Adaptive Boundary Approach for EMF Exposure Assessment in Broadband Measurements

Dragan Kljajic, **Nikola Djuric**, **Karolina Kasas-Lazetic**, **and Danka Antic**
Faculty of Technical Sciences, University of Novi Sad
Trg D. Obradovica 6, Novi Sad 21000, Serbia

Abstract— Recently proposed boundary approach for exposure assessment of humans to electromagnetic field (EMF), regarding the continuous broadband EMF monitoring, offers daily upper and lower exposure boundaries. This means that the range with the potential exposure of the general population, as well as the occupational one, can be located in real time. As an advancement of this method, this paper presents a novel approach based on the adaptation of exposure boundaries in order to reduce the difference between them and this will increase the precision of the assessment. Frequency spectrum analysis has been applied, determining the appropriate reference levels for boundary calculation on a particular in-situ location. The results of the performed in-situ test measurement of the high-frequency electric field strength have shown attainment in the reduction of boundaries difference of 36.25%, consequently resulting with the increased precision of the daily exposure assessment for the broadband EMF monitoring.

1. INTRODUCTION

Two most commonly applied approaches for the in-situ measurements of electromagnetic field (EMF) level are the frequency selective and broadband approaches. Even though worldwide researches have shown that, for many cases, the general public exposure is well below the established guidelines, long-term EMF monitoring is an important issue from an environmental protection point of view.

The broadband measuring approach seems to be a more appropriate solution, for the requirements of the continuous and long-term monitoring of the real-time EMF level fluctuations in the environment. This approach results with the single value of the overall and cumulative EMF strength, unlike the frequency selective approach, which simultaneously offers a number of EMF values for each separate frequency in a particular frequency range.

Thus, in order to provide the long-term continuous supervision of the overall and cumulative level of EMF over the observed area, the Serbian electromagnetic field monitoring network — SEMONT has been recently tested [1, 2]. The SEMONT is based on the utilization of autonomous and independent field sensors that perform broadband EMF monitoring, radiated from all active sources around the sensor nodes.

Unfortunately, due to the lack of information on the operating frequencies of EMF sources, the utilization of the broadband measuring approach leads to difficulties in performing the exposure assessment of humans. These difficulties occur since it is not known which of reference levels has to be applied when the comparison of measured values has to be done.

In order to solve this issue, the boundary exposure assessment approach has been proposed, calculating the daily upper and lower boundaries of exposure [3]. That approach has already been implemented into the SEMONT monitoring system and is applicable for both the low-frequency and the high-frequency EMF measurements.

2. THE BOUNDARY ASSESSMENT APPROACH

Regrettably, there is no recommended specific procedure for a comprehensive exposure assessment of the human population in case of the broadband EMF monitoring. On the other hand, some baseline instructions are provided in the standard SRPS EN 50492:2010 [4], suggesting the comparison of the obtained measured value with the lowest reference level in the frequency range of the used field probe in order to obtain the global exposure ratio (GER).

Based on this suggestion, the recently proposed boundary approach suggests the comparison of the obtained measured values with the lowest and highest reference levels in the field probe's frequency range [3]. Applying such an approach, the upper and lower boundaries of exposure can be determined. In case of the high-frequency electric field measurements, the boundaries are calculated via following expressions:

$$GER_{low} = \left(\frac{E_m}{E_{ref\ \max}}\right)^2 \quad \text{and} \quad GER_{up} = \left(\frac{E_m}{E_{ref\ \min}}\right)^2, \tag{1}$$

where E_m is the broadband measured electric field strength value, while $E_{ref\,\min}$ and $E_{ref\,\max}$ are the minimum and maximum electric field reference levels, over the frequency range of the applied field probe, defined by the corresponding legislation for the general population, as well as the occupational exposure. In this paper, the exposure assessment has been done considering reference levels prescribed by the Serbian legislation [5].

Combining the proposed boundary approach and the results of the continuous in-situ EMF broadband monitoring, the daily boundaries can be obtained, showing the fluctuation of the potential exposure over a long period of time, as it is depicted in Fig. 1 [2].

For the purpose of this initial research, a simple test measurement of the high-frequency electric field strength was conducted on the location of the campus area of the University of Novi Sad. Four-hour broadband monitoring of the electric field strength was performed regarding the SEMONT's measurement procedure [2], in the frequency range of 100 kHz up to 6 GHz, applying Narda NBM-550 handheld broadband meter equipped with EF 0691 field probe. This equipment has very similar features as the sensor nodes of the SEMONT system.

Based on the acquired measurement results, the *GER* boundaries calculation was performed according to the Equation (1), where the minimum and maximum reference levels in the observed frequency range were chosen according to the Serbian legislation [5]. Results of the upper and lower *GER* boundaries calculation are shown in Fig. 2.

