2nd PANHELLENIC CONGRESS OF MEDICAL PHYSICS
4-6 OCTOBER 2024| EUGENIDES FOUNDATION

Georeference mapping of EMF exposure at crowded public places

Vasiliki Softa[1], Christos Christakis[2], Fotini Kosma[2], Charilaos Tyrakis[1], Constantinos Koutsojannis[3], Kiki Theodorou[1], Constantin Kappas[1]

[1]Medical Physics Laboratory, Faculty Of Medicine, School of Health Sciences, University of Thessaly, Larissa, Greece

[2]Department of Public and One Health, School of Health Sciences, University of Thessaly, Larissa, Greece

[3]Director of Laboratory of Health Physics & Computational Intelligence, University of Patras, Patra, Greece

1. Background-Aim

- Over the last 20 years, due to technological development, communication has become easier by using mobile phones, computers, and the internet, therefore, have become affordable to the major part of the population.
- This advancement has provoked a glut of reactions concerning the influence it has on human healthassociated with long-term exposure to radiofrequency of electromagnetic radiation, particularly, in crowded places, due to the existence of many devices that are being used at the same time within the same space.
- These areas include urban centers, bustling commercial districts, stadiums, etc., where the frequency of the population expands exposure to electromagnetic radiation, prompting reactions.

→ The necessity for a complete display of electromagnetic radiation allows researchers to recognize which areas have been exposed, along with the exposure of population.

→ For this reason, georeferencing mapping processes are produced regarding exposure to electromagnetic fields.

→ The purpose of this work is to **study the exposure, of the general population, to electromagnetic radiation in crowded places** (for example squares) **in the city of Larisa**, one of the five largest cities in Greece.

→ Practically, our purpose was to **measure the RF field strength evaluating RF compliance with the ICNIRP's [2020] 2020 permissible upper limits in children population** (children exposure).

2. Materials & Methods

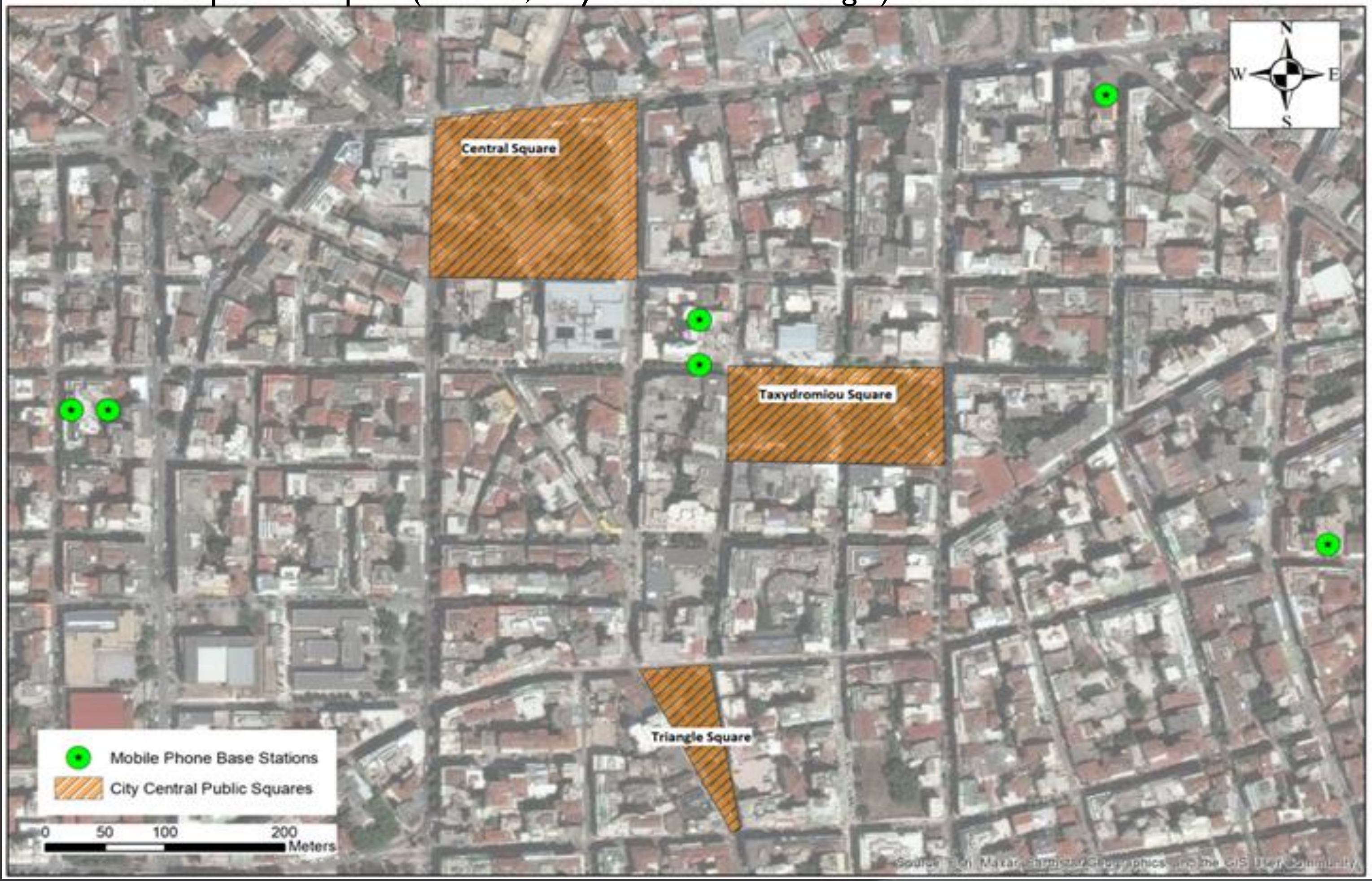
→ We assessed the impact of mobile electromagnetic radiation on the human population in three biggest squares in the city of Larissa.

