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Time evolving clustering of the low-frequency magnetic field radiation emitted from laptop computers

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ABSTRACT

The study presents a new time evolving clustering method for tracing the evolution of magnetic field ranges emitted from laptops over time. It is an extension of K-Medians algorithm for which cluster set found at current time point depends not only on the current measured values but also on the cluster sets found at the previous time points. The method is employed on the measured magnetic field radiation of the laptops in the extremely low frequency range at multiple frequencies of TCO standard. Specifically, a new measurement methodology of the magnetic field to which the users of the laptop are exposed in the office environment is proposed. The level of the magnetic field variation in time is measured. Results show that method can be employed to detect the most dangerous magnetic field ranges in laptop areas. Also, it is usable by manufacturers for advancing the safe laptop design or by laptop users for safer and more appropriate use.

1. Introduction

The use of electricity has become an integral part of our civilization. The electric and magnetic fields exist whenever an electric current flows. Hence, they appear close to the electric appliances or electric transmission lines. The level of the electric field can be reduced by a proper shielding. On the contrary, reducing the magnetic field level is a much more difficult task. According to its frequency, the magnetic field can be divided into: (i) low frequency magnetic field, (ii) radio-frequency and (iii) microwave. The low frequency magnetic field is specified in TCO standard in the frequency range from 5 Hz to 400 kHz [22]. Most of the magnetic field is created from the electric power, which has the frequency of 50 Hz (Europe) or 60 Hz (America).

Electric apparatus, due to the current flow, is surrounded by the magnetic field [18]. The magnetic field emission of the laptops is especially interesting as a research topic, because laptops are widely used elsewhere especially by the younger population. The laptop users are typically in close contact during typing or hands resting with the body of the laptop. In recent times, the material of the laptop body is chosen to satisfy ecological standards [22], i.e. to be easily recyclable and to have the weight as low as possible. Hence, the laptop body is usually made of a material that is not suitable for reducing the level of magnetic field [4,25]. Furthermore, due to the specific laptop design, the vicinity of the magnetic field emitters like processor, cooling system, hard disk, memory, graphics card is quite small. Hence, if the laptop is poorly designed, the level of its magnetic field emission can be very high. In this case, it can be said that the laptop has bad ergonomics. Accordingly, it can be a potential hazard to the users health, especially during long time exposure.

The risk of the human exposure to the low frequency magnetic field has been extensively analyzed in recent times [3,13,14]. Many studies support the claims that long exposure to the highest level of the magnetic field has negative impact on the human health and can yield to the appearance of serious illnesses [20]. Hence, the policy of creating the standards for critical level of the environmental condition, which includes the magnetic field exposure, is mandatory. Accordingly, many standards have been proposed. TCO standard, which is widely accepted worldwide by manufacturers, represents the standard proposed by the organization of the Swedish Confederation of Professional Employees (In Swedish

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Tjänstemännens Centralorganisation). TCO'05 standard refers to the problem of laptop certification. It proposes a set of criteria which provide relevant testing methods for the laptop [22]. In the domain of the magnetic field, TCO standard suggested the measurement methodology as well as the safe limits of the magnetic field exposure. It proposed that the magnetic field is measured at different positions which are 0.30 m in the front, in the back and away of the laptop from its center position (center position between the screen and the laptop body). Furthermore, it divides the low frequency magnetic field into two bands: TCO band I and II, where band I is from 5 Hz to 2 kHz, while band II is from 2 kHz to 400 kHz. The safe reference limit for the band I is 0.2 μT and 0.025 μT for the band II [22]. TCO band II has a much stricter safe limit. Still, it is less probable to be violated according to the measurement given in Ref. [6].

