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Research into the methodology for measuring electromagnetic fields generated by base transceiver stations

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Abstract: The electric field strength is a legally defined, directly measurable quantity for the evaluation, assessment, and objectivity of electromagnetic fields in the environment. This contribution is devoted to the analysis of the temporal dependency of changes in the intensity of electric fields generated by base stations of mobile operators. It focuses mainly on the time interval, the location of the measuring point, and the selected day during the week in which the electric field effort measurement was performed. Measurements were made at the selected industrial site and at the designated measurement sites. Measurements were made on selective days of the week and on selective hours from 8 AM to 8 PM. The contribution shall analyse in detail the specific days and times of measurement using the ANOVA and Scheffe's method. The lowest values measured were recorded over the weekend and in the evening. The evaluation of the measured data was aimed at demonstrating the reasonableness of the choice of measurement time to the values of the measured values. Dependencies are found for the selected function of the selected locality-industrial zone.

Keywords: Electric field; Base station; Intensity; Cumulative values

1. Introduction

Mankind is constantly exposed to electromagnetic fields arising from natural or non-natural sources [1]. The mobile phone base stations are a significant source of electromagnetic fields (EMF) [2], which can transmit and receive wireless signals. In general, the base station serves as a central connection point for a wireless communication device. The increase in the number of mobile phone base stations over the last decade has raised concerns about the effects of electromagnetic fields on the human body and health [3]. Therefore, there is a need to measure and study electromagnetic fields in their vicinity.

In their study, Giudici et al. [2] performed electromagnetic field measurements in the homes of 354 participants living within 250m of a mobile phone base station. Measurements showed that the measured exposure was higher during walks than at home, and during the day than at night, but there was no difference between weekends and weekdays. In their paper, Cerezci et al. [4] investigated the EMF exposure levels of people living near mobile phone base stations over a three-year period. Due to the growing number of base stations over the years and the change in technology, it was found that the average levels of exposure to electromagnetic fields in the city have been increasing to some extent every year. In the article [5], the authors present quantitative data on the exposure of the public in various indoor, outdoor, and transport

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environments. Radiofrequency electromagnetic field (RF-EMF) levels tended to increase with increasing urbanity. The paper by Alahidin et al. [6] deals with the measurement of EMF in the vicinity of a residential area over a period of two weeks with varying time intervals. The measuring equipment was placed 50 meters from the base station with a height of 2 meters above the ground. From the results obtained, the exposure at home ranges from 0.83 V/m to 7.3V/m with the maximum value of radiation level recorded at night. Renke et al. [7] investigated the levels of electromagnetic radiation emitted from base stations in residential areas in Kolhapur, a district located in west Maharashtra. They monitored various measuring sites (hall, terrace, room, etc.), and in all locations, the measured values were well below the maximum permissible exposure level. In [8], personal exposure to EMF of 75 volunteers in Spain was analysed. The personal exposure to RF-EMF fell well below the limits recommended by the ICNIRP and showed great temporal and spatial variability. In the publication [9], studies that address EMF exposures of general population are summarised. They state that distance from the station is not a primary affecting factor, while orientation to the main lobe significantly affects the exposure. In [10], the authors analyse daily changes in measured EMF levels in two different locations in Poland (a small town with dispersed buildings and a large city with dense buildings). The research was carried out using selective electromagnetic meters as well as EMF meters with spectral analysis. The authors [11] have carried out several measurements of selective in-situ frequencies and broadband measurements in urban and suburban environments. Measurements showed that EMF exposure was greater in urban than in suburban environments. In [12], a mapping methodology was proposed to assess EMF exposure more effectively while creating a global picture of exposure in the area. Kurnaz et al. [13] in their study performed 24-hour EMF measurements in the frequency range from 100kHz to 3GHz. At the measuring sites that are consistent with the base stations, the EMF value varies with the time of measurement. The EMF value measured in the afternoon is approximately 32% higher than at night. The measurement of EMF in the vicinity of base stations is also addressed by Büyükuslu et al. [14]. The measurements were performed over a period of one year at different distances (5m, 10m, and 50m) from the mobile phone base station antennas. The authors in [15] focused on exposure to radiofrequency electromagnetic fields, as they are not at all constant in time. In the study, they analyse the importance of considering the hour and day of the measurement with respect to the daily temporal variability of RF signals. Gong et al. [16] monitored the environment around base stations. They found that the requirements of electromagnetic limits for environmental control were met at all monitoring sites in urban areas. In the [17] study, temporal trends of RF-EMF exposure in different microenvironments of three European cities were assessed. Exposure levels were still well below the regulatory limits of each country. Based on the results, it was concluded that continuous monitoring is necessary to identify areas of high exposure and to anticipate the critical evolution of RF-EMF exposure in public places. The authors Sagar, S. et al. [18] found significant differences among studies according to the type of measurement procedure, which precludes a cross-country comparison or evaluation of time trends. Based on their research, they conclude that a comparable concept of RF-EMF monitoring is needed to accurately identify typical RF-EMF exposure levels in the daily environment.

