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# Monitoring of electromagnetic field levels

Recommendation ITU-T K.83

ITU-T

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## Monitoring of electromagnetic field levels


### Summary

Recommendation ITU-T K.83 gives guidance on how to make long-term measurements for the monitoring of electromagnetic fields (EMF) in the selected areas that are under public concern, in order to show that EMFs are under control and under the limits. The purpose of this Recommendation is to provide for the general public clear and easily available data concerning electromagnetic field levels in the form of results of continuous measurement.


### History

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### Keywords

RF EMF, RF EMF monitoring system, RF EMF monitoring website.


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## Introduction

Electromagnetic fields are imperceptible and unknown for the general public. This unawareness and imperceptibility generate distrust and rejection among the population, which can result in social conflicts and lead to delays in the deployment of new wireless technologies.

One solution to these problems can be the control of the electromagnetic emissions by taking measurements and having a proper communication. Measurements turn emissions into something objective and, when presented to the public in an understandable format, help diminish the unawareness and helplessness of the public.

The measurements of electromagnetic fields described in this Recommendation meet three requirements: must be objective, reliable, and continuous. The objectivity of the measurements is achieved whenever a public and/or independent body carries out the taking of the measurements and manages their publication. Reliability derives from compliance with international norms and standards regarding the measurement of electromagnetic fields and by an accredited calibration of the measuring equipment. The continuous taking of objective and reliable measurements (24/365) provides permanent monitoring of emissions and a maximum transparency.

For years, in various parts of the world, broadband systems have been used for the continuous measurement of electromagnetic fields with satisfactory results, increasing citizens' confidence in governments, and reducing their fear and ignorance regarding electromagnetic emissions. An alternative are the frequency selective measurement systems which should be applied to meet particular requirements. Other Recommendations, such as ITU-T K.52, ITU-T K.61 and ITU K.70, provide guidance on measurements methods that can be used to achieve a compliance assessment. These are also effective approaches to reduce concern undertaken by some countries.

This Recommendation presents the basis for the implementation of continuous measurement systems for electromagnetic emissions, in order to constitute a common practice at the international level for this type of measurements.

## Recommendation ITU-T K.83

# Monitoring of electromagnetic field levels

## 1 Scope

This Recommendation specifies the methods and characteristics of the monitoring system to be used for the continuous monitoring of electromagnetic fields emitted by radio transmitters, both in the broadband and in the frequency selective measurement systems, in order to assess the long-term exposure of people to electromagnetic fields in the band of 9 kHz-300 GHz.

## 2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.113] Recommendation ITU-T K.113 (2015), *Generation of radio-frequency electromagnetic field level maps*.

[EN 50383] EN 50383 (2010), *Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz-40 GHz)*.

[EN 50400] EN 50400 (2005), *Basic standard to demonstrate the compliance of fixed equipment for radio transmission (110 MHz-40 GHz) intended for use in wireless telecommunication networks with the basic restrictions or the reference levels related to general public exposure to radio frequency electromagnetic fields, when put into service*.

[EN 50413] EN 50413 (2008), *Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz-300 GHz)*.

[EN 50492] EN 50492 (2008), *Basic standard for in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations*.

[ICNIRP] ICNIRP (1998), *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)*.

[IEC 62311] IEC 62311 (2007), *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz-300 GHz)*.

[IEEE C95.3] IEEE Std C95.3-2002, *IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz-300 GHz*.

[ISO/IEC Guide] *ISO/IEC Guide to the Expression of Uncertainty in Measurement*, 1995.

## 3 Definitions

This Recommendation defines the following terms:

**3.1 averaging time (tavg)**: Appropriate time over which exposure is averaged for purposes of determining compliance with the limits.

**3.2 electric field strength (E)**: Magnitude of a field vector at a point that represents the force ($F$) on a small test charge ($q$) divided by the charge:

$$E = \frac{F}{q}$$

The electric field strength is expressed in units of volt per metre (V/m).

**3.3 exposure**: Exposure occurs whenever a person is exposed to electric, magnetic or electromagnetic fields.

**3.4 exposure ratio**: The assessed exposure parameter at a specified location for each operating frequency of a radio source, expressed as the fraction of the related limit.

For assessments against reference levels:

Between 9 kHz and 10 MHz:

$$ER = MAX\left[\left(\frac{E}{EL}\right),\left(\frac{H}{HL}\right)\right]$$

Between 100 kHz and 300 GHz:

$$ER = MAX\left[\left(\frac{E}{EL}\right)^2,\left(\frac{H}{HL}\right)^2\right]$$

or between 10 MHz and 300 GHz:

$$ER = \left(\frac{S}{SL}\right)$$

where:

- $ER$ is the exposure ratio at each operating frequency for the source
- $EL$ is the investigation E-field limit at frequency $f$
- $HL$ is the investigation H-field limit at frequency $f$
- $SL$ is the equivalent plane-wave power density limit at frequency $f$
- $E$ is the assessed E-field at frequency $f$ for the source
- $H$ is the assessed H-field at frequency $f$ for the source
- $S$ is the assessed equivalent plane-wave power density at frequency $f$ for the source
- $f$ is each operating frequency of the source

*ER* is applicable to limits based on national regulations, or if they are not defined then in ICNIRP principles.

**3.5 far-field region**: Region of the field of an antenna where the radial field distribution is essentially dependent inversely on the distance from the antenna. In this region, the field has a predominantly plane-wave character, i.e., locally uniform distribution of electric field and magnetic field in planes transverse to the direction of propagation.

NOTE – In the far-field region, the vectors of the electric field $E$ and the magnetic field $H$ are perpendicular to each other, and the quotient between the value of the electric field strength $E$ and the magnetic field strength $H$ is constant and equals the impedance of free space $Z_0$.

**3.6 impedance of free space**: The impedance of free space $Z_0$ is defined as the square root of the free space permeability $\mu_0$ divided by the permittivity of free space $\varepsilon_0$:

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 120\pi \cdot \Omega \approx 377\Omega$$

**3.7 linearity**: Maximum deviation over the measurement range of the measured quantity from the closest linear reference curve defined over the range.

**3.8 magnetic field strength (H)**: The magnitude of a field vector in a point that results in a force ($F$) on a charge $q$ moving with the velocity v:

$$F = q(v \times \mu H)$$

The magnetic field strength is expressed in units of amperes per meter (A/m).

**3.9 modulation**: The process of modifying the amplitude, phase and/or frequency of a periodic waveform in order to convey information.

**3.10 near-field region**: Region generally in proximity to an antenna or other radiating structure, in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point. The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complex in structure.

**3.11 permeability (μ)**: Magnetic permeability of a material is defined by the magnetic flux density $B$ divided by the magnetic field strength $H$:

$$\mu = \frac{\left\|\vec{B}\right\|}{\left\|\vec{H}\right\|}$$

where μ is the permeability of the medium expressed in henry per metre (H/m).

**3.12 permittivity (ε)**: Property of a dielectric material (e.g., biological tissue). In case of an isotropic material, it is defined by the electrical flux density $D$ divided by the electrical field strength $E$:

$$\varepsilon = \frac{\left\|\vec{D}\right\|}{\left\|\vec{E}\right\|}$$

The permittivity is expressed in units of farads per metre (F/m).