→ The city of Larisa is located in central Greece and host a population of approximately 150.000 residents.

→ The city center consists of a three-square complex among a wide net of pedestrian streets.

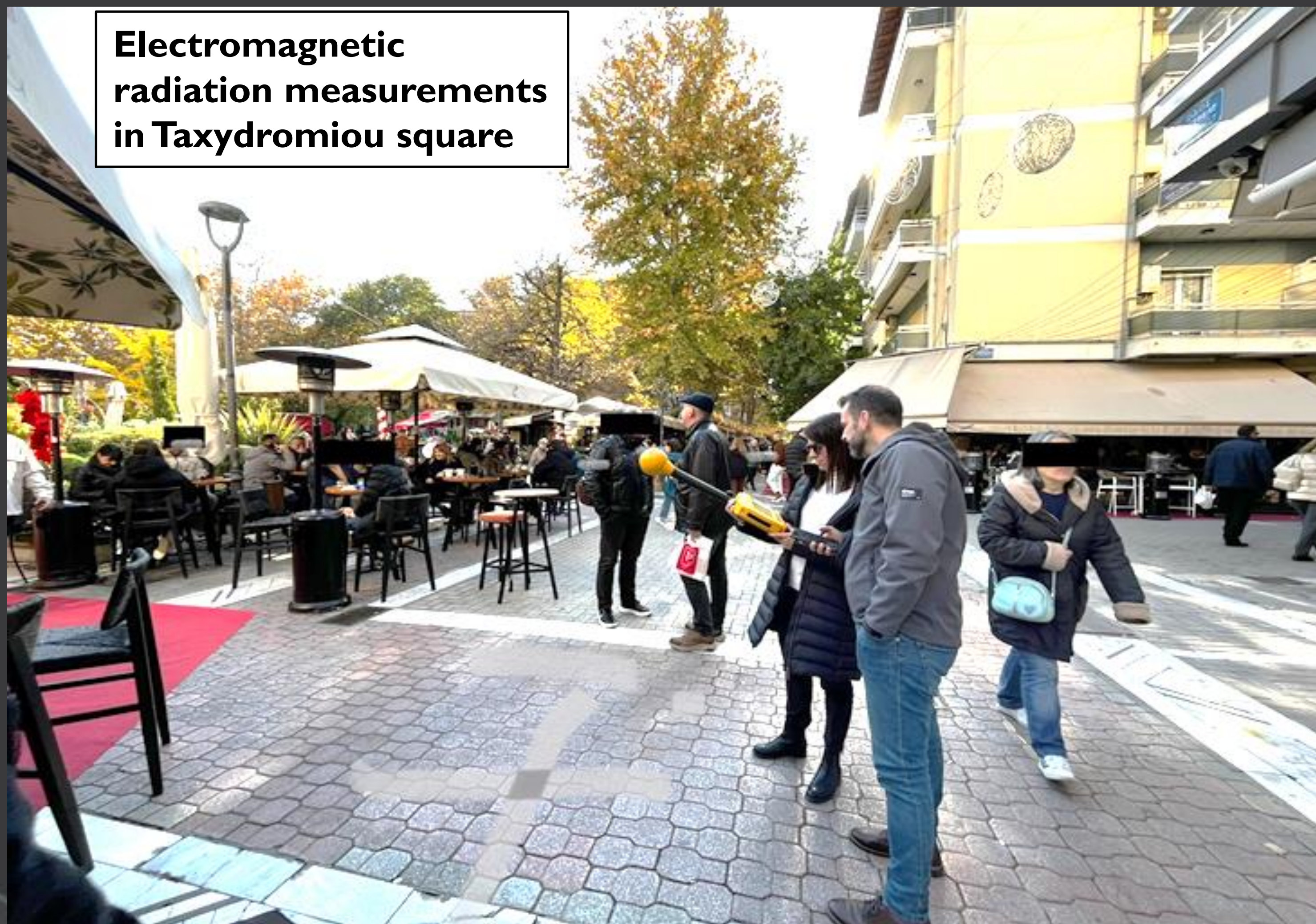
→ The three largest squares in Larissa were selected for the measurement of electromagnetic radiation.

The three-square complex (Central, Taxydromiou and Triangle) with the nearest base station.



- Four hundred and ninety-six (496) spot measurements were carried out in three squares of Larisa city, encompassing these crowded public urban locations.
- Measurements were conducted in hours 09:00 am to 03:00 pm on two Saturdays to ensure sufficient crowd and increased traffic.
- We covered the entire surfaces of the squares with points uniformly spaced every 5 meters.

2. Materials & Methods



Electromagnetic radiation measurements in Taxydromiou square

Utilizing the SRM-3006 portable spectrum analyzer (Narda Safety Test Solutions, Pfullingen, Germany), we evaluated radiofrequency exposure within the ranges of 420 MHz to 6 GHz in areas designated for sensitive land use.

Following the established protocol, the laboratory recorded both the 6-minute average and maximum electric field (E) values in various scenarios:

→ **Active**: Activating a user equipment (mobile phone) it commenced downloading 4K resolution YouTube content or/and performed a speed test

