Evaluation of electromagnetic pollution index (EMPI) emitted from multiple sources

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Abstract. In this paper the cooperative electromagnetic pollution index (EMPI) from many RF sources is evaluated in terms of three components which are strength of magnetic and electric field expressed in A/m and V/m, respectively, and irradiated power in W/m². They are generated by a portable laptop computer (LC) with a liquid crystal monitor and other three sources in front area of it. The LC radiation interference with radiation from mobile phone, Wi-Fi and microwave oven in the radio frequency range from 300 Hz up to 3GHz has been measured. The experiment involves testing 45 different points in the keyboard area and 45 points in the in front area of the PC in its operating state. After that a comparison was made between the calculated values for multiple sources framework and the measured experimental values. Then these EMPI values have been compared with the internationally recommended SAR values.

Introduction

This article provides a method of experimental measurement for electromagnetic pollution (EMP) caused by multiple sources in the radio wave frequency range. This work is one of the first studies to compare the most interesting results and ideas related to EMP exposure of RF sources and suggest possible ways of reducing it. We equip a comprehensive experiment measuring for electromagnetic pollution existing multiple sources as unique framework and also offer a tutorial on the metrics, international projects as well as limits on the exposure for radio wave radiation and standard values for EMR. This structure brings a full operation as in laptop computer desktop.

The EMF radiation originated a problem to the human being, whose in generally comes from sources which generate electric and magnetic field of wireless communication and others non-ionizing radiation fields. Hence, it depends on some parameters like field strength, distance and the altitude, duration of exposure that determine the health hazard for the users of the laptop computer and other electronic devices. One of the ways to estimate the level of EMFs is to test it with portable meters.

In this century, the use of laptop computer (LC) has widely grown. It is particularly true for the younger inhabitants appropriate to its portability, it is quite common habits for use the laptop computer close to our body. It is also in touch with the part of skin, bones, blood, lymph, etc. Popular and constant use of the laptop computer (LC) in more cases might matter some negative wares to the user’s health. Moreover, the raised worry about focusing in weakness health of the exposed person is explicit [1]. It is depending on the impact of the non-ionizing electromagnetic radiation distinguished by the down frequency in the range to 300 Hz. Accordingly the secure and sufficient identically, World Health Organization (WHO) has reported that the electromagnetic hypersensitivity principality includes dermatological, neurasthenic and botanical symptoms [1]. Some principality of electromagnetic hypersensitivity is shortness of breathing, arrhythmia, fatigue and nausea, memory and concentration.
problems, headache, blurred eyesight, limb pains, muscle stiffness, burning sensations, etc. [2-6]. Parallel studies and independent research have similar result and typical conclusions were gained, which pliable them to assessment the secure level of the magnetic field density as amounting to 0.33 A·m⁻¹. Ahlbom et al. [7] and Neutra et al. [8] suggested that current density above density than the secure level of 0.33 A·m⁻¹ up the hazard of developing leukemia by a factor of two. Besides, their survey results [7,8] could not prove any increased hazard of developing another cancer diseases inclusive glioblastoma. It is to be confirmed that this secure level is an estimated assesses as and such as has not been definite by any accurate calculations.

Methodology

We measured the uniform ultra-low frequency magnetic field generated by laptop computer and other three radio frequency wave sources in its surrounding area (figure 1). The laptop consists of several electric and electronic components that are interconnected. At normal operational situation of the LC, these components are powered by current I. The magnetic field is created by the current flow through these components. Based on Bio-Savard’s law, the magnetic field B created by the direct current I is specified in equation (1).

\[
B = \frac{\mu \cdot I}{4 \pi} \int \frac{dl \cdot F}{r^2}
\]

(1)

\[
j \left( \frac{A}{m} \right) = \sum_{i=1}^{n} j_i
\]

(2)

The field determines the level of the radio frequency electromagnetic pollution created by the portable computers as well as interference of electromagnetic pollutions produced from nearly located other three sources which are mobile phone, Wi-Fi and microwave oven. The measurements were made in the keyboard area and in front of portable computer. In order to estimate this effect, we used a portable TM-195 RF three axis field strength meter TENMARS TEST & MEASUREMENT INSTRUMENTS (figure 2) and an EMF meter – low frequency Electromagnetic field intensity EMF 829 (figure 3). The magnetic field strength in the RF range from 400Hz to 3GHz has been measured. The experiment includes testing of 18 different positions for 15 cases illustrated in the figure 1 for the portable computer (LC) and its interaction with other three sources in normal operating condition. The measurement of the electromagnetic pollution expressed in A/m was performed in the laptop neighborhood. The measured data were compared with the electromagnetic safe limit values and other parameters suggested by some organizations like ICNIRP (International commotion Non Ionizing radiation protection) [9]. The paper assesses the level of the electromagnetic pollution generated by the portable computer (LC) Lenovo ideapad 100-15IBD Processor Intel ® core (TM) i3-5005u CPU@2.00GHz. In the experiment the portable computer was tested in natural operating state. After that the LC was connected to Wi-Fi 2300 MHZ and the second stage of the measurements was done. Then a mobile Huawei Y7 Prime 2018 with frequency 1.4 GHz + 1.1 GHz and 1800 MHz was added in the 3rd stage of the measurements. Then a microwave oven with frequency 2450 MHz was added. The measurement of the EMP is perfect in the laptop vicinity. EMI parameters from different home appliance devices in different frequency ranges and their impact on the human’s health is reviewed in [10,11].

