STUDY OF THE POWER-FREQUENCY MAGNETIC FIELDS IN RESIDENCES AND SCHOOLS

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REZUMAT. In ultimii douăzeci de ani, unele studii epidemiologice au sugerat o posibilă legătură între expunerea umană la câmpuri magnetice de foarte joasă frecvență – cauzate, în principal, de producerea, distribuția şi utilizarea energiei electrice – şi diferite forme de cancer sau alte probleme de sănătate. Dimpotrivă, alte studii au sugerat că nu se poate demonstra niciun fel de asociere directă. Totuşi, din moment ce problema rămâne controversată, caracterizarea nivelurilor de expunere la astfel câmpuri este extrem de importantă. În acest context, lucrarea de față prezintă rezultate ale unui studiu preliminar realizat în 15 locuințe şi câteva laboratoare universitare.

Cuvinte cheie: câmpuri magnetice de foarte joasă frecvență, expunere umană, măsurări, locuințe, şcoli

ABSTRACT. Over the past two decades, a number of epidemiological studies have suggested a possible link between the human exposure to extremely low frequency (ELF) magnetic fields, primarily associated with the generation, transmission and use of the electrical energy, and various cancers or other health problems. On contrary, other studies have suggested that no definite correlation could be demonstrated. However, as possibility of adverse health effects is still controversial, evaluating the residential and occupational ELF exposure remains a very important issue. In this paper, we present results of a preliminary survey conducted in a number of 15 residences and a few university laboratories.

Keywords: ELF magnetic fields, human exposure, measurements, residences, public schools

1. INTRODUCTION

The distribution and use of the electrical power generate both electric and magnetic fields. The electric fields are directly related to the level of voltage, while the magnetic fields are produced by the movement of the charge. Depending on the country, these fields are generated at a frequency of either 50 Hz or 60 Hz, being referred to as extremely-low frequency (ELF) fields.

At the present time, there is no proven evidence that the exposure to low-level electric fields is a health hazard (excluding, of course, electric shock). A large number of scientific studies performed on animals and cells have not found a health risk. On the other hand, some epidemiological studies have suggested that there might be a weak association between the prolonged exposure to magnetic fields higher than 0.4 μT and an increased risk of childhood leukemia. For other diseases, the scientific evidence is even weaker or sufficient to give confidence that the ELF magnetic fields do not cause the disease – for instance, cardiovascular diseases or breast cancer [1]-[4].

However, as the issue of ELF exposure remains very controversial, characterizing the residential and occupational exposure levels continues to attract great interest from various authorities and scientific community [5]-[8]. In such a context, this paper presents measurement results of a preliminary survey conducted in a number of residential and school environments, as a starting point in implementing a larger, more comprehensive study of exposure to power-frequency magnetic fields in Iasi, Romania.

2. ELF EXPOSURE GUIDELINES

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published, in 1998, guidelines on exposure limits for all electromagnetic fields (EMF), including ELF [9]. These guidelines provide adequate protection against known health effects and those that can occur when touching charged objects in an external electric field. The limits of exposure recommended in many countries are broadly similar to those of ICNIRP, which is the formally recognized non-governmental organization in non-ionizing radiation (NIR) protection for the World Health Organization (WHO), the International Labour Organization (ILO) and the European Union (EU).

For power-frequency fields, ICNIRP has established guidelines for occupational and general public exposures to both electric and magnetic fields. For 50 Hz magnetic fields, the ICNIRP reference levels for occupational and residential exposures are 500 µT and 100 µT, respectively. Note that, fields of such magnitudes are generally found only in limited occupational settings and for very short periods of time for the general public.

In 2006, Romania has transposed in binding national legislation the Directive 2004/40/EC of the European Parliament and the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (EMF), and the Recommendation 1999/519/EC on the limitation of exposure of the general public to EMF (0 Hz to 300 GHz). The limits in both the Recommendation and the Directive are derived from the ICNIRP Guidelines, published in 1998. In 2010, ICNIRP has issued new guidelines for EMFs with frequencies between 1 Hz and 100 kHz [10], but these have not yet led to changes in EU legislation.

3. INSTRUMENTATION

It is known that, in general, the magnetic fields from AC systems contain a moderate amount of harmonics, primarily the third harmonic [5], [11]. In order to measure such fields, a handheld magnetic field meter with an adequate frequency response must be used. A broadband meter will measure the magnitude of the field over some extended frequency range below and above the fundamental frequency, approximately 30 Hz to 1000 Hz [12], [13].