**3.13 power density (S)**: Radiant power incident perpendicular to a surface, divided by the area of the surface. The power density is expressed in units of watt per square metre (W/m$^2$).

**3.14 relevant source**: A radio source which, at a given measurement point, has an exposure ratio larger than 0.05.

**3.15 root mean square (rms)**: Effective value or rms value obtained by taking the square root of the average of the square of the value of the periodic function taken throughout one period.

**3.16 total exposure ratio (TER)** [EN 50383]: The total exposure ratio is the maximum value of the sum of exposure ratios of the equipment under test and all relevant sources over the frequency range 9 kHz to 300 GHz.

$$TER = ER_{EUT} + ER_{RS}$$

where:

| | |
|---|---|
| $ER_{EUT}$ | is the assessed exposure ratio from the equipment under test |
| $ER_{RS}$ | is the assessed exposure ratio of all the relevant sources |

**3.17 unperturbed field**: Field that exists in a space in the absence of a person or an object that could influence the field.

NOTE – The field measured or calculated with a person or object present may differ considerably.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CDMA Code Division Multiple Access

DVB-T Digital Video Broadcasting – Terrestrial

EMF ElectroMagnetic Field

ER Exposure Ratio

ICNIRP International Commission on Non-Ionizing Radiation Protection

IEC International Electrotechnical Commission

IEEE Institute of Electrical and Electronics Engineers

RBW Resolution Bandwidth

RMS Root Mean Square

TER Total Exposure Ratio

WCDMA Wideband CDMA

## 5 Physical quantities, units and constants

The internationally accepted SI-units are used throughout this Recommendation.

| Quantity | Symbol | Unit | Dimension |
|---|---|---|---|
| Current density | J | ampere per square metre | $A/m^2$ |
| Electric field strength | E | volt per metre | V/m |
| Electric flux density | D | coulomb per square metre | $C/m^2$ |
| Frequency | f | hertz | Hz |
| Magnetic field strength | H | ampere per metre | A/m |
| Magnetic flux density | B | tesla ($Vs/m^2$) | T |
| Permeability | μ | henry per metre | H/m |
| Permittivity | ε | farad per metre | F/m |
| Wavelength | λ | metre | m |
| ***Physical constant*** | | ***Magnitude*** | |
| Speed of light in a vacuum | c | 2'997 × 108 m/s | |
| Permittivity of free space | $\varepsilon_0$ | 8'854 × $10^{-12}$ F/m | |
| Permeability of free space | $\mu_0$ | 4π × $10^{-7}$ H/m | |
| Impedance of free space | $Z_0$ | 377 ohms (approx. 120πΩ) | |

## 6 General process

This Recommendation defines the methods that shall be used to determine the total exposure ratio (TER) over a certain period to perform a time dependent evaluation of EMF exposure. Two methods are recommended: using the frequency selective measurement or using the broadband measurement.

The frequency selective measurement procedure is based on [EN 50413] and [IEC 62311].

The broadband measuring method is based on [EN 50413] and [IEC 62311]. It allows obtaining the total radiation level in the form of electric field strength (E) in the frequency band of interest, averaged over a certain period of time. If the measurement is performed in the near-field region, then the evaluation of the total radiation level for the magnetic field strength (H) is necessary.

This method is applicable in those cases where the total summation of the emissions of a said frequency band is required to be measured. It allows obtaining a rapid measure of the total emission level of the band with a low cost.

The broadband method should not be applied:

- If it is necessary to know the radiation levels by frequency.
- If the value given exceeds the minimum reference level in the frequency band to be measured.
- If the sensitivity of the equipment is not low enough to obtain a radiation value, but legislation in force requires giving a radiation value.
- To measure frequencies under 100 kHz, since the total summation of the emissions is not a valid method for these frequencies.

### 6.1 Description of the general method

The measurement is continuously and automatically carried out over the targeted frequency range. In many cases, the frequency range 80 MHz-3 GHz is appropriate.

The frequency range should be extended, if it is required, to cover all frequencies operating in the considered area.

If the measurement is carried out within the reactive near field (distance < $\max(\lambda, D, D^2/(4\lambda))$ – where $\lambda$ is the wavelength and D is the maximum size of the antenna) of the relevant emitters (ER > 0.05), the validity of the measurement result should be justified by a detailed analysis.

NOTE – For a distance of 10 m, the conditions for radiating near field or far field are met for all emitters above 30 MHz.

The range for low frequency measurements is from 0 Hz up to 100 kHz and the range for high frequency measurements is from 100 kHz up to 300 GHz [EN 50413].

In the case of low frequency fields, electric (E) and magnetic (H) fields must be assessed separately.

In the case of high frequency fields and far-field conditions, either electric (E), magnetic (H) or power density (S) may be used for the assessment.

In the case of near-field conditions, both electric (E) and magnetic (H) field components must be assessed.

Figure 1 gives an overview of the procedure for a site.

