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Measurement of Extremely Low Frequent Magnetic Induction in Residential Buildings

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ABSTRACT: In this paper are present the results of measurements of magnetic induction at some locations in city Bor (the east Serbia) dating from the household electric devices and transformer stations suited near the residental areas. Stress is on the extremely low frequent electromagnetic radiation from transformer stations and other high voltage instalations in urban areas. Risk of the extremely low frequent electromagnetic radiation of frequency 50 Hz on human health, by measuring the magnetic induction, is considered. The measured data are compared with the corresponding ones in literature, as well as with the critical values suggested by the Serbian Ministery of Environment, Mining and Spatial Planning. It is shown that some of them produce a very strong electromagnetic field, so that people should stay far from them. The necessity to relocate the transformer stations to the safe distance from residental areas, as well as the regular control of the positions of the household electrical equipments in the residental places, are strongly recommended.

Key words: Electromagnetic,Field, Human health, Non ionizing, Safety limit value

INTRODUCTION

Humans are continuously exposed to the electromagnetic radiation (EMR) from natural (cosmic rays, geomagnetic radiation, solar radiation) and manmade (electrical appliaces) sources. Significant growth of the EMR level has been noted in recent fifty years as a consequence of the tehnological development, i.e. of the increasing use of the electrical devices. Regarding the effect of the radiation to the environment the EMR can be divided to the ionized and non-ionized radiation which are characterized by the frequences above and below the 10^{17} Hz, respectively. Here we are interested in the non-ionized EMR of the extremely low frequency (ELF) electromagnetic field (EMF) from the interval: 0-300 Hz. This ELF EMF is characteristic of the electrical appliances supplied by the public electrical network.

Some scientists recognized that the occurrence of hypersensitivity to EMR stems from a common exposure, such as wireless systems and electrical appliances in the home or in the workplace, others suggest that electromagnetic hypersensitivity is psychosomatic or imagined (Johansson, 2006, Genuis and Lipp, 2012). The correlation between the long exposure to the ELF electromagnetic field and increasing number of children suffering from the leukemia (Calvente *et al.*, 2010), as well as the breast cancer among woman is indicated. It is shown that the risk can increase for smaller fields intensities too. However, the correlation is not strongly proved due to the mutual effects of many external conditions in human environment. In the review paper (Genuis, 2008), the full list of deseases caused by the exposure to the low-frequency EMF is presented. It is shown that it can produce the reproductive disfunction in the human population. The problem was specially visible among the employees in the power plants. In this group the chromosom anomaly have been found. In addition, the increased number of children sufering

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from the brain and spinal cord tumors is found in their families. The correlation between the children leukamia and breast cancer among women with the exposure to the EMR was observed in many investigations. The ELF EMR can also affect central nervous system increasing the risk to the amyotrophic lateral sclerosis, Alzheimer's disease, insomnia, headaches, sexual dysfunction, chronic fatigue, learning and memory problems, and many neuropsychiatric problems. The increased level of the EMR, specially the high intensity EMR, inevitably increases the risk to human health (Genuis, 2008). On the oher hand many reasearches do not agree with results presented above. Let mention the publication of Etzel and Balk (2011) in which is the authors argued that physiological or pathological effect of AC magnetic fields below 10 μT are theoretic impossible.

