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ON A LONG-TERM SURVEY OF THE MAGNETIC FIELD IN A LABORATORY

BY

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Abstract. In this paper we conducted a study referring to survey of background magnetic field in a laboratory of Electrical Engineering Faculty, where students carry out didactic activity. Based on three sets of measurements made in the 2017-2023 period, a characterization of the main field sources and the background magnetic field was performed. During this period, the power supply network has suffered some changes, and in terms of the used instruments, it was switched from spot measurement performed with commercial instruments to continuous long-term surveys performed with automatic survey systems made and calibrated by authors. In addition to considering the spatial variation of the magnetic field, the study determines and analyzes the temporal variations of the background magnetic field, namely the daily, weekly and monthly variability. Thus, a great temporal variability of the magnetic field was identified with the week days and even months, can be reached in the ratios between the magnetic field averages on the week days and on the months of the year of order 4/1 or even 5/1.

Keywords: background magnetic fields, temporal variability, automatic long-term survey, spot measurements, spatial variation of magnetic field.

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1. Introduction

Low frequency magnetic fields have a significant influence (Bonato, 2023) both in the electromagnetic biocompatibility (Alnamir, 2018) and in the electromagnetic compatibility. For this reason, various studies (Magne, 2011) were performed in these fields (Bedja, 2009), especially in the residential environment (Gobba, 2011; Ju, 2010).

The obtained values from the magnetic fields analysis in this environment (Chervenkov, 2021; Ursache, 2016) are compared with the maximum permissible limits of certain national and international standards (Hotarare nr. 520/2016; Directive 2013/35/EU; ICNIRP 1998 and 2010; IEEE 2019). Because the magnetic field has a great spatial and temporal variability (Munno, 2010), its characterization can be quite difficult. For this reason, measuring equipment and strategies (David, 2012; Pavel, 2018; David 2022) specific to the environment in which the study (Chen 2013) is carried out.

Based on information obtained from previous studies started in 2004 (David, 2009; Lunca 2012; Nica 2016; David 2022) in the 2017-2023 period several other sets of measurements were performed in the considered laboratory to characterize the background magnetic field generated by the power supply network, and the results are analysed in this paper.

In this laboratory located on the ground floor of the Faculty of Electrical Engineering, students perform laboratory works using equipment of the measurement systems type (oscilloscopes, spectrum analysers, distortionometers, computing systems, signal generators), which generates relatively low intensity magnetic fields In addition to determine the background magnetic field, as well as its temporal variability, the measurements were made at as great distances as possible from these sources whose placement is decided by the students and which works only during the laboratory works.

In addition to determining the magnetic background fields, the magnetic fields near the main field sources were determined, which have a fixed position and permanent operation.

A continuous automatic long-term survey was also performed for an interest point in order to determine the temporal variability of the magnetic field based on a very large number of continuous measurements every few seconds for all weekdays.

To performing the measurements and analysing the results of this paper, some information regarding the magnetic field in the considered laboratory was also used in which the authors made measurements since the 2000s (David, 2022), even if in the meantime some changes occurred, both in terms of field source (power supply system) and the instrumentation used for measurements.

2. Materials and Methods

For measuring magnetic induction, B, three instruments were used, namely a commercial instrument, PCE-G28 gaussmeter with triaxial sensor, having a frequency band of 40 Hz – 400 Hz and an error of 4% and two automatic measuring instruments, made by authors, also triaxial, having a frequency band 40 Hz – 20 kHz and a measurement uncertainty of 5%.

These two automatic measuring instruments can perform both spot measurement and long-term survey. At the same time, they can save both the measured values and the time during which the measurements were made, which is an advantage over the commercial instrumental used, especially if you want a correlation between the magnetic field values measured with different equipment and at different times.

The studied laboratory area, with the most important magnetic field sources (general electrical panel, which supplies more laboratory power from the faculty building - GEP and three electrical panels, just for studied lab, namely EP1, EP2, EP3) and the points at which the magnetic field measurements were performed for background magnetic field estimation are presented in Fig. 1.

