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# Pilot Electromagnetic Field Measurements in Certain Areas in Greece

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## Abstract

This paper reports preliminary electromagnetic field measurements conducted indoors in selected locations in Greece. The paper focuses on the electromagnetic radiation (EMR) of the extremely low-frequency (ELF) and radiofrequency (RF) frequency bands because these bands are considered as possible human carcinogens according to the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). ELF electric and magnetic fields and RF electric fields were measured indoors in several locations in urban, suburban and rural areas of the Zakynthos and Lesvos islands, suburban houses of Ileia Prefecture (Peloponnisos) and urban dwellings of Attica.

A total number of 4816 measurements were taken in Zakynthos (276), Lesvos (964), Ileia (29) and Attica (3547) in the frequency range 50 Hz–2500 MHz. Measurements were conducted with NARDA EMR-300 RF survey meter (3935), Aaronia HF and NF spectrum analyzers (795), HI 3604 Holaday ELF survey meter (48) and ANTENNESSA EME SPY (38). The maximum electric field strengths were in most cases below 5 V/m. Strength of electric fields up to 3000 V/m were addressed near high voltage power transmission lines. Stronger average electric fields were measured in urban areas. The strengths of the magnetic field were in most cases lower than 1000 nTesla (1 μTesla), but values up to 6000 nTesla (6 μTesla) were observed near high voltage power transmission lines. The results indicated that the EMR strength values varied but were all below domestic and international established limits.

**Keywords:** Electromagnetic field; Electromagnetic radiation; Extremely low frequency; Radio-frequency; Electric field; Magnetic field

## Introduction

Electromagnetic radiation originates from the environment namely outer space, sun and earth. The modern digital communications have raised significant concerns about their potential health problems mainly due to the increased use of the associated devices [1-9]. Digital communication devices are updated continuously. They include, radio transmitters and receivers, radars, televisions, computers, mobile phones, wireless fidelity (WiFi) net devices and digital enhanced cordless telephone (DECT) bases. The human exposure depends on the electromagnetic field strength, the distance from the device and, in the case of directional antennas, the proximity to the main beam [10-21].

In 1999, the Council of the European Union [22] (1999/519/EC) recommended limitations of exposure of the general public to EMR in the frequency range of 0 Hertz to 300 GHz. The recommendation contained basic restrictions about the current density that is induced in the body by these frequencies. It also suggested reference levels for the corresponding EMR strength outside human body. In 2013, the European Parliament and the Council published the Directive 2013/35/EU [23] regarding the exposure of humans to electromagnetic fields. This Directive issued the exposure limit values and action levels in the frequency range from 0 Hz to 10 MHz for non-thermal effects and in the frequency range from 100 kHz to 300 GHz for thermal effects. It is worth mentioning, that most action levels for exposure to electric and magnetic fields from 100 kHz to 300 GHz are frequency dependent (Table B1) [23] and that the exposure limit values for the exposure of the electromagnetic fields from 100 kHz to 6 GHz are expressed in terms of six-minute values of the Specific Absorption Rate (SAR) (Table 1A). Another institution, namely the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has issued in 1998 Guidelines regarding the limitation of the human exposure to time-varying EMR fields [24]. In 2010, ICNIRP has issued new Guidelines for the EMR of frequencies between 1 Hertz and 100 kHz [25]. According to the ICNIRP Guidelines [25], the overall weight of evidence up-to-date does not indicate that electromagnetic fields cause long-term health effects such as cancer. Low frequency EMR induces currents in the human body. Other body reactions generate currents as well. The exposure to low-frequency electric fields causes well-defined biological responses, ranging from perception to annoyance, through surface electric-charge effects. The evidence for other neuro-behavioral effects on brain electrical activity, cognition, sleep, and mood is much less clear. In addition, the epidemiological studies have not shown an association between human adverse reproductive outcomes and maternal or paternal exposure to low frequency EMR. On the other hand, the main effect of RF EMR exposure is the heating of tissue. Consequently, proper guidelines for RF fields are set to prevent health effects caused by localized or whole-body heating. As far as the protection of workers is concerned, engineering and administrative controls should be undertaken as well as personal protection programs. Appropriate protective measures must be implemented as well when exposure in the workplace results in the basic restrictions being exceeded. Moreover,

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everyday chronic low-intensity (above 0.3–0.4 μTeslat) power frequency magnetic field exposure is associated with an increased risk of childhood leukemia. However, the causal relationship between magnetic fields and childhood leukemia nor any other long term effects have been established. Noteworthy is also the statement of 2009 [26] of ICNIRP, because in this document, ICNIRP has reconfirmed the validity of its 1998 Guidelines for the EMR of frequencies between 100 kHz and 300 GHz. The SCENIHR [8] discriminates, four main frequency bands regarding the exposure to EMR: (i) RF EMR (100 kHz<f ≤ 300 GHz); (ii) intermediate frequency (IF) EMR (300 Hz<f ≤ 100 kHz), (iii) ELF EMR (0<f ≤ 300 Hz) and (iv) static fileds (0 Hz). A new emerging band is also the one of tera frequencies ($0.3 \times 10^{12} < f \leq 0.3 \times 10^{12}$ Hz). Note that the number of studies which investigated the corresponding biological effects is still small, although increased over the past 10 years. Note also that due to the expected increase in the use of THz technologies, more research is recommended [8] focusing on the effects on skin (long-term, low-level exposure) and cornea (high-intensity, short term exposure).

The following section outlines five significant frequency bands regarding the exposure of humans to EMR fields.

## ELF fields

The term ELF refers to EMR of frequencies between 1 Hz and 300 Hz. ELF EMR is mainly man-made. The sources are numerous and include electric power systems, electric and electronic appliances and industrial devices. For example, the alternating electromagnetic fields that are employed in dwellings are between 50 and 60 Hz in most countries. The electric field strength of EMF EMR is typically between 5 V/m and 50 V/m, whereas the magnetic field strength is between 0.01 μTesla and 0.2 μTesla [27-29]. Considerably higher field strength may be accounted in some occupational settings but only for short duration [30-31]. Observational studies have shown that movement in strong static ELF magnetic fields may cause subjective symptoms like vertigo or nausea. These are more likely to occur at magnetic field strengths above 2 Tesla [8,32-36]. Note that the earth's magnetic field is between 25 μTesla and 65 μTesla (from equator to poles) and is a static ELF field that is present everywhere in the earth. The limits for the general public for the 50 Hz EMR fields are 5000 V/m for the electric field strength and 100 μTesla for the magnetic field strength [25,37]. It should be noted however that the EU member states can have different approaches [38]. The occupational electric field strength should be on the maximum 10 kV/m whereas the maximum magnetic field strength should not be over 500 μTesla.