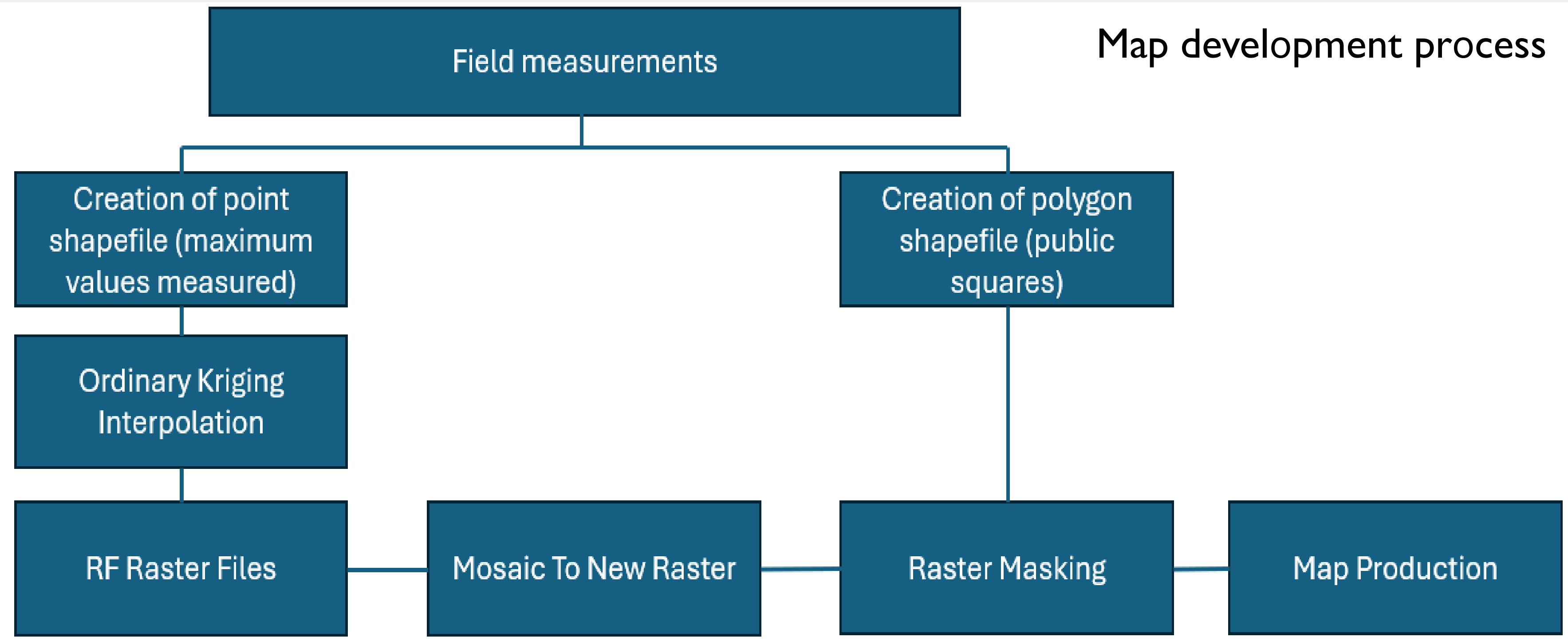
→ **Non-Active**: The measurements were taken while the mobile phone continued to remain active without downloading any data from the Internet.

2. Materials & Methods

- The collected data are statistically evaluated to present the mean values, maximum values, and possible variations in the levels of electromagnetic radiation. Data analysis was conducted using SPSS.
- The selected squares were categorized based on traffic and the population density. We categorized central and triangle square as low traffic and low population density complex and Taxydromiou square as a high traffic and high population density.
- Mood's median test analysis was conducted in two distinct scenarios, specifically categorizing the data into Low Traffic, Maximum, and High Traffic, Maximum for the two groups.
- This statistical test was chosen due to its suitability for comparing median values when dealing with non-normally distributed data. The significant level for both tests are $\alpha = 0.05$. If $p > \alpha$ then, no significant difference between the two samples. If ($p < \alpha$) then, the two samples (Non-Active and Active groups) are different.

To create the electromagnetic environment maps, we used ArcGIS 10.8.1 software. Due to the uncontinuity of the electromagnetic radiation data recorded, we utilized the Ordinary Kriging Interpolation tool, to produce a continuous raster file for each city central square concerning RF values calculated for Active and Non-Active scenario respectively.