Exposures to ELF magnetic fields are particularly high in residences near high voltage power lines and transformer stations. However, indoor levels appear to be lower than outdoor levels. Qin et al. (2012) found that electric field intensity was significantly lower inside buildings than on the roofs of homes near 110-kV power lines in Chongqing, China. In Bor, Serbia, some housing units are built with transformer stations located indoors adjacent to or below apartments used for human occupancy. The authors suggest the physical structure of apartment buildings may significantly protect from the EMF negative effects, or absorb the electric field generated by highvoltage lines or transformer stations, but to date no studies have been done on these particular housing units. While some shielding in the occupied apartment area in Serbia near the transformer stations is applied to protect from the EMF effects the regulator limits for EMF are often exceeded. Kandel *et al.,* 2013 performed measurements of magnetic field near outdoor transformer stations. Authors mapped the magnetic field around and above the transformer stations. The high MFs are restricted to the immediate vicinity of the stations. The values smaller than 0.4 μT are obtained at distances higher than 3 m around the transformer stations, and at distances higher than 2m above the transformer stations. Characterization of ELF MF exposure in apartments near and above transformer stations, located in the same buildings, were performed in several countries Finland (Illonen *et al.,* 2008), Hungary (Thuroczy *et al.,* 2008), Israel (Hareuveny *et al.,* 2011) and Switzerland (Roosli *et al.,* 2011). Authors confirmed that only the apartments located right above a transformer station as highly exposed to MFs. In mentioned apartments measured values of magnetic induction are significantly higher than in other apartments in the same building.According to the international commission for the non-ionized radiation (ICNIRP GUIDELINES, 1998) the referent limit level value for people is 5/*f*, while the same for the employee within the risk working conditions is 25/*f,* respectively. Low-frequencies EMF were classified as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC 2002). Accoridng to the safety rules possed by the the Serbian Environmental Protection Agency, as a institution under supervision of the Serbian Ministery of Energy, Development and Environmental Protection (SMEDEP) (MOSEP, 2009), the referent limit level of the magnetic induction for the EMF frequency, *f*, from 25 Hz to 800 Hz is 2/*f.* The referent limit level can be defined as the critical radiation level above which the environment conditions are unsafe for humans. Thus the referent limit level for $f = 50$ Hz is 0.04 μT. The Ministery of Energy, Development and Environmental Protection of Republic of Serbia occupational safety and environment protection brought the low on the non-ionized radiation protection (MOSEP, 2009), which determines the risk conditions and protection measures in the critical situations.

In our paper the characterizations of the ELF radiation in the apartments, measuring the ELF magnetic induction, are done. Generally, sources of the ELF radiation are electrical devices. Because of that, measurements of ELF magnetic induction of some household electrical devices, with special attention on monitors and TVs with cathode ray tubes (CRT) are done. Let note that in the last few decades children spend a lot of time in the front of monitors and CRT TVs. However, in residential buildings with transformer stations additional sources of the ELF radiation are transformer stations. Measurements of ELF magnetic induction in building with transformer station, in apartment near/above the transformer stations, are performed

MATERIALS & METHODS

The ELF magnetic induction is determined by the measuring device EMF 828 (producted by Lutron Electronic Enterprise CO., LTD). The calibration of the device is done by the producer using equipments calibrated to traceable international standars ISO 9001 Quality Menagement System Certifed by SGS. The device was purchased two months before the first measurements (June– July 2012). The whole measurement procedure is ended in January 2013. The EMF 828 can measure the magnetic induction in the range from 0.01 μT to 2 mT, and the frequency range from 30 Hz to 300 Hz. It posesses three measurement extents: 20 μT, 200 μT and 2000 μT, which are characterized by different measurement precision, 0.01 μT, 0.1 μT and 1 μT, respectively. The measurement device EMF 828 can measure all three components of

the magnetic induction (B_x, B_y and B_z), so that the total intensity of the magnetic induction can be determined by the expression $B = (B_x^2 + B_y^2 + B_z^2)^{1/2}$.

Before each measurement, the instrument was switched on about 10 minuts, with aim to adapt to the environment conditions. In addition, the change of the device position is followed by one minute relaxation before the start of the new measurement. The results presented in tables and figures are averaged from 10 repeated independent measurements. Let mention that the measurement's positions in each apartments are selected according to the arrangement of the furniture inside them. During the measurement procedure all electrical devices were turned off (except the refrigerator) in goal to determine the magnetic induction only from the transformer stations.