## RF fields

RF EMR is generated mainly by mobile telecommunication systems, broadcasting transmitters, radar installations, microwave ovens (MWOs), certain medical applications and equipment for electronic article surveillance and identification. At the beginning of the 20th century there was an increased exposure to RF EMR due to the presence of mobile phones in the market which resulted in steady and rapid growth of the number of base stations. In Europe, the percentage of mobile phone users reached up to 80% of population while more than 2 billion people used it worldwide in 2006 [6]. Mobile telephony companies claim nowadays that the SIM cards are more than the earth's population. However, despite the increasing development of new RF technologies scientific knowledge is still limited.

In typical dwellings RF fields depend on factors such as the existence of radio, television and mobile phone antennas, the operational and activity characteristics of mobile phones, DECT base stations, wireless local area network (WLAN) net devices and MWOs. Note that the radio and television transmitters have a large coverage area and for this reason they operate at power levels up to 1 MW [39]. Nevertheless, this does not cause significant human exposure because the antennas stand in sparsely populated areas. Furthermore, the power level inside a building can be up to 100 times lower than that outside the building [40]. Inside a building the exposure may also vary from floor to floor. For example, there was a case in a study, where exposure on the higher floors was found to be double (and more variable) compared to the lower floors of the building [41].

The field strength limits for the general public for the 900 to 2200 MHz frequency band, are from 41 V/m to 61 V/m for the electric field and between 0.14 μTesla and 0.20 μTesla for the magnetic field [8,24,26,38]. The corresponding occupational limits are between 90 V/m and 137 V/m for the electric field and from 0.30 μTesla to 0.45 μTesla for the magnetic field strength [8,24,26,38].

## Mobile phones

Most mobile phones in Europe use the global system for mobile communications (GSM) (operating at 900 MHz), the digital communication system (DCS) (operating at 1800 MHz and the Universal Mobile Telecommunications System (UMTS) (operating between 1900 MHz and 2200 MHz. The radiation people receive from a mobile phone handset depends on various factors such as the characteristics of the device (particularly the type and location of the inherent antenna), the distance and the way each one keeps the handset, the distance from the outdoor antenna of each company, on whether the user is in motion (for example, inside a car) and most importantly, on the adaptive power control of the device, which may reduce the emitted power by orders of magnitude (up to a factor of 1,000). In areas where there are many phone-users, the mobile handset can work at maximum power for quite a long time. The power level of a mobile handset, inside a building, is, in general, higher than outdoors (can reach a value of 2 W), because walls have shielding properties [6,42].

## DECT devices

All wireless devices generate RF, but the exposure from wireless phones and their stations (DECT, 1880–1900 MHz) is usually lower than that of mobile phones. A cordless phone, found in a typical house, produces about 1–10 mW of (time-averaged) power, considerably less than that of a mobile phone handset (125–250 mW, time-averaged), because the 'wireless' signal has to travel only a few meters compared to the signal of the mobile phone system that can travel for kilometers. The exposure from a DECT device is even less, as the cordless phone base station is not held close to the head, and, as mentioned, the field strength falls rapidly with distance [6-8].

## WiFi net devices

WiFi net devices of domestic use operate typically at field power densities of 0.5 $mW/m^2$ or less. The average power depends on the 'network' traffic a Nevertheless the field power density values are typically lower than the ones of the mobile phone network. In some cases however, the exposure to RF fields from WiFi net devices can overcome the one from GSM, DCS and UMTS devices [6-8].

# Materials and Methods

The present study utilized four instruments: (1) NARDA EMR-300 RF (3935 measurements); (2) Aaronia HF and NF spectrum analyzers

(795 measurements); (3) ANTENNESSA EME SPY (38 measurements); (4) HI 3604 Holaday ELF survey meter (24 measurements). NARDA EMR-300 RF was used for strength measurements of electric and magnetic fields in the frequency range between 3 kHz and 60 GHz. Aaronia HF and NF analyzers determined electric and magnetic fields in the range 100 MHz to 6 GHz (HF) and at 50 Hz (NF). ANTENESSA EME SPY analyzed electric field strength spectra in the range 88 MHz to 2.5 GHz. HI 3604 Holaday ELF survey meter was employed for measuring electric and magnetic field intensities at 50 Hz. Due to its confined upper threshold (5.02 V/m) ANTENESSA EME SPY was narrowly utilized in this study.

4816 measurements were conducted in the following locations: (a) Attica (3547 measurements); (b) Lesvos island (964 measurements); (c) Zakynthos island (276 measurements); (d) Ileia-Peloponnisos (29 measurements). Selected instruments were used per location. This was due to restrictions in time and availability of the employed instrumentation in combination with the geographical dispersion of the locations. The employed instrumentation per location was as follows: (i) NARDA EMR-300 RF, Aaronia HF and NF, ANTENESSA EME SPY and HI 3604 Holaday ELF in Attica; (ii) NARDA EMR-300 RF in Lesvos Island; (iii) Aaronia HF and NF in Zakynthos island; (iv) ANTENESSA EME SPY in Ileia in Peloponnisos.

The measurements sites were apportioned in each location. Some sites were located near high voltage power lines. In each site the duration of each measurement was between 5 minutes and 15 minutes with the apparatus standing in the center of the room regardless of the existence of any other devices. These criteria were considered as a standardization compromise during real measurement practice. In each site the measurements were averaged in time according to the international suggestions [25,26]. Additionally, in selected sites, measurements were repeated at the central axis of the room, one meter above the floor and at a distance of 0 m, 1 m and 2 m away from the wall while designated EMR sources were enabled (switched on). For repeated RF measurements the enabled sources were the microwave oven, the DECT base the Wi-Fi net modem and a mobile phone while making a call. Especially for the mobile phone call, the communication provider was additionally recorded so as to determine the specifications of the corresponding cellular network. For repeated 50 Hz measurements the enabled EMR sources were all the available lighting lamps of the room and any existing cathode-ray tube monitors. Especially for the sites located near high voltage power lines additional measurements were taken outdoors in the porch of the accessed dwellings.

The whole approach constitutes the first step for the delineation of the distribution of EMR in the accessed locations and sites under variable measurement conditions. The latter variability was adopted so as to outline factors which can potentially affect indoor EMR assisting hence the formulation of a functional protocol for future EMR measurements.