The instrumentation involved in this survey is shown in Fig.1. It consisted in two commercial field meters that operate in the frequency range from 30 Hz to 300 Hz (single-axis C.A 40 gaussmeter, from Chauvin Arnoux, and tri-axis 480826 EMF tester, from Extech Instruments), together with an interfacing, single-axis field meter developed at our faculty [14], operating in the frequency range from 40 Hz to 150 kHz.

Generally, the two commercial meters were used for performing spot measurements of the background magnetic field, by individually evaluating the r.m.s. values of the magnetic flux density in three orthogonal directions and then computing the resultant, whereas the third instrument was used for field monitoring and waveform analyses in conjunction with a PC and a signal analyzing device, respectively. For all instruments, the r.m.s. value of the resultant field was calculated with the formula:

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2}\ , \qquad (2)$$

where B_x, B_y and B_z are the r.m.s. readings taken on three orthogonal directions, with the mention that, in the case of single-axis field meters, obtaining these components has required to manually position the external loop sensor.

4. RESIDENTIAL MEASUREMENTS

A number of 15 houses from urban and suburban areas of the Iasi city were investigated. Because such studies are intrusive by their nature, spot measurements of the background magnetic field were carried out over a period of 15 minutes (one measurement per minute). Usually, the measurements were performed at or near the center of each room, with the pick-up sensor placed at a height of 1 m above the ground and at least 1 m distance from any operating appliance. In a few cases, they were taken under low-, normal- and high-power conditions, as a function of the number of electrical systems operated at a given moment [12]. Also, to get a better idea about the temporal variation of the ELF magnetic field, the measurements in two residences were repeated at different days, within an interval of two months.

Single-axis C.A 40 Gaussmeter, Chauvin Arnoux	**Tri-axis 480826 EMF tester, Extech Instruments**	**Single-axis MFM 1.0 magnetic field meter, developed at our faculty**
		

Fig. 1. Instrumentation used for the survey

Examples of measurement results obtained in low-, normal- and high-power conditions are given in Table 1. As expected, increasing the amount of electrical power used in the house leads to increasing the level of the background magnetic field. Probably, if a normal-power assessment cannot be performed (for instance, there are no information from the resident with respect to the normal layout and use of the electrical appliances), a low-power assessment will be closer to the average conditions than a high-power one.

Table 1

The background magnetic field measured in two one-bedroom apartments, in different power conditions

Measurement conditions	Magnetic flux density*, B (nT)			
	Bedroom		Kitchen	
	Apt. 1	Apt. 2	Apt. 1	Apt. 2
All electrical systems and appliances turned off, except refrigerator (low-power conditions)	41.63	35.23	67.28	22.65
Normal use of electrical systems and appliances (normal-power conditions)	80.34	40.67	130.6	32.80
Most electrical systems and appliances turned on (high-power conditions)	189.9	53.17	–	139.8

*The average of 15 measurements taken over a period of 15 minutes.

Overall, a simple analysis of all recorded data revealed that the background magnetic field may vary greatly from one residence to another (ratios between averaged flux densities up to 15), but significant differences can also be observed in the magnetic field levels measured over time in the same residence, even at the same location. For instance, as presented in Table 2, the background magnetic field recorded in the bedroom of Apt. 1, over 10 different measurement times, varied between 58.53 nT and 171.70 nT.

Table 2

The background magnetic field measured in a one-bedroom apartment, at 10 different times

Measurement date	Magnetic flux density*, B (nT)	
	Bedroom	Kitchen
March 23	80.34	130.6
April 02	129.7	129.1
April 11	69.21	141.2
April 25	147.2	105.7
May 03	93.05	81.87
May 04	69.73	110.5
May 07	58.53	105.4
May 17 (morning)	154.1	91.42
May 17 (evening)	171.7	166.5
May 18	63.99	133.4

*The average of 15 measurements taken over a period of 15 minutes.

Despite the large temporal and spatial variability, all measurement results – summarized with the arithmetic mean of the 15 measurements taken at each location – were found to be much lower than the reference level of 100 µT, set by ICNIRP for 50 Hz fields. Otherwise, the maximum local value recorded during the entire survey was 328.3 nT, while the minimum local value was only 21.88 nT. Generally, lower values were observed in the suburban area (in 5 from 6 investigated residences, the averaged magnetic flux densities did not exceed 40 nT, during the day).

Besides spot measurements of the background magnetic field, exposure levels from a number of randomly selected household appliances were also measured. As can be seen in Fig. 2 and Fig. 3, close to electrical appliances, the exposure levels are higher, but – as expected – they are decreasing rapidly with distance. Note that, all these levels were obtained by powering down most electrical systems in the house, except the appliance subjected to investigations. In Fig. 2, the curves having unfilled markers are associated to the second Y-axis.

