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Utilization of the boundary exposure assessment for the broadband low-frequency EMF monitoring

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ABSTRACT

Exposure to low-frequency electromagnetic fields (EMF) has become an issue considering a number of high-power low-frequency EMF sources installed in residential environment. Therefore, the EMF monitoring and appropriate exposure assessment are highly important regarding the safety, since residents can spend considerable time in the vicinity of such high-power objects. This short paper brings the case study related to the broadband continuous monitoring of the low-frequency magnetic field in the vicinity of the outdoor power substation, as a particularly important and interesting EMF source. Moreover, the exposure assessment of the general population, performed by a newly proposed adaptive boundary exposure approach, is presented. This approach assesses the upper and lower daily exposure boundaries, offering the range where real exposure is positioned. The reduction of difference between boundaries can be attained by frequency spectrum analysis, while in this case study the initial boundary difference was reduced from 99.6% to 33.3%.

1. Introduction

The investigation, measurement and, in modern days, long-term monitoring of electromagnetic fields (EMF) is of great importance, together with the corresponding exposure assessment to EMFs.

The document of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)" [1] is one of the most commonly used in the area of EMF investigations. The document offers basic recommendations for the establishment of the exposure limits for both the general and occupational population, based on numerous laboratory and epidemiological studies.

ICNIRP's document offers an approach for comprehensive exposure assessment that implies EMF measurements based on the frequency selective measuring approach and frequency dependent reference levels [1,2]. Unfortunately, such approach is not suitable for broadband measurements, due to not knowing the frequencies on which the EMF sources emit and reference levels that should be used. Therefore, a new exposure assessment approach, based on adaptive exposure boundaries, has been proposed [3]. This approach was established with the high-frequency electric field strength measurement [3,4], providing the ability of being suitable for the low-frequency magnetic field, as well [5].

In this paper, the case study of the adaptive boundary approach implementation, for the low-frequency EMF measurements, is presented. Section "Low-frequency test measurement" brings the description of the chosen measurement location, as well as the basic information on used measuring procedure and equipment. Results of the performed measurement and the application of adaptive boundary exposure assessment are presented in the section "Test measurement results". Discussion of the obtained results is offered in the "Conclusion" section.

2. Low-frequency test measurement

Having in mind that power substations, such as the substation "Novi Sad 7", located in the city of Novi Sad, the Republic of Serbia, are installed in the residential areas, it is highly important and publicly strongly demanded that EMF levels in such areas are in compliance with the prescribed reference levels [1,6,7]. Therefore, the real-time in situ monitoring of the low-frequency magnetic field is more than necessary.

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2.1. Test measurement location

The substation "Novi Sad 7" is located in the suburb of the city of Novi Sad, named Telep. This high-power 110/25/35 kV outdoor substation is fed by 110 kV three-phase power lines, which cross Ohridska Street and enter into the substation, as presented in Fig. 1. Besides, there are several 25/35 kV underground power cables that exit from the substation along Heroja Pinkija Street. Those cables supply the consumers in Telep and other suburbs of Novi Sad.

Since there are several private households in the close vicinity of this power distribution object, the surrounding area should be considered as a highly sensitive zone regarding potential EMF exposure. Likewise, the presence of pedestrian pathways near the substation's courtyard, where pedestrians pass during the day, is an additional reason for the investigation and monitoring of the magnetic field in this area.

However, the most interesting section of the substation's surroundings is in Ohridska Street, above which three-phase power lines pass (at the height of about 10 m from the ground), and enter the substation, as depicted in Fig. 1 and in Fig. 2. These power lines also pass near the private household garden and a business building. Moreover, in this street there is no walking path, so the pedestrians walk over the traffic lane, distinguishing this lane as a primary monitoring place.