## Results and Discussion

Figures 1-4 and Table 1 present noteworthy results derived from the indoor EMR measurements implemented in Greek dwellings at the frequency of 50 Hz. As aforementioned, for the EMR measurements at the 50 Hz frequency, the Aaronia NF spectrum analyzer was used in Attica and Zakynthos island and the HI 3604 Holaday ELF in Attica. Figure 1 presents the histogram of the logarithms of the electric field strengths measured indoors in Attica with the Aaronia NF spectrum analyzer. This histogram shows a tendency to the typical normal

| Location | Floor | *Inside a room* | | *Porch* | |
|---|---|---|---|---|---|
| | | Electric Field (V/m) | Magnetic Field (μT) | Electric Field (V/m) | Magnetic Field (μT) |
| A | 1st | 2 | 0.686 | 8 | 0.69 |
| | 2nd | - | - | 117 | 0.83 |
| | 3rd | 1.6 | 0.8 | 348 | 0.833 |
| B | 1st | 4 | 1.2 | 159 | 1.65 |
| | 2nd | 2 | 2.7 | 315 | 3.2 |
| C | Ground 1 | 10 | 3.17 | 313 | 6 |
| | Ground 2 | 16 | 1.5 | 5 | 1.5 |
| | Roof 1 | 1.5 | 1.2 | 350 | 0.7 |
| | 1st | 3.5 | 1.2 | 270 | 3 |
| | 2nd | 8 | 2 | 3000 | 2.8 |
| | 3rd | 25 | 0.7 | 65 | 0.35 |
| | 4th | 1.5 | 0.35 | 150 | 0.15 |

**Table 1:** Indoor and outdoor measurements of EMR at the frequency of 50 Hz in Attica dwellings located near high voltage power lines. Employed instrument: HI 3604 Holaday ELF

distribution plots. For this reason the whole data set of the electric field strengths measured indoors in Attica with the Aaronia NF spectrum analyzer were fitted to the log-normal distribution. The normality check of the aforementioned logarithms of the electric field strengths were checked via the Kolmogorov–Smirnov (KS) test. It was found that the data of Figure 1 were distributed normally at the 95% confidence interval (CI). Note that due to the confined number of measurements of Figure 1, only the five histogram bins of Figure 1 passed the normality test. Similarly, the logarithms of the indoor magnetic field strengths of the dwellings in Attica and Zakynthos island that were measured with the Aaronia NF spectrum analyzer, followed also the log-normal distribution at the 95% CI. Note that in Zakynthos island, only magnetic field strength measurements were performed due to time constraints. Despite that, Figure 2 presents the box and whiskers plots of the measured magnetic field strengths, instead of the corresponding logarithms. This type of presentation was selected so as to outline potential differentiation between the different measured directions of the magnetic field strength. Note, that the semi-logarithmic plot suppresses the information and hence may not show the differences. It is significant to mention that the Aaronia NF spectrum analyzer provided information as those presented in Figure 2. The different magnetic field strength directions measured with the Aaronia in Zakynthos island did not differ between them at the 95% CI (paired t-test of the corresponding logarithms). On the contrary, in Attica the xy directional measurements of the indoor magnetic field strength, were significantly higher that those of the other directions. The yz and xz directional measurements did not present significant differences between them (paired t-tests between groups in the corresponding logarithms). This finding was considered peculiar. Nevertheless this finding could not be attributed to the specific measurement conditions of Attica, for example proximity to specific 50 Hz sources. Note also, that the overall magnetic field strength distribution passed the KS test despite that the number of directional measurements was identical in all three directions. A systematic investigation of this behavior will be implemented in the future. In addition, the normality of the logarithmic transformation of the magnetic field strengths at 50 Hz, allowed the use of unpaired t-test in the corresponding logarithms between Attica and Zakynthos. Importantly, significantly higher (95% CI) indoor magnetic field strengths were measured in Attica compared to those of the Zakynthos island (unpaired t-test of the logarithms of data). This finding is also characteristically shown in Figure 3 where the mean and maximum values of the measured indoor magnetic field

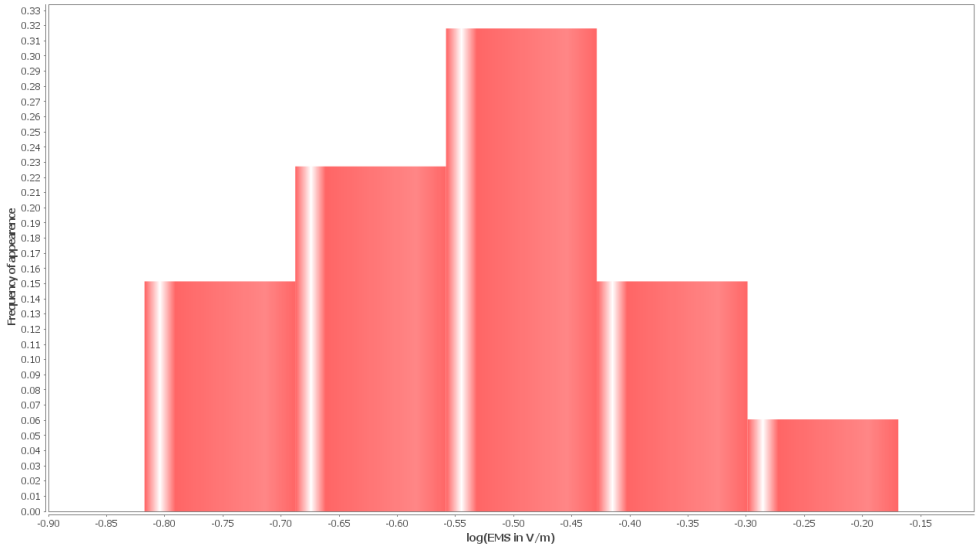


**Figure 1:** Histogram plot of the logarithms of measured strength of electric field (EFS) indoors in sixty eight sites in Attica at the 50 Hz frequency. Employed instrument: Aaronia NF spectrum analyzer.

