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STUDY ON LONG-TERM CHANGES IN THE ELECTROMAGNETIC ENVIRONMENT USING DATA FROM A CONTINUOUS MONITORING SENSOR

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Abstract

With the proliferation of base stations through mobile telephony development projects, as well as the diversification of telecommunications services, medical technology, and household appliances, there has been increasing concern among the population regarding the excessive use of electromagnetic fields. This concern is also due to the absence of direct perception of electromagnetic phenomena. The perception of the presence of a high-intensity electromagnetic field is indirect, through mechanical, thermal, optical, and acoustic effects. This paper aims to analyze the evolution of the electromagnetic field in the environment and consequently human exposure to it over a one-year period, from September 2022 to September 2023. The study is based on data collected from a non-ionizing radiation monitoring sensor in Timişoara. We used the Holt-Winters and ARIMA methods for analysis and prediction, and since the sensor includes frequency filters for separating received frequencies, we analyzed three frequencies and a wide band. The study shows a fluctuation over time of the electromagnetic field, without exceeding the reference level according to OMS 1193/2006.

Index Terms-electric, electromagnetic, frequency, OMS, prediction

1 Introduction

Wireless communication technology has experienced rapid development, and along with it, public concern regarding the perceived risk of exposure to electromagnetic fields has increased. As concerns about exposure to electromagnetic fields have grown, the first standards and regulations for protection against electromagnetic radiation have been developed and implemented. The international organization ICNIRP (International Commission on Non-Ionizing Radiation Protection)

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has contributed to the establishment of these standards. In 1999, the European Union adopted "Recommendation 1999/519/EC on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)."[1]. Thus, in Romania, this recommendation is transposed in the form of the "Order of the Minister of Public Health no. 1193/2006 for the approval of the Norms regarding the limitation of exposure of the general population to electromagnetic fields from 0 Hz to 300 GHz "[2], a document that is approved by (ICNIRP). Over time, research in this field has continued to advance, and standards and regulations have been updated and revised based on new discoveries and understandings regarding the impact of electromagnetic fields on health and the environment.

The assessment of human exposure is a constant concern and is encountered in specialized studies from various countries. A spatiotemporal model of radiofrequency field exposures has been evaluated in Chengdu [3], in China, to establish if there are sources whose emission causes exposure above the relevant levels provided in guidelines and standards (ICNIRP şi GB 8702-014). The analyzed data was collected from three categories of areas: commercial area, urban residential area, and rural residential area, using a system installed on a car for two years. No levels exceeding the established exposure limits were recorded.

Another study was conducted in a province of Turkey[4], For two years, taking into account the variations throughout the day. The study aimed to assess the population's exposure to radiofrequency fields in relation to the limits set by ICNIRP and ICTA (Turkey's Information and Communication Technologies Authority). Following the analysis of the data, it was found that during the day, the field levels were with $35,4\%$ higher compared to the levels during the night.

In Greece, there was a study [5] spanning a period of 20 years, regarding the long-term changes in the electromagnetic field, using data obtained from monitoring sensors and thus assessing human exposure to these fields. The study found that there is a fluctuation in the radiofrequency electromagnetic field.

Results of measurements in outdoor, urban environments are highlighted in the paper "Prediction of RFEMF Exposure by Outdoor Drive Test Measurements" [6], in which the artificial neural network (ANN) model was explored for spatial reconstruction, with real data, of exposure to radiofrequency electromagnetic fields. Measurements were taken on the electromagnetic field intensity in Paris, covering a distance of 65 km , in a wide band. With the collected data, two different models were constructed. An ANN1 model where the N nearest base stations were considered regardless of their operator, and in another model, ANN2, which contains base stations belonging to the same operator, grouped into blocks, each block containing $N = 3, 5, 7$ base stations. At the end of the study, it was found that the ANN1 model has better prediction quality as N increases (for N = 7), but the processing time increases, and with the ANN2 model, there is no improvement in prediction by increasing the number of base stations from 3 to 7 .

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2 Experimental setup and data collection

As part of the electromagnetic field monitoring project in urban areas with heavy traffic, the data is made available to the public through the ANCOM platform (National Authority for Management and Regulation in Communications)[7], stations are installed throughout Romania that continuously monitor and transmit the data to the information platform every 24 hours.