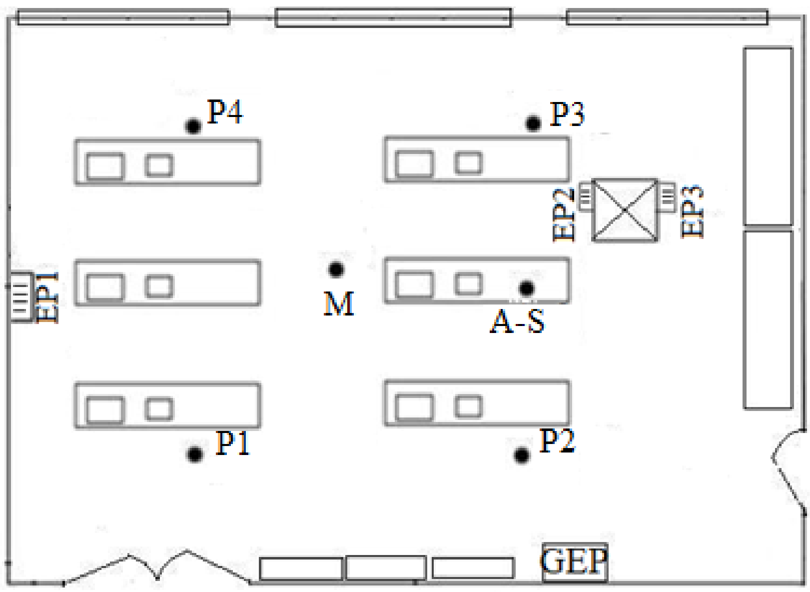

Fig. 1 – The studied laboratory area.

Since background magnetic field measurements performed over a consecutive 13 months (April 2004 -April 2005) in the same laboratory (David, 2022) have resulted the highest magnetic field values are in April and March, and the lowest values are in August, only these three months are considered in this study.

The first set of measurements was performed in seven different days from April 2017 to determine the spatial variation of the magnetic field. For this purpose, measurements were made in the middle of the laboratory (M) and in the middle of the distance between the centre and the four corners (P1, P2, P3, P4) of the laboratory, at various heights from the floor (0 meters, 1 meter and 2 meters). As these five points are considered when determining the background magnetic field, they are located at relatively long distances from fixed sources, but also compared to mobile electrical equipment that is used only during laboratory hours.

In addition to determining the background magnetic field, spot measurements were also performed to determine the magnetic field near the most important sources (EP1, EP2, EP3 and GEP).

To determine the temporal variability of the background magnetic field, a continuous automatic measurements of B were performed in the working area of the students (A-S), using the automatic field survey systems.

In April 2017 the continuous automatic field survey was carried out in seven different weekdays only in the time interval 8.00-20.00 (12 hours survey on each day). Of course, this period of continuous survey also includes the hours in which students carried out didactic activity in the laboratory.

In seven different days from March 2018, the measurements according to the same strategies were resumed both for measuring the background magnetic field and for determining the magnetic fields near the most important field sources (EP1, EP2, EP3 and GEP).

The last set of measurements was made in August 2023, the month in which no didactic activity is performed, and the consumption of electricity in the entire building where the laboratory is located is much diminished, because it is the period of summer holiday. The processes for determining of background magnetic field and the magnetic field near the most important field sources (the spatial variation of the field) were the same, as in previous sets. This time, automatic field survey in A-S point was performed continuously, between August 16 and August 24. In this way, it can be considered both the magnetic field during the day and the magnetic field during the night, for a period longer than one week.

3. Results

The results of these three sets of measurements made in the period 2017-2023 to determine the spatial variation of the background magnetic field, the spatial variation of the fields generated near the main field sources, as well as the temporal variability of the field obtained by automatic long-term survey in a single point are summarized below.

3.1. Spatial variation of the magnetic field

Regarding the spatial variation of the background magnetic field in Table 1, the field values are given both in the five points (M, P1, P2, P3, P4) in which the measurements were made, at various heights from the floor (0 meters, 1 meter and 2 meters), as well as the background magnetic field values (BMF) obtained as an average of the magnetic fields from the five points. Also, the considered values in Table 1 are the average values for the respective points resulting from all measurements made in April 2017, respectively March 2018, respectively August 2023.