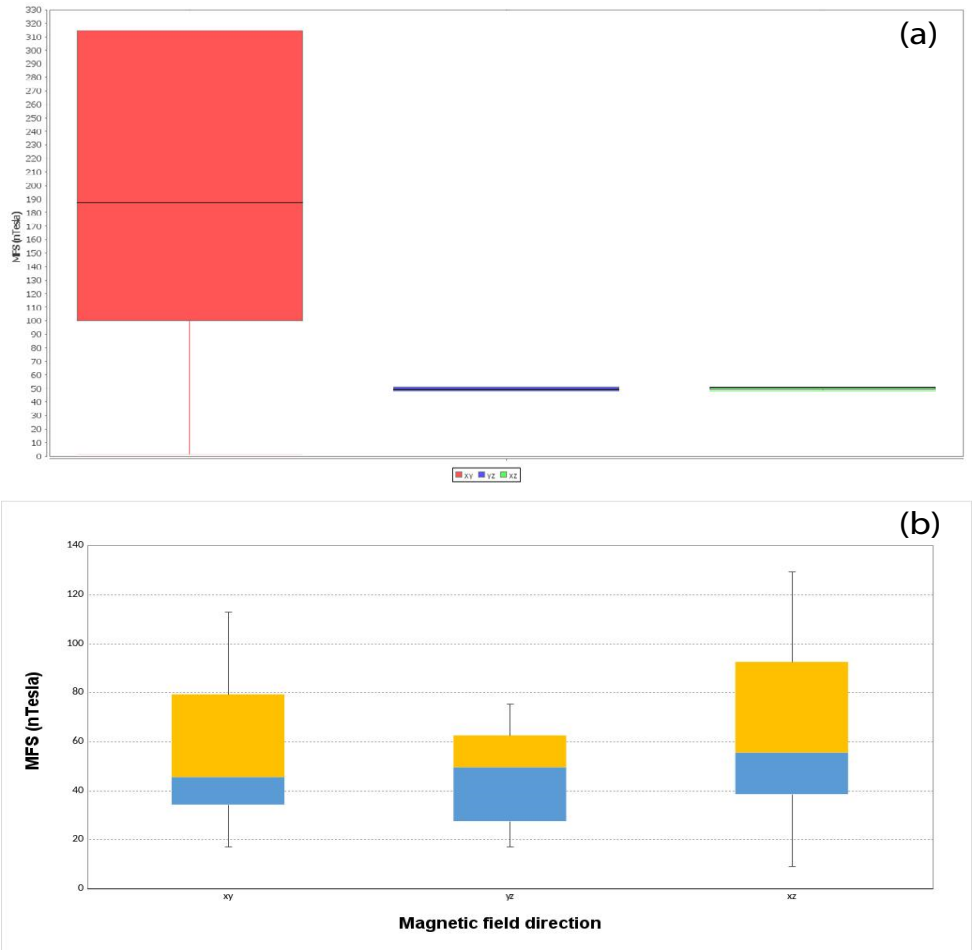


**Figure 2:** Box and whiskers plots of indoor magnetic field strength (MFS) at the 50 Hz frequency in the xy,yz and xz directions from **(a)** one hundred seventy eight measurements in Attica and **(b)** forty six measurements in Zakynthos island. Employed instrument: Aaronia NF spectrum analyzer.

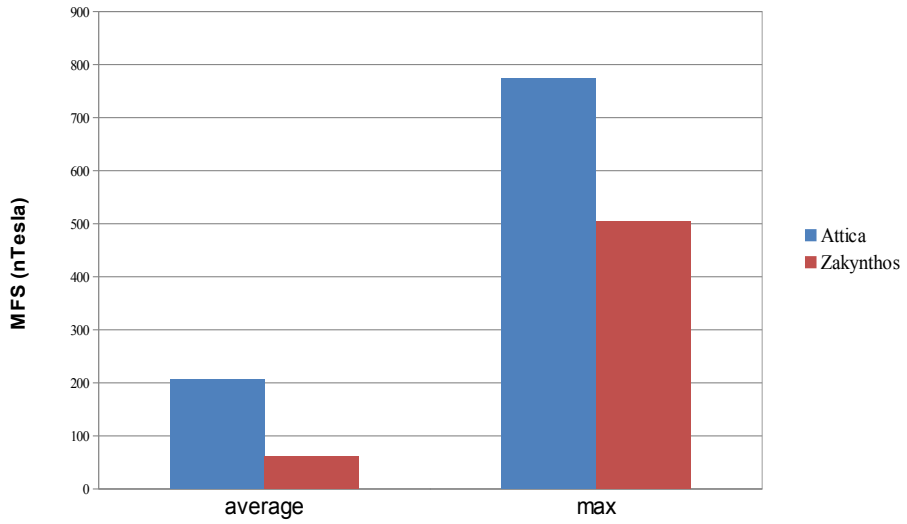


**Figure 3:** Indoor measurements at the frequency of 50 Hz. Average and maximum (max) values of the magnetic field strength (MFS) in Attica and Zakynthos. Employed instrument: Aaronia NF spectrum analyzer.

strengths between Attica and Zakynthos are given. The maximum and average values of magnetic field strength between Attica (68 measurements) and Zakynthos Island (138 measurements) differed. The maximum magnetic field strength measured indoors in Attica was 774 nTesla. The corresponding strength in Zakynthos island was 504 nTesla. Average indoor electric field strength in Attica was 206 nTesla (standard deviation of 179 nTesla). The corresponding average value in Zakynthos island was 63 nTesla (standard deviation of 52 nTesla).

Table 1 shows very significant information regarding the indoor and outdoor electric and magnetic field strengths of dwellings located near high voltage power lines. Despite that all electric and magnetic field strengths of Table 1 are below the international limits [8,24,25,27,28,38] it is important to note the following significant issues: (a) nearly all measured magnetic field strengths, indoors and outdoors, were higher than those of Figure 2. Note that all measurements of Figure 2 were taken from dwellings away from high voltage power lines. (b) Significant magnetic field strengths equal or higher to 2700 nTesla were addressed in four cases. (c) Very high electric field strengths were measured indoors and outdoors reaching the strength of 3000 V/m. (d) The electric field strength was lower indoors than outdoors in each investigated dwelling. (e) In some cases the electric field was lower indoors and in the remaining cases it was higher. All magnetic field strengths (indoor-outdoor) were comparable and rather elevated (see also b). (f) A slight tendency to increase up to at some height can be outlined from Table 1, both for electric and magnetic field strengths. All aforementioned results are however ambiguous due to the restricted number of measurements. Nevertheless, some tendencies were outlined. From this viewpoint, this type of experimentation was useful for the formulation of the protocol for systematic measurement of electric and magnetic field strengths of indoor EMR in Greece.

Figure 4 presents significant results from the indoor measurements of electric and magnetic field strengths at different distances when potential designated sources of bias at the 50 Hz were switched on. The magnetic field strengths at contact with the wall of the room (zero meter distance, Figure 4b) show a tendency to be higher than those of the one and two meters distances. However, when the data of Figure 4b were log-normally transformed this tendency was diminished. Namely it was found that the distance from the wall of the room was not associated with the magnetic field strength measured indoors (paired t-test to logarithms). On the contrary, the same test showed a different tendency for the indoor electric filed strength in Attica in respect to the distance from the wall (Figure 4a). Through the KS test in the logarithms of the mean indoor electric field strengths of Figure 4a it was found that the electric field strength at 0 m was statistically larger relative to the one at 1 m and this is in turn larger than the one at 2 m. Another interesting finding is that the presentation of electric and magnetic field versus distance should be semi-logarithmic. Nevertheless it should be mentioned that all the above findings can be significantly altered in the future because the employed sample size for the analysis was limited.