The monitoring stations with fixed sensors are placed in public spaces, schools, university centers, public squares, in the vicinity of which there are multiple sources of radio emissions.

The equipment used for the continuous monitoring of the electromagnetic field is of the Narda AMB 8059 type and meets the ITU-T K. 83 requirements for continuous multi-band monitoring of the electromagnetic field [8]. The Narda AMB 8059, a remotely controlled module, is equipped with a triaxial isotropic probe that performs wideband measurements of the electric field (E) with a frequency range of 100 kHz to 7 GHz (a range that includes the bands used in Romania for 5G), and three frequency bands from the mobile telephony spectrum: 925 MHz - 960MHz, 1805MHz - 1880MHz, 2110MHz− 2170 MHz .

The monitoring equipment has low energy consumption, but to be operational 24/7 it can be powered by a solar panel or batteries, thus its energy autonomy can be extended up to 80 days. Additionally, it includes internal memory for storing collected information, which can be expanded. Recorded data is transmitted to the server/PC via an integrated modem. An internal GPS module allows for its localization.

The recorded values of the electric field intensity (RMS) are either peak values or maximum values recorded in the monitored frequency bands, or temporally averaged values over 6 minutes.

$$E_{RMS} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(E_i)^2} \tag{1}$$

where n represents the total number of discrete values, and E_i represents the discrete values of the electric field intensity.

On the building of the Politehnica University of Timișoara (UPT), such a monitoring station is installed.

On the roof of the building, numerous mobile base stations are installed, but an important contribution also comes from the base stations and antennas located on the building of the West University of Timișoara (UVT), situated in the vicinity of the UPT building. Additionally,

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Fig. 1: Screenshot of the map showing the sensor location [7]



Fig. 2: Placement of the sensor on the UPT building[7] being a university area, the traffic on the mobile networks is high, so it is expected that the data recorded by the monitoring station would be higher compared to other less populated areas with lower antenna.

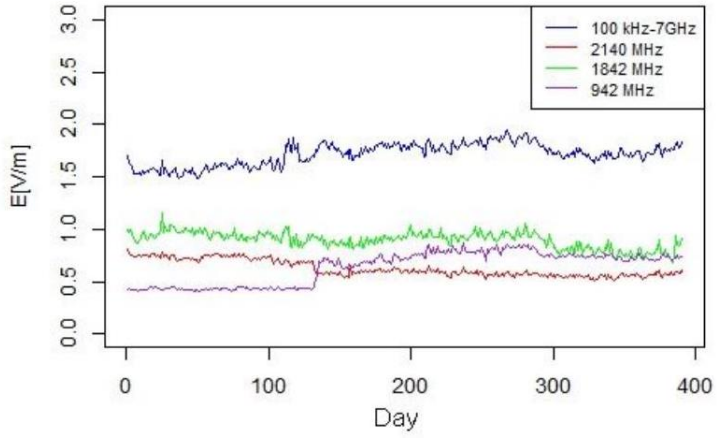
The data obtained from the sensor was checked to ensure there were no missing or outlier values. Additionally, we removed zero values recorded as average values that had corresponding non-zero peak values, and vice versa.

The values used in the study are daily average values of the data recorded by the sensor, in the wide band ($100\text{kHz} - 7\text{GHz}$) and for the three frequencies: 2140 MHz, 1842MHz, and 942 MHz , during the period from September 2022 to September 2023, as shown in Figure 3.

Fig. 3: Average values of the electric field intensity over a period of one year

In this graph, on the vertical axis, we represent the electric field intensity, measured in V/m, with values ranging approximately between 0.4 V/m and 2 V/m. On the horizontal axis, we represent the days of the year, from 0 to 400 . Each band/frequency is represented by a different color. The highest average values of the electric field, values approaching 2 V/m, are in the wide band. Moderate values, between 1.2 and 0.75 V/m, are at the frequency of 1842 MHz , while the other two have values below 1 V/m. This graph provides a perspective on how

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the electric field intensity varies over the course of a year, for different frequencies.

3 Model and experimental validation

We used the simplified Holt-Winters method (simple exponential smoothing model), without trend and without seasonality, to adjust the level of the time series. The method uses the weighted sum of present and past terms, giving higher weights to present series terms and lower weights to past terms. Thus, by applying this method to the daily averaged values for the four frequency domains, we obtained predictions for the next value of the electric field.