Table 1
Spatial variation of the magnetic field in different points from Laboratory

High	Period	B [nT]					
		M	P1	P2	P3	P4	BMF
0 meters	*April 2017*	*383*	*152*	*1000*	*654*	*182*	*474.2*
	March 2018	*312*	*164*	*800*	*362*	*64*	*340.4*
	August 2023	*44*	*30*	*112*	*46*	*42*	*54.8*
1 meter	*April 2017*	*412*	*100*	*583*	*434*	*82*	*322.2*
	March 2018	*200*	*122*	*400*	*383*	*153*	*251.6*
	August 2023	*37*	*30*	*96*	*42*	*42*	*49.4*
2 meters	*April 2017*	*420*	*114*	*373*	*362*	*120*	*277.8*
	March 2018	*124*	*83*	*250*	*322*	*122*	*180.2*
	August 2023	*33*	*33*	*67*	*42*	*33*	*41.6*

Even if, when determining the background magnetic field, the measurements were made at a certain distance from the all sources, the highest values of the background magnetic field were obtained in point P2, which is located closest to the GEP. For example, the arithmetic means of all field values measured in point P2, during April 2017 has the highest value, namely B = 1000 nT. The next point where the field values are relatively high is point P2, which is located near sources EP2 and EP3.

Also, the highest field values of background magnetic field were in April 2017 and March 2018 and the lowest in August 2023. The ratio between the maximum value (March 2023 or April 2023) and the minimum value (August 2023) can reach approximately 5/1 or even 6/1.

For comparison we mention that in a previous study based on performing in the same laboratory a few spot measurements each day for a period of 13 consecutive months (April 2004 -April 2005) the ratio between the highest average value (B = 600 nT for the whole month Aprile 2004) and the lowest average value (B = 170 nT for the whole month August 2004) is approximately 3.4/1 (David, 2022).

This decrease in the background magnetic fields for August 2023 can be explained by the fact that in August there is a holiday and therefore a lower activity and consumption, but also by the fact that after 2018 changes were made to main magnetic field source, namely the general electric panel-GEP.

Thus, the highest value obtained for the background magnetic field, as the arithmetic mean of the fields for all five points, was 474 nT, in April 2017.

Because the main sources generating magnetic field are both in the working area of the students and near P2, a great importance was given to the analysis of the field generated by them.

Therefore, measurements were performed in the close proximity of the main laboratory sources at various heights from the floor, and the results obtained in the three sets of measurements are given in Table 2.

Table 2

Spatial variation of the magnetic field near principal sources from Laboratory

High	Period	B [nT]			
		GEP	EP1	EP2	EP3
0 meters	*April 2017*	*3250*	*250*	*220*	*230*
	March 2018	*1594*	*137*	*157*	*146*
	August 2023	*855*	*30*	*88*	*51*
1 meter	*April 2017*	*4520*	*450*	*350*	*330*
	March 2018	*4332*	*305*	*249*	*127*
	August 2023	*2640*	*52*	*102*	*66*
2 meters	*April 2017*	*2200*	*320*	*280*	*250*
	March 2018	*1868*	*119*	*144*	*154*
	August 2023	*1369*	*41*	*88*	*37*

Even though the highest magnetic field values identified in this laboratory were near GEP, it was found that near the other sources, are high field values at a height of 1 meter. Therefore, using this measurement method, we can identify, approximately, the area of the magnetic field generating source, both vertically and horizontally.

Given that the highest magnetic field values from the entire studied area were identified near GEP, we have made measurements at different distances from this source and various heights from the floor, and the results are presented in Table 3.

Table 3

Spatial variation of the magnetic field near GEP from Laboratory

Distance from source	High	B [nT]		
		April 2017	March 2018	August 2023
0 meters	*0 meters*	*3250*	*1594*	*855*
	1 meter	*4520*	*4332*	*2640*

	2 meters	*2200*	*1868*	*1369*
0.5 meters	*0 meters*	*736*	*360*	*250*
	1 meter	*950*	*810*	*430*
	2 meters	*630*	*524*	*394*
1 meter	*0 meters*	*459*	*273*	*190*
	1 meter	*594*	*503*	*260*
	2 meters	*330*	*274*	*207*
1.5 meters	*0 meters*	*245*	*128*	*95*
	1 meter	*370*	*250*	*120*
	2 meters	*145*	*125*	*105*

It can be seen that the highest field values generated by this source were at 1 meter height from the floor and about 1.5 meters away from it, the field values decrease significantly, even below 400 nT. At the same time, we notice that the highest field values of B are in April 2017.