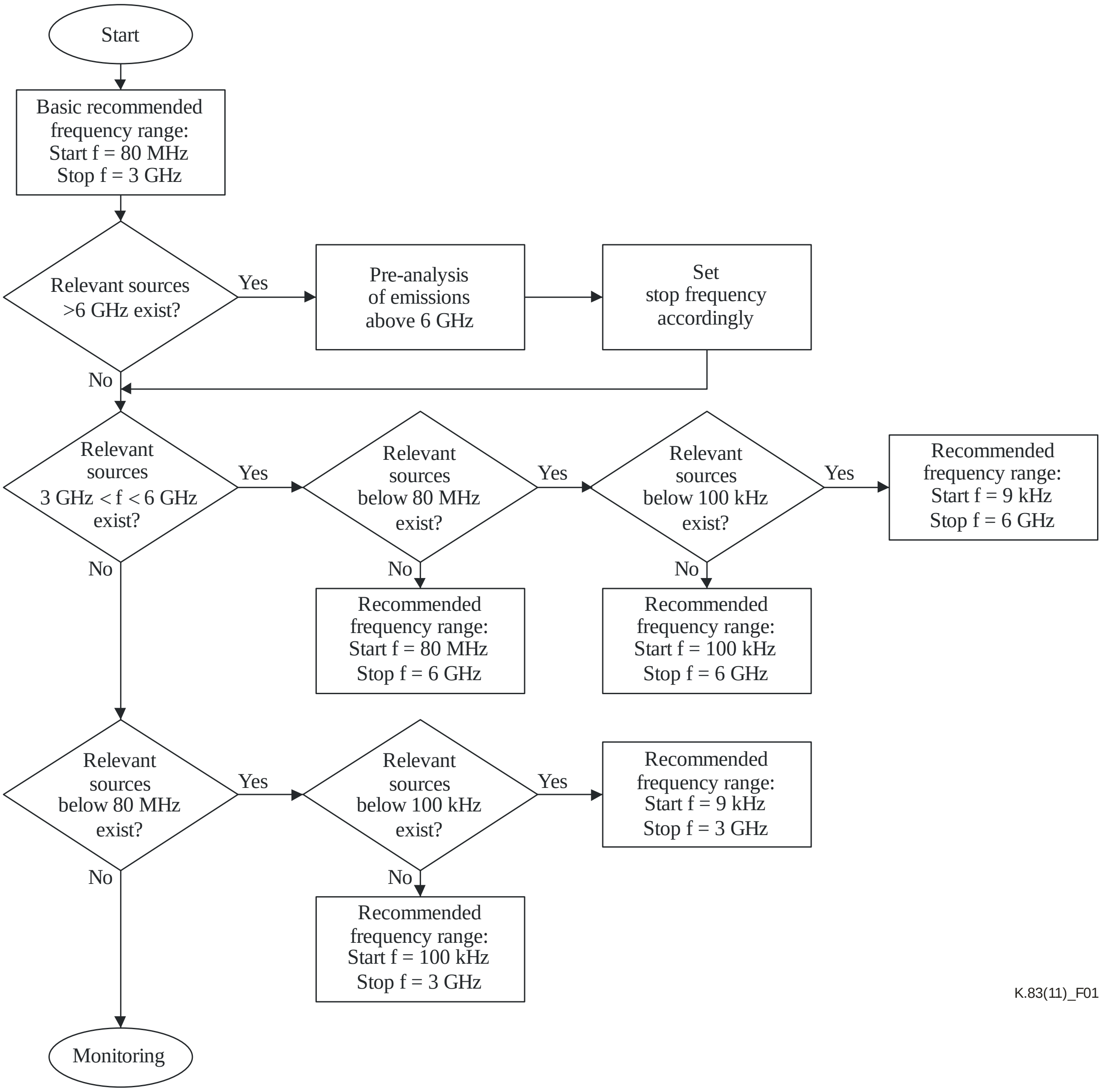



**Figure 1 – Site evaluation procedure**

## 6.2 Exposure limits

The limits for general public exposure specified in the national regulations, or if they do not exist in the ICNIRP limits as well as conditions for simultaneous exposure to multiple frequency fields shall apply for the purposes of this Recommendation.

From such derived field strengths $E_i$, the TER for the complete frequency range is derived:

In the case of ICNIRP guidelines, the total exposure ratio (TER) criteria refers to electrical stimulation effects ($a$ = 87 V/m; $El$ is the frequency dependent limit):

$$\sum_{i=1\text{Hz}}^{1\text{MHz}} \frac{E_i}{El_i} + \sum_{i=1\text{MHz}}^{10\text{MHz}} \frac{E_i}{a} \leq 1$$

The total exposure criteria refers to thermal effect circumstances ($c = 87/f^{1/2}$ V/m, *El* is the frequency dependent limit):

$$\sum_{i=9\text{kHz}}^{1\text{MHz}} \left(\frac{E_i}{c}\right)^2 + \sum_{i=1\text{MHz}}^{300\text{GHz}} \left(\frac{E_i}{El_i}\right)^2 \leq 1$$

## 7 Frequency selective measurement procedure

The measurement consists of repeated measurement cycles, each representing one measurement result. Each cycle consists of the steps according to Figure 2.

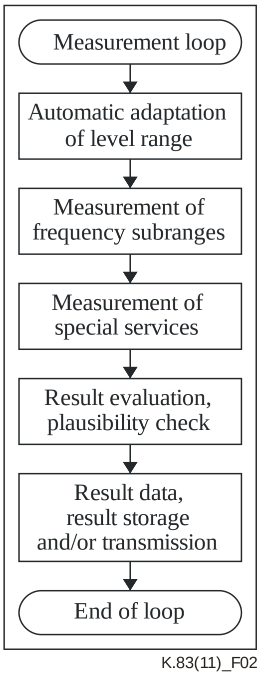



**Figure 2 – Measurement loop**

### 7.1 Frequency sub-ranges

The frequency range is divided in sub-ranges depending on the Region.

For each sub-band, the maximum detectable level is at least the limit value. The minimum detectable level is required in case no emissions above the threshold value are present. It can be achieved with adopted settings of, e.g., attenuation, bandwidth. An instantaneous dynamic range of 60 dB must be achieved for each level setting. Another signal present in any other sub-range and bigger than 25% or at least 3 MHz off the measurement frequency must cause no overload or measurement error, if its field strength is below the exposure limit.

### 7.2 Automatic level range determination

The parameters (e.g., attenuation, preamplifier) for each sub-range are adopted automatically during each cycle to achieve best possible sensitivity without signal distortion due to overload (e.g., in preamplifiers, mixers) from other emitters in the same or other sub-bands.

### 7.3 Measurement of frequency bands

For each frequency band, the measurement should be done using a detector according to the national regulations. If there are no national regulations, then the rms level should be used according to the ICNIRP guideline. The measurement time for each band is chosen according to the typical time behaviour of the emitters. The measurement is repeated with increasing sensitivity (e.g., smaller bandwidth) as long as no emission above and less than two emissions below the threshold are detected and the minimum detectable level is not reached. The noise floor of the measurement system is discriminated independent from the sensitivity setting and therefore not used as a measurement value.

### 7.4 Measurement of special services

Special services, e.g., broadband services (e.g., WCDMA, DVB-T), signals with high crest factors and radar signals are measured with specific settings (at least zero span, measurement time and signal adopted bandwidth). Depending on the signal type, RMS or peak detector shall be used. [EN 50492], Annex E shall be used for further evaluation of the settings.

A result value obtained here at a frequency $f_0$ replaces the swept measurement achieved in clause 7.3 in the frequency range $f_0 \pm ½$ RBW.

An extrapolation of the field strength at maximum traffic of a cellular network is not carried out.

### 7.5 Result evaluation

Measurement result consists of values achieved according to clauses 7.2 and 7.3 that fulfil the criteria of clause 6.2 stored as relevant emissions and used for the TER calculation.

For a plausibility check and the detection of unusual transmissions (e.g., broadband interferers), bandwidth and field strength limits can be defined for every frequency band. If the emission is outside the limit, a warning is added for the operator. In case no limit is defined for a frequency range or the measurement is not possible (e.g., insufficient S/N for determination of occupied bandwidth), the plausibility check is skipped for this frequency. The next measurement cycle is started independent from the plausibility check result.

NOTE – In case of automatic data transmission and central data management, the plausibility check can be also centralized.

As additional information date, time, actual measurement position, ambient temperature and humidity and system status and warnings are added to the measurement result.

This result is stored internally (offline evaluation) or transmitted automatically via a data link to a server (online evaluation).

### 7.6 Measurement equipment, general requirements

The measurement equipment consists of the following parts:

- Measurement probe.
- Frequency selective measuring instrument, which processes the signal from the probe and indicates the value of the EM field quantity.
- Measurement automation.
- Mechanical and protective housing.

The system parameters, as defined in this clause, are valid for the completely assembled unit as installed on site.

The measurement equipment shall be calibrated as a complete system at the measurement frequencies according to [EN 50383]. The calibration shall take into account the high crest factor of some signals or combinations of signals.

### 7.7 Measurement probe

Isotropic measurement shall be used to determine the field value used to assess the human exposure. The isotropy shall be analysed according to [EN 50383], and the isotropy deviation shall be less than 2.5 dB in the frequency range up to 3 GHz and less than 3.5 dB for 3 to 6 GHz. In the extended frequency range 3 to 6 GHz and above, the isotropy may increase to 3.5 dB.