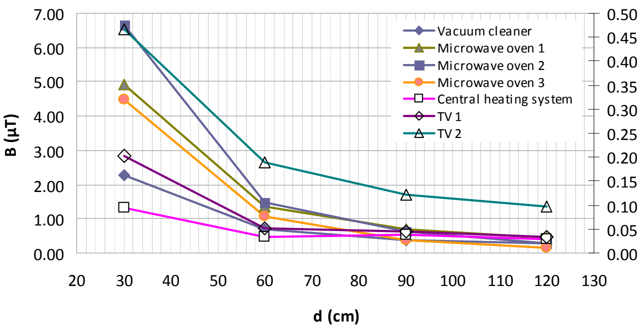


Fig. 2. Magnetic field levels from household appliances

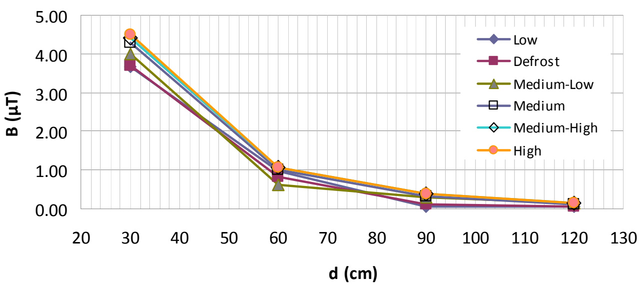


Fig. 3. Magnetic field levels corresponding to various operating modes of a microwave oven

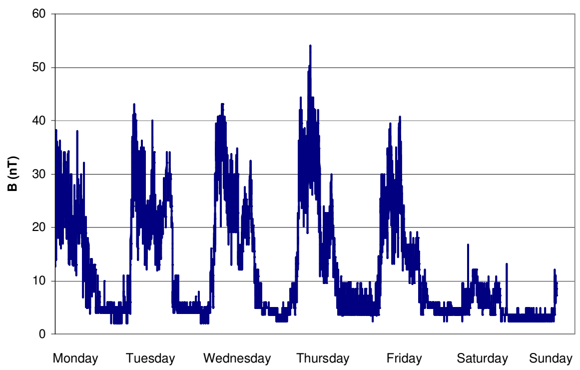
5. LABORATORY MEASUREMENTS

The background magnetic field in two laboratories of our faculty – one primarily used for research and the other for teaching – was also investigated. In the first lab, which is located at the 4th floor of the building, spot measurements were taken hour by hour, over a working week, at four distinct locations (P1 ÷ P4), where the laboratory staff spends most of its time. In addition, by adopting a sampling interval of 1 minute, the vertical component of the background magnetic field was logged at the center of the room, over the entire week. The measured levels were found to be very low (tens of nT), being comparable to the weakest fields found in residences.

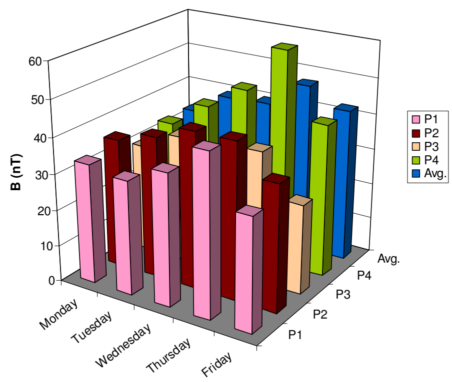
As presented in Fig. 4, a slight increase in the ELF field can be observed at the middle of the week, but the averaged flux densities corresponding to the four locations do not exceed 75 nT. During the night and in the weekend, the field levels are even lower, with no more than 10 nT ÷ 12 nT at the center of the room. A similar weekly trend was also observed at a later stage, after repeating the entire measurement process, but the averaged magnetic flux densities ranged from about 80 nT to 132 nT.

In the second laboratory, which is located at the ground floor of the building, the ELF magnetic field is much higher. As shown in Fig. 5 (a), the vertical component of the magnetic field, logged over a period of 24 hours at the center of the room, exceeded 1.2 μT during the day and did not fall below 300 nT during the night. And this time, the sampling interval was established to 1 minute.

Subsequent measurements revealed slightly lower levels. For instance, in Fig. 5 (b), which represents the magnetic field distribution in the laboratory at a later date, the r.m.s. values of the magnetic flux density at the nodes of a 1 m by 1 m grid vary from 134.91 nT to 763.54 nT. They are taken at exactly 1 m from the ground, with no electrical equipments in operation.