Figures 5-9 and Table 2 present the results from indoor measurements of the EMR of the RF range. The RF Data were analyzed according to the frequency bands of Table 2. These were basically the ones used by ANTENESSA EME SPY, however they can be applied to any device. As aforementioned, the EMR measurements in the RF frequency range were conducted in Attica and Lesvos island with NARDA EMR-300 RF, in Attica and Zakynthos island with the Aaronia HF spectrum analyzer and in Attica and Ilia Prefecture in Peloponnisos with the ANTENESSA EME SPY. Figure 5 shows the histogram of the collected one thousand seven hundred forty seven indoor measurements of electric field strength measured in Attica with the NARDA EMR-300 RF. Note, that the elevated amount of measurements imposes the histogram to tend to the form of the log-normal distribution. This distribution was found to be log-normal at the 95 CI if however a maximum of 15 bins were employed in the plot. It is very interesting that the box and whiskers plots (Figure 6) of the indoor RF measurements of the electric field strength at the frequency bands of Table 2 with the ANTENESSA EME SPY, showed that the corresponding values in Attica were higher than the ones in Ileia in Peloponnisos. This figure also shows that the maximum and all median

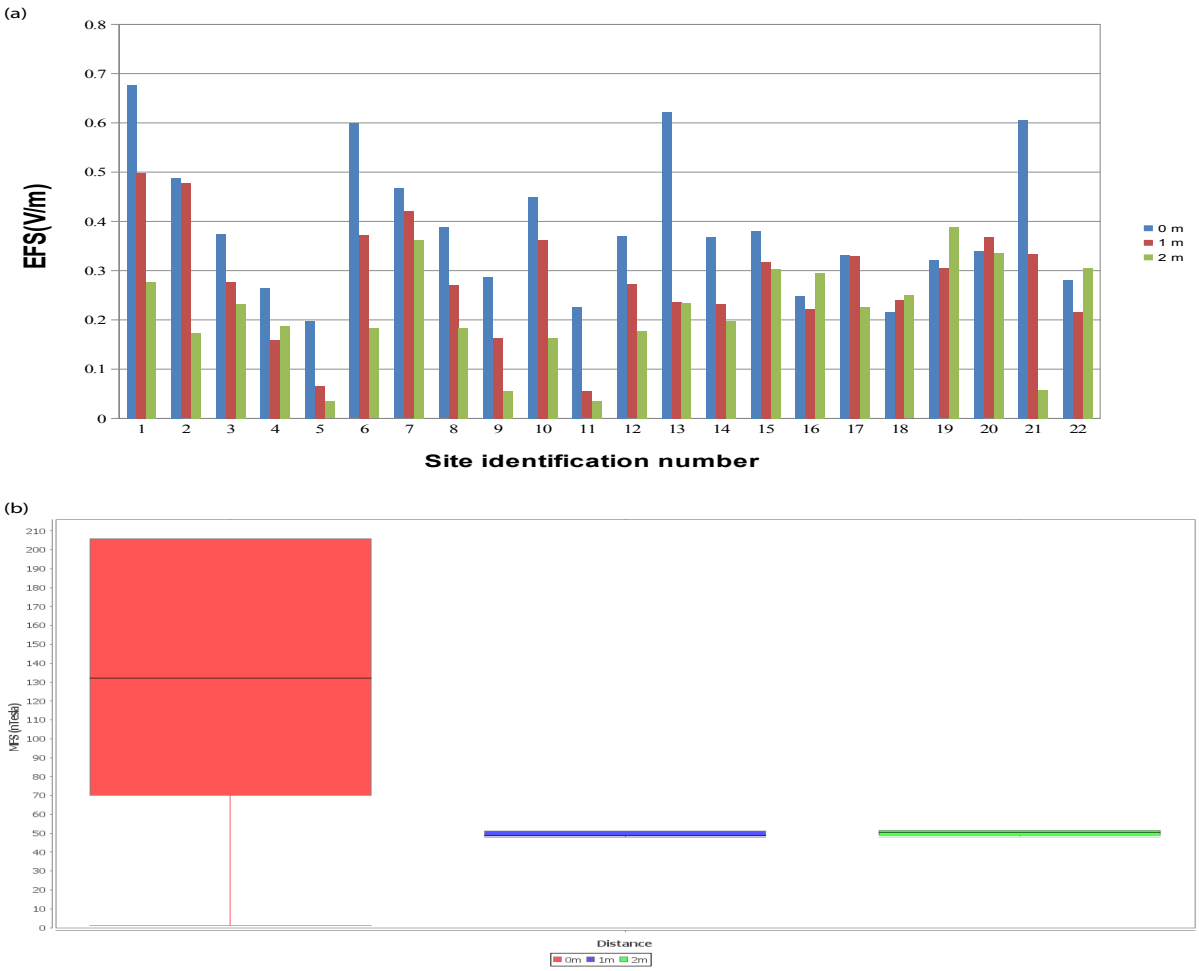


**Figure 4:** Indoor EMR measurements versus distance from the wall of the room. (a) Distribution of electric field strength (EFS) in twenty two sites in Attica and (b) Box and whiskers plot of magnetic field strength (MFS) in forty three sites in Attica. Employed instrument: Aaronia NF spectrum analyzer.