Map development process

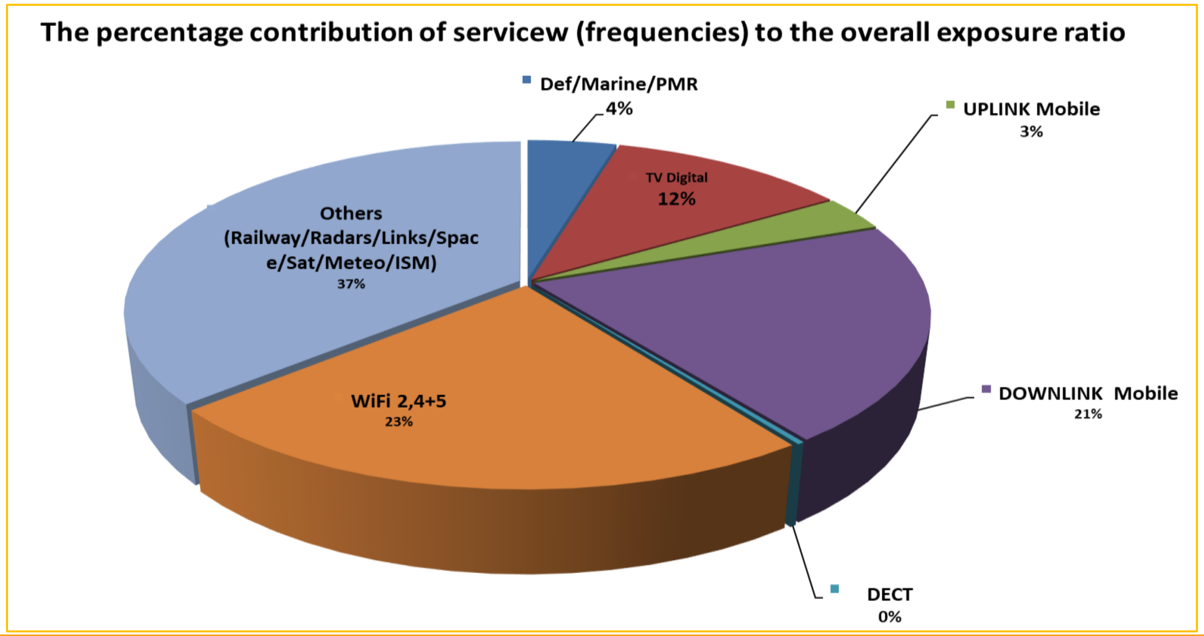


3. Results

→ **At the first case (low traffic, maximum exposure index)** the p-value was 0.871, p > a, so **there is no significant difference between two samples.**

→ **At the second (worst) case (high traffic, maximum exposure index)** the p-value was 1, p > a, so there is **no significant difference between two samples**.

Only 16% corresponds to mobile phones, while the majority, 52%, corresponds to railways, radars, links, space, sat, meteo.



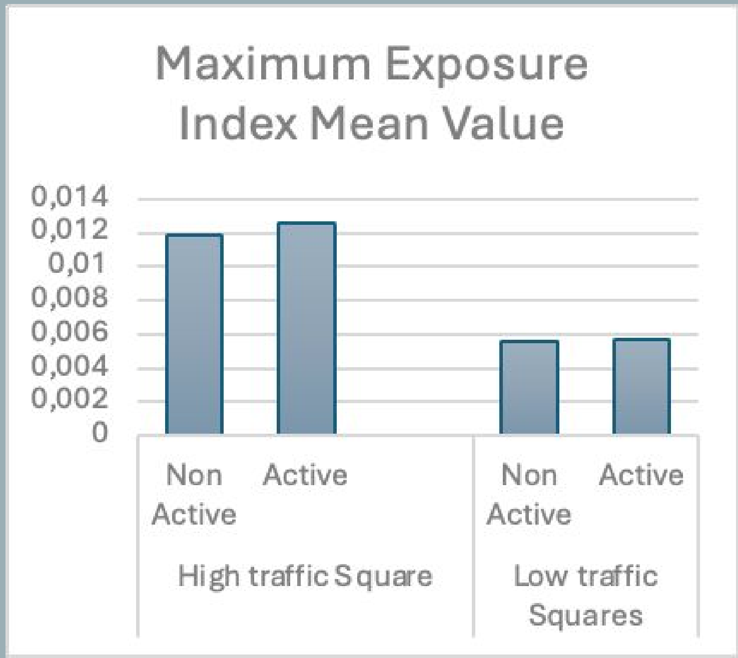
Parameter	*Status*	*Median*	*Mean*
Average	*Non Active*	*0,0012*	*0.00175*
	Active	*0,0012*	*0,00173*
Maximum	*Non Active*	*0,00325*	*0,00558*
	Active	*0,00325*	*0,00569*