The measurement is carried out at a height of concern (typically 1.5 m above floor level). If the frequency range is split into more than one probe, field probes below 130 MHz may be mounted within a height range of 1.3 m to 1.7 m.

The size of each probe should be smaller than 150 mm. Interaction between the probes, radome and the measurement equipment shall be taken into account for isotropy, sensitivity and measurement uncertainty evaluation.

If active probes are used, 1 dB compression point must be higher than the measurement range.

### 7.8 Measurement instrument

The measurement range of the instrumentation is required to be in accordance with the field strengths to be measured. The sensitivity should be sufficient to determine the lowest level to be measured within the accuracy at that level, as stated by the instrument's manufacturer. By a preselector, strong emissions in other frequency bands are suppressed. Preamplifiers shall be used only after the preselector to avoid unrecognized overload effects. The frequency range of the measuring equipment should be sufficient to cover the frequencies of the EM field sources to be characterized.

For the measurement of special services, the radio bandwidth should cover 10 Hz to 10 MHz, including channel filters for typical services, e.g., WCDMA, DVB-T.

### 7.9 Measurement control

The measurement control shall monitor the system status. In case of a detected interruption in the measurement procedure, the system shall recover on its own, start the measurement cycle again and send out a warning. The results of the interrupted measurement cycle are deleted; results of already finished cycles stay valid. In case of a detected hardware failure, the measurement is set invalid.

### 7.10 Mechanical and protective housing

The measuring equipment shall be appropriate to the environmental conditions (e.g., temperature, humidity, wind speed, vibration) to be expected during the monitoring period at the measurement site.

## 8 Broadband measurement procedure

### 8.1 Measuring equipment

In order to take the broadband measurement, the instrument to be used consists of an equipment which has a broadband probe and measures the electromagnetic field. This equipment will consist of:

- Broadband probe.
- Measurement instrument, which processes the signal from the probe and provides the measurement of the field strength.
- Protection.

It is essential that the measuring equipment provide the RMS (*root mean square*) value of the electric field strength in order to compare the levels measured with the exposure limits.

The measuring equipment should be calibrated as a whole, and the said calibration should be registered.

## 8.2 Measurement probe

The broadband probe provides an independent measurement of the frequency, which integrates all of the emissions in a desired frequency band. One must use a broadband probe that covers the band of interest. This probe must be isotropic, and the isotropic deviation must be less than 2.5 dB for frequencies up to 3 GHz, and less than 3.5 dB for higher frequencies. Each one of the three field components must be measured possibly at the same time in order to have a correct total field result. Besides, the probe must have a dynamic range adapted to the levels that one wants to measure.

The deviation of the measurement due to the variation of the response of the probe with the frequency must be less than ±3 dB for the interest frequency band.

The catchment area of the probe should be sufficiently separated from the readout unit through a high impedance connection and low permittivity materials that minimize the interaction between the field and the connection circuitry.

## 8.3 Measurement instrument

The function of the measurement instrument is to calculate the field level based on the information given by the probe. The sensitivity of the equipment must be sufficient to discriminate the minimum desired field level with adequate precision. Similarly, the dynamic range of the equipment should be adapted to the measurements to be taken.

Probe + measurement instrument as a whole should provide the RMS (*root mean square*) value of the field strength.

Besides, the measurement instrument should manage the automation of the measurements for them to be continuous, with the sampling and defined average periods. A sampling rate of at least 1 second is recommended and the average period should be 6 minutes, as specified by [ICNIRP], and it should be continuous or "sliding" over time, in order to avoid losing data, as specified by [IEEE C95.3]. It should have an adequate storage capacity for measurements, which in any case should exceed one week.

It is also responsible for monitoring the status of the system, generating alarms in case of any anomaly in the operation.

## 8.4 Protection

The measuring equipment should be adapted to environmental conditions (temperature, humidity, rainfall, wind, etc.) that can be expected in the location point. To this end, we will employ a properly conditioned mechanical protection.

## 8.5 Measurement method

The procedure to be followed is:

### 8.5.1 Selection of the probe

In the first place, it is important to choose correctly the measurement probe, so that it should adapt both to the frequency margin and to the necessary dynamic range of the field strength.

Probes offer absolute field values, without frequency information. It will be necessary to compare the obtained value, which is the total strength field of all the spectral components in the bandwidth to be measured, with the minimum value of the exposure limit. It is interesting to observe that the bandwidth of the probe should be adjusted as closely as possible to the bandwidth to be measured, so that the minimum exposure limit coincides with that of the frequencies that you want to measure.

#### 8.5.2 Selection of the measurement site

The measurement should be taken at a height of concern (typically 1.5 m above the floor level). Thus, the measuring equipment should be located so that the catchment area of the probe is located at that height.

The measurement point should be chosen so that it represents the highest level of exposure that a person may be subjected to, taking into account all possible sources of emissions. This maximum can be determined either empirically through a quick scan with a field measuring equipment, or by a calculation of the theoretical propagation from nearby transmitting antennas. It is important to keep the probe away from metal surfaces (several times the diameter of the probe) to avoid coupling effects that would distort the measure.

The measured field value must correspond to the "undisturbed" field. This means that all possible influences of assembling on the field should be minimized. To this end, the equipment should be assembled on a non-conductive support, with low permittivity, and any possible metallic fittings should be far enough from the probe. Besides, one should take all the necessary measures so that any moving object or person may not approach the equipment while it is measuring.

#### 8.5.3 Automatic taking of the measurements

The equipment should operate autonomously once it is put into operation. The same equipment will manage the taking of the measurements and its automation, so that the measurements will be continuous and uninterrupted.

Field measurements should be an average of duration to be defined by national regulations or 6 min should be used according to the [ICNIRP] guideline. Each measurement should be stored in the equipment memory, pending to be recovered by the system manager.

### 8.6 Measurement of exposure to multiple sources or frequencies

Exposure to a single frequency is an ideal case. The most general case is that of exposure to various sources or to a single source with various frequencies. Considering this general case, it can, however, be easily proved mathematically that if the value measured by the equipment does not exceed the most restrictive exposure limit in the frequency band to be measured, then the contributions at different frequencies will also be below the said limit, since:

$$E_{tot} = \sqrt{\sum_{i=1}^{n} E_i^2}$$

## 9 Uncertainty

The uncertainties shall be estimated in compliance with methods described in [EN 50413], [EN 50383], and [ISO/IEC Guide]. The contributions to the total uncertainty of the measurement can be obtained through the appropriate measurements performed on the equipment, or according to manufacturer's specifications, that can be taken as tolerances, with rectangular distribution.

The expanded uncertainty with a confidence interval of 95% [EN 50413], [EN 50383], and [ISO/IEC Guide] shall not exceed 4 dB.

The contributions of each component of uncertainty shall be registered with their name, probability distribution, sensitivity coefficient and uncertainty value. The results shall be recorded in a table as described in Table 1. The combined uncertainty shall then be evaluated according to the following formula:

$$\mathrm{u}_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot \mathrm{u}_i^2}$$

where $c_i$ is the weighting coefficient (sensitivity coefficient). The expanded uncertainty shall be evaluated using a confidence interval of 95%. The coverage factor to be employed is 1.96, which is the one provided by the confidence interval of 95% for a near-normal distribution, typical in most measurements.