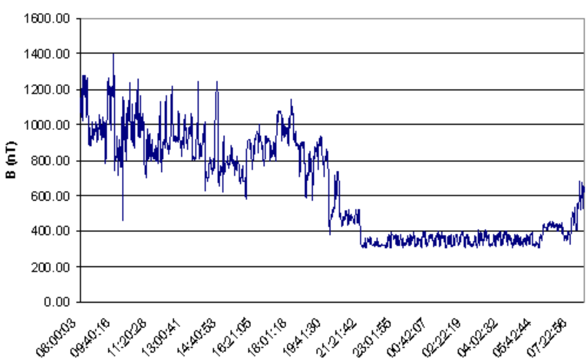


a) 7-day temporal variation of the vertical component of the magnetic field at the center of the laboratory

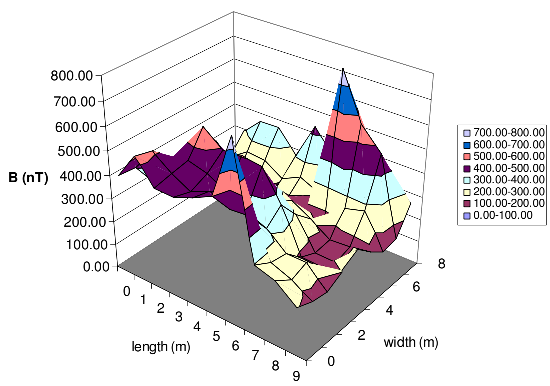


b) Daily averages of the magnetic flux density at four distinct locations, P1 ÷ P4

Fig. 4. The background magnetic field in Laboratory 1 (one-week survey)



a) The vertical component of the magnetic field at the center of the laboratory over a period of 24 hours



b) The magnetic field distribution in the laboratory, at the middle of the week

Fig. 5. The background magnetic field in Laboratory 2

The spectral analysis of the background magnetic field in Laboratory 1, performed at different moments of the day, established that the highest levels of exposure are indeed associated with the power frequency and its third harmonic. As presented in Fig. 6 below, the total harmonic distortion (THD) can be quite large, possibly due to an increased amount of non-linear loads in the building (e.g., fluorescent lamps).

The time-domain and frequency-domain representations in Fig. 6 were successively captured, by using a Fluke 43 Power Quality Analyzer working in the Scope mode and the Harmonics mode, respectively. For these measurements, the PQ analyzer was directly connected to the analog output of the MFM 1.0 magnetic field meter, designed by the authors, which provides a high-level signal coming from the loop sensor circuit.

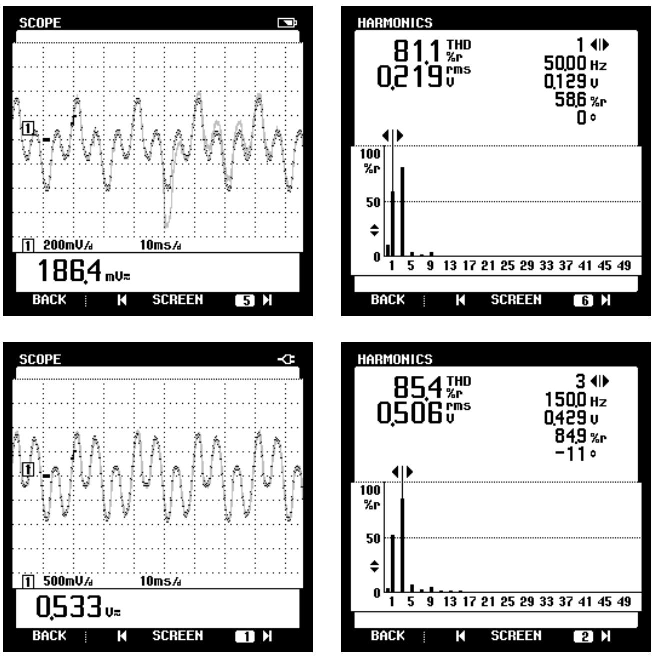


Fig. 6. Waveforms and frequency-domain representations of the magnetic field in Laboratory 2

5. CONCLUSIONS AND FUTURE WORK

✓ Overall, a high temporal and spatial variability of the background magnetic field was observed during this preliminary survey. All measured fields, also including those from appliances, were well below the reference level for the general public, 100 µT.

✓ The highest levels of exposure were measured close to electrical appliances (not all were presented in this paper). At a distance of 30 cm, the magnetic fields surrounding the selected household appliances are more than 100 times lower than the given reference level, within the limits specified in the literature for different categories of appliances.

✓ Amongst the spot measurements performed, we did not find residential settings with background magnetic fields exceeding 0.4 µT. Such levels were found in a teaching laboratory of our faculty, located at the ground floor of the building.

✓ Information from the present study will be used as basis for a more comprehensive survey of the residential ELF magnetic fields in Iasi, with improved procedures regarding house selection, measurement methodology, data analysis, etc.

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