Tablet Computers and Extremely Low-Frequency Magnetic Field Emission

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Abstract – **In this paper, the tablets' emission of the magnetic field in the extremely low frequency region has been explored. The experiment is conducted on five Android tablets. For the testing purposes, we used the measurement geometry which is previously proposed for the measurement of laptop's magnetic field. The measured values are compared to the TCO proposed safe standard. At the end, the list of the proposed suggestions in order to avoid the exposure to the high magnetic field from the tablets is proposed. The obtained measurement values can be invaluable for users as well as for designers of the tablets.**

Keywords – **Magnetic field, Measurement, Statistical analysis, Tablet computers.**

I. Introduction

Magnetic fields can be created naturally or artificially. If it has a natural origin, then it is created by Earth. In contrast, the artificial magnetic field is the product of electric current which is flowing usually through electrical and electronic device. Hence, the magnetic fields are present everywhere in our environment. One of the main characteristics that define a magnetic field is its frequency. The magnetic field of different frequencies can interact with the human's body in different ways. Although, it is not destructive as ionizing radiation, such as gamma rays, cosmic rays, and X-rays, it can have some potential negative effects to the humans.

The magnetic field is the strongest if it is close to their origin. However, it decreases rapidly if we are getting away from the source in the case of low frequencies. It should be noted that the magnetic field is resistant to the walls of the building, but some materials can block its spreading.

The time varying magnetic fields produced by electrical appliances is understood as the extremely low frequency (ELF) magnetic field. The ELF magnetic field contains the frequencies from 50 Hz to 300 Hz. Hence, it is everywhere around us.

In this paper, we have special attention to the extremely low frequency magnetic field. Its source can be: transmission lines, substations, kitchen appliances, computers, office equipment, etc. At low frequencies, the levels of induced currents inside the body are too small to produce obvious effects. In spite of that, these fields induce currents within the human body, which can be sufficient to produce a various effect to the humans during a long work. Also, there is no doubt that short-term exposure to very high levels of magnetic fields can be harmful to the human health. The current public concern focuses on possible long-term health effects caused by exposure to magnetic fields at levels below those required to trigger acute biological responses. Up to date, the extensive research in many studies which have been conducted in an ELF magnetic field area did not give a clear answer how it is harmful to the human health. With more and more research expertise available, it has become increasingly likely that exposure to electromagnetic fields constitutes a serious health hazard. Nevertheless, some uncertainties remain. The original scientific discussion about the interpretation of controversial results has shifted to become a societal as well as the economic issue.

International guidelines and national safety standards for magnetic fields are developed on the basis of the current scientific knowledge to ensure that the fields humans encounter are not harmful to health. ICNIRP issues guidelines on the basis of the current scientific knowledge [2]. Most countries draw on these international guidelines for their own national standards. Standards for low-frequency magnetic fields ensure that induced electric currents are below the normal level of background currents within the body. The TCO standard proposed the prescribed geometry of the measurement and test procedure with the following reference values of magnetic flux density [3]:

- For a band I (5 Hz to 2 kHz), $\leq$ 200 nT measured at 0.30 m in front of and around the laptop computer,
- For band II (2 kHz to 400 kHz), $\leq$ 25 nT measured at 0.30 m in front of and around the laptop computer.

A tablet computer, commonly shortened tablet, is a mobile computer with a touchscreen display, circuitry, and battery in a single device. Tablets come equipped with sensors, including cameras, a microphone, an accelerometer and the touchscreen display. The touchscreen display uses the recognition of finger or stylus gestures replacing the mouse and keyboard. They usually feature on-screen, pop-up virtual keyboards for typing. Tablets may have physical buttons for basic features such as speaker volume and power, and ports for network communications and battery charging. They are characterized and grouped according to the size of the screen. It is supposed that the smallest tablet incorporates the screen of at least 7".

Up to now, many researchers [4], [5], [6], [7], [8], [9] measured magnetic field produced by laptops of different brands. The magnetic field values were considerable higher

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than the values recommended by some recent guidelines for laptops magnetic field emissions [6], [10] and those considered the risk of tumor development. Refs. [4], [5] showed that the EMF values became alarmingly high when the laptop was used close to the body. According to ref. [5], the laptop induces currents that are within 34,2% to 49,8% ICNIRP [2] when is close to the body, which is very important to the adult's body and to the fetus in pregnant women. Also, the power adapter induces strong intra-corporal electric current densities in the fetus and in the adult subject, which are respectively 182-263% and 71-483% higher than ICNIRP basic restriction recommended to prevent adverse health effects [5].

Ref. [9] has shown that laptops may be harmful to sperm with samples exposed to a wireless internet connected laptop showing a significant decrease in sperm motility and an increase in sperm DNA fragmentation. These researchers considered that keeping a laptop connected wirelessly to the internet on the lap near the testes may result in decrease male fertility. Ref. [11] pointed that DNA reacts to electromagnetic fields, making the long-term consequences of repeated microwave exposures to genetic material. Laptop computers are the high-energy source of thermal, electric and electromagnetic fields. The thermal effects can be blocked by using a lap pad, an electric field can be blocked by reflective material or metal, but magnetic field components cannot be blocked. However, situation with tablets is even worse due to their higher portability.