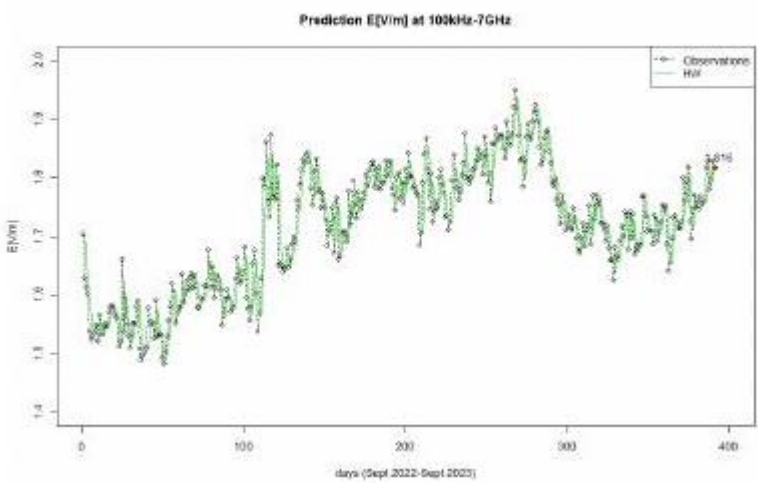


Fig. 4: Holt-Winters method E[V/m] in the 100kHz − 7

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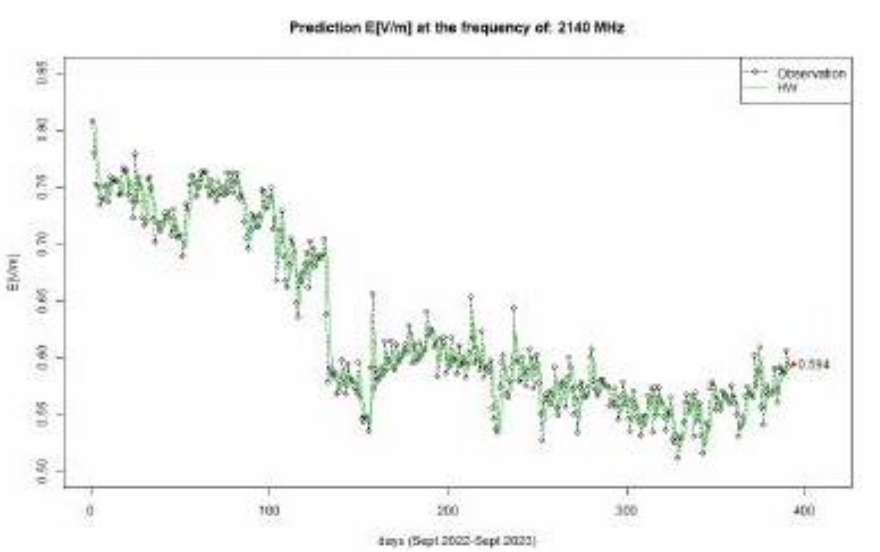