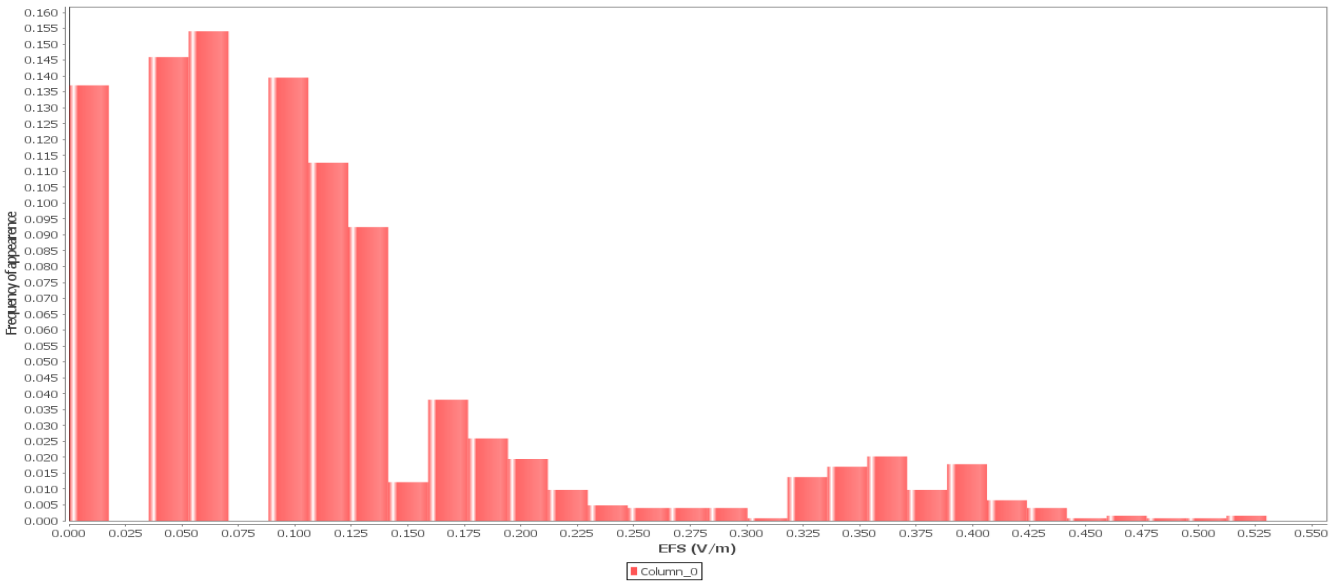


**Figure 5**: Histogram plot of indoor electric field strength (EFS) in one thousand seven hundred forty seven Attica dwellings. Employed instrument: NARDA EMR-300 RF.

| Name | Frequency MHz |
|---|---|
| FM | 88-108 |
| TV 3 | 174-223 |
| Tetrapol | 380-400 |
| TV 4 and 5 | 470-830 |
| GSM Tx -Transmitted radio signal | 880-915 |
| DCS Tx -Transmitted radio signal | 1710-1785 |
| DCS Rx - Received radio signal | 1805-1880 |
| DECT | 1880-1900 |
| UMTS Tx -Transmitted radio signal | 1920-1980 |
| UMTS Rx - Received radio signal | 2110-2170 |
| WiFi net | 2400-2500 |

**Table 2:** Frequency bands employed for the analysis of the indoor RF EMR measurements.

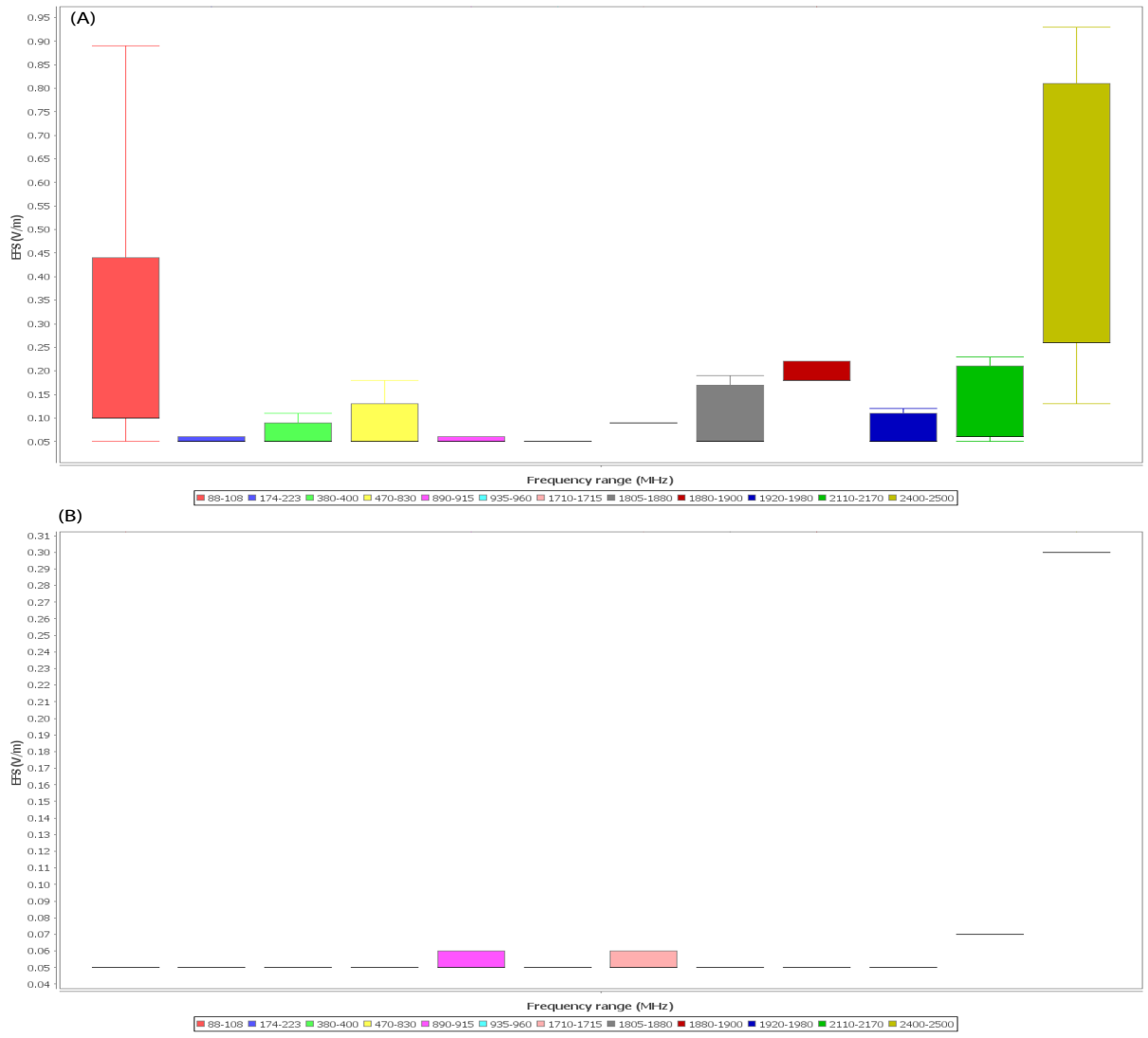


**Figure 6:** Indoor RF measurements of electric field strength (EFS) in **(a)** twelve dwellings in Attica and **(b)** thirty one dwellings in Ileia in Peloponnisos. EMR are presented according to the frequency range of Table 2. Employed instrument: ANTENESSA EME SPY.