3.2. The temporal variability of the magnetic field at a point

If the presented results are based on spot measurement and represent basically the spatial variation of the background magnetic field as well as of the magnetic field in close proximity of the main field sources, for point A-S in the students' work area, continuous long-term automatic survey was performed.

The survey results performed in point A-S, obtained in several days from April 2017, between 08:00 – 20:00, are given in Fig. 2 and Table 4.

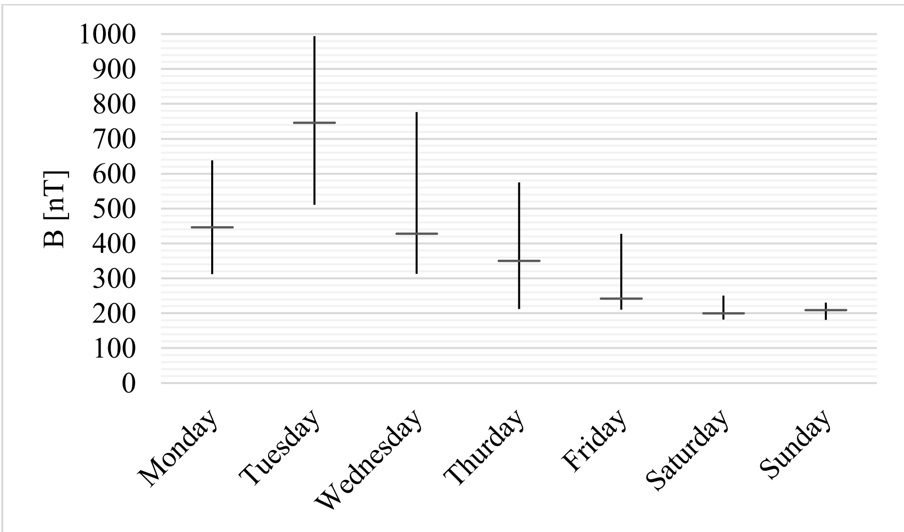

Fig. 2 − The magnetic field variability in A-S point for one week (08:00-20:00) in April 2017.

It can be seen that the maximum value of B for all 7 days of the week was obtained on Tuesdays namely, 994 nT and the minimum value was identified on Sunday, namely 181 nT. It was found that the ratio between the highest average value (B=746 on Tuesday) and lowest average value (B=200 nT on Saturday) is 3.73. The differences between the magnetic field values on weekdays and weekends are due to the reduced activity therefore consumption at the end of the week throughout the building where the laboratory is located.

Table 4

Statistical processing of measurements for a week period (08:00-20:00) in April 2017

Survey		Brms [nT]				$\frac{t_{over\ average}}{t_{survey}}$ [%]
Day [dd.mm.yyyy]	Number of measurements	Min.	Average	Max.	Standard dev.	
Monday [17.04.2017]	*43200*	*311.63*	*446.29*	*638.17*	*18.69*	*48.27*
Tuesday [25.04.2017]	*43200*	*510.93*	*746.36*	*994.04*	*32.76*	*49.65*
Wednesday [26.04.2017]	*43200*	*313.04*	*428.30*	*776.76*	*27.63*	*37.65*
Thursday [13.04.2017]	*43200*	*211.78*	*350.96*	*575.41*	*25.85*	*35.54*
Friday [21.04.2017]	*43200*	*210.36*	*242.53*	*427.76*	*7.47*	*22.84*
Saturday [08.04.2017]	*43200*	*182.34*	*200.18*	*250.65*	*10.24*	*34.65*
Sunday [09.04.2017]	*43200*	*181.03*	*209.09*	*230.43*	*6.34*	*25.19*

In Table 4 were presented: the period in which the survey was performed, the number of measurements for each day, the minimum, maximum and average values of the magnetic field, respectively the standard deviation and the average value from the survey period was exceeded, expressed as a percentage.

In the third set of measurements, a long-term survey of the magnetic field in A-S point was performed, which lasted over seven consecutive days (24 hours/24 hours).

From this registration, in Fig. 3 and Table 5 only the data obtained in the range of 08:00-20:00 were extracted to be compared with those in the previous set that were also registered each day of the week, only in the same time interval (08:00-20:00).