Table 1 gives a practical guideline to set up an uncertainty budget for EMF measurements.

There may be other uncertainties, which are not listed, and some of the listed uncertainties may not be present or may not be significant in the overall assessment.

**Table 1 – Uncertainty assessment**

| Error sources | Description | Uncertainty value % $uv_i$ | Probability distribution | Divisor $k_i$ | $c_i$ | Standard uncertainty % $u_i = uv_i/k_i$ |
|---|---|---|---|---|---|---|
| **Measurement equipment** | | | | | | |
| Calibration | [EN 50383] | | Normal | 1 or k | 1 | |
| Isotropy | [EN 50383] | | Normal | 1 or k | 1 | |
| Linearity | [EN 50383] | | Rectangular | $\sqrt{3}$ | 1 | |
| Measurement device | | | Normal | 1 or k | 1 | |
| Noise | | | Normal | 1 | 1 | |
| Mismatch | [EN 50383] | | U-shape | $\sqrt{2}$ | 1 | |
| Influence of temperature and humidity on the measurement equipment | [EN 50383] | | Rectangular | $\sqrt{3}$ | 1 | |
| **Environmental parameters** | | | | | | |
| Perturbation by environment | | | Rectangular | $\sqrt{3}$ | 1 | |
| Influence of the body | [EN 50492] | | Rectangular | | | |
| **Post-processing** | | | | | | |
| Spatial averaging | [EN 50492] | | Rectangular | $\sqrt{3}$ | 1 | |
| Combined standard uncertainty | | | $u_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$ | | | |
| Expanded uncertainty (confidence interval of 95%) | | | Normal | | | $u_e = 1.96 \cdot u_c$ |

## 10 Report on the measurement results

As stated in the introduction, taking measurements is as important as the correct communication of the results to solve the public concern about electromagnetic radiation.

Therefore, when communicating the results of the measurements taken, the following aspects should be taken into account:

- Comprehensibility: Results should be clear and comprehensible for the general public, without excessive technicalities. It is important to show the results compared with the applicable limit values.

- Accessibility: Results should be published on the Internet, and the access to them should be easy for the general public; that is to say, the link should be accessed from home pages and not from inside pages of a web site with a difficult access.
- Details: All possible information about how the measurements are taken should be provided:
  - measurement location (by its geographical positioning on a map [ITU-T K.113]),
  - description of the measurement site,
  - date and time,
  - description of the measurement method: broadband, frequency selective, average time, position of the probe, etc.,
  - identify the measurement equipment,
  - record calibration details for any instrumentation used,
  - identify who has done the assessment,
  - record when and where the assessment was performed,
  - record the relevant sources considered and associated parameters,
  - include the value of parameters used in the assessment and any assumptions made,
  - record the results of total exposure ratio measurements.

# Appendix I

## Links to the official websites with results of the EMF monitoring

(This appendix does not form an integral part of this Recommendation.)

As an example, Tables I.1 and I.2 contain an alphabetical list of the links to the official websites of the Regulatory Agencies in which the information with results of the EMF monitoring are presented. Table I.3 lists the links to the official websites of the Regulatory Agencies where results of EMF measurements are presented.

**Table I.1 – Links to the websites with results of EMF monitoring (Governments)**

| Country | Institution | Website | Contact details |
|---|---|---|---|
| Argentina | Universidad Nacional de La Plata | https://itma-cem.unlp.edu.ar | Calle 50 esq 115 Piso 3 (1900) La Plata, Argentina<br>Tel: +542214236609<br>monitorcem@cespi.unlp.edu.ar |
| Colombia | ANE (Agencia Nacional del Espectro) – National Spectrum Agency of Colombia | http://smrni.ane.gov.co/es/public/colombia/ | ANE<br>Calle 93 # 17-45 Piso 4. Bogotá D.C. Postal code: 110221.<br>Tel: (57+1) 6 00 00 30<br>contactenos@ane.gov.co |
| El Salvador | ITU pilot project, SIGET (Superintendencia General de Electricidad y Telecomunicaciones) | http://rni.siget.gob.sv/<br>http://www.siget.gob.sv/rni<br>http://www.siget.gob.sv/rni/cartas/<br>http://rni.siget.gob.sv/gmap/ElSalvador.html | Sexta décima Calle Poniente y 37Av. Sur #2001, Col. Flor Blanca, San Salvador, El SalvadorTel: (503) 2257-4438<br>E-mail: info@siget.gob.sv |
| Germany | Federal Network Agency<br>Fourteen monitoring stations available on request and relocated after three months. | http://emf3.bundesnetzagentur.de/ams.html | Bundesnetzagentur Section 414 Postfach 80 01<br>D-55003 Mainz<br>E-Mail:<br>monitoring@bnetza.de |
| Hungary | National Media and Communications Authority (NMIA) | http://emirpub-prod.nmhh.hu/pubrendszer-web/eszmog/meresiAdatok.jhtml | |
| Italy | ARPAE (Regional Agency for the Prevention, Environment and Energy) | https://www.arpae.it/<br>https://www.arpae.it/dettaglio_generale.asp?id=2618&idlivello=1534 | Via Po, 5 – 40139 – Bologna (Bologna)<br>Tel: 051 6223811 |

**Table I.1 – Links to the websites with results of EMF monitoring (Governments)**

| Country | Institution | Website | Contact details |
|---|---|---|---|
| Israel | Israel Ministry of Environmental Protection | http://www.sviva.gov.il/subjectsEnv/Radiation/Pages/Non-Ionizing-Monitoring.aspx | Israel Ministry of Environmental Protection<br>http://www.sviva.gov.il/English/ResourcesandServices/PublicInquiries/Pages/ContactUs.aspx |
| Korea | Korea Communications Agency | http://118.37.76.251:9080/download.htm<br>this application is available for mobile phones. | Korea<br>760, Bitgaramro, Sanpo-myeon, Naju-si, Jeollanam-do(520-833)<br>Tel: 82-61-350-1604<br>Mobile: 82-10-8860-0845<br>e-mail: geo0707@kca.kr |
| Panama | Autoridad Nacional de los Servicios Públicos, ASEP (Public Services National Authority) | http://170.82.247.23/es/public/asep-panama/ | ASEP<br>0816-01235, Zona 5 Panamá.<br>Tel: (507) 508-4500<br>atencionalusuario@asep.gob.pa |
| Romania | ANCOM<br>http://www.ancom.org.ro | http://www.monitor-emf.ro/en/map/ | 2 Delea Noua Street Bucharest 3, Postal Code 030925, Bucharest, Romania<br>sesizare@ancom.org.ro<br>Phone: 0372. 845.845Free line: 0800 855 855 |
| Spain – Catalonia | Generalitat de Catalunya<br>Telecommunication and Information Technologies Centre | http://governancaradioelectrica.gencat.cat/web/guest/home | Carrer de Salvador Espriu, 45-51<br>08908 L'Hospitalet de Llobregat<br>Tel: 93 557 40 00 |
| Turkey | Bilgi Teknolojileri ve İletişim Kurumu<br>(Information and Communication Technologies Authority, ICTA) | http://ema-olcum.btk.gov.tr | Bilgi Teknolojileri ve İletişim Kurumu<br>Eskişehir Yolu 10.Km No: 276 Posta Kodu: 06530 Çankaya/Ankara<br>Tel: (0312) 294 72 00<br>https://www.btk.gov.tr/iletisim |
| Uruguay | URSEC (Communication Services Regulatory Unit) | http://201.217.159.117:8085/gmap/index.html | www.ursec.gub.uy |
| Serbia | Regulatory Agency for Electronic Communications and Postal Services | http://emf.ratel.rs/eng/index | RATEL<br>Palmotićeva 2, 11103 Belgrade, Republic of Serbia Tel: 011-3242-673<br>E-mail: ratel@ratel.rs |