In the cases when the magnetic induction produced by the household devices is measured the measurement setup was situated at distances $d = 0$ cm and $d = 30$ cm from device. The values of the magnetic induction from TVs and monitors were determined from three different positions (behind, beside and in the front of devices). The results of measurements of ELF magnetic induction from the transformer stations, in one settlement in Bor (one Serbian City), are shown in the following. In Fig. 1 the schematic view of city settlement is given, with buildings signed as A1 to A8. In some of them: A1, A4, A5, and A8, the transformer stations were located at the ground floor, with apartments near, and above stations (see arrows in figure). The buildings A2, A3, A6 and A7 did not have transformer stations inside them, while A1 and A2, A3 and A4, A5 and A6, as well as A7 and A8 shared the transformer station. Distance between two adjacent buildings was about 20 m. The measurements od ELF magnetic induction in buildnigs A1, A4, A5 and A8 are performed. The postions of apartments near and above the transformer stations, in buildings A1, A4, A5 and A8, with respect to the transformer stations are shown in Fig. 2. On Fig. 2. the size of apartments are noted. The measurements of ELF magnetic induction were done at different positions outside of transformer stations (outside the buildings), at metal doors, metal windows on the transformer stations, and at outside bricks wall of buildings. Metal doors and metal widows of transformer stations were constructed to include small holes for ventilation and cooling of equipment inside the transformer stations. For the outside bricks wall of transformer stations in building A8, the magnitude of the ELF magnetic induction was measured at different distances at 1 m above the ground.

In Apartment I and Apartment II the ELF magnetic induction is measured at the wall nearest to the transformer station, at height 1 m above the floor and on the ground. In Apartment III, which is located above transformer station, the ELF magnetic induction is measured at 0.5 m above the floor. The measurements were done in all apartments (Apartment I, Apartment II and Apartment III) in buildings A1, A4, A5 and A8. The

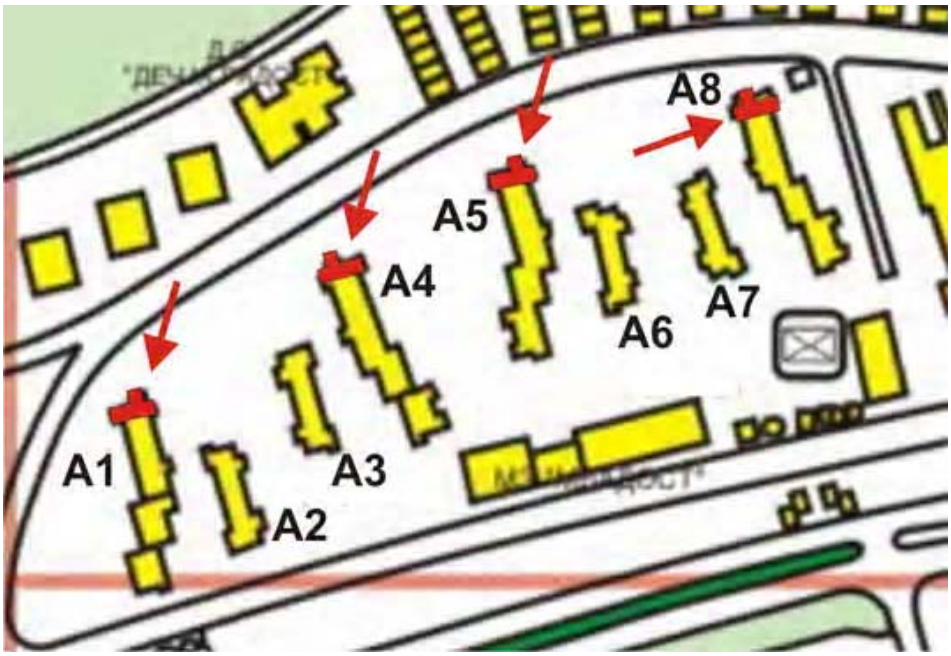

Fig. 1. Part of schematic plan view of the city Bor. The arrows indicate positions of the transformer stations

