One Year Period Survey of Residential Magnetic Fields

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Abstract **-** This paper presents the results of a one year period survey of the 50 Hz magnetic fields in some dwellings and laboratories. By performing a great number of measurements, the authors considered the spatial and temporal variability. Thus, we determined the daily, weekly, monthly and annual variability of the magnetic field. We also made the time and frequency domain measurements of B, to characterize the harmonics contents of the residential magnetic field. This study is important in the field exposure estimation and the design of the power supply systems for the generated magnetic field reduction.

I. Introduction

It is important to have knowledge of the electromagnetic environment both for the medical domain (biological and health effects of the electromagnetic field) and for the electrical engineering domain (electromagnetic compatibility). Referring to the former aspect, the interaction between the weak fields and the biological systems or the long time exposure of humans at low-level fields is a very up-to-date theme. In this paper the measurements of the power line (50 Hz) magnetic fields in residential areas are made. For these specific areas, the levels of the magnetic fields are smaller, their harmonics contents are greater and the fields have great temporal and spatial variations [1], [2], [3]. By performing a large number of measurements in a year period, we obtained information regarding the temporal variation of the magnetic field (a day, a week, a month, all the year) in same places - two dwellings and two laboratories, [4]. Additionally, the waveform and the harmonics contents of the magnetic fields in residential areas were represented in some cases.

II. Instrumentation and methodology

In order to measure 50 Hz magnetic fields, two types of instruments were used: an ELF 01 magnetometer, made by Terraflux Control Iasi; an active magnetic field sensor having a 40 Hz ÷ 200 kHz frequency range, made and calibrated by the authors in their laboratory. The former instrument displays the root mean square (r.m.s.) of the field. The latter magnetic sensor, connected to the Fluke 43 Power Quality Analyzer, permits the time domain measurements and harmonics representation of the fields, being very useful in the field sources identification. These two magnetic field meters are single axis type instruments. By using the ELF 01 magnetometer, the three orthogonal components of the magnetic fields (B_x, B_y, B_z) were measured for each point and the root mean square (r.m.s.) value of the resultant magnetic field was determined with the relation:

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2} \quad (1)$$

In order to consider the spatial variability of the magnetic field, we made measurements in five points (one in the middle of the room and four at halfway distance between the middle and the corners), and by averaging the B values for these points, the magnetic field in that room or laboratory at a certain time was obtained. All measurements were made at about 1 meter height from the floor.

In order to consider temporal variability magnetic field measurements in a year period were made. In some days successive measurements were made to evaluate the short time variability (minutes) of B, and hourly measurements to evaluate the variability for a period of a day. Because it is very difficult to measure the field at a fixed hour and each day for a long period of time, by statistical processing, we tried to obtain realistic exposure estimation.

Although spot measurements were made in many laboratories of the Faculty of Electrical Engineering from Iasi, only two laboratories were considered for the long term survey of magnetic fields. Laboratory 1 is situated on the ground floor of the building and Laboratory 2 is situated on the fourth floor of the same building. Because the first laboratory is very large, two independent zones (zone 1 and zone 2) were considered here.

The two apartments for which the magnetic field measurements were made are situated in two blocks with identical construction, but located in different residential districts. Apartment 1 is situated on the third floor and it is adjacent to other apartaments, and Apartment 2 is situated on the first floor and beside the apartaments from the upper and lateral positions, under it there is a medical analyses laboratory.

III. Measurement results

The measurements were made in the March 2004 –April 2005 period in Laboratory 1 (zone 1 and zone 2), Laboratory 2, Apartment 1 (bedroom1 - b1, living room - l, kitchen - k, bedroom 2 - b2) and Apartment 2 (bedroom - b, living room - l, kitchen - k).

We try to characterize the background magnetic field for these laboratories and these rooms. When possible, during measurements all electrical utilities from the rooms or laboratories considered were switched off.