**Table I.2 – Links to the websites with results of EMF monitoring (Non-Government)**

| Country | Institution | Website | Contact details |
|---|---|---|---|
| Andorra | Andorra Telecom | https://www.andorratelecom.com/en/public-action/social-activity/electromagnetic-field/ | https://www.andorratelecom.com/en/contact/ |
| Greece | NTUA<br>Mobile Radiocommunications Laboratory of the National Technical University of Athens and the Radiocommunications Laboratory of the Aristotle University of Thessaloniki | http://www.pedion24.gr/en/results_en.jsp | N.T.U.A.<br>E-mail: pedion24@mobile.ntua.gr<br>Telephone: (+30) 210 7724196<br>Fax: (+30) 210 7723851<br>Mail Address:<br>Mobile Radiocommunicarion Lab 9, Iroon Polytechniou Str<br>GR15773, Zografou Campus<br>Athens, Greece |
| Spain | Vitoria-Gasteiz City Council | https://www.vitoria-gasteiz.org/wb021/was/contenidoAction.do?lang=en&locale=en&idioma=en&uid=_6a6e93ad_11a9a62c81b__7fd7 | Ayuntamiento de Vitoria-Gasteiz<br>Plaza España 1, 01001 Vitoria-Gasteiz<br>informacion@vitoria-gasteiz.org |
| Switzerland | Cantons of Uri, Schwyz, Obwalden, Nidwalden, Luzern and Zug | http://e-smogmessung.ch/i4Def.aspx?tabindex=0&tabid=437 | |

**Table I.3 – Links to websites with other EMF results (not monitoring)**

| Country | Institution | Website | Contact details |
|---|---|---|---|
| Brazil | ANATEL | https://www.anatel.gov.br/dados/medicoes-de-campo-eletromagnetico | Agostinho Linhares de Souza Filho / Stevan Grubisic<br>Linhares@anatel.gov.br / Stevan@anatel.gov.br<br>National Telecommunication Agency SAUS Q. 6 Bloco E 10º Andar Brasilia – DF – Brazil Zip Code 70070-940 |
| France | Agence Nationale des Fréquences | http://www.cartoradio.fr | |
| Ireland | Commission for Communications Regulation (ComReg) | http://www.comreg.ie/licensing_and_services/nir.554.444.html<br>*(sample of sites measured yearly since. Initially 400 sites in 2003-04 and down to 40 sites in 2012)* | Commission for Communications Regulation, One Dockland Central, Guild Street,<br>Dublin, D01 E4X0<br>consumerline@comreg.ie |
| | | | |
| Spain | Ministry of economic affairs and Digital Transformation<br>Secretaría de Estado de Telecomunicaciones e Infraestructuras digitales | https://geoportal.minetur.gob.es/VCTEL/vcne.do | P. de la Castellana, 162. 28071 – Madrid<br>+34 91 258 28 52 |
| United Kingdom | OFCOM | https://www.ofcom.org.uk/phones-telecoms-and-internet/coverage/mobile-operational-enquiries/audit-info | |

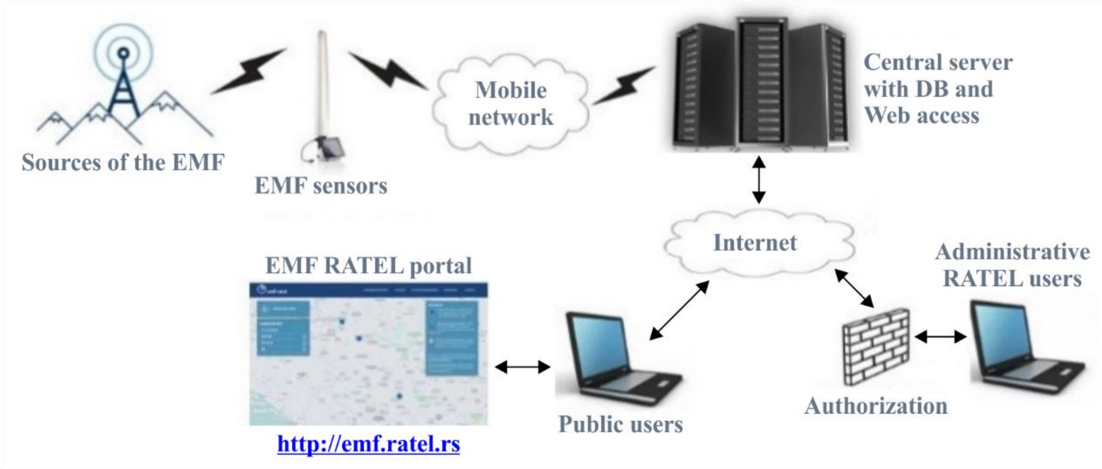
# Appendix II

## Examples of the existing websites with EMF monitoring results

(This appendix does not form an integral part of this Recommendation.)

This appendix gives examples of results presented in websites dedicated to EMF monitoring.