During the measurement of low-frequency magnetic field emissions, magnetic flux density was characterized in terms of field amplitude and "weighted peak" (WP) index, [4], [12], [13], that implement the weighted peak approach, which is well suited in the case of complex waveforms. Security limits for exposure to a magnetic field are different according to the different authors: 1μT [14], 0,4 μT [15], [16], 0,2 μT [17]. Ref. [18] suggests that exposure to 1 μT EMF alters sleep by reducing total sleep time and sleep efficiency. Ref. [19] postulates experiments that may be used to characterize the nature of the transduction step in which a magnetic or electric field is converted into a biological signal.

In this paper, we conducted the experiment on tablet to measure and evaluate their ELF magnetic field emission. Hence, any high frequency magnetic field emission from the tablets' component like WIFI, 3G/4G or similar is out of the scope of this paper. To our best knowledge, there have been no study of this problem yet. Because of wide-spreading of tablet computers among the younger population, it is of great importance. It should be pointed that the experimentation was conducted on typical tablets. It means that we tested tablets with screens from 7" to 10" wide which are usually made of gorilla glass in its front, and of plastic material in its bottom. Also, we made an assumption that the users' hands are in close contact with touch area as well as its back. Furthermore, the tablets are tested in their typical use, i.e. internet browsing.

The rest of the paper is organized as follows. Section 2 describes the measuring method and equipment. Section 3 defines the experiment. Section 4 presents the results and gives the discussion. Section 5 draws the conclusions.

II. METHODS AND MATERIALS

A. Static magnetic filed

The method consists of measuring the extremely low-frequency magnetic field produced by the tablet computers. In normal operation, the tablet's components are supplied by current *I*. The current *I* is flowing through electronic or electrical components, which induces the magnetic-field. The measuring devices usually register the scalar components of the magnetic induction: B_x, B_y and B_z. Accordingly, the root mean square (RMS) of magnetic induction *B* is calculated as:

$$B = \sqrt{B_x + B_y + B_z} \tag{1}$$

B. Measuring devices

Magnetic field measurement is performed by EMF measuring device Lutron EMF-828 with separate probe, including sensing head. Fig. 1 shows the measuring device Lutron EMF-828 with its probe.

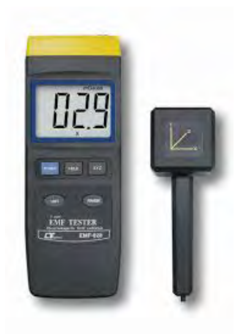

Fig. 1. Measuring device Lutron EMF-828 with separate probe

The calibration of the measurement device is performed according to ISO 9001 by the producer of the equipment. Lutron EMF-828 measures the scalar components of the magnetic induction B_x, B_y and B_z in the range between 0.01 μT and 2 mT. It is measured in the extremely low-frequency range, i.e. between 30 and 300 Hz. The device has three measurement extents: 20 μT, 200 μT and 2 mT. The precision of the measurement is of the order of 0.01 μT for the measurement extent of 20 μT, 0.1 μT for the measurement extent of 200 μT and 1 μT for the measurement extent of 2 mT.

C. Tablet measuring positions

Similarly to [7], the magnetic field is measured at nine different positions at the tablet touchscreen at the top and at nine different positions at the bottom of the tablet. We use measuring in direct contact because it is a typical way of using the tablet. Fig. 2 shows the measurement positions at the top and at the bottom of the tablet computer.

T1	T2	T3
T4	T5	T6
T7	T8	T9

(a)

B1	B2	B3
B4	B5	B6
B7	B8	B9

(b)

Fig. 2. Measurement positions: (a) at the top, (b) at the bottom

III. Experiment

The experiment is conducted on 5 different tablet computer. All tablets are using the Android operating system. The tablets are tested in their typical working condition, i.e. internet browsing. The magnetic field is measured ten times at the measurement positions at the top: T1…T9, and at the bottom: B1…B9. The average values of the measurement are used as a reference. Hence, we measured magnetic field of the tablets at no distance from the touchscreen display or its bottom. We make this assumption taking into account typical use of tablets where users have fingers on tablet top and/or bottom positions all the time. Also, the measurement is carried out 30 cm away from the tablet in all four directions. At these points, the obtained magnetic field was below 0.02 μT. It can be considered as the background magnetic field. Hence, it is negligible.

IV. Results and Discussion

The results of the measurement are given in Fig. 3.

Each area is given by the number representing the level of the emitted magnetic field in μT. As a thresholding (dangerous) level, we used TCO proposed reference level of 0.2 μT.

Table 1 shows the levels of the extremely low frequency magnetic field that are emitted by the top parts of tablets in the min-max manner.