Fig. 5: Holt-Winters method $E[V/m]$ at the frequency of 2140 MHz GHz band

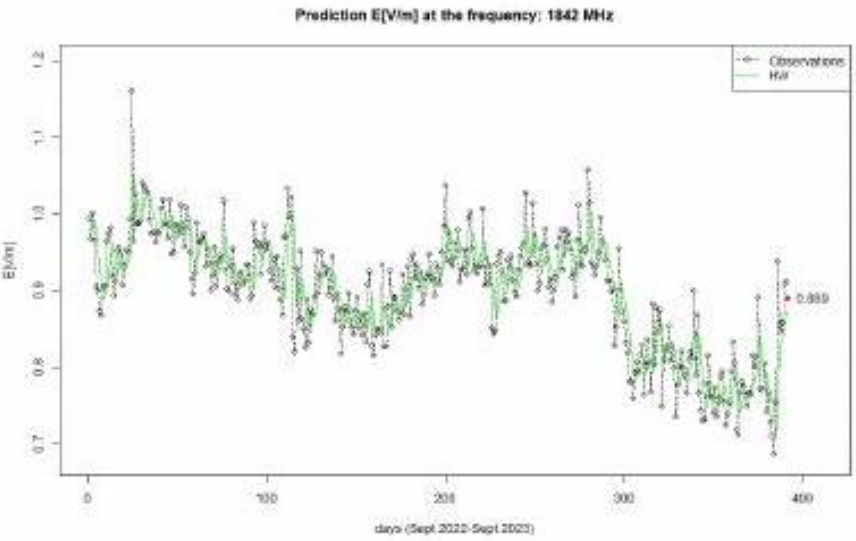


Fig. 6: Holt-Winters method E[V/m] at the frequency of 1842 MHz

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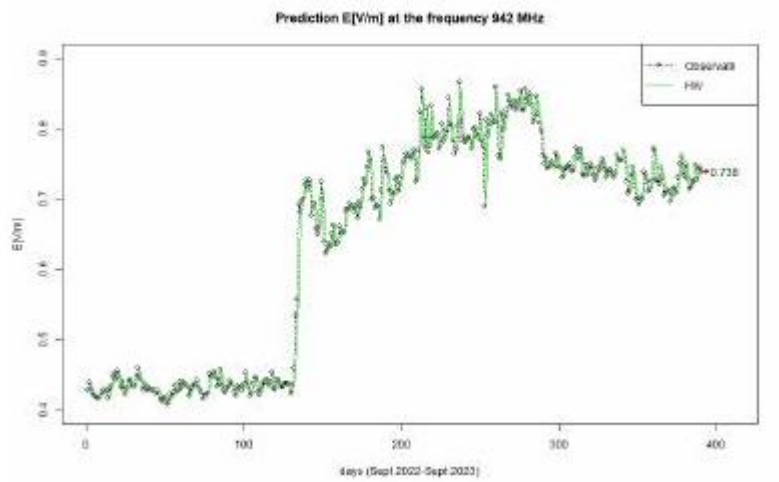


Fig. 7: Holt-Winters method E[V/m] at the frequency of 942 MHz

Another method we used in the time series analysis is ARIMA (p,d,q) (AutoRegressive Integrated Moving Average), composed of p - the number of autoregressive terms, d - the number of differencing needed to make the series stationary, and q - the number of moving average terms. We obtained the optimal parameters for ARIMA considering the AIC (Akaike Information Criterion) to identify the model that best balances complexity and data fitting.

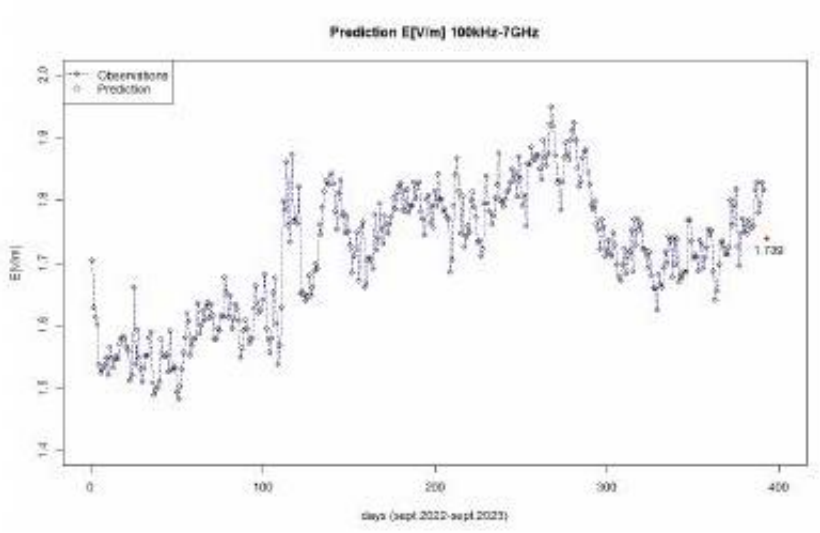


Fig. 8: The ARIMA $(3, 2, 0)$ method $E[V/m]$ in the 100kHz − 7GHz band

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Thus, for the data in the 100kHz−7GHz band, we obtained the ARIMA(3,2,0) model; for the 2140 MHz frequency, we obtained ARIMA$(1, 2, 0)$; for the 1842 MHz frequency, we obtained ARIMA(2,1,2); for the 942 MHz