The measured data for this productive electromagnetic frame work were processed by using a program Statistical Package for the Social Science (SPSS) in order to know the population parameters and describe the relationship between appreciate variables as well as the correlation factor, regression coefficients and the distribution of electromagnetic pollution for the magnetic field component. Then all measured values were summarized in simple way and compared in between and then were compared with the magnetic field secure limit values which are proposed by ICNIRP and IEEE.

Scenario of experiments

The experiment geometry is presented in figure 1. We have done our experiment at distances as follows: the length, width and height for the laptop are 25, 36 and 25 cm. The area in front of the LC is equal to the same values – 25, 36 and 25 cm. We have done the measurements for all the points at height of 5cm. In the measurement scenario we divided the cases into three groups. First: one source, second: two sources, third: three and four sources group. Then we compared the EMP magnetic field strength component in (A/m) with the standard value which is recognized by ICNIRP. The electromagnetic pollution index (EMPI) measured is defined as values of the magnetic field strength (A/m) consisting of 15 different cases (points in figure 1). It represents the electromagnetic pollution index emitted from the LC and the interaction with three other sources in its neighborhood for 18 points (9 top measured points – marked as topmp1 to topmp9) and 9 points in frontal area (front measured point – marked as infmp1 to infmp9) of the LC neighborhood. In the measurement scenario and data analysis we borrowed Brodic’s methods [12,13]. The interaction with other three sources in top and in front of the laptop area consists of 18 measurement points by measuring the magnetic field strength component for each of 15 cases as shown in table 1.
(a,b), table 2 (a,b) and table 3 (a,b). These tables show the comparison for maximum and average values at top and in front points side for all cases in our case study. The values were measured by the test meter (TM195) which has a high resolution where it informs by 0.1 µA/m for the magnetic field strength.

Figure 1. Location of 18 points to measure the electromagnetic pollution index emitted from the LC and its interaction with three other sources in LC neighborhood

Figure 2. TM-195 RF three axis field strength meter

Figure 3. EMF meter Detector 3axis field strength

Results and discussion

Table 1. EMPI measured values for the magnetic field strength (A/m) component in case of one source at top & front side points side

Table 1a. Average values at top & front points side magnetic field strength (A/m), one source

| Mobile phone | Portable computer (LC) | Wi-Fi | Microwave oven (Mic) |
|--------------|------------------------|-------|-----------------------|
| Top          | 0.070                  | 0.0283| 0.0103                | 0.049                  |
| Front        | 0.0566                 | 0.0384| 0.0101                | 0.039                  |

Table 1b. Maximum values at top & front points side magnetic field strength (A/m), one source

| Mobile phone | Portable computer (LC) | Wi-Fi | Microwave oven (Mic) |
|--------------|------------------------|-------|-----------------------|
| Maximum top  | 0.178                  | 0.07397| 0.021                | 0.083                  |
| Maximum front| 0.1432                 | 0.06897| 0.0189                | 0.068                  |

Figure 4 illustrates comparison between the average level (a) and the maximum level (b) of magnetic field strength in (A/m) for cases of one source of radio frequency sources at top and in front parts points of laptop computer and interaction of these sources in normal operating.
Figure 4a & b demonstrates that the maximum values of the measured magnetic field strength are from 0.021 to 0.178 A/m at the top parts point of laptop and from 0.0189 to 0.143 A/m at in front parts point of laptop computer area. The average values of magnetic field strength are from 0.0103 to 0.070 A/m at top point and from 0.0101 to 0.0566 A/m at in front parts points of laptop computer (LC) area. These magnetic field strength values are obtained in normal operating mode in case of one source of radio wave frequency.

Table 2. EMPI measured values for magnetic field strength (A/m) component in case of two sources at top & front side points

| Top & in front points magnetic field strength (A/m) | Mob & Wi-Fi | LC & Wi-Fi | Wi-Fi & Mic | Mob & LC |
|--------------------------------------------------|-------------|------------|-------------|---------|
| Average (top)                                    | 0.0922      | 0.0342     | 0.0426      | 0.0978  |
| Average (in front)                               | 0.0819      | 0.0333     | 0.0384      | 0.0899  |

Table 2b. Maximum values at top & front points side magnetic field strength (A/m) two sources

| Top & in front points magnetic field strength (A/m) | Mob & Wi-Fi | LC & Wi-Fi | Wi-Fi & Mic | Mob & LC |
|--------------------------------------------------|-------------|------------|-------------|---------|
| Maximum (top)                                    | 0.18        | 0.0699     | 0.0684      | 0.179   |
| maximum (in front)                               | 0.148       | 0.0754     | 0.0652      | 0.155   |

Figure 5 illustrates comparison between the average level (a) and the maximum level (b) of magnetic field strength in (A/m) for cases of two sources of radio frequency sources at top and in front parts points of laptop computer (LC) and interaction of these sources in normal operating.