Table I
The Min-Max of the Top Measured Magnetic Field (in μT)

Tablet	Top Minimum	Top Maximum
Tablet 1	0.04	0.15
Tablet 2	0.06	0.43
Tablet 3	0.02	0.22
Tablet 4	0.05	0.86
Tablet 5	0.06	0.45

Table 2 shows the levels of the extremely low frequency magnetic field that are emitted by the bottom parts of tablets in the min-max manner.

Table II
The Min-Max of the Bottom Measured Magnetic Field (in μT)

Tablet	Bottom Minimum	Bottom Maximum
Tablet 1	0.05	0.20
Tablet 2	0.07	0.86
Tablet 3	0.01	0.51
Tablet 4	0.05	0.96
Tablet 5	0.07	0.01

From Fig. 3 or from Tables 1-2 (see max levels), it is obvious that all tablets have dangerous areas, which emitted the magnetic field level above the reference one. Still, 3 out of 5 tablets have dangerous levels on the both sides of the tablets, i.e. the top as well as at the bottom. Also, it worth to note that left and right side areas are the most exposed to the tablet's users due to their way of working with tablets.

T1

0.15	0.09	0.04
0.06	0.10	0.06
0.05	0.08	0.04

T2

0.13	0.43	0.09
0.26	0.26	0.13
0.06	0.25	0.05

T3

0.09	0.15	0.13
0.02	0.22	0.22
0.09	0.12	0.06

T4

0.06	0.20	0.86
0.07	0.13	0.06
0.06	0.08	0.05

T5

0.08	0.23	0.09
0.45	0.23	0.07
0.31	0.06	0.07

T1

0.09	0.15	0.05
0.18	0.10	0.06
0.05	0.20	0.06

T2

0.25	0.49	0.13
0.31	0.26	0.07
0.11	0.86	0.08

T3

0.35	0.20	0.06
0.51	0.20	0.01
0.05	0.35	0.46

T4

0.06	0.29	0.96
0.05	0.08	0.07
0.05	0.13	0.07

T5

0.08	0.10	0.07
0.08	0.07	0.10
0.11	0.06	0.07

Fig. 3. Magnetic field measurement level (Top position represents measurement at the top of the tablet (touchscreen display area). Bottom position represents measurement at the bottom areas of the tablet. Colored fields represent the areas with higher emission than it is allowed)

T1

0.06	-0.06	-0.01
-0.13	0.00	0.00
0.00	-0.12	-0.02

SUM

-0.28

T2

-0.12	-0.06	-0.03
-0.05	-0.01	0.06
-0.05	-0.60	-0.04

SUM

-0.91

T3

-0.26	-0.05	0.07
-0.49	0.02	0.21
0.04	-0.23	-0.40

SUM

-1.09

T4

0.00	-0.09	-0.09
0.02	0.05	-0.01
0.01	-0.05	-0.02

SUM

-0.18

T5

0.00	0.13	0.02
0.37	0.16	-0.03
0.20	0.00	0.00

SUM

0.84

Fig. 4. The difference of the top and bottom measured magnetic field levels (with given sum of all below)

Fig. 4 shows the difference of the measured magnetic field levels between the top and bottom area. The sign – in difference represents a higher level of the magnetic field emission at bottom than at the top areas of the tablets. From Fig. 4, it is an obvious that 4 out of 5 tablets have higher levels of the magnetic field emission at their bottom. It can be concluded that such magnetic field emission is caused by the battery, which is mainly situated at the bottom part of the tablets.

From the given study, it is an easy to conclude that the tablets did not emit the level of the magnetic field like laptops [7]. However, their emission is also above the proposed reference level by TCO. Brief comparison with laptops (battery powered) showed that the level of ELF magnetic field emission is from 0.2 µT to 4.5 µT at the top and from 0.2 µT to 3.5 µT at the bottom [7]. Consequently, tablets emitted at the top from 0.02 µT to 0.86 µT and at the bottom from 0.01 µT to 0.96 µT. Still, the comparison is not quite fair because the laptops have much more computer processing power than tablets. Also, it is worth to note that tablets have higher levels of emission at the bottom. It can be assumed that the gorilla glass at the top is much more resistant to the magnetic field radiation than the plastic materials at the bottom of the tablets.

Hence, during the use of the tablets some precaution is necessary. Among them, the most important are: (i) Making breaks during the long working hours with tablets, (ii) Using tablet's stand whenever possible, (iii) Using external keyboard whenever possible, (iv) Buying tablets made from better plastic or composite materials, which did not allow high emission of the magnetic field, (v) Using gloves that reduce the level of the magnetic field exposure, and (vi) Do not use the tablets on your knees.

V. Conclusion

The given study presented one of the very first experiments conducted on tablets in order to measure their emission of the magnetic field. Because, the tablets are very spread in the younger population, it is very important to determine the level of the magnetic field that they emit and compare them to the proposed safe limit standards like TCO. The results of the study showed that the level of the magnetic field emission is typically above the safe limits. Hence, some precautions during the tablet use are necessary. At the end, the list of suggestions for the safe work with tablets was proposed.

Future works will be oriented toward exploring the higher number of testing tablets in their normal use or in so-called under stress condition (gaming or similar).

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