The present article deals with the analysis of the intensity of electric fields generated by mobile base stations. For research, we chose the industrial zone. For the purposes of the analysis presented, the statistical methods of measurement of measured data — ANOVA and Scheffe's method — were used to assess changes in the electric field strength. The measured data were evaluated according to the daily time (from 8:00 to 8:00 00 hours), on the day of the week (measurements on each day of the week), and on the measurement site in the selected location. The main objective of the evaluation is to determine the dependency of the electric field strength on the selected parameters and to analyse them in detail. This contribution will be used for further research and, for the design of the EMF measurement methodology in the Slovak Republic.

2. Experimental Section

At present, the legislation and methodological procedures resulting from technical standards in force do not lay down any requirements regarding the time of the day or the day of the week in which the measurement is to be carried out. Requirements shall be specified for the location of measuring points, including the selection of the site so that the site is exposed to the maximum EMF intensity. There is an accredited testing laboratory at the authors' workplace and the authors have so far carried out measurements of hundreds of base stations. Based on the acquired knowledge of the situation, we know that measurements are made based on the customer's requirements at the time and time necessary to match the laboratory's capacity. The main purpose of the experiment is to demonstrate whether the chosen parameters need to be considered when planning the measurements. The experiment was designed to determine the significance or insignificance of selected parameters by mathematical methods and to recommend modifications to the currently used methodologies.

2.1. Characteristics of the measurement location

Experimental measurements of the intensity of electrical fields generated by base stations of mobile operators were performed at a selected site. An interesting area was the industrial zone, where industrial and administrative buildings are located. Companies usually use Internet networks and communication systems that are a source of electromagnetic fields.

Our measurement sites are located near a mobile base station labelled MBTS. For the measurements, seven measurement sites, labelled M1–M7, were selected. The measurement sites were chosen to characterise the selected location, considering the directional characteristics of the antennas. Measurements at all measurement sites were performed at the time of peak load of the base stations from 8 am to 8 pm at 2-hour intervals throughout the week. Figure 1 shows the location of measurement sites.

Figure 1: Location of measurement sites in scale 1:4500.

The distance of each measurement point from the MBTS mobile base station is shown in Table 1.

Measurements were performed at each measurement site using a Narda SRM-3006 measuring instrument consisting of a spectrum analyser and an isotropic probe for measuring the electric field component with the frequency band of the measurement chain from 420MHz to 6GHz. The measuring device was placed on a carbon tripod at a height of 1.5m. The output of the measurements is cumulative values of the electromagnetic spectrum intensity and the frequency spectrum. The measurement time was set to six minutes because this is the time of manifestation of thermal effects. The measurement was performed in the frequency band with the minimum display frequency Fmin – 700MHz, and maximum display frequency Fmax – 3500MHz. The location of the measurement sites M2 during the measurement is shown in Figure 2.

Table 1: Distance of measurement sites from MBTS.

	M1	M2	M3	M4	M5	M6	M7
MBTS	65 m	45 m	25 m	90 m	140 m	124 m	255 m


Figure 2: Location of measurement site M2 during the measurement.

3. Results and Discussion

The main outputs of individual measurements are the cumulative electric field strength values and frequency spectrum graphs for each measurement. Providing data from all measurement sites would

Table 2: Descriptive statistics of cumulative EF strength values (mV/m) – measurement sites here.

Characteristics	Measurement site						
	M1	M2	M3	M4	M5	M6	M7
Mean	486.4	804.4	741.3	840.7	854.2	714.9	945.0
Standard deviation	79.2	179.2	136.8	179.5	184.6	109.0	242.1
Maximum	709.4	1267.0	1064.0	1314.0	1371.0	929.8	1623.0
Minimum	348.0	482.2	504.6	552.0	521.4	447.4	582.4
Range (Max-Min)	361.4	787.8	559.4	762.0	849.6	482.4	1040.6

go beyond the scope of the contribution. The resulting numerical characteristics at individual measurement sites (regardless of the day and time of measurement) for a given MBTS station are shown in Table 2.

The measured values show that the lowest average value was recorded at measurement site M1, being up to 48.5% lower than the highest average value measured at measurement site M7. A graphical representation of the values by means of boxplots is shown in Figure 3. The analysis of the values shows that the resulting value is influenced by the location of the measurement site.