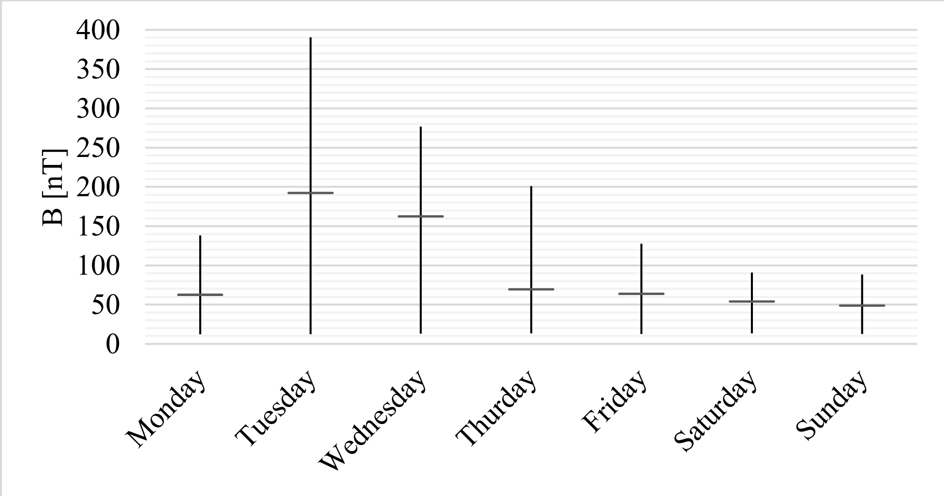

Fig. 3 − The magnetic field variability in A-S point for one week (08:00-20:00) in August 2023.

For this period the maximum value of magnetic field was recorded on Tuesday, being of approximately 391 nT and the minimum value was recorded on Sunday, being 12.5 nT.

This time, the ratio between the highest average value (B=192.49 on Tuesday) and lowest average value (B=48.98 nT on Sanday) is 3.93.

Table 5

Statistical processing of measurements for a week period (08:00-20:00) in August 2023

Survey		Brms [nT]				$\frac{t_{over\ average}}{t_{survey}}$ [%]
Day [dd.mm.yyyy]	Number of measurements	Min.	Average	Max.	Standard dev.	
Monday [21.06.2023]	*57493*	*12.38*	*62.94*	*138.17*	*34.04*	*39.63*
Tuesday [22.06.2023]	*57493*	*12.31*	*192.49*	*390.54*	*22.31*	*34.18*
Wednesday [23.06.2023]	*57493*	*13.04*	*162.77*	*276.76*	*26.27*	*38.99*
Thursday [17.06.2023]	*57493*	*13.54*	*69.87*	*201.09*	*19.46*	*36.96*
Friday [18.06.2023]	*57493*	*12.49*	*64.14*	*127.76*	*15.41*	*33.23*
Saturday [19.06.2023]	*57493*	*13.42*	*54.23*	*90.94*	*9.28*	*38.16*
Sunday [20.06.2023]	*57493*	*12.56*	*48.98*	*88.43*	*5.42*	*22.77*

The results for the whole week (day and night), for August 2023 are given in Fig. 4 and Table 6.

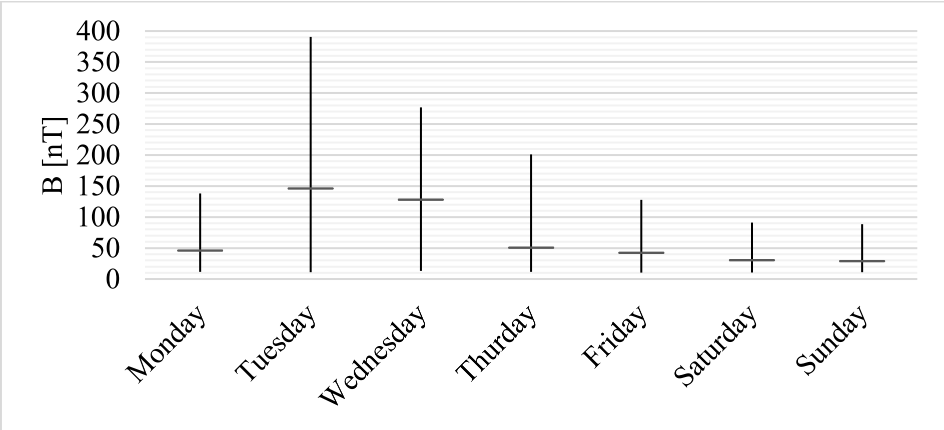

Fig. 4 − The magnetic field variability in A-S point for one week (24 hours/day) in August 2023.