A. Results for Laboratory 1

Laboratory 1 is situated on the ground floor of the Electrical Engineering Faculty. Because this laboratory is very large, two independent zones (zone 1 and zone 2) were considered here. The magnetic field in this laboratory was generated by currents in grounding systems, wiring arrangements, electrical transformer and stray currents in the building.

In two days when the power line of the building was interrupted, we also measured the magnetic field. This magnetic field is due to the sources from the outer perimeter of the edifice.

Table 1 shows these values as compared to the magnetic fields measured under normal conditions (power line connected), in the same days after about one hour.

TABLE 1. The values of B in Laboratory 1 with power line interrupted, respectively connected

Date	Power line of the building interrupted		Power line of the building connected	
	Zone 1	Zone 2	Zone 1	Zone 2
Thursday, 17. 02. 2005	10,92 nT	10,29 nT	436,4 nT	116,52 nT
Sunday, 19. 02. 2005	4,42 nT	5,63 nT	95,3 nT	55,39 nT

Table 2 summarizes the measurement results of 50 Hz magnetic field in Laboratory 1 for the March 2004 - February 2005 period. This table presents the resulting extremes (Min/Max), mean values and standard deviation of the magnetic induction B for one of the days, one of the weeks, one of the months and finally, for the whole year period.

TABLE 2. The values of B in Laboratory 1 expressed in nT for some observation periods

Observation time	Extremes Min-Max		Mean value		Standard deviation (SD)	
	Zone 1	Zone 2	Zone 1	Zone 2	Zone 1	Zone 2
One day 16. 02. 2005	216,16-496,49	149,77-324,05	379,15	236,40	92,64	54,12
One week 18.07.2004-24.07.2004	151,88-258,92	98,72-189,53	207,05	147,69	39,65	33,27
One month January 2005	98,63-673,84	59,23-480,22	328,83	214,60	188,46	125,16
One year March 2004-Feb.2005	54,77-1024,14	43,48-640,7	318,15	226,49		

As far as temporal variability is concerned, we determined the short time variability and the long time variability of the magnetic field.

With a view to determine the short time variability (about 10 minutes), the measurements were repeated 3-5 times in this period. Standard deviations for these measurement sets range between 2 % and 30 % from the mean values. Generally, the standard deviation was about 10 % from the mean value for the measurements made in about 10 minutes.

The variation of B, obtained by making 12 measurements from 8 a.m. to 8 p.m. during one day (16th February 2005) is shown in Table 2 and represented in Fig.1.