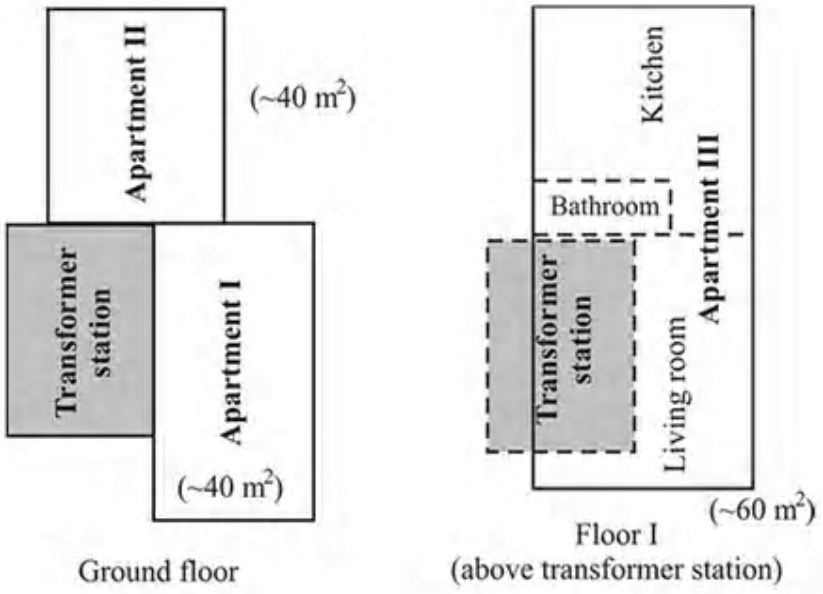

Fig. 2. The positions of apartments with respect to the transformer stations: ground floor apartments near the transformer stations (Apartment I and Apartment II) and the first floor apartment just above the transformer station (Apartment III)

additional measurements are performed in one apartment located near the transformer station and just above the steam heating substations in building, in winter. The heating substation is located below the toilet and two bad rooms in mentioned apartment. For the safety limit value of ELF magnetic induction is chosen value $B = 0.2$ μT. The safety limit is determined to be of the order of 0.3 μT following the literature (Calvente et al, 2010). This value is correlated with the increasing number of children suffering from leukemia.

RESULTS & DISCUSSION

The measured values of the ELF magnetic induction from the household electric devices are shown in Table 1. The values of ELF magnetic induction near the TV screens and PC monitors, for three positions (behind, beside and in the front of device) are listed in Table 1. The values of ELF magnetic induction, higher than safety limit value ($B = 0.2$ μT) are noticed by bolded leters.

The measured values of ELF magnetic induction for metal door and metal windows of transformer stations in buildings A1, A4, A5 and A8, are presented in Table 2, as well as the minimal and maximum measured values. For building A8, the ELF magnetic induction detected on outside bricks wall of transformer station in function of the distance from the transformer stations outside of buildings is illustrated in Fig. 3. In this figure the safety limit value ($B = 0.2$ μT) is noticed with solid lines.

Table 1. The measurement results of the magnetic induction *B* (μT), produced by the appliaces in the household (CRT denotes the cathode ray tube), at distances *d* = 0 cm and *d* = 30 cm

Magnetic induction *B* (μT)		
Electrical Aparats	***d* = 0 cm**	***d* = 30 cm**
TV CRT beside	**3.6884**	**0.51391**
TV CRT behind	**15.74995**	**1.45997**
TV CRT front	**10.82347**	**1.43213**
LCD PC beside	**0.44777**	0.08185
LCD PC behind	0.1118	0.06083
LCD PC front	0.06782	0.06083
CRT PC beside	**1.00125**	0.05916
CRT PC behind	**1.84635**	0.10344
CRT PC front	**4.11496**	**0.32062**
PC Speakers	**4.37035**	0.13638
Vacuum cleaner	**11.2513**	**1.06024**
Desktop PC	**5.51104**	0.08602
Water heater	**16.80268**	0.01
Burner	-	**1.73494**
Microwave oven	**94.33091**	**6.12372**
Heater front	**5.23832**	0.01732
Heater behind	**14.27936**	**0.26038**
Neon light aparaturs	**26.33611**	**0.44609**
Hair dryer	**6.15439**	**0.57974**
ELDI heater	**4.66436**	**0.52943**