Unlike the obtained results only for the period 08:00-20:00, when considering the whole days (00:00-24:00) the average values are smaller, Also, the ratio between the highest and lowest value of the magnetic field average, for this case, is 5.03.

Table 6

Statistical processing of measurements for a week period (24 hours/day) in August 2023

Survey		Brms [nT]				$\frac{t_{over\ average}}{t_{survey}}$ [%]
Day [dd.mm.yyyy]	Number of measurements	Min.	Average	Max.	Standard dev.	
Monday [21.06.2023]	*114986*	*11.63*	*46.29*	*138.17*	*29.65*	*26.69*
Tuesday [22.06.2023]	*114986*	*10.93*	*146.26*	*390.54*	*23.42*	*28.18*
Wednesday [23.06.2023]	*114986*	*13.04*	*128.30*	*276.76*	*25.01*	*21.28*
Thursday [17.06.2023]	*114986*	*11.78*	*50.96*	*201.09*	*11.32*	*26.65*
Friday [18.06.2023]	*114986*	*10.36*	*42.53*	*127.76*	*14.37*	*33.26*
Saturday [19.06.2023]	*114986*	*10.42*	*30.63*	*90.94*	*10.50*	*23.07*
Sunday [20.06.2023]	*114986*	*11.03*	*29.10*	*88.43*	*14.93*	*21.46*

Comparing Table 6 with Table 5, a significant decrease in mean value is observed, but also a sensitive decrease in minimum value and standard deviation.

4. Conclusion

In this paper we made a study of the spatial and temporal variability of the magnetic field in a technical faculty laboratory in the period 2017-2023. Throughout the period, the low frequency magnetic field measurements were made in order to characterize the main existing sources but especially of the background magnetic field. The measurements were performed both with commercial equipment and with instruments made by the authors, which allowed both spot measurements and automatic long-term survey. To determine the long-term exposure, several sets of measurements as well as continuous automatic survey were performed, organized by days, weeks, months, even years. The highest magnetic field value was identified near the general electrical panel (4520 nT) at 1 meter high from the floor, in April 2017.

Regarding the background magnetic field, the maximum value was also obtained in April 2017 at the floor level, of approximately 474 nT. The lowest magnetic field values for a period of one year were identified in August.

In April 2017 and in August 2023, the automatic long-term survey was performed for all week days in view to determine the temporal variability of the magnetic field.

Analyzing the obtained results by continuous automatic long-term survey on all weekdays, it was found that the ratio between the highest mean values (workday) and the lowest (weekend) are about 4 if only the working hours (08:00-20:00) are considered, respectively 5 if the whole day (00:00-24:00) is considered.

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O SUPRAVEGHERE PE TERMEN LUNG A CÂMPULUI MAGNETIC ÎNTR-UN LABORATOR

(Rezumat)

În această lucrare am efectuat un studiu care se referă la supravegherea câmpului magnetic de fond într-un laborator al Facultății de Inginerie Electrică, unde studenții desfășoară activitate didactică. Bazându-ne pe trei seturi de măsurări efectuate în perioada 2017-2023 se efectuează o caracterizare a principalelor surselor de câmp, dar mai ales o caracterizare a câmpului magnetic de fond din laboratorul considerat. În această perioadă sistemele de alimentare cu energie electrică au cunoscut unele modificări, iar în ceea ce privește instrumentația utilizată s-a trecut de la măsurători în anumite puncte și la anumite momente de timp efectuate cu instrumente comerciale, la supravegheri pe termen lung efectuate cu sisteme de supraveghere automate realizate și calibrate de autori. Pe lângă considerarea variabilității spațiale a câmpului magnetic, în lucrare se determină și analizează variațiile temporale ale câmpului magnetic de fond, anume variabilitatea zilnică, săptămânală și lunară. Astfel a fost identificată o mare variabilitate temporală a câmpului magnetic cu zilele săptămânii și cu lunile anului, putându-se ajunge la raporturi între mediile câmpului magnetic pe zilele săptămânii și pe lunile anului de ordinul 4/1 sau chiar 5/1.