### II.1 EMF monitoring system in Serbia




K.83(20)_FII.1

**Figure II.1 – RATEL EMF monitoring system overview**

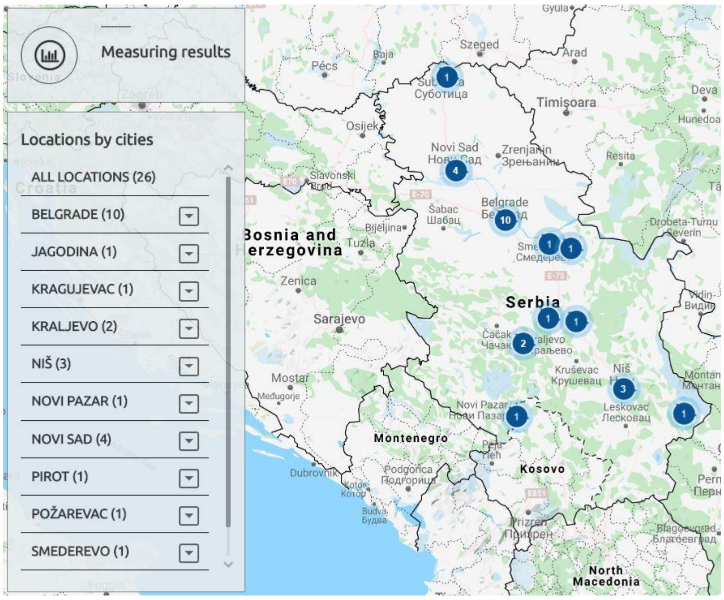



**Figure II.2 – Measuring stations positions on the interactive map**


**Figure II.3 – Student dormitory "4.april", Belgrade – Field and exposure levels**

## II.2 EMF monitoring system in Korea (Republic of)

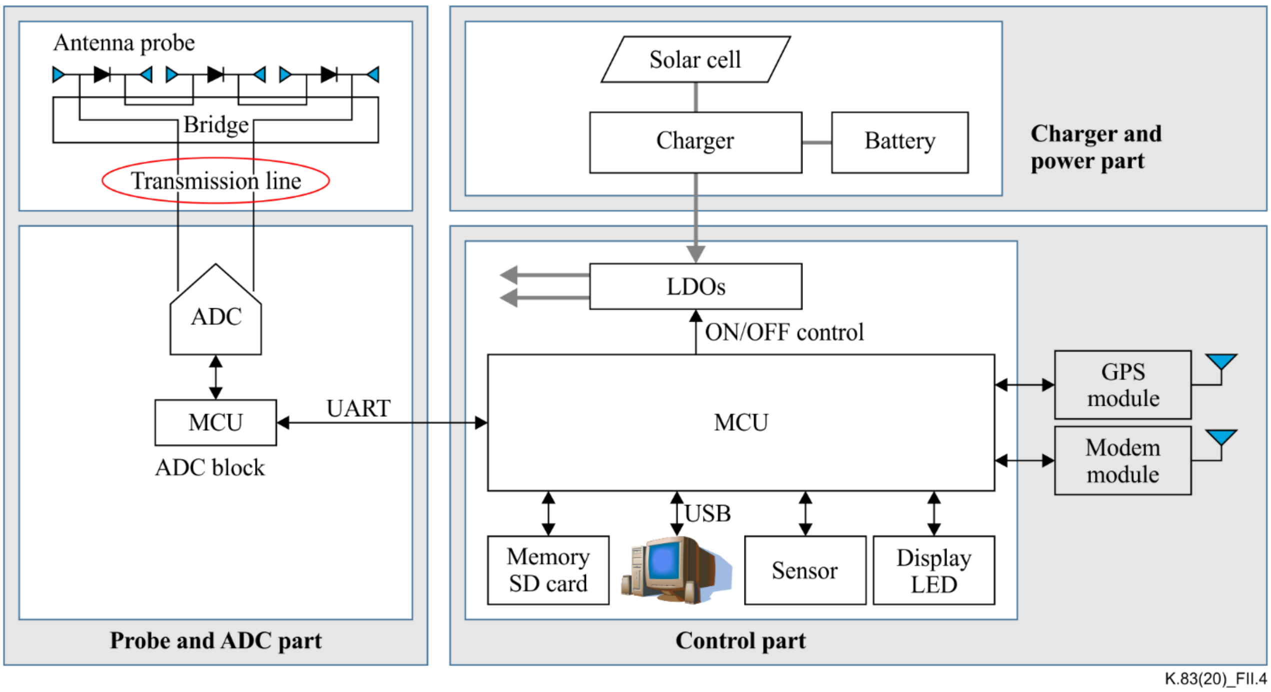



**Figure II.4 – Broadband EMF area monitor block diagram**

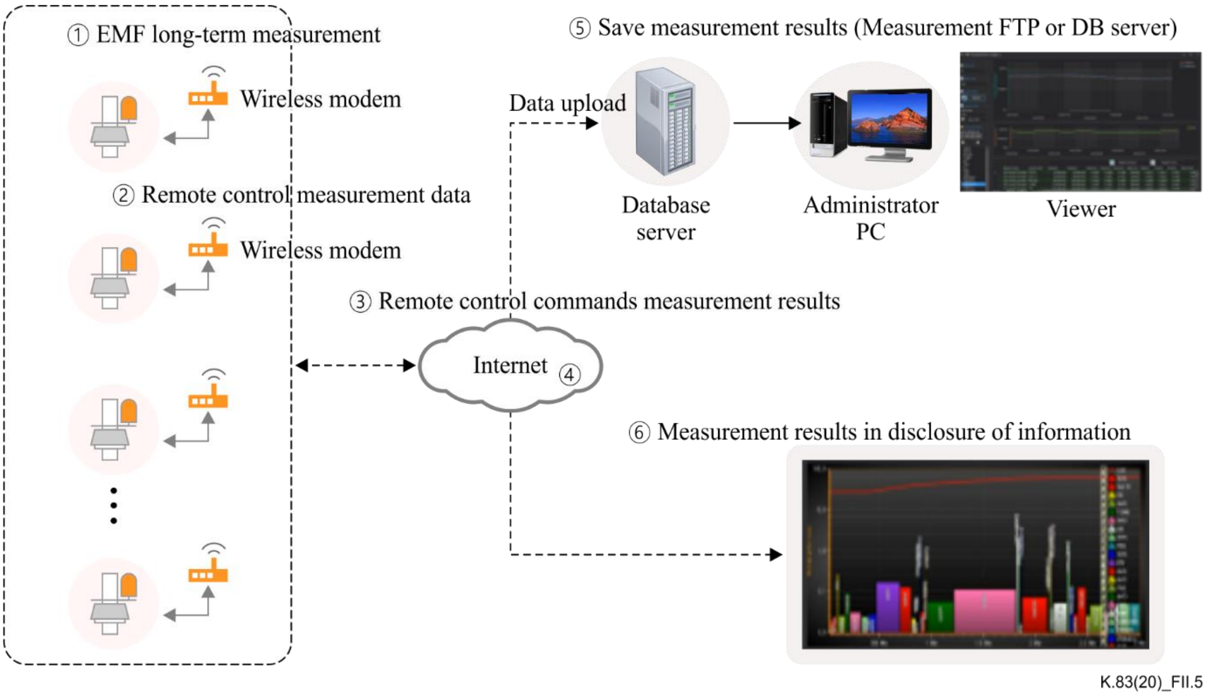