time averaged electric field strength values, in Attica, appeared in the WiFi net region (2400-2500 MHz: 0.26 V/m, Table 2), although the highest value was found in the GSM transmitted signal region (890-915 MHz: 4.47 V/m, Table 2). It also shows that the maximum of all medians as well as all maximum electric field strength values in Ileia in Peloponnisos appeared in the WiFi net region (2400-2500 MHz: 0.31 and 0.30 V/m respectively, Table 2). Figure 7 shows the same tendency for the mean and maximum electric field strength in the FM and TV3 (Table 2) frequency ranges. The latter can be also reinforced by the findings of Figure 8 where the magnetic field strength in different frequency bands are shown for forty six dwellings of Zakynthos. Nevertheless, more measurements are required in order to establish such tendencies on a rigid statistical basis. Figure 9 presents the distribution maps of sampling sites in the islands of Zakynthos and Lesvos. Measurements in Zakynthos island were confined mainly to the capital town of Zakynthos. The RF EMR measurements in Lesvos Island were confined to the capital (Mytilini) and to the large town Agiassos. Figure 9b presents the distribution of measurement points in Agiassos together with the distribution of the electric field strengths that were measured with NARDA EMR-300 RF. The Kriging method was employed for mapping. The measurements are comparable to the electric field strengths found in the other locations. Importantly, for the same instrument (NARDA EMR-300 RF) as derived from the measurement data of Lesvos island, the electric field values (median, 3rd percentile, maximum) in Lesvos island (Mytilene and Agiasos) (964 measurements) compared to the ones in Attica (1244 measurements) has shown that (a) the 75 percent of the electric field strengths measured in Lesvos island was 0.27 V/m, whereas the corresponding value in Attica was 0.14 V/m; (b) the maximum electric field strength values in Lesvos island was 5.6 V/m and in Attica 0.53 V/m. For comparison it is noted that during magnetic field measurements in Attica, the 25 percent of the 1727 measured values were below 3.0 nT, while the 75 percent of the measurements were below 5.2 nT.

The presented electric field strengths in the mobile phone, Wi-Fi net and DECT frequency ranges were in the majority of cases much lower than 41-61 V/m, namely they were lower than the ICNIRP RF reference guidelines for the general public [24,26]. The electric field strength values in Lesvos Island were significantly higher than the ones in Attica. However, this may be due to the differentiation in the spatial sampling between Lesvos Island and Attica. In any case, care should be taken in the future, especially regarding the proximity to base stations of mobile telephony because there are published studies [43,44] which show that in the frequency range of body resonance (100 MHz) and from 1 to 4 GHz for bodies shorter than 1.3 m in height (corresponding approximately to children aged 8 years or younger), the induced specific absorption rate (SAR) to human body could be, even at the recommended reference level, up to 40% higher than the current basic restrictions even under worst-case conditions as the ones of the houses in the vicinity of high-voltage transmission lines. Note, that there are studies which have shown that the exposure to such type of EMR may be responsible for childhood leukemia [6-8,16,45,46]. Interestingly, the results of this study showed that the typical magnetic field strength values in Attica at 50 Hz were higher than the corresponding values observed in Zakynthos. In the RF region, the electric field strength values were also higher than the ones in Ileia in Peloponnisos. In addition, the comparison of EMR strength in the portable phone frequency range showed that the electric fields in the DCS range were higher in Attica. On the other hand, in the GSM range, the electric field strengths were higher in Zakynthos. Despite the noteworthy total number of measurements of this study, the results showed that the EMR strength values varied greatly and that they were affected at least by the local conditions. It is significant however that the majority of the measured indoor electric and magnetic field strengths were well below domestic and international established limits. A clearer picture of the highly variable EMR indoor strength values will be created when additional work and more measurements are implemented.

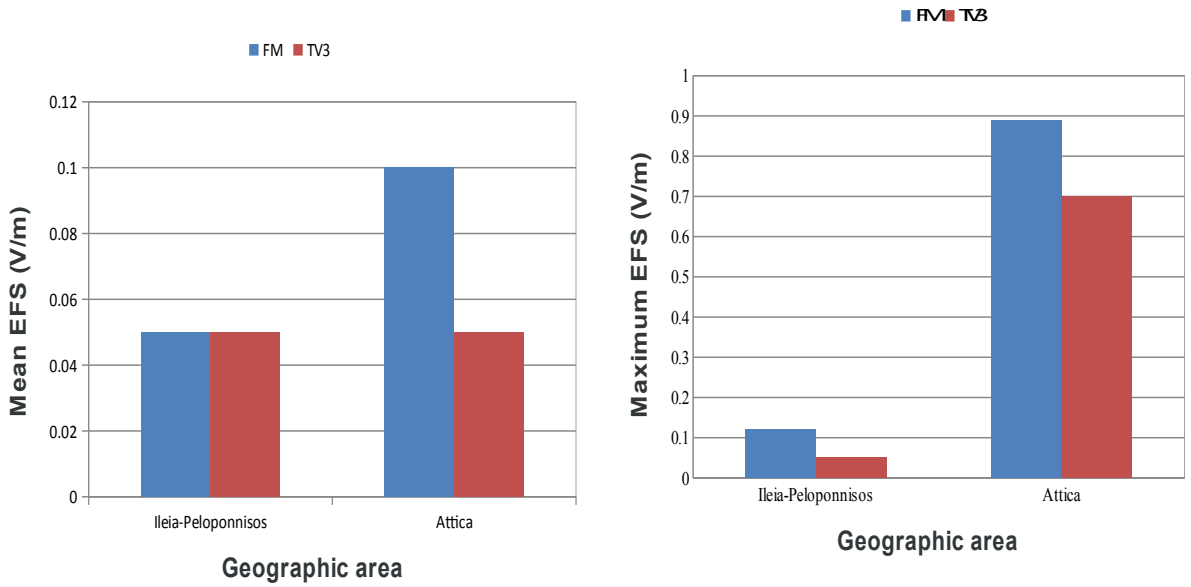


**Figure 7:** Mean and maximum indoor electric field strength (EFS) in two selected frequencies of Table 2 in Ileia and Attica. Employed instrument: ANTENESSA EME SPY.