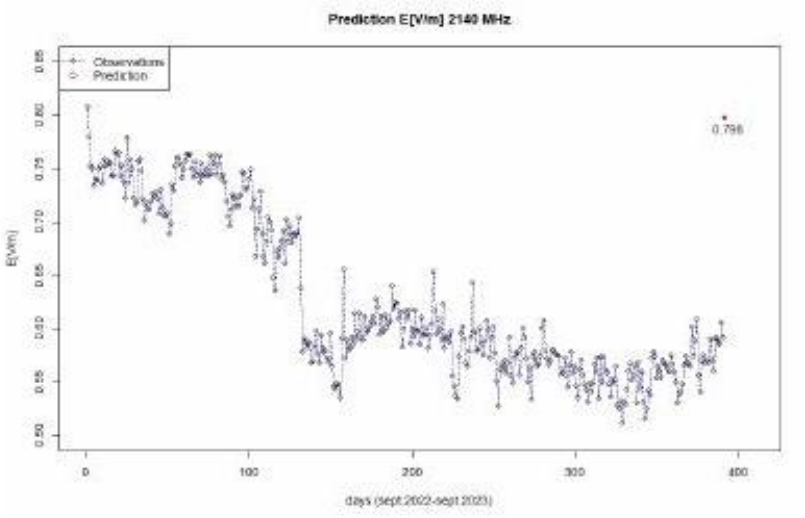


Fig. 9: The ARIMA $(1, 2, 0)$ method E[V/m] at the frequency of 2140 MHz

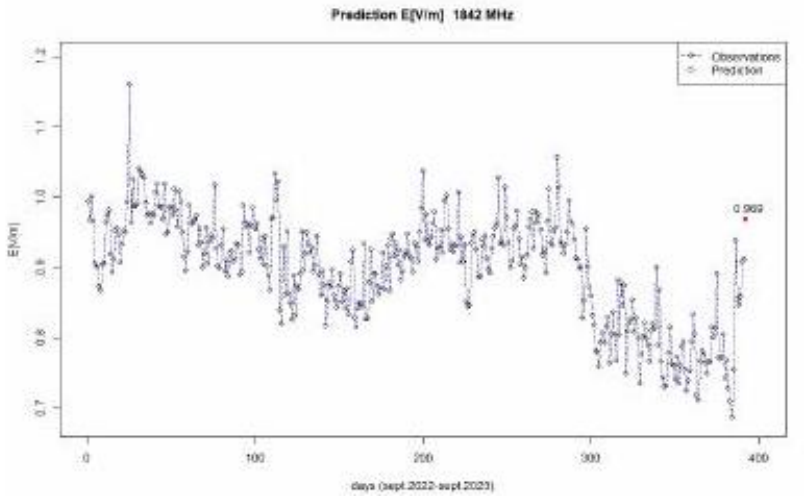


Fig. 10: The ARIMA $(2, 1, 2)$ method E[V/m] at the frequency of 1842 MHz

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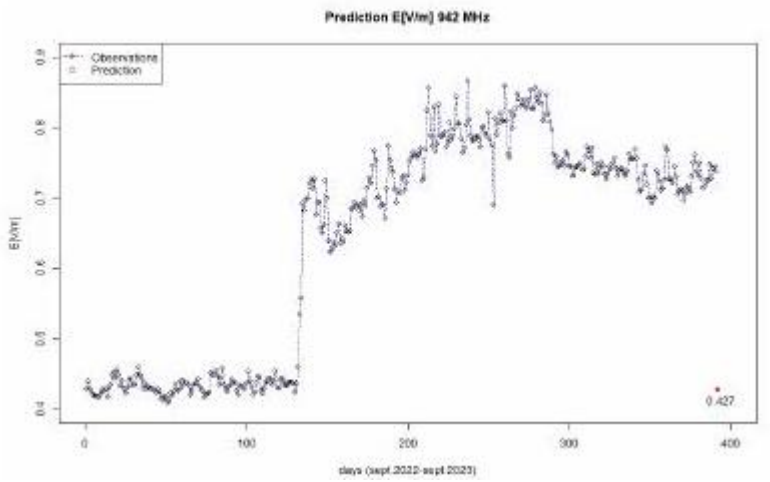


Fig. 11: The ARIMA($1, 2, 0$) method E[V/m] at the frequency of 942 MHz The values predicted by the two methods were compared with the last value in the series, kept for verification of the predictions, and we highlighted them in the graph 12 .