**Figure II.5 – Frequency selective EMF area monitoring architecture system**

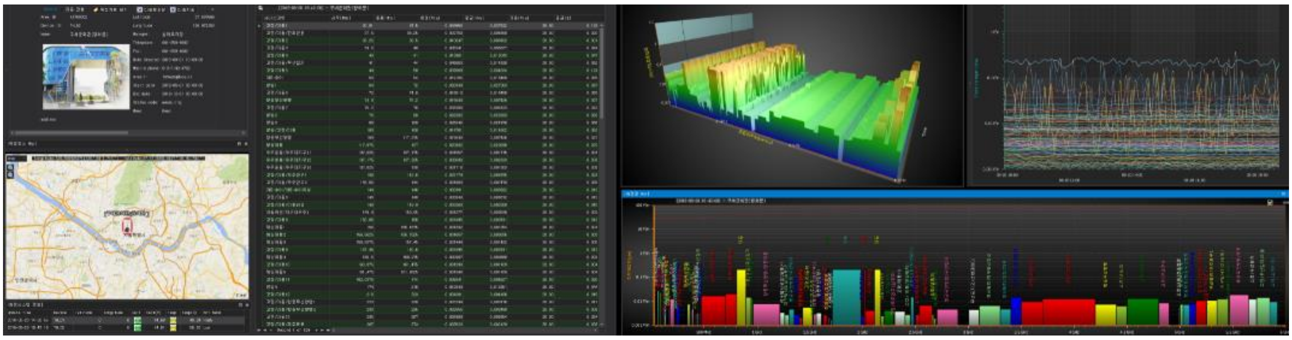


**Figure II.6 – Frequency selective EMF monitoring analysis (Korea KCA)**

## II.3 EMF monitoring system in Panama

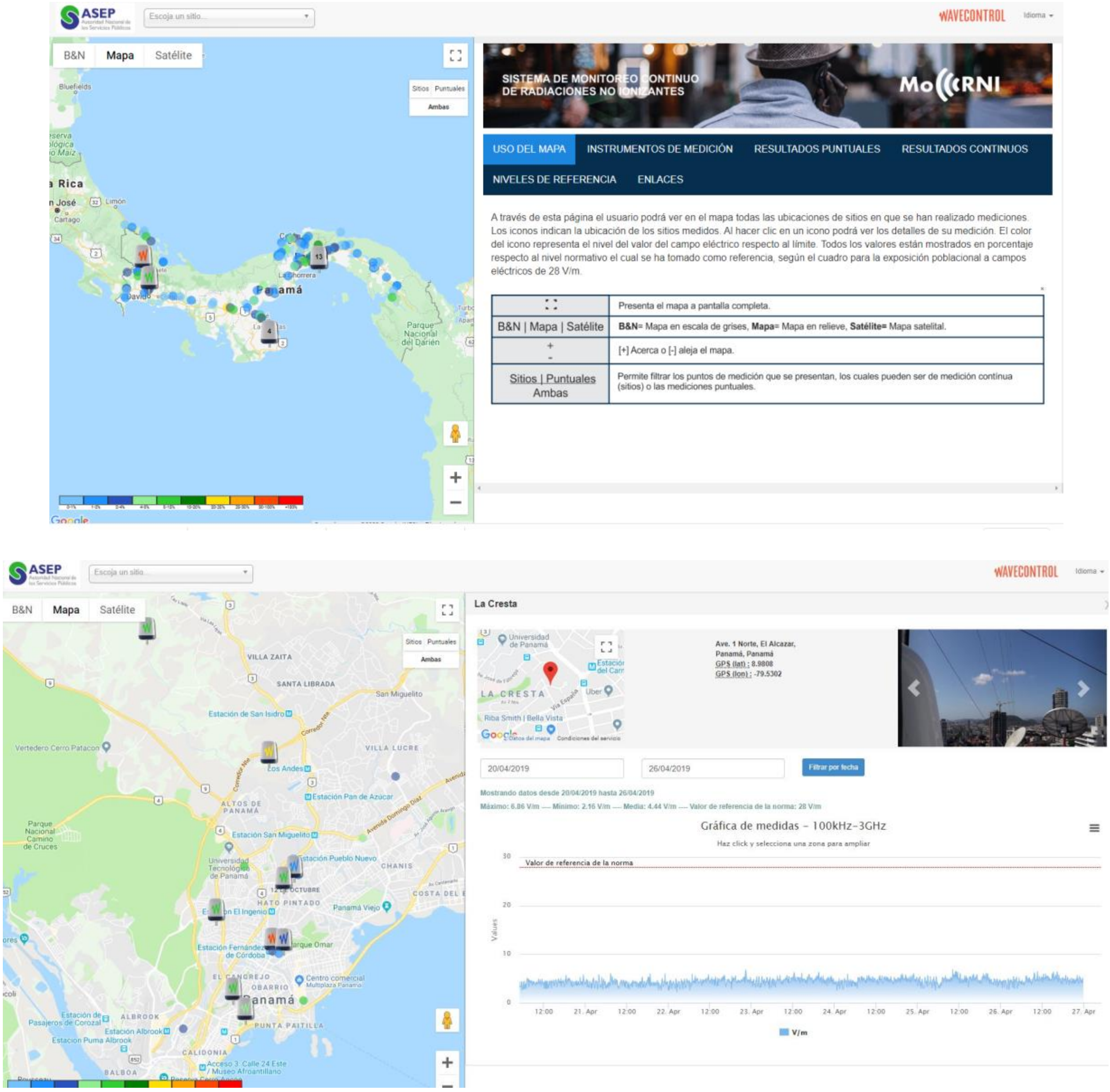



**Figure II.7 – EMF monitoring system in Panama**

## II.4 EMF monitoring system in Uruguay

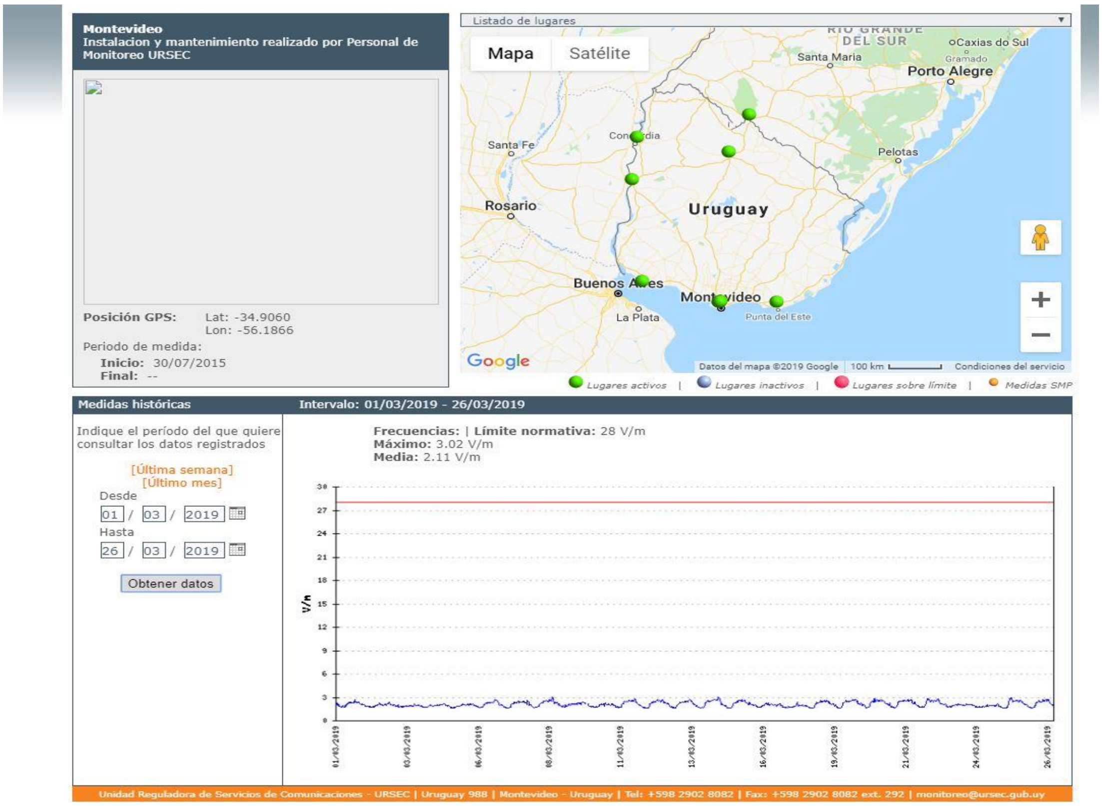



**Figure II.8 – EMF monitoring system in Uruguay**

## II.5 EMF monitoring system in Colombia