Figure 5a & b shows that the maximum values of the measured magnetic field strength are from 0.0684 to 0.180 A/m at the top points of the laptop and from 0.0652 to 0.155 A/m at in front parts of the laptop computer area. While...
the average values of magnetic field strength are from 0.0342 to 0.922 at top points and from 0.0333 to 0.0899 A/m at front points of the laptop computer area. These magnetic field strength values are obtained in normal operating mode in case of two sources of radio frequency wave.

Table 3. EMPI measured values for magnetic field strength (A/m) component in case of two sources of radio frequency. The measured values of magnetic field strength at top & in front points from two sources are given in the following table.

| Top & front points | Magnetic field strength (A/m) |
|--------------------|------------------------------|
|                     | Mob & LC & Wi-Fi             |
| Average (top)       | 0.838                        |
| Average (in front)  | 0.0732                       |

Table 3a. Average values of the magnetic field strength (A/m) at top & front side points from three and four sources.

Table 3b. Maximum values of the magnetic field strength (A/m) at top & front side points from three and four sources.

Figure 6 illustrates comparison between the average level (a) and the maximum level (b) of the magnetic field strength in (A/m) for cases of three and four sources of radio frequency sources at top and front parts points of the laptop computer and interaction of these sources in normal operating.

Figure 6a & b shows the maximum values of the measured magnetic field strength are from 0.0941 to 0.1895 A/m at the top parts point of the laptop and from 0.0768 to 0.158 A/m at front parts point of the laptop computer area. While the average values of the magnetic field strength are from 0.0178 to 0.0923 at top point and from 0.0123 to 0.0848 A/m at front point points of the laptop computer area. These magnetic field strength values are obtained in normal operating in case of three & four sources of radio wave frequency. Therefore, figure 5 (a, b) and figure 6 (a, b) illustrate the interference based on the formula (2) and composed of the others three sources, which are mobile phone 1800 MHz, wifi 2300 MHz, microwave oven 2450 MHz near the laptop portable computer (LC) Lenovo ideapad 100-15IBD Processor Intel® core (TM) i3-5005u CPU@2.00GHz.

Table 4 shows a comparison of the maximum top measured points values with ICNIRP standard values limits [9] and their increased factors.
Table 4.

| Sources        | Standard values | \( H \, (A/m) \) measured value > Standard values | Increasing over standard values, % |
|---------------|----------------|--------------------------------------------------|-----------------------------------|
| \( \geq 2\mathrm{GHz} \) | 0.00375f_{1/2} | -                                               | -                                 |
| \( \geq 3\mathrm{GHz} \) | 0.16           | -                                               | -                                 |
| Measured value (Two sources) | 0.16          | \( 0.1799 \, \text{(case No 5)} \)             | 12.4%                             |
|                  |                | \( 0.179 \, \text{(case No 8)} \)              | 12.06%                            |
|                  |                | \( 0.178 \, \text{(case No 10)} \)             | 11.4%                             |
| Measured value (Three sources) | 0.16          | \( 0.189 \, \text{(case No 12)} \)             | 18.4%                             |
|                  |                | \( 0.186 \, \text{(case No 14)} \)             | 16.6%                             |
| Measured value (Four sources) | 0.16          | \( 0.1897 \, \text{(case No 15)} \)            | 18.7%                             |

Conclusion

The article discusses the problem associated with the electromagnetic pollution index from multiple sources of the magnetic field, which exists around any laptop computer. The electromagnetic pollution measurements of the magnetic field strength (A/m) component were implemented by two devices: the portable TM-195 RF field strength meter and low frequency Electromagnetic field intensity meter EMF 829. The results obtained showed that the critical levels of the measured EMPI sometimes significantly exceeded the proposed safe limits as shown in table 4: the cases Nos 5,8,10,12,14&15 demonstrate their increasing factor by 12.4%, 12.06%, 11.4%, 18.4%,16.6% and 18.7%, consequently. Main reason of such exceeding is interference of RF radiation with small differentiating frequencies (the beating effect). Such signals with magnitude over the safe level are periodical and permanently affecting the user in spite of the fact that the EMPI from every device can be lower than the safe level. Therefore, any user should avoid spatial and temporal vicinity of different RF sources.

However, the average values in cases of multiple sources increased also if we compare that in cases of one source which indicates the presence of obvious electromagnetic interferences from multiple sources.

The study pointed to those positions of the computer where the measured EMP I level was significant. This information can be used for the safe and secure use of the laptop and other multiple sources.

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