Table 2. Values of magnetic induction *B* (μT) at the outer sides of transformer stations, outside the the buildings

Building	Magnetic induction *B* (μT)
A1	1.48 – 6.16
A4	1.27 – 5.96
A5	1.26 – 12.28
A8	2.51 – 5.50

The measurements of ELF magnetic induction are performed in all available apartments near and above transformer stations, in all buildings with transformer stations (A1, A4, A5 and A8). In these measuremets, the measured values are aproximately equal in all apartemts at the same positions in order to the ransformer stations. In the following we list a few examples of the measurement of ELF magnetic induction. The values of the ELF magnetic induction from transformer stations in two apartments, near and above the transformer station are shown in Figs. 4 - 7.

In the figures the relative positions of the measurement places are noted. The values of ELF magnetic induction in several positions in Apartment I, near the transformer station are presented in Fig. 4. The values of the ELF magnetic induction at the wall behind the transformer station, in Apartment II, are shown in Fig. 5. The dependence of the ELF magnetic induction on distance 1 m above the floor in flat 1 is shown in Fig. 6. The horizontal line indicates the safety limit value of ELF magnetic induction, $B = 0.2$ μT.

The measured values of the ELF magnetic induction and relative positions of the measurement places in the living room of Apartment III, located above transformer station, are shown in Fig. 7. The arrows with sign 0.5 m indicate the upper value measured at 0.5 m from the floor.

In addition, the results of measurement of ELF magnetic induction in apartment near the transformer station and just above the steam heating substations in building, in winter, are presented in Table. 3.

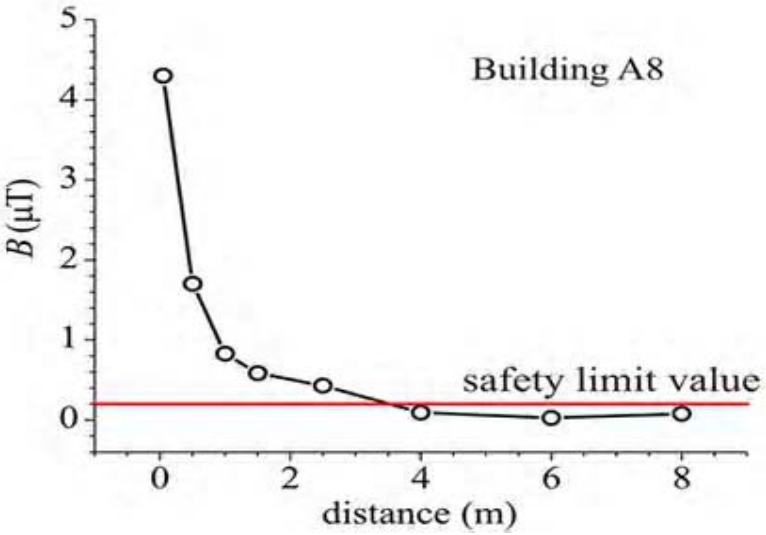

Fig. 3. Magnetic induction *B* (μT) in function of distances, in (m), from outside wall of the transformer stations in A8 building