The nearest private house is distanced only 24 m from the vertical projection of the middle conductor of the power lines, as depicted in Fig. 2. Unfortunately, the power lines pass directly over the garden of this household, increasing the concern of residents on possible negative health effects during their daily gardening chores. Likewise, there is a commercial building, distanced 20 m from the vertical projection of the middle conductor, while a commercial driveway and a gate of this building are even closer to the middle conductor, at a distance of only 8 m, as presented in Fig. 2.

The frequent usage of the narrow traffic lane by pedestrians, as well as the close proximity of the mentioned buildings to the power lines, distinguish this location as highly attractive for the continuous and long-term monitoring of the low-frequency magnetic field.

2.2. Measuring procedure and measuring equipment

The initial measurement was performed in two phases [5], applying the handheld Narda EFA 300 measuring instrument [8], equipped with the isotropic B-field probe. The phases of the measurement were time-separated, conducting the preliminary field scanning and four hours broadband continuous monitoring in the first phase; in the second phase, the frequency spectrum analysis was performed using the SPECTRUM FFT/HARMONICS mode of the Narda EFA 300 instrument [8].

Fig. 1. Location of the "Novi Sad 7" substation.

3. Test measurement results

This section explains the utilization of the proposed adaptive boundary approach for the magnetic field exposure assessment, while additional details can be found in [3–5].

3.1. Boundary exposure assessment

Initially, the boundary approach was used to assess the potential exposure [3–5], evaluating upper and lower exposure boundaries by the following expressions:

$$GER_{low} = \frac{B_m}{B_{ref\max}(f_1)} \quad and \quad GER_{up} = \frac{B_m}{B_{ref\min}(f_2)}, \tag{1}$$

where B_m is the instantaneous broadband measured value of the magnetic flux density, while $B_{ref\ min}(f_2)$ and $B_{ref\ max}(f_1)$ are minimal and maximal prescribed reference levels, in the frequency range of the applied field probe (5 Hz to 32 kHz).

For this case study, $B_{ref\ min} = 2.5\ \mu T$ (for the frequency $f_2 = 32$ kHz) and $B_{ref\ max} = 640\ \mu T$ (for the frequency $f_1 = 5$ Hz) reference levels were selected, in accordance with the Serbian legislation [7], for the general population. Results of the global exposure ratio (*GER*) [4] boundaries assessment are shown in Fig. 3.

Unfortunately, an extensive range between those boundaries can be noticed, requiring an appropriate measure to quantify it. Therefore, in order to describe the range between *GER* boundaries, the relative difference δ was introduced, defined by the following equation:

$$\delta = \frac{GER_{up} - GER_{low}}{GER_{up}} \cdot 100\% = \left[1 - \frac{B_{ref\ min}}{B_{ref\ max}}\right] \cdot 100\%. \tag{2}$$

For the initial exposure assessment, the relative difference between *GER* boundaries is 99.6%, of the upper boundary, referring that the range where real exposure can be found is considerable. Hence, should this gap be reduced, it could be possible to evaluate the present exposure more precisely.

The main idea for the assessment improvement and difference reduction lies in uncovering the set of frequencies on which the EMF emission exists, and selecting new and more appropriate reference levels. By performing the spectrum analysis, the true frequency range of EMF emission can be determined, instead of the presumed one that corresponds to the instrument's field probe range. Consequently, the new $B_{ref\ min}$ and $B_{ref\ max}$ reference levels can be selected, matching the present spectrum closely and reducing the difference between initial *GER* boundaries.

3.2. The frequency selective measurement

The preformed spectral analysis resulted with active frequencies, as presented in Fig. 4, where it can be observed that 50 Hz is a dominant frequency, as expected.

Considering the measurement range of the used instrument, from 100 nT to 32 mT [8], the values below 100 nT, in Fig. 4, can be neglected, probably being the consequence of the detected noise or the uncertainty of the measuring instrument. However, since this is an initial study, in the case that they could be considered as good ones, without being neglected, those values could initiate the spectrum shrinking, as follows.

At the beginning, the visual inspection of the site showed no presence of any source of static or very slowly changed magnetic field; hence, narrowing is possible from the left side of the basic