The calculation of the upper and lower exposure boundaries results with a certain difference between them, which can be described by the relative difference δ as

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

In the observed frequency range, $E_{ref\ \min} = 11\,\mathrm{V/m}$ (for frequency $f = 400\,\mathrm{MHz}$) and $E_{ref\,\max} = 34.8\,\mathrm{V/m}$ (for frequency $f = 100\,\mathrm{kHz}$) [5]. Consequently, the relative difference between *GER* boundaries is 90% from the upper boundary, which presents a significant discrepancy, as it can be observed from Fig. 2.

However, the real exposure is somewhere between *GER* boundaries and the most precise method to determine it is to use the frequency selective measuring approach, as suggested in the Guidelines of International Commission on Non-Ionizing Radiation Protection (ICNIRP) [6].

Unfortunately, the exposure per frequency approach, given in these Guidelines, could not be applied for broadband EMF measurements, since there is a lack of information on present frequencies on which EMF sources radiate. Thus, this paper proposes the investigation of *GER* boundaries

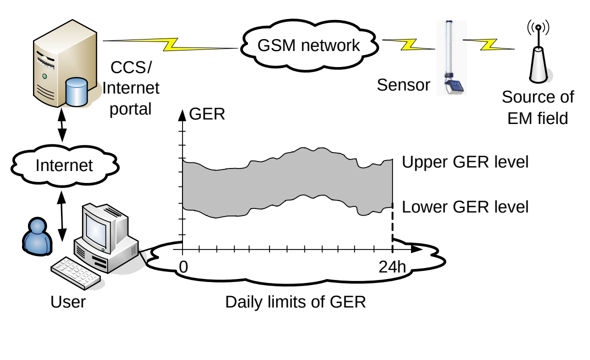

Figure 1: Presentation of daily boundaries of the *GER* to the public.

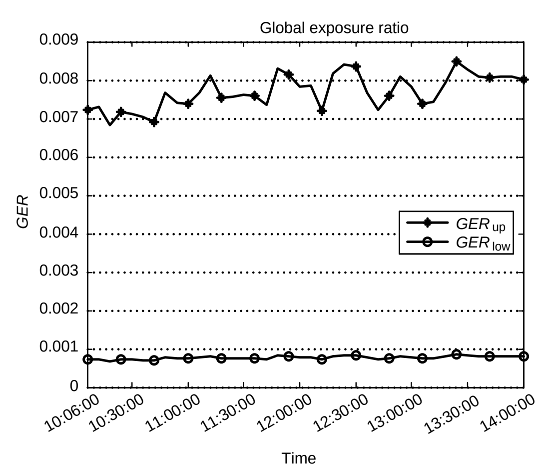

Figure 2: Broadband exposure assessment of the general population on an in-situ measurement location.

adaptation and the reduction of difference between them by adopting new and appropriate reference levels for a particular in-situ location. With the reduction of *GER* boundaries, a smaller range could be offered, where the real exposure can be positioned, resulting with a much better insight onto the exposure on a particular in-situ location.

3. THE ADAPTIVE BOUNDARY APPROACH

The broadband measuring approach offers results of the overall and cumulative value of EMF at a particular in-situ location, without the ability to identify active EMF sources in the surroundings, nor their operating frequencies. Choosing the lowest and highest prescribed reference levels in the observed broadband frequency range for $E_{ref\,\min}$ and $E_{ref\,\max}$, consequently leads to the underestimation and the overestimation of *GER* boundaries. This situation occurs since the measured results are compared only with these two limits, while the reference levels for other frequencies are not taken into consideration.

Regarding the particular location, it is possible that only few field components in the whole frequency spectrum contribute to the overall measured EMF value. Thus, it is clear that the observed frequency range can be narrowed and new reference levels can be chosen, reducing the gap between *GER* boundaries. This is the main idea of the adaptive boundary approach.

Latest researches have shown that the most dominant sources of the high-frequency EMF emission in the environment are those reserved for GSM 900, GSM 1800 and UMTS 2100 communications services [7, 8]. Having in mind this fact, the shrinking of the observed broadband frequency range is possible in case that it is proven that the contribution from other frequencies and EMF sources to the overall EMF strength is practically negligible, as it is presented in Fig. 3.

One way to determine in-situ active frequencies is by a spectrum scanning. Thus, the adaptation of *GER* boundaries is based on the utilization of the frequency selective in-situ measurement combined with the broadband EMF monitoring.