Exposure Index for active and non-active cases measured on the **low traffic squares** (n = 496).

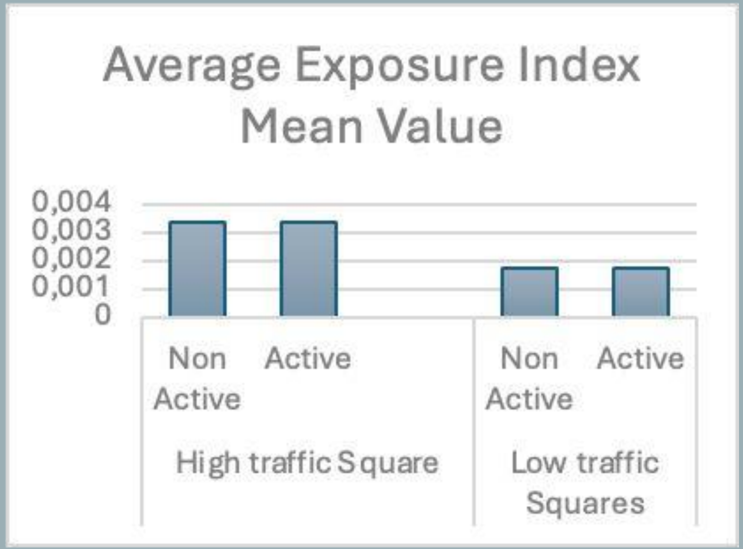
Exposure Index for active and non-active cases measured on the **high traffic squares** (n = 496).

Parameter	*Status*	*Median*	*Mean*
Average	*Non Active*	*0,0033*	*0.0035*
	Active	*0,0033*	*0,0034*
Maximum	*Non Active*	*0,00131*	*0,00119*
	Active	*0,00131*	*0,00125*