In this paper, the laptop emitted magnetic field in the extremely low frequency or TCO band I range without the influence of the Earth magnetic field (below 50 Hz) is in the focus. More specifically, we introduce a new clustering method for tracing the evolution of the magnetic field ranges at multiple frequencies of TCO standard over time. Obtained cluster set corresponding to magnetic field ranges considers the measured magnetic field value at current time and also the history of the ranges until current time. The algorithm is employed on data measured from different laptops in a time interval in the complete frequency range. However, we express certain concerns to the suggested measurement methodology proposed by TCO standard as in Ref. [6]. Essentially, the proposed methodology is not quite reasonable from the users point of view. If we take into account the typical way of using the laptop in the office, then we realize that the laptop user continually works with the keyboard or the touchpad. All the time, the users fingers and hands are in close contact with the body of the laptop. Unfortunately, that fact is not supported by the TCO proposed measurement standard. Hence, we propose a new measurement methodology of the magnetic field that incorporates typical laptop use in the office. In this way, we can measure the real exposure of the users to the magnetic field emitted by the laptop, i.e. when they are in close contact with it. Still, we include the safe reference limit proposed by TCO standard in the band I frequency range, i.e. in the extremely low frequency range. Clustering method applied on measured data reveals three different frequency sub-ranges where magnetic field radiation is uniform, while sub-ranges exhibit strong differences each others. Application of the method on each frequency sub-range detects magnetic field ranges from which the most dangerous laptop areas can be discovered. In particular, we show that specific laptop components associated to these areas strongly emit at extremely low frequency range. It is also important to note that time step approach to magnetic field measurement and estimation to the very best of our knowledge has not been presented in the literature yet. Still, this approach is very important for the laptop user. Hence, caution is mandatory for laptop users when they are in touch with their laptops. Finally, suggestions are provided to users and companies producing laptops to circumscribe the magnetic field radiation risk.

Hence, we propose a new methodology for detection of magnetic field ranges produced by laptop which includes the following:

1. The proposed methodology introduces a new time evolving clustering algorithm to detect magnetic field ranges varying on time. It strongly differs from methodology introduced in [7,8].
2. Algorithm is applied on measured data, where measurement strategy extends TCO standard in measurement geometry and measures the magnetic field variation in time.
3. The proposed algorithm discovers three frequency sub-ranges of uniform magnetic field.
4. The obtained sub-ranges are used to detect magnetic field ranges associated to dangerous laptop areas.

The paper is organized as follows. Section 2 gives a description of the measurement process. Section 3 explains the time evolving process of clustering. Section 4 introduces evaluation indexes. Section 5 explains the experiment. Section 6 gives the measurement results and discusses them. Section 7 draws conclusions.

2. Measurement process

2.1. The magnetic field

The laptop is an electronic system which consists of many electronic components. These components need a power supply to operate flawlessly. Hence, a current flows through the different components, creating a laptop's surrounding magnetic field. It is established according to the Biot-Savart law as a vector of the magnetic induction **B(r,t)** [18]. It comprises the direction and magnitude, because of its vector nature. Because the magnetic induction in a certain point in space is distant from its source, then its direction can be decomposed into the unit directional vectors $\hat{\mathbf{x}}$, $\hat{\mathbf{y}}$, and $\hat{\mathbf{z}}$ along the axes x, y and z, which are previously given by composite vector **r**. Furthermore, **B(r,t)** consists of its scalar components $B_x(t)$, $B_y(t)$ and $B_z(t)$, along the axes x, y and z:

$$\mathbf{B}(\mathbf{r},\mathbf{t}) = B_x(t) \cdot \hat{\mathbf{x}} + B_y(t) \cdot \hat{\mathbf{y}} + B_z(t) \cdot \hat{\mathbf{z}}. \quad (1)$$

All measuring devices register the scalar components $B_x(t)$, $B_y(t)$ and $B_z(t)$ at the specific measurement position in a certain moment of time. Accordingly, the total magnetic induction at time t is given as [18]:

$$B(t) = |\mathbf{B}(\mathbf{t})| = \sqrt{B_x(t)^2 + B_y(t)^2 + B_z(t)^2}. \quad (2)$$

The obtained value of $B(t)$ is measured at different frequencies of the measurement extent.

2.2. Measuring device

In the process of measurement, we use the measuring device AARONIA electromagnetic field spectrum analyzer Spectran NF-5035 [1]. It can measure the minimum, maximum, average and true root mean square (RMS) magnetic induction from 1 pT to 2 mT in the frequency range between 1 Hz and 30 MHz. Although it has six initially defined frequency measurement extents, the measured ranges can be custom defined. All measured data are directly saved to a computer via USB connection in .csv spreadsheet files to be further processed.

Fig. 1 illustrates the AARONIA spectrum analyzer Spectran NF-5035 in combination with its integrated software for the real-time measurement.

2.3. Experiment

In our experiment, we assume that the laptop is used in the office environment. It means that the laptop is placed on the office desk during the work, i.e. testing. Furthermore, the laptop is used for typical office operations like web browsing, typing in a word processor, or calculating spreadsheets. The aforementioned implies that the emitted magnetic field of the laptop is mainly at the laptop top parts. In the office, the portable computers are set on the office desk, which is usually made of wood or plywood with a thickness of approximately 18 mm. The extremely low-frequency magnetic