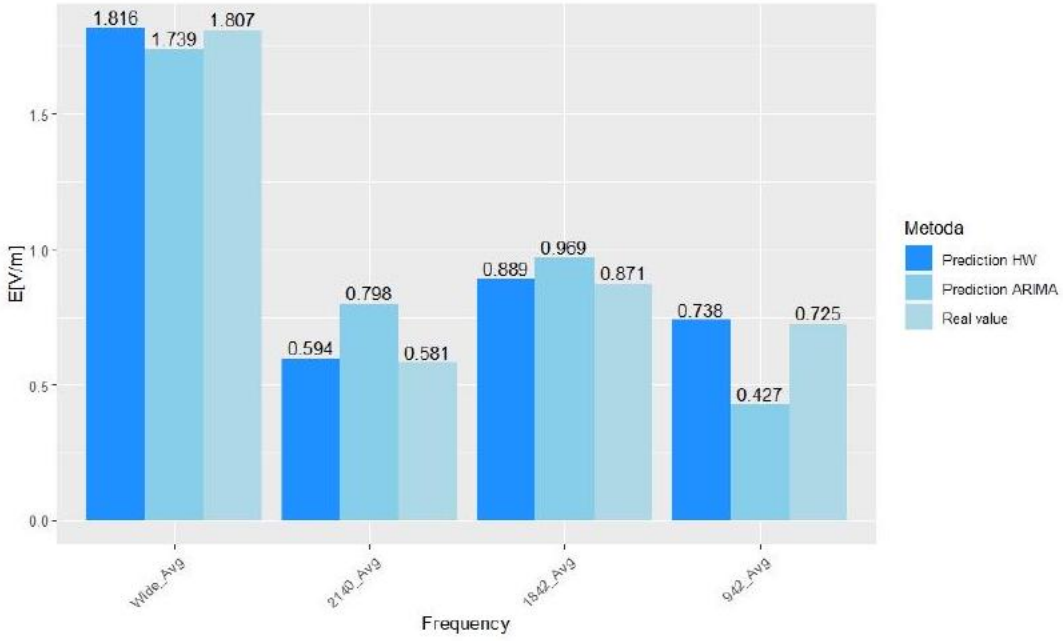


Fig. 12: Predicted values vs. actual value, for the average values of the electric field

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A better prediction is observed using the exponential smoothing method. The smallest fluctuation in deviation from the actual value is achieved by the Holt-Winters method.

Following the use of the two methods, we calculated the deviations from the actual value for each frequency domain using the formula:

Deviation = Predicted value - Actual value

TABLE I: Prediction deviations

Frequency	deviation from the actual value	
	Holt-Winters	ARIMA
100kHz − 7GHz	0,009	$-0,068$
2140 MHz	0,013	0,217
1842 MHz	0,018	0,871
942 MHz	0,013	$-0,298$

In conclusion, the graph shows that both prediction methods can be useful, but the Holt-Winters method tends to be more accurate in this dataset. The ARIMA model has mixed performance and may require additional adjustments to improve prediction accuracy in some cases.

To track how the level of the electric field in the wide band has evolved, we analyzed the months of September 2022 and September 2023.

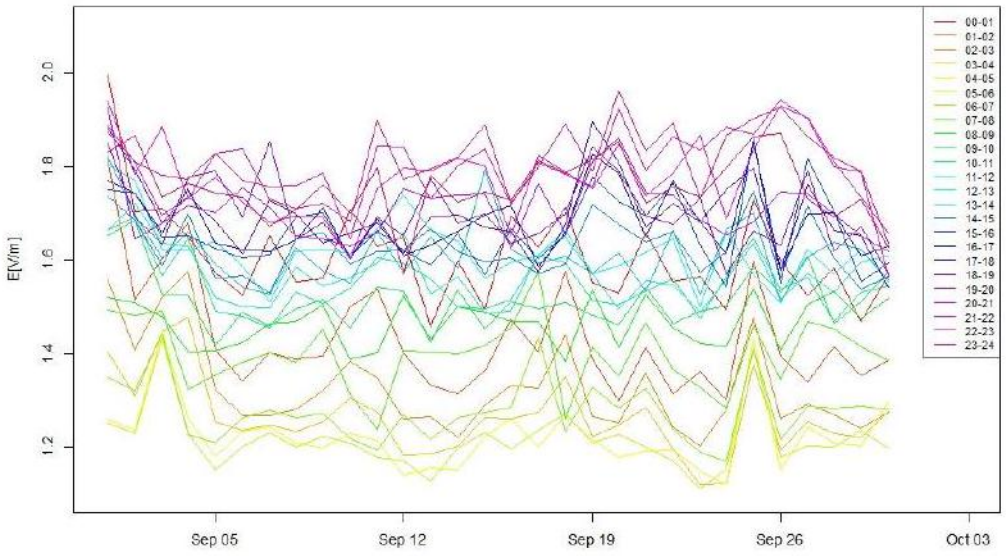


Fig. 13: The average values, per one-hour intervals, of the electric field intensity in the 100kHz − 7GHz band in September 2022

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I averaged the electric field values over hourly intervals for the two months.