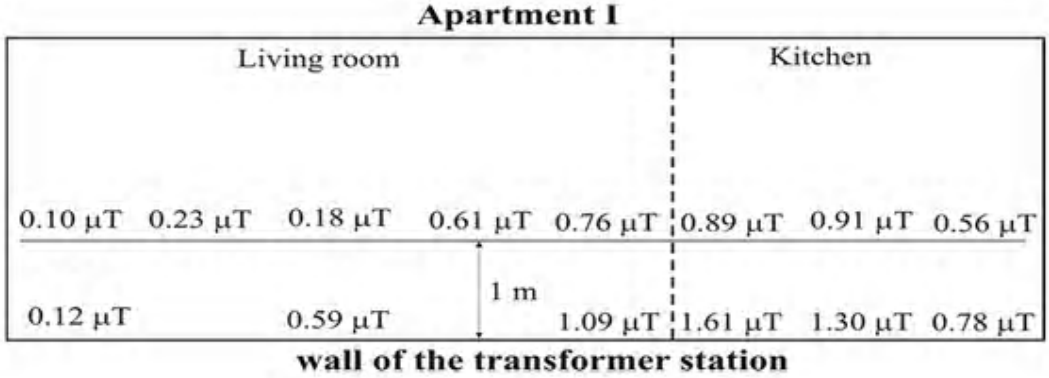

Fig. 4. Values of magnetic induction in Apartment I, at diferent wall locations (as indicated on the figure)

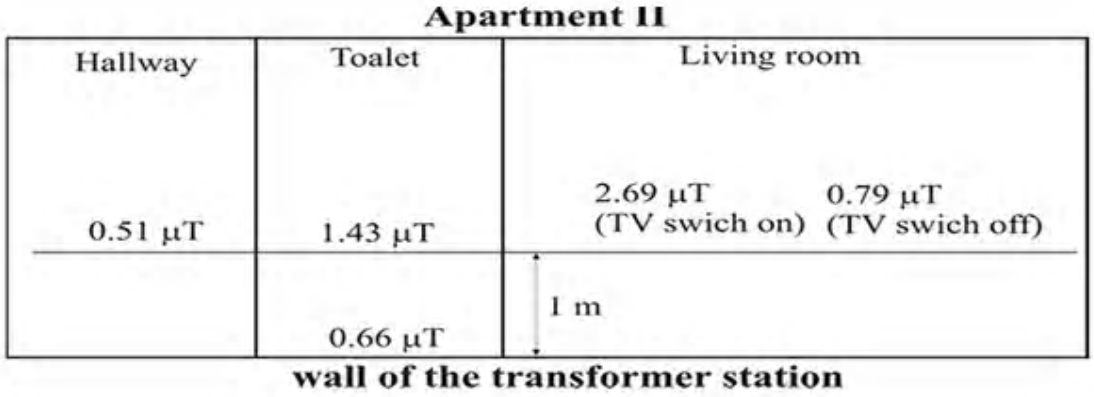

Fig. 5. Values of magnetic induction at diferent wall locations (as indicated on the figure): at distance of 10 cm from the wall, in the Apartment II

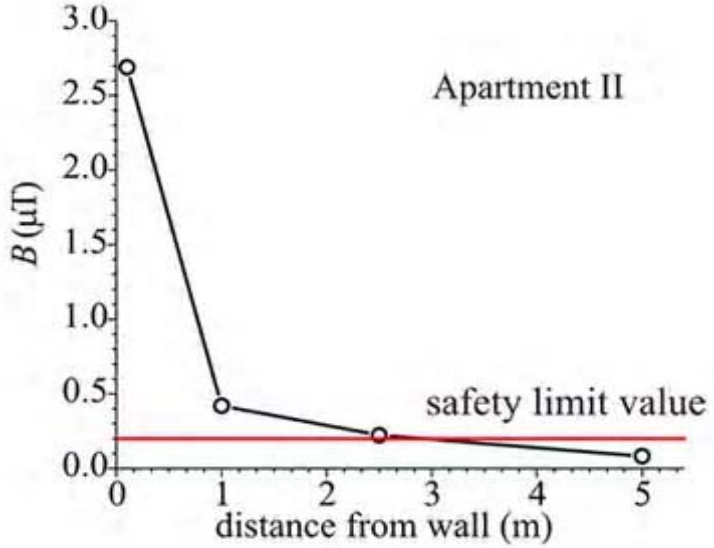

Fig. 6. The magnetic induction in function of distances from wall, at the 1 m from the ground