3. Results

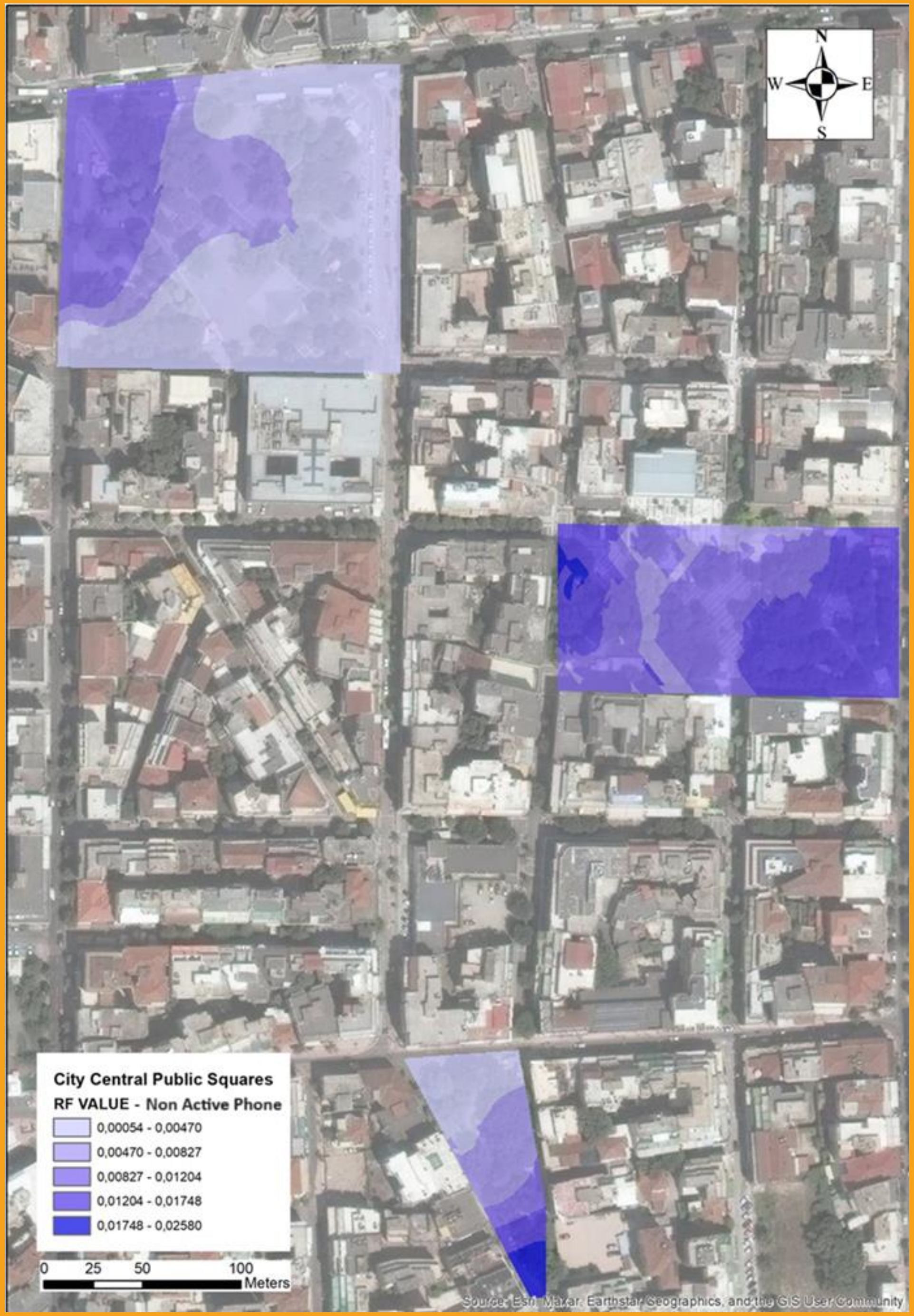


Comparison of average exposure index, mean value for all the cases.



Comparison of maximum exposure index, mean value for all the cases.

The maximum exposure index of **Non-Active** Mobile Phone case for all the crowded squares.



The maximum exposure index of **Active** Mobile Phone case for all the crowded squares

4. Conclusions

The electromagnetic field (EMF) measurements reveal that the levels of exposure in the studied areas, including the larger squares in the city of Larissa's are consistently below the established upper limits thus **the concurrent use of various electronic devices and communication networks does not lead to considerable EMF exposure of the general population**.

We have demonstrated that being **in a highly frequented square, whether actively downloading data or not, results in minimal additional radiation compared to other users**.

→ Due to the homogeneity of the field, the radiation levels experienced by individuals in the square remain consistent, regardless of their specific data usage.

→ The beamforming effect seems to be important when you are located close to the antenna (a few meters away) but is not playing an important role when you are 50-100m away (homogeneous field characteristics appear).

→ The integration of this geographical context into our measurements enhances the relevance and applicability of our findings to real-world scenarios.

Limitations:

- The measurements were conducted at specific points in time and locations, and the exposure levels may vary under different conditions.
- The number of the data are limited, so in the future will be performing more measurements in crowded places.
- **Future research** could involve **continuous monitoring and the inclusion of additional parameters** for a comprehensive understanding of electromagnetic exposure.