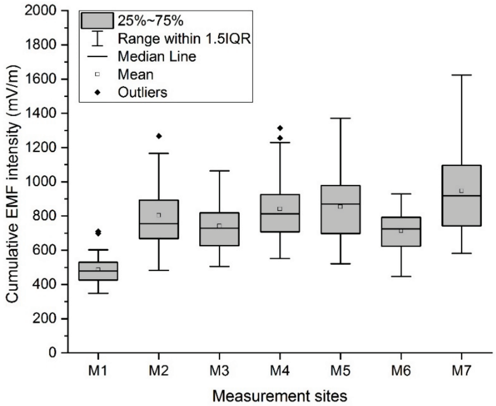

Figure 3: (a) Boxplot of cumulative EF strength value – measurement sites.

Based on previous analyses, a significant influence of the choice of measuring point on the resulting value was expected. This assumption was based on the real existence of base stations of different performances, the different orientations of the transmitting antennas, and the different distances from the measuring point. Analysis of these values can then confirm this assumption and assess the significance of the location of the measurement site.

3.1. Analysis of measured data

Present data for measurement results are from Tuesday, Wednesday, Friday, and Saturday. Figure 4 shows a graph of the cumulative values measured at all measurement points of M1-M7, for the selected measurement on each day and at the time of measurement of 10am. In the graph, the differences between the individual measuring points but also the measurement dates are clearly visible. The cumulative values of the electric field strength were the most severe on Saturday, measured for all measuring points. This is the weekend in which lower levels of movement in the direct industrial zone were also observed.

The highest cumulative values of electric field strength have been measured at the measurement point M7. The measuring position of M2 and M7 was situated in the same direction of the main radiating lobe of the MBTS base station but at different distances. The measuring point M2 was 45 m from MBTS and the measuring point M7 was 255 m. Table 3 shows the cumulative EF strength values (mV / m) for two selected sites M2 and M7 for the selected hours (10am, 2pm, 6pm, and 8pm) and for selected measurement days (Tuesday, Wednesday, Friday, and Saturday).

In Figures 5 and 6, a graphical representation of the measured cumulative values of electric field strength for the measurement location M2 and M7 at the selected measurement dates and times are given. Based on this image, we can see that the measurements made in the evening hours recorded a lower electric field strength.

The output from the measurements is the frequency range. Figure 7 shows the frequency spectra graphs for the measuring point M2 and M7. Graphics show peaks at a certain frequency. The red-highlighted peaks are located at a frequency of 900MHz. The measured value of electric field

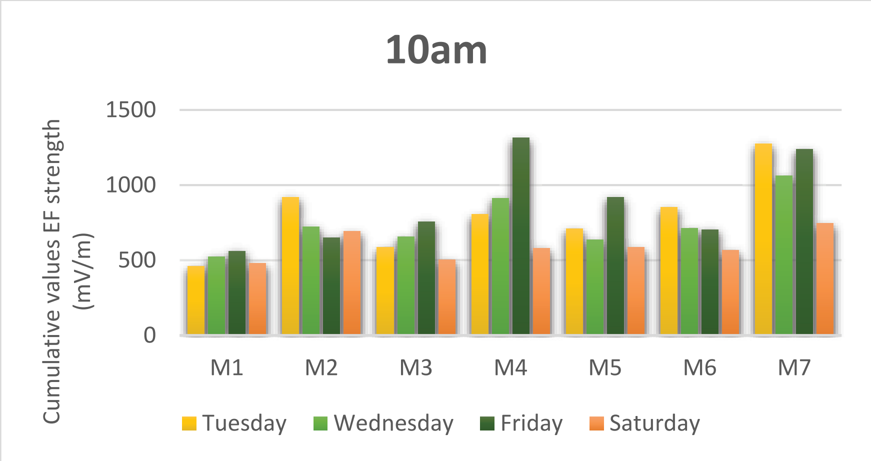

Figure 4: Graphical representation of cumulative EF strength value at 10am, for selected measurement days, and for whole measurement sites.

Table 3: Cumulative EF strength values (mV/m) at measurement sites M2 and M7.

Measurement Day	Time of measurement/ Measurement site							
	10am		2pm		6pm		8pm	
	M2	M7	M2	M7	M2	M7	M2	M7
Tuesday	918.1	1274	827.8	1517	684.6	1089	707.2	713.5
Wednesday	722.3	1062	1150	1343	643	735.1	668.4	690.3
Friday	650.8	1240	876.8	1360	834.4	751.3	667	697.2
Saturday	692.3	744.9	656.9	1035	850.7	875.2	715.2	767.2

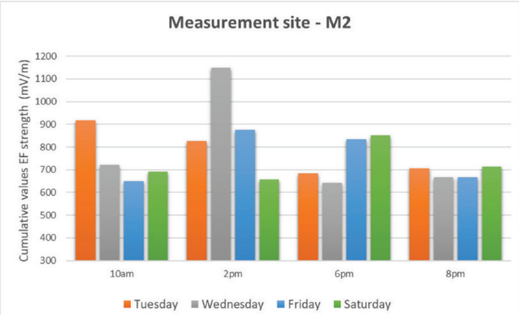

Figure 5: Graphical representation of cumulative EF strength value for measurement site M2, for selected measurement days, and time of measurement.