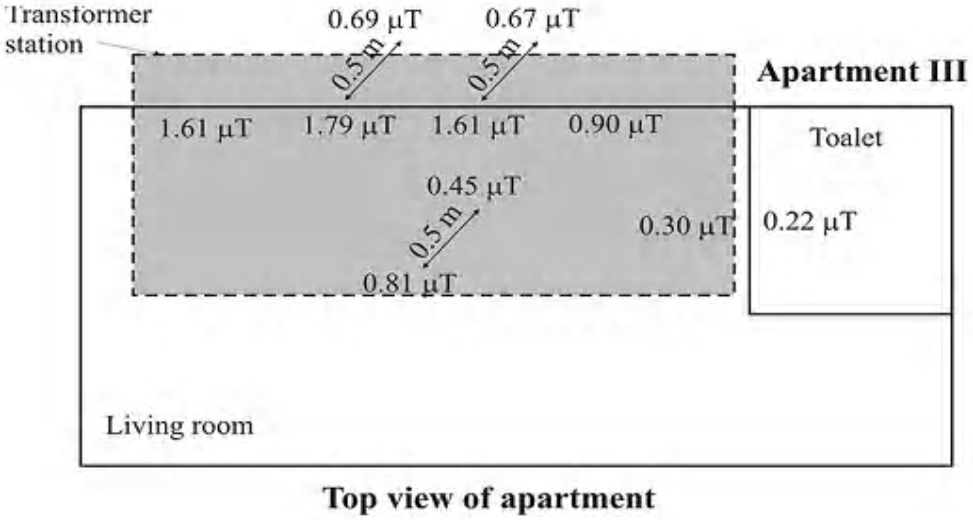

Fig. 7. Top view of part of Apartment III, under transformer stations. Values of magnetic induction at diferent floor location (as indicated on the figure), at distance of 10 cm from floor, in the flat above transformer stations. Values of induction above arrows (0.5 m), represent magnetic induction on 0.5 m above floor

Table 3. Values of magnetic in apartment near transformer stations and above steam heating substations

Rooms	Magnetic induction B (μT)	
	On the floor	0.5 m from the floor
Badroom1	0.86 – 1.05	0.74 – 0.81
Badroom 2	0.77 – 1.01	0.57 – 0.86
toilet	≈ 3.14	0.93 – 1.48

The results of measurement in Table 1 show that the highest values of the ELF magnetic induction are produced by the micowave oven, boiler, vacuum cleaner, neon tube (tube inductor), and burner. Therefore the estimation of the safe distance from the listed devices is crucial to protect people from the impact of the dangerous effects of the ELF magnetic field. Let note in this context that yet at the distance of 30 cm the ELF magnetic induction around many devices can reach values higher than the proposed safety limit value. Special attention should be given to the devices which work contnuously for a long time period as computers, TVs, and neon light tube aparatures. The TV and PC have higher values of the ELF magnetic induction for an order with respect to the safety limit (B = 0.2 μT). The safety limit value is the most significantly exceeded in the case of monitors and TVs with the cathode tubes. Comparatively at the distance of 30 cm, the PC monitor is more safe than the TV with the CRT. The most dangerous is the radiation from TV and PC monitors behaind and near these devices. On the other hand, the LCD monitor is the most safe among the similar devices exceeding the safety limit only at the very short distances (near the LCD monitor).

As can be seen in Fig. 3. which presents the ELF magnetic induction in function of distances from the transformer stations, the ELF magnetic induction at the distances longer than 4 m, has a value smaller than safety limit value. Similar results were obtained for outdoor transformer stations (Kandel *et al.,* 2013). So that in apartments locations near and above the transformer stations the safety limit can be significantly excedeed.