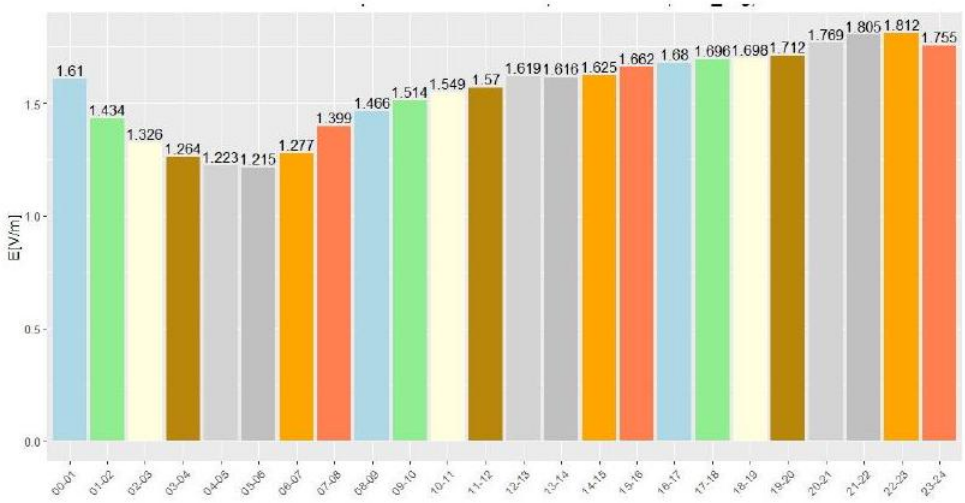


Fig. 14: The average values, per one-hour intervals, of the electric field intensity in the 100kHz-7GHz band in September 2022

We observe high values in the hourly interval $00-01$, which gradually decrease until around 05-06. This is followed by an approximately 25% increase until around noon, when the values remain relatively constant until 19. After this time, the values tend to increase until a peak around 23, then decrease slightly until 24 .

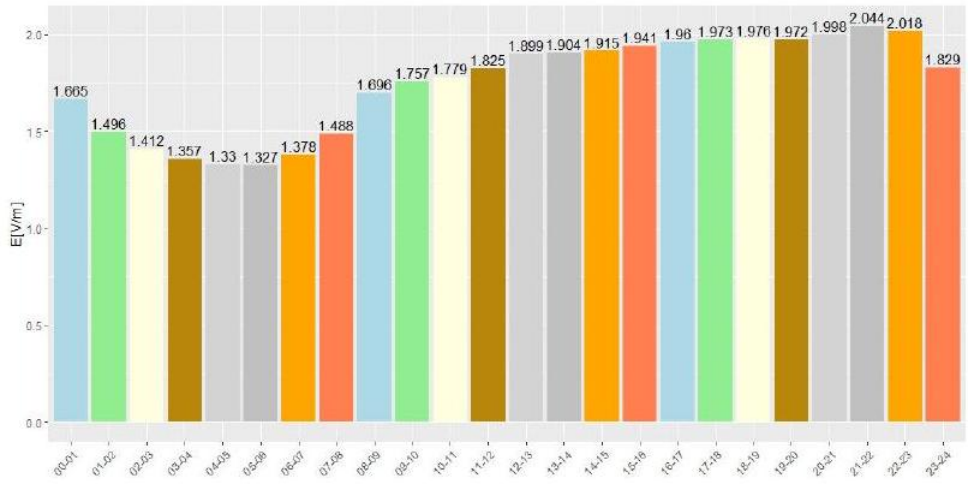


Fig. 15: The average values, per one-hour intervals, of the electric field intensity in the 100kHz-7GHz band in September 2023

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For the month of September 2023, the same diurnalnocturnal pattern is observed, with lower values at night and higher values during the day and evening. The absolute difference between the maximum value, recorded in the 21-22 PM time interval, and the minimum value, recorded in the 5-6 AM time interval, is 0.717 [V/m] higher, and the percentage difference shows that the value 2.044 is approximately 54.03% higher than 1.327 .