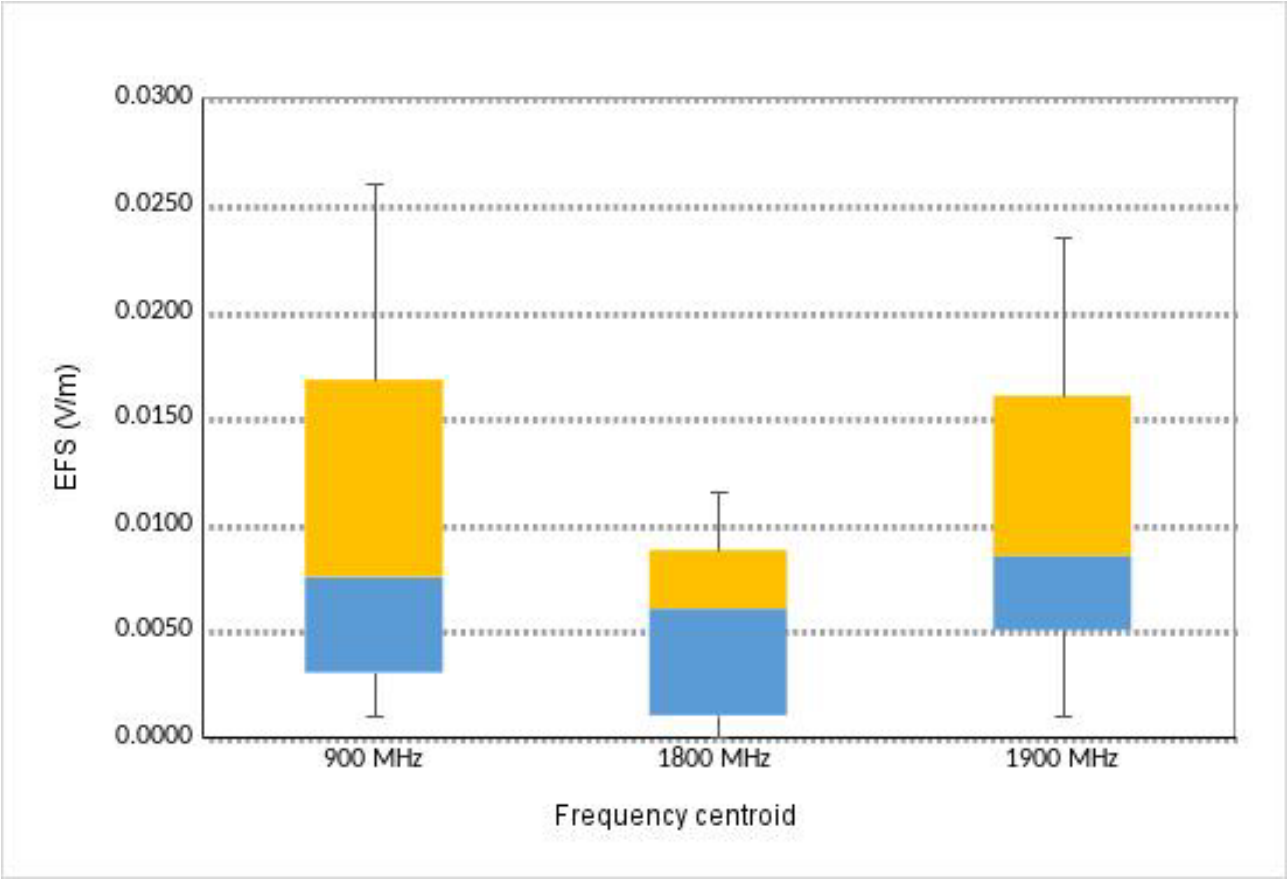


**Figure 8:** Indoor RF measurements of electric field strength (EFS) in different frequency bands of forty six dwellings Zakynthos. Employed instrument: Aaronia HF spectrum analyzer.

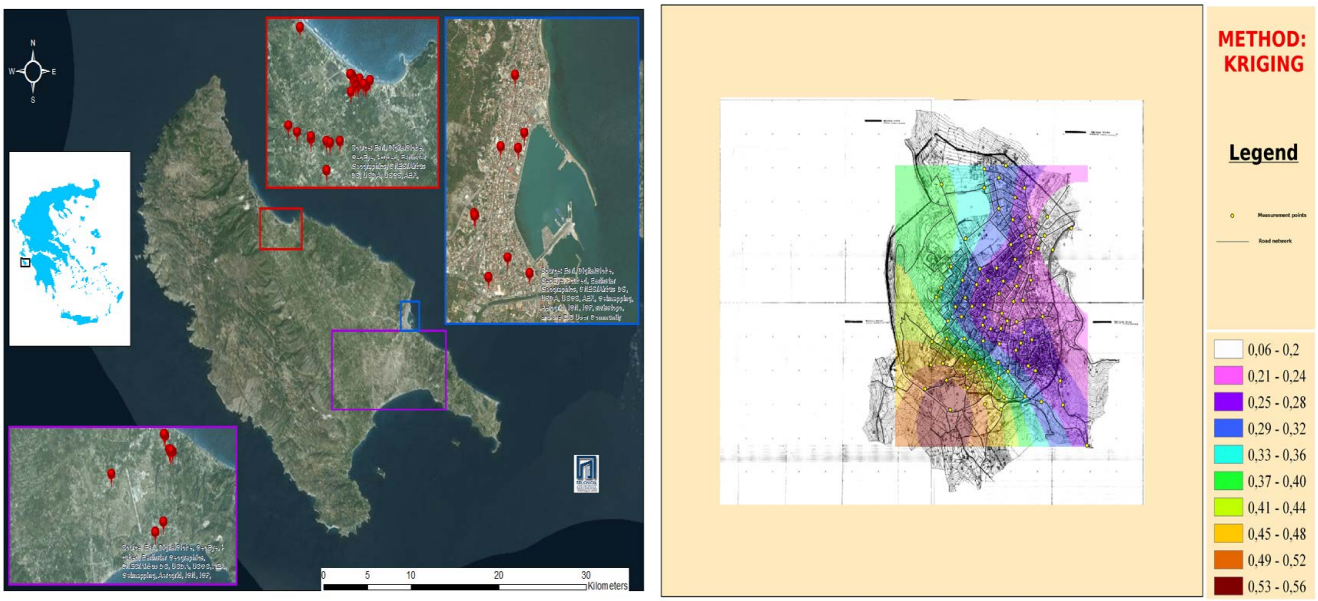


**Figure 9:** Maps of distribution of (a) measurement points in Zakynthos island and (b) measurement points and electric field strength in Lesvos island. The colorbar in (b) represents electric field strength in V/m. Employed Instruments: Aaronia NF spectrum analyzer in a and NARDA EMR-300 RF in b.

## Conclusions

The following important findings were derived from the present study:

(1) The measured electric and magnetic field strengths followed the log-normal distribution;

(2) At the 50Hz frequency, the indoor magnetic field strengths in Attica were significantly higher than those of the Zakynthos Island;

(3) The different magnetic field strength directions measured with the Aaronia NF at the 50 Hz in Zakynthos island did not differ between them. In Attica the xy directional 50 Hz measurements of the indoor magnetic field strength, were significantly higher than those of the other directions. Hence it is significant to measure magnetic field strength in all planes of direction or with spherical symmetry;

(4) The electric and magnetic field strengths at 50 Hz near high voltage power lines are considerable higher than those found in typical dwellings. This issue is of significance and should be addressed when 50 Hz EMR measurements are implemented;

(5) Under the same methodology, the RF electric field strengths in Attica were greater than the ones in Zakynthos Island and Ileia and the RF electric field strengths in Lesvos island were higher than those in Attica. This indicates that for future measurements there is a necessity to conduct similar measurements in all future areas of study;

(6) Higher RF electric field strength values appeared in the and in the GSM transmitted signal frequency region. This finding should be addressed in the future.

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