The results of measurements of the ELF magnetic induction in apartments near the transformer stations (Apartment I and Apartment II) and above transformer stations (Apartment III), are presented in Fig. 4 (Apartment I), Fig. 5 and Fig. 6 (Apartment II) and Fig. 7 (Apartment III), respectively. The highest values of the ELF magnetic induction in Apartment I (Fig. 4) are in the kitchen. From Fig. 5 and Fig. 6 it can be seen, that the safety values of the ELF magnetic induction in Apartment II are observed only in the second half of the room which is far from the ELF magnetic induction source. Here is worth to note that Apartments I and Aparment II (as well as the other ones in the same block) are studias, so that the living room and badroom are suited togheter. In Apartment II the highest value of the ELF magnetic induction is observed in the living room when the TV was switched on (TV with cathode tube) and in the toilet. This agrees with the results in Table 1., where the increased level of the ELF magnetic induction is found near CRT TV. In Aparment III (Fig. 8), results are very similar to results in Apartment II. Only the half of room is safe for living, i.e. ELF magnetic induction values are smaller than safety limit value.

In the case with heating substations under apartments (Table 3), values of ELF magnetic inductions are significantly greater than safety limit value (four times). On this place it is necessary to note that in the living room and kitchen the values of ELF magnetic induction were approximately equal to the safety limit value. Safety limit value 0.2 ìT, chosen in our paper, is slightly greater than the regulatory limits (Safety Rules, 2009) discused in the introduction of paper. For example, according to the international commission for the non-ionized radiation the referent limit level value for people is 0.1 ìT, and according Serbian Ministery of Energy, Development and Environmental Protection referent limit level value is 0.04 ìT. Reason is the existence of contradictory data about dangerous effects of ELF electromagnetic field, and values of ELF electromagnetic field to humans. Value we have chosen as a safety limit is defined with respect to this shown in paper of Calvente et al., 2010, which consider the correlation of the high ELF radiation and frequency of the cases of leukemia among the children. In addition, the measurements of ELF magnetic induction were performed in apartments far from transformer stations, in buildings with transformer stations, and in apartments in buildings without the transformer stations. All these values in cases when electrical equipment in apartment are disconected, are smaller than safety limit value, i.e. approximately are in the interval: 0.01 ìT - 0.05 ìT. In the cases with switched on the electrical devices (for example refregerator, CRT TV, PC) the same range of values is observed, 0.01 ìT - 0.05 ìT, except in the case in the just near the electrical devices (Table 1). Results of measurement of ELF magnetic induction, presented in our paper, are in agreement with previously obtained results published in (Illonen *et al.,* 2008, Thuroczy *et al.,* 2008, Hareuveny *et al.,* 2011, Roosli *et al.,* 2011), where was noted that measured values of ELF magnetic induction in apartments near and above transformer stations are significantly higher than in other apartments in the same building.

Although this study did not consider self-reported health effects of the building occupants, we note that several residents volunteered their health information to the study personnel during the process of collecting data about the EMF effects. Occupants in apartments with transformers complained of headaches, nervousness, weakness, dizziness, breast cancer, and leg and hip discomfort. One occupant stated that fish died soon after an aquarium was placed on the wall closest to the transformer room These findings are interesting considering ELF hypersensitivity has been found in other studies, although there is disagreement whether these effects are physiological or psychosomatic (Genius, 2008).

CONCLUSION

In this paper we present the results of measurements of ELF magnetic induction at some locations in city Bor (the east Serbia) dating from the household electric devices and transformer stations suited near the residental areas. Special attention is paid to the measurement of the ELF magnetic induction in the living environment. We found out that a number of household electric devices broadcast very strong magnetic field. However, for most of them the ELF magnetic induction levels were not found to exceed these proposed by the Ministry of Energy, Development and Environmental Protection of Republic of Serbia. Exceptions are the electric devices as TVs (with cathode ray tube) and PC monitors. Investigations also have shown that the most dangerous for humans' health are the transformer stations suited in the residental areas. Although our research is based on the measurements performed locally (area of city Bor in the east Serbia) the main findings qualitatively agree with that announced in the literature. Therefore we strongly recommend necessity to relocate the transformer stations to the safe distance from residental areas and regular control of the positions of the household electrical equipments in the residental places. We plan to continue our investigations by spreading the measurement area which will give us possibility to perform serious statistical analysis, as well as to improve the existing measurement equipment.

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