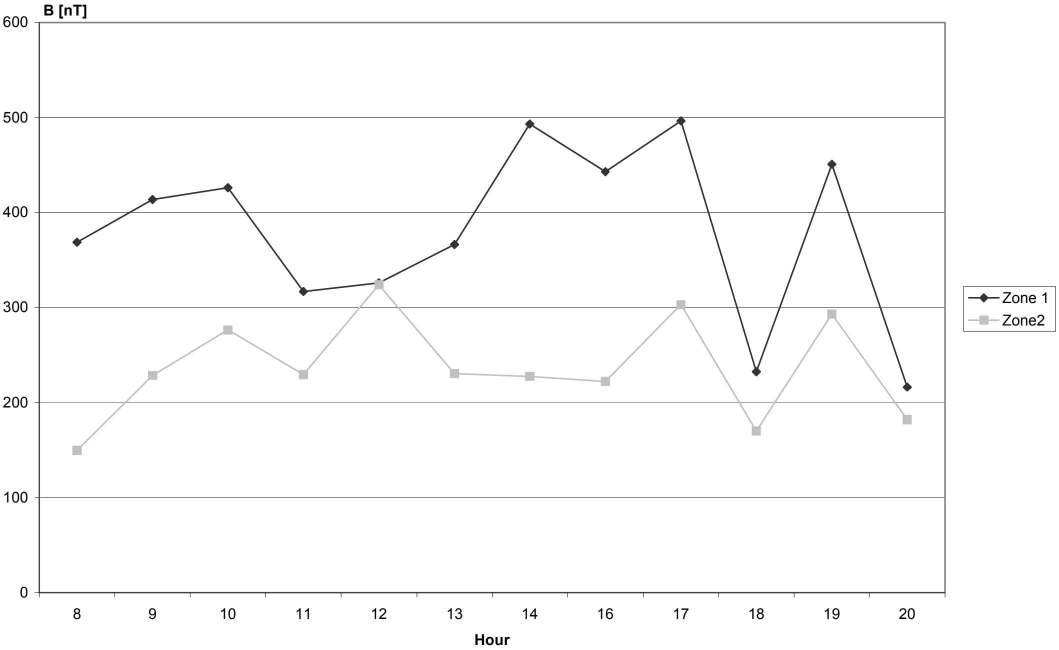

Figure 1. B variation for 16th February 2005 in Laboratory 1.

In Fig. 2 are represented the mean values for every day of the week (e.g. mean values for all results on Mondays in the period March 2004 – February 2005) and, in the last two sets of columns, the mean value for all the seven days in a week "averaged" in a year period, only for work days "averaged" in the same period, respectively.

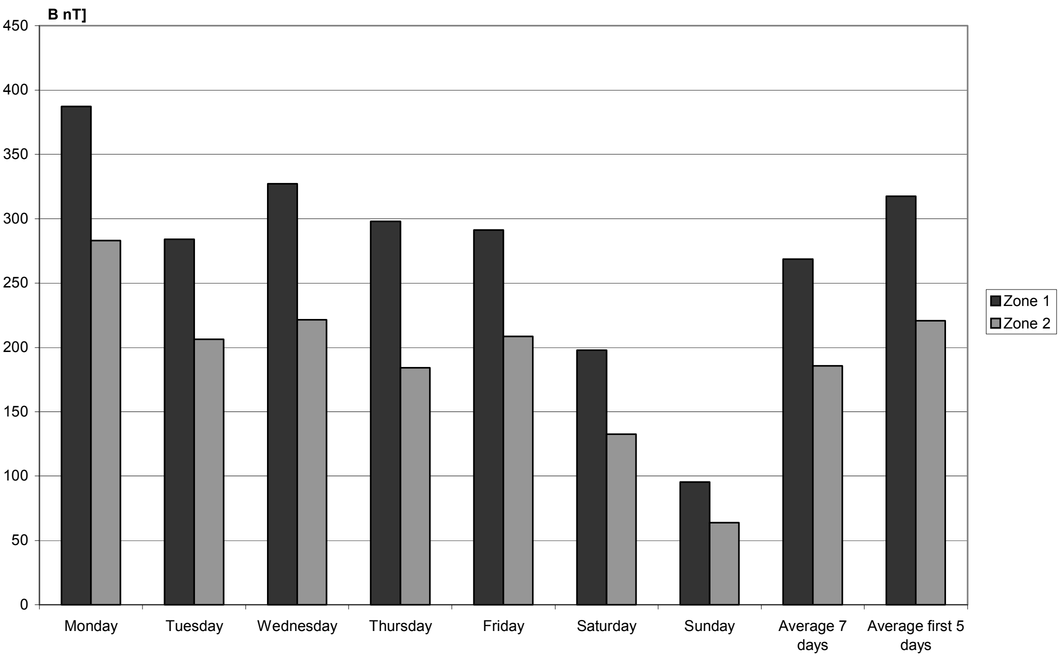

Figure 2. The average values of B in Laboratory 1 per days of the week for the period March 2004-February 2005.

In Laboratory 1 there are great differences between the levels of the magnetic field during the workdays and at the week-end, especially on Sundays (the variation factor of the magnetic field is greater than 3).

The mean values for each month from March 2004 to April 2005 are shown in Fig. 3.