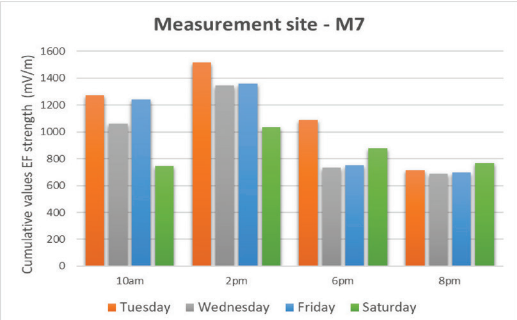

Figure 6: Graphical representation of cumulative EF strength value for measurement site M7, for selected measurement days, and time of measurement.

strength was at the measuring point M2 305,7mV/m and at the measuring point M7 823,7mV/m. The difference in these values is characterised by a decrease in the intensity of the electric field in the environment.

The impact of the time of measurement during the day on the resulting value is characterised by the variance of values measured during individual days. From the results, it is clear that the choice of time of measurement does not significantly affect the measured values. In general, the lowest values were recorded in the evening at 8pm. There were occasional local extremes, not corresponding to this statement, which was probably caused by increased data flow at the time of measurement (e.g. running backup data).

4. Conclusions

The objective of the pilot experimental research was to measure and investigate changes in EMF intensity depending on the time of the day and

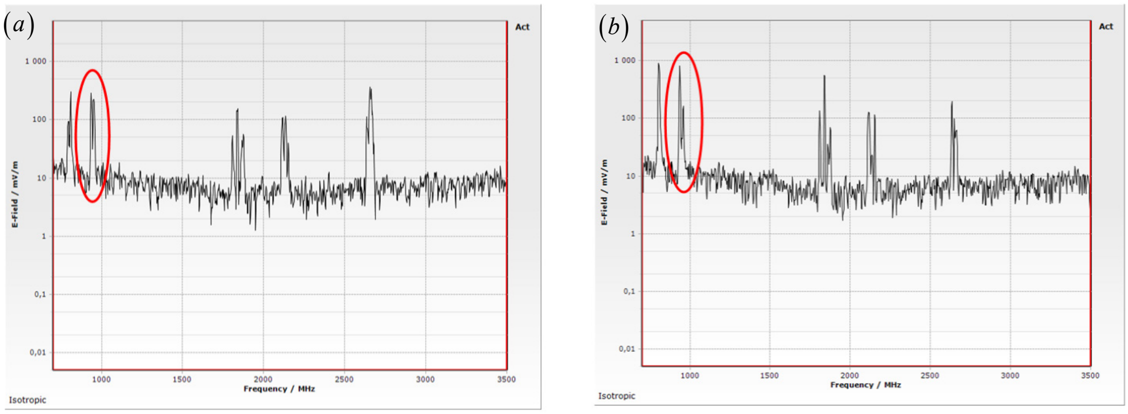

Figure 7: Measurement output – frequency spectrum (Tuesday starting at 2pm, instrument generated graph) a)Measurement site M2, b)Measurement site M7.

the day of the measurement. At the same time, we also assessed the impact of the location of the measurement site. Although the choice of measurement site is to a large extent determined by the relevant legislation, it is important to know the characteristics of the variance of EMF intensity values depending on the location of the measurement site, especially in urban agglomerations with tens to hundreds of base stations. For this reason, the measurements were carried out at two-hour intervals at the time of base station peak load (from 8am to 8pm) and on each day of the week from Monday to Sunday.

The analysis and evaluation of research results show that the resulting value of cumulative EMF intensity measured at a certain time, or on a certain day is significantly affected by the measurement site in particular.

The results of the experiment can be summarized as follows:

Impact of measurement site

– *The impact of the measurement site on the resulting value was expected and proven by the experiment. Differences of up to 50% were observed. In measurements, there are often cases when the measured EMF intensity values are within 5–10% of the action values defined by the current legislation.*

– *It follows that at low EMF intensity values, the precise location of the measurement site can be neglected only in screening and indicative measurements. However, we emphasise the fact that at least basic rules for the selection of measurement sites must be respected when locating the measurement site.*

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