By comparing the obtained average electric field values with the reference levels according to OMS 1193/2006, we obtained the graph below.

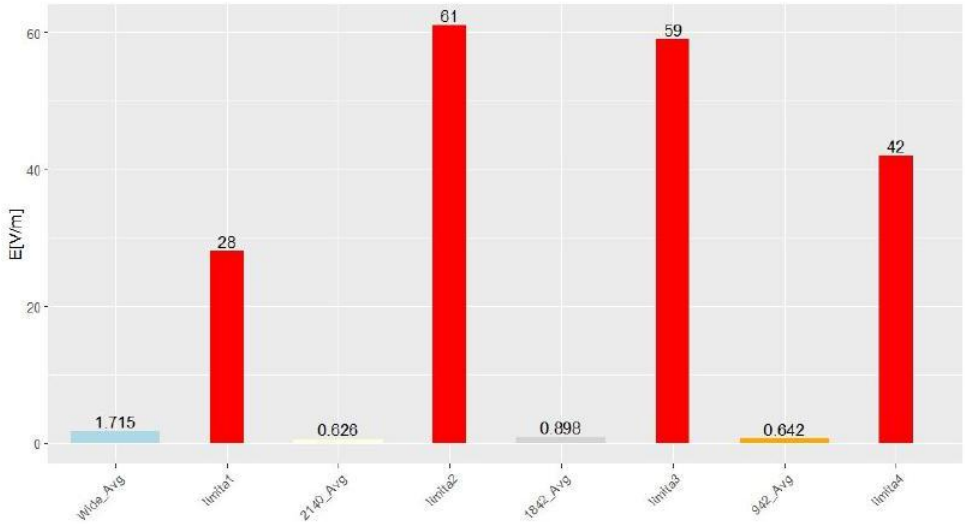


Fig. 16: Evaluation of the electric field and comparison with reference levels according to OMS 1193/2006

4 Conclusions

I conducted a statistical analysis of a database containing records related to the electric field level $E[V/m]$ (RMS values temporally averaged). The recordings were collected by the sensor installed on the UPT building. Values of the electric field were collected in a broad frequency range ($100\text{kHz} - 7\text{GHz}$) and on three specific frequencies ($2140\text{MHz}, 1842\text{MHz}, 942\text{MHz}$), primarily used by mobile phone operators.

From the graph showing the average electric field intensity values over a one-year period, I observed a decrease in the electric field level received at the frequency of 2140 MHz at the beginning of January 2023, which coincided with an increase in the level received at the frequency of 942 MHz . These increases/decreases in levels can be explained by reconfigurations resulting from the upgrading of base stations.

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I performed a time series analysis using the HoltWinters and ARIMA methods to obtain a prediction of the last value in the dataset, which was then compared with the actual measured value. Using both methods, I obtained deviations ranging between $1\% - 1.2\%$ for the Holt-Winters method and between $0.59\% - 1.37\%$ for the ARIMA method. Both prediction methods can be useful, but the Holt-Winters method tends to be more accurate for this dataset. The ARIMA method has mixed performance here and may require further adjustments to improve prediction accuracy.

I calculated the hourly averages of the electric field, in the $100\text{kHz} - 7\text{GHz}$ band, for each hour of the day aggregated for the entire month (considering September 2022 and September 2023) to monitor the evolution of the field level. I found that there is a diurnal-nocturnal pattern, with lower values during the night, towards the morning, and higher values throughout the day and late evening. These differences reach up to approximately 54% higher late at night compared to the lowest values in the early morning.

At the end of the analysis, I compared the average electric field values from the period of September 2022 to September 2023 with the reference level according to WHO 1193/2006 and concluded that there are no exceedances. Moreover, the measured values represent 1 6% of the maximum level provided in the legislation. The obtained graph clearly illustrates the significant difference between the actual values and the legislative limits, emphasizing compliance with safety regulations.

Acknowledgment

Thank you for the guidance and support to Mr. Romeo Negrea and to Mr.Teodor Petrita.

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