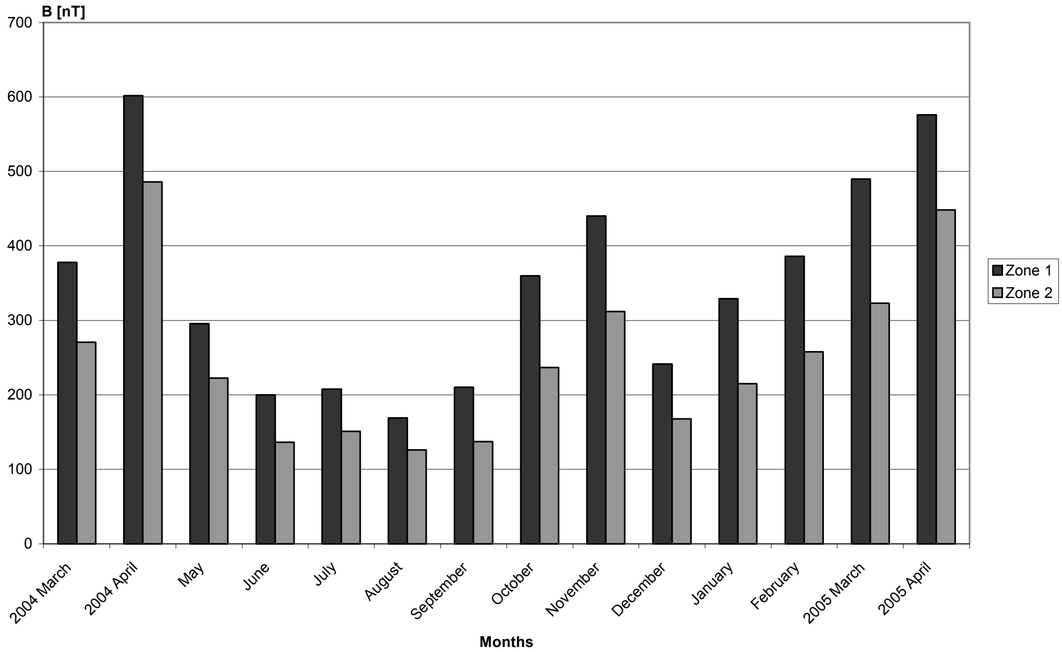

Figure 3. The average values of B in Laboratory 1 per months of the year for the period March 2004-April 2005.

The annual variability of the magnetic field (the variation factor between months being about 2÷3) is due to the current variability with the seasons and activity in the building (e.g. in December, many measurements were made during the holidays)

As far as spatial variability is concerned, we determined the mean value for five points from the laboratory. The association between the mean values of B from five measurement points and the values of B in the centre of Laboratory 1 (only one point measurement) for measurements made in October 2004 is shown in Fig. 4.