In order to verify the proposed adaptive approach, the spectrum scanning at a test measurement location was performed. Results of the performed scanning confirmed the assumption on the dominance of the mobile phone communications services in surroundings. Hence, the appropriate shrinking of the observed broadband frequency ranges from 925 MHz to 2200 MHz (comprising only downlink of GSM 900, GSM 1800 and UMTS 2100 services), leading to the selection of new minimum and maximum reference levels: $E_{ref\,\min} = 16.728\,\mathrm{V/m}$ (for frequency $f = 925\,\mathrm{MHz}$) and $E_{ref\,\max} = 24.597\,\mathrm{V/m}$ (for frequency $f = 2200\,\mathrm{MHz}$) [5]. Consequently, the relative difference between the adapted *GER* boundaries is now 53.75% from the upper boundary, while the attained reduction of the difference between the exposure boundaries is depicted in Fig. 4.

The performed analysis shows that, involving a frequency selective measurement, a reduction in

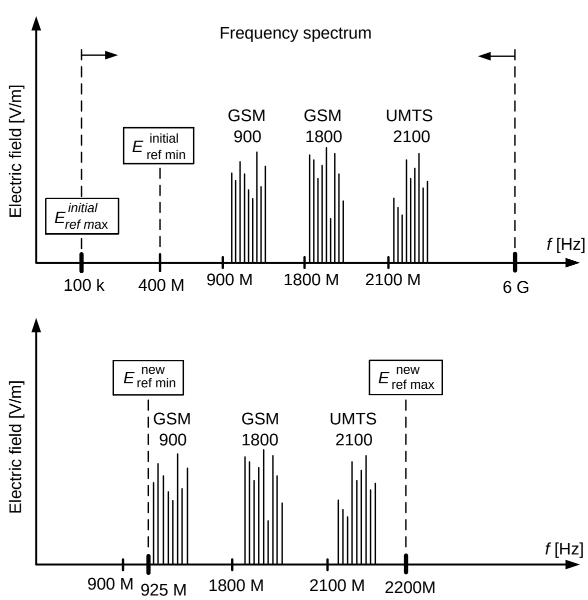

Figure 3: Shrinking of the observed frequency range.

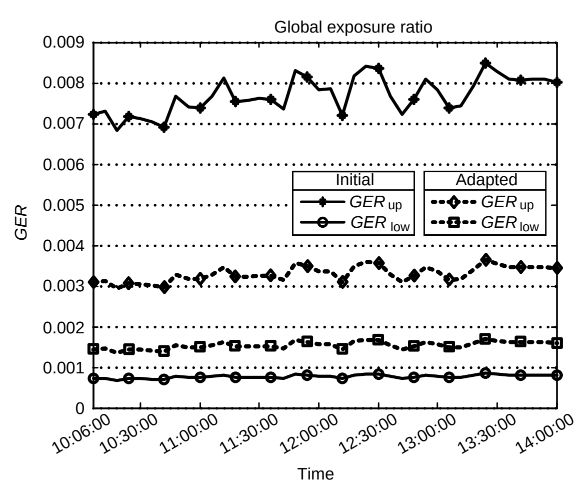

Figure 4: Adaptation of exposure boundaries.

boundaries difference of 36.25% is attained. However, the real exposure is again somewhere between *GER* boundaries, though in this case the precision of assessment is improved, accomplishing a much clearer insight of the human exposure to EMFs at a particular in-situ measurement location.

Generally, a combination of both measuring approaches at in-situ measurement locations could help in advancing the efficiency of systems for the broadband EMF observation, such as the SEMONT system. The implementation of the suggested adaptive boundary approach into those systems could offer the improvement in the accuracy of the assessment of possible long-term exposure of the public to non-ionizing radiation in the environment.

It is important to emphasize that the dominance of EMF sources varies with the measurement location; thus, depending on active frequencies in the sensor node surroundings, the corresponding narrowing of the spectrum could be performed, as well as the appropriate adaptation of exposure boundaries.

4. CONCLUSION

In this paper, one of the possible solutions for the advancement of the proposed boundary exposure assessment approach is presented. This approach is suitable for the purposes of the broadband EMF monitoring in the environment, and is already implemented into the SEMONT monitoring system.

Results of the performed test measurement showed that information on frequency spectrum in the vicinity of the measurement location could enhance the proposed boundary approach through the adaptation of calculated exposure boundaries and the reduction of difference between them.

The results also revealed that the adaptive boundary approach could offer a clearer overview of human exposure to EMF in the environment and increase the precision of the daily exposure assessment on a particular in-situ location. Moreover, performing the periodic EMF spectrum scanning at the position of the SEMONT's sensor nodes could help in the advancement of the efficiency of such monitoring system regarding the precision of the exposure assessment of human population, as well as the occupational one.

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