5. References

- Alexias, A.; Kiouvrekis, Y.; Softa, V.; Kappas, C.; Tyrakis, C.; Theodorou, K. RF-EMF EXPOSURE LEVELS IN SENSITIVE LAND USE IN GREECE: EDUCATIONAL UNITS CENSUS IN THE MUNICIPALITY OF KORYDALLOS. Radiation protection dosimetry 2020, 190, 193–199.
- Kiouvrekis, Y.; Manios, G.; Tsitsia, V.; Gourzoulidis, G.; Kappas, C. A statistical analysis for RF-EMF exposure levels in sensitive land use: A novel study in Greek primary and secondary education schools. Environmental research 2020, 191.
- Birks, L.E.; Struchen, B.; Eeftens, M.; van Wel, L.; Huss, A.; Gajšek, P.; Kheifets, L.; Gallastegi, M.; Dalmau- Bueno, A.; Estarlich, M.; et al. Spatial and temporal variability of personal environmental exposure to radio frequency electromagnetic fields in children in Europe. Environ. Int. 2018, 117, 204–214.
- Frei, P.; Mohler, E.; Bürgi, A.; Fröhlich, J.; Neubauer, G.; Braun-Fahrländer, C.; Röösli, M. Classification of personal exposure to radio frequency electromagnetic fields (RF- EMF) for epidemiological research: Evaluation of different exposure assessment methods. Environ. Int. 2010, 36, 714–720.
- Kiouvrekis, Y.; Alexias, A.; Filipopoulos, Y.; Softa, V.; Tyrakis, Ch., D.; Kappas, C. Unsupervised Machine Learning and EMF radiation in schools: a study of 205 schools in Greece. European Journal of Medical Physics, ECMP, Torino, Italy, July 2021.
- Song, X.; Han, M.; Chen, Y.; Yue, Y. Public exposure to broadband electromagnetic fields and its association with population density and building density: The case study of Beijing. Heliyon 2023, 9.
- Saliev, T.; Tachibana, K.; Bulanin, D.; Mikhalovsky, S.; Whitby, R.D. Bio-effects of non-ionizing electromagnetic fields in context of cancer therapy. Frontiers in bioscience (Elite edition) 2014, 6, 175–184.
- Liu, J.; Wei, M.; Li, H.; Wang, X., Wang, X.; Shi, S. Measurement and mapping of the electromagnetic radiation in the urban environment. Electromagnetic biology and medicine 2020, 39, 38–43.
- Rinaldi, A.M. A GIS-based system for electromagnetic risk management in urban areas. Journal of Location Based Services 2009, 3, 3-23.
- Gonzalez-Rubio, J.; Najera, A.; Arribas, E. Comprehensive personal RF-EMF exposure map and its potential use in epidemiological studies. Environmental Research 2016, 149, 105-112.
- Pesaresi, C.; Pavia, D. Radio Base Stations and Electromagnetic Fields: GIS Applications and Models for Identifying Possible Risk Factors and Areas Exposed. Some Exemplifications in Rome. ISPRS Int. J. Geo-Inf 2021, 10, 3.
- Ramirez-Vazquez, R.; Escobar, I.; Thielens, A.; Enrique Arribas. Measurements and Analysis of Personal Exposure to Radiofrequency Electromagnetic Fields at Outdoor and Indoor School Buildings: A Case Study at a Spanish School. IEEE 2020, 8, 195692 – 195702.
- Tyrakis, C.; Theodorou, K.; Kiouvrekis, Y.; Alexias, A.; Kappas, C. Radiofrequency Exposure Levels in Greece. Bioelectromagnetics 2023, 44, 17–25.
- Jawad O., Lauro D.; Benlarbi-Delai A.; Dricot J.M.; De Doncker P. Study of Human Exposure Using Kriging Method. Progress In Electromagnetics Research B 2014, 61, 241-252.