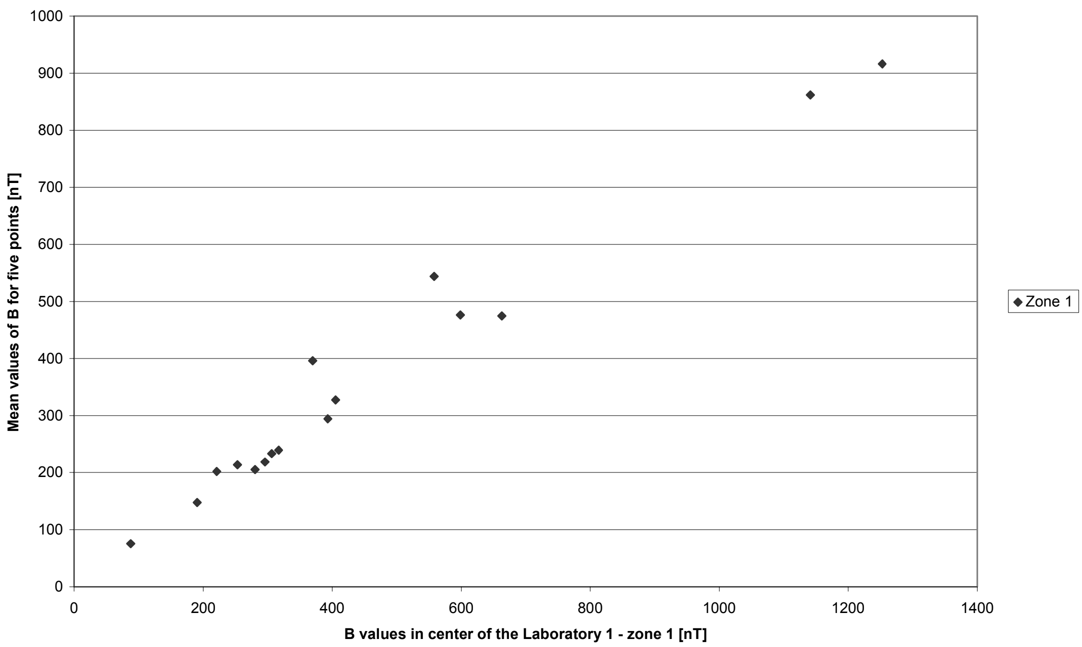

Figure 4. Relation between mean values of B for five point measurement and B values in the centre of Laboratory 1 – zone 1

Because the "Pearson product moment correlation coefficient" or correlation coefficient "r", calculated for the data from Fig. 4 is 0,97, it results that there is a very strong relationship between the mean values of B from the five measurement points and the values of B in the centre of Laboratory 1 (only one point measurement).

By using an active magnetic field sensor (made and calibrated by the authors) connected to the Fluke 43 Power Quality Analyzer, we also made the time domain measurements and the harmonics representation of the fields. A waveform and the harmonics contents of the magnetic field for one measurement made in Laboratory 1 are shown in Fig. 5.

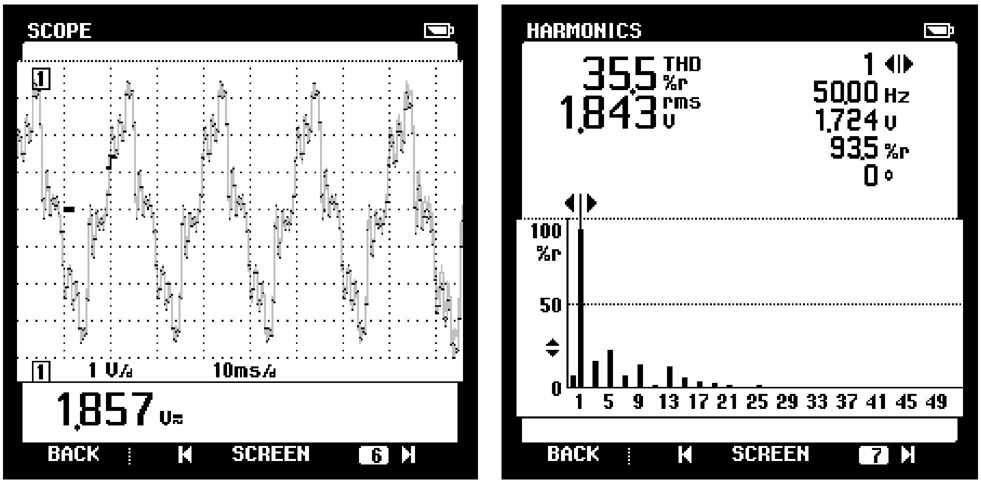

Figure 5. The time and frequency domain representation of the power frequency magnetic field from Laboratory 1.

In the case of this particular measurement the sensor was rotated to obtain the maximum magnetic field. The rms value of this component (semi-major axis for elliptical polarization of the B vector) was about 490 nT, and the peak to peak value of this component of B was about 1850 nT. From Fig. 5 it may also be observed that the harmonic content of the background magnetic field in Laboratory 1 is very important.

B. Results for Laboratory 2, Apartment 1 and Apartment 2

Tables 3, 4 and 5 summarize the measurement results of the 50 Hz magnetic field in Laboratory 2, Apartment 1, Apartment 2 for the period March 2004 - February 2005. The resulting extremes (Min/Max), mean values and standard deviation of the magnetic induction B for one of the weeks, one of the months and for the whole year period are presented in these tables.

TABLE 3. The values of B in Laboratory 2 expressed in nT for some observation periods

Observation time	Extremes Min - Max	Mean value	Standard deviation
One week	9-26,33	17,99	6,93
One month	12,37-45,51	28,297	9,62
One year	5,42-57,54	22,69	11,53

TABLE 4. The values of B in Apartment 1 expressed in nT for some observation periods

Observation time	Extremes Min - Max				Mean value				Standard deviation			
	b1	l	k	b2	b1	l	k	b2	b1	l	k	b2
One week	22 33	20 42	27 40	15 55	26,8	28,9	32,8	38	4,7	8,3	4,8	17
One month	20 72	20 52	19 44	15 55	33,2	30,4	32,5	37,4	14	8,7	6,9	13
One year	20 101	19 76	19 63	15 70	45	36,7	37,6	42,6	21	14	10	13

TABLE 5. The values of B in Apartment 2 expressed in nT for some observation periods

Observation time	Extremes Min -Max			Mean value			Standard deviation		
	b	l	k	b	l	k	b	l	k
One week	184 317	129 289	182 406	231,2	218,3	269,6	49,2	60,1	76,8
One month	146 356	124 434	182 517	235,9	220,6	286,9	60,9	82,8	90
One year	36,5 651,5	57 654,5	30,5 694,9	232,3	224,3	269,7	124,6	131	132

For Laboratory 2, the field variability between the work and the weekend days (variation factor about 1,5) and the field variability between the months of the year (variation factor about 2) are smaller than those corresponding to Laboratory 1.
As for the two apartments, there is not a field variability correlated with the days of the week (work and weekend days) and the magnetic field variation factor between the months of the year is about 2.

IV. Conclusions

We made measurements of the 50 Hz background magnetic fields in two laboratories and two apartments for a long period of time, with a view to determine the levels of fields, their spatial and temporal variability, their harmonic content, etc. The measurements began in March 2004 and will continue, having a dynamic character by the introduction of new types of magnetic sensors and new investigations (e.g. time domain measurements), in order to characterize the residential magnetic fields.

The results of a year period measurements of the power frequency magnetic fields evinced:
- A great dispersion of the field levels both in case of the same measurement place (e.g. in Laboratory 1, the magnetic induction ranges between 55 nT and 1024 nT), and in the case of the same type places. Thus, the mean value of B for one year period survey in Laboratory 1 is 318 nT and in Laboratory 2 is 23 nT, respectively about 40 nT for Apartment 1 and about 250 nT for Apartment 2.
- A great temporal variability of the field levels in one and the same place. In Laboratory 1 the variation factor of the magnetic fields per days of the week is about 3 and the variation factor per months of the year is 3. In Laboratory 2, the corresponding parameters are 1,5 and respectively 2. For Apartment 1 and Apartment 2 there is not a field variability correlated with work and weekend days, and the magnetic field variation factor between the months of the year is about 2.
- In what concerns the spatial variability of the 50 Hz background magnetic fields, there is a very strong relationship between the mean values of B from five measurement points and the values of B in the centre of the laboratories or rooms (e.g., r = 0,97, for Laboratory 1).
- To characterize the 50 Hz background magnetic fields in residential areas a good planning or designing of measurements (sampling in time and sampling in areas, etc), an adequate instrumentation and a statistical processing of the obtained data are necessary.

We will continue this survey in residential areas with the transient magnetic fields measurement and mapping of the magnetic fields near sources (transformer station, appliances, etc.).

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