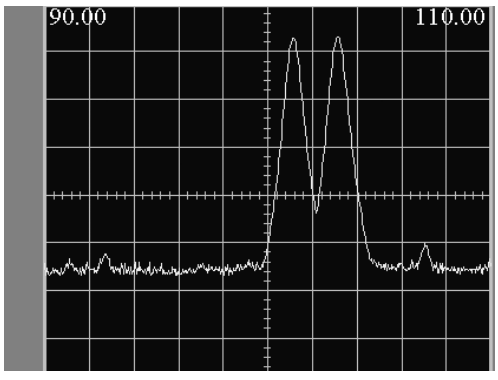

Fig. 2. The maximum E values in 90 MHz ÷ 110 MHz frequency range, obtained with the adjustable dipole antenna

For the greatest value of the field situated at about 102 MHz, supplementary measurements were made by using the adjustable dipole antenna with spectrum analyser in 90 MHz÷110 MHz frequency range.

TABLE 4. The maximum and average values of electric fields in 100 kHz ÷ 500 MHz frequency range

Frequency	Maximum values		Average values	
70 MHz	125 dBμV/m	1,78 V/m	123 dBμV/m	1,413 V/m
102,1 MHz	134 dBμV/m	5,01 V/m	132 dBμV/m	3,981 V/m
157,1 MHz	127 dBμV/m	2,24 V/m	-	-
159,1 MHz	114 dBμV/m	0,5 V/m	-	-
174 MHz	105 dBμV/m	0,16 V/m	-	-
181 MHz	106 dBμV/m	0,2 V/m	101 dBμV/m	0,11 V/m
198 MHz	128 dBμV/m	2,51 V/m	127 dBμV/m	2,239 V/m
387 MHz	99 dBμV/m	0,089 V/m	96 dBμV/m	0,063 V/m
462 MHz	104 dBμV/m	0,16 V/m	97 dBμV/m	0,071 V/m

The results are presented in Fig. 2, where only the fields emitted by two FM radio stations (101,1 MHz and 103,12 MHz) appear. Table 5 presents the maximum and averaged values of fields, obtained by using the adjustable dipole antenna.

TABLE 5. The maximum and average electric field values for two frequencies

Frequency	Maximum field (E)		Average field (E)	
101,1 MHz	128 dBμV/m	2,51 V/m	126 dBμV/m	2 V/m
103,12 MHz	128 dBμV/m	2,51 V/m	127 dBμV/m	2,24 V/m

In this way were separated these two emitted frequencies which appeared united in Fig 1 and Table 4.

Magnetic field "H" measurements

Beside the electric field E, we also measured the magnetic field H using the 901 Loop Probe.

The maximum and average values of the electric equivalent field (H multiplied by 377) and the magnetic field H (the measured quantity) for one-minute measurement time, obtained by using the 901 H Field Loop Probe in "full span" mode, are shown in Table 6.

TABLE 6. The maximum and average values of E equivalent and H in 9 kHz÷2,7 GHz frequency range

Frequency	Maximum values (E_{eq}, **H**)		Average values (E_{eq}. **H**)	
72 MHz	116 dBμV/m **64,48 dBμA/m**	0,631 V/m **1,67 mA/m**	105 dBμV/m **53,48 dBμA/m**	0,178 V/m **0,47 mA/m**
105 MHz	114 dBμV/m **62,48 dBμA/m**	0,501 V/m **1,33 mA/m**	110 dBμV/m **58,48 dBμA/m**	0,312 V/m **0,83 mA/m**
198 MHz	119 dBμV/m **67,48 dBμA/m**	0,891 V/m **2,36 mA/m**	115 dBμV/m **63,48 dBμA/m**	0,562 V/m **1,49 mA/m**
462 MHz	97 dBμV/m **45,48 dBμA/m**	0,071 V/m **0,19 mA/m**	90 dBμV/m **38,48 dBμA/m**	0,032 V/m **0,085 mA/m**
930 MHz	94 dBμV/m **42,48 dBμA/m**	0,05 V/m **0,13 mA/m**	-	-

Similar to the electric field measurements, the maximum values and the average values of magnetic field were measured with the 901 H field probe in 100 kHz÷500 MHz frequency range. The results are shown in Table 7.

TABLE 7. The maximum and average values of magnetic fields in 100 kHz÷500 MHz frequency range

Frequency	Maximum values (E_{eq}, **H**)		Average values (E_{eq}, **H**)	
71,1 MHz	119 dBμV/m **67,48 dBμA/m**	0,891 V/m **2,36 mA/m**	116 dBμV/m **64,48 dBμA/m**	0,630 V/m **1,67 mA/m**
102,1 MHz	116 dBμV/m **64,48 dBμA/m**	0,63 V/m **1,67 mA/m**	110 dBμV/m **58,48 dBμA/m**	0,316 V/m **0,84 mA/m**
197 MHz	120 dBμV/m **68,48 dBμA/m**	1 V/m **2,65 mA/m**	119 dBμV/m **67,48 dBμA/m**	0,891 V/m **2,36 mA/m**
462 MHz	98 dBμV/m **46,48 dBμA/m**	0,079 V/m **0,21 mA/m**	92 dBμV/m **40,48 dBμA/m**	0,04 V/m **0,11 mA/m**

Figure 3 shows the maximum magnetic field values in 100 kHz÷500 MHz frequency range.

The equivalent electric field obtained with the 901 H field probe is about 3÷10 smaller than the electric field measured with the 904 E field probe. Thus, similar to the first transmitter, the field configuration is complex and both components of the field (E and H) must be measured. In Tables 6 and 7 the magnetic fields values expressed in dBμA/m and mA/m are given. Also, by comparing Fig. 1 and Fig. 3 we can see that, the number of emission frequencies identified with the electric field sensor is greater than the one obtained with the magnetic field sensor.

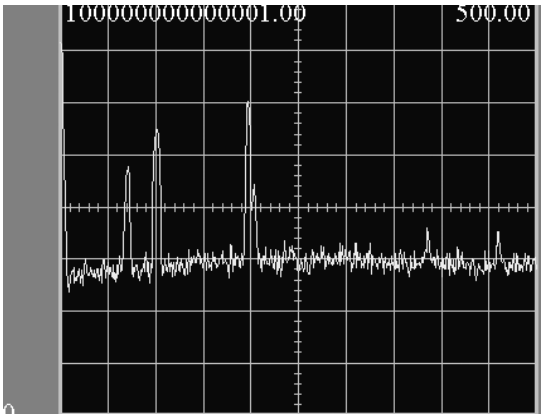

Fig. 3 The maximum H values in 100 kHz ÷ 500 MHz frequency range, with the 901 H field probe

IV. Conclusions

Using many field sensors, comparative measurements of the electromagnetic fields near two broadcasting towers were made. Our aim was to obtain a lot of information about the electromagnetic fields in a short time. The electromagnetic fields in these zones have a complex configuration with great spatial and temporal variability. Thus, for a complete characterisation of the fields, many measurements of E and H fields must be made, and the measurement time is very large. The maximum and average values of E and H in some populated areas, near the transmitters were determined. In this areas the fields are about 30 ÷ 100 times greater than the fields measured in the town situated at about 10 km distance. Nevertheless, in the measurement areas, the field values were under the maximum recommended levels**.**

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References

[1] K. D. Kruse, J. L. Haseborg, "EMC Environment for automobile between 10 kHz÷1 GHz frequency dependence, parasitic radiators, shielding effects", *Proc on EMC*, Zurich, pp. 661- 666, 1993.
[2] D. Wessels, "Implantable Pacemakers and defibrillators: Devices Overview & EMI considerations", *2002 IEEE EMC International Symposium*, pp. 911-915, 2002.
[3] B. S. Galvao, G. Santos, H. Onusic, L. F. Sant'Anna "Electromagnetic Environmental Measurements in Specific Populated Areas of Brazil", *2001 IEEE EMC International Symposium*, Montreal, 2001.
[4] R. Coray, J. F. Gassmann, "RF Exposure in a Shortwave Transmitter Environment Including the Influence of Buildings Structure and Human Body", *Proc on EMC*, York, pp. 13- 16, 1994.
[5] F. Gassman, J. Furrer, "An Isotropic Broadband Electric and Magnetic Field Sensor for Radiation Hazard Measurements", *Proc. on IEEE International EMC Symposium*, Dallas, pp. 105 -109, 1993.
[6] D. A. Weston, *Electromagnetic Compatibility. Principles and Applications*, Marcel Dekker, Inc., New York, 2000.
[7] J. Baumann, G. J. Behrmann, H. Garbe, "Long-Term Survey of the Background Electromagnetic Environment in Switzerland", *Proc on EMC*, Zurich, pp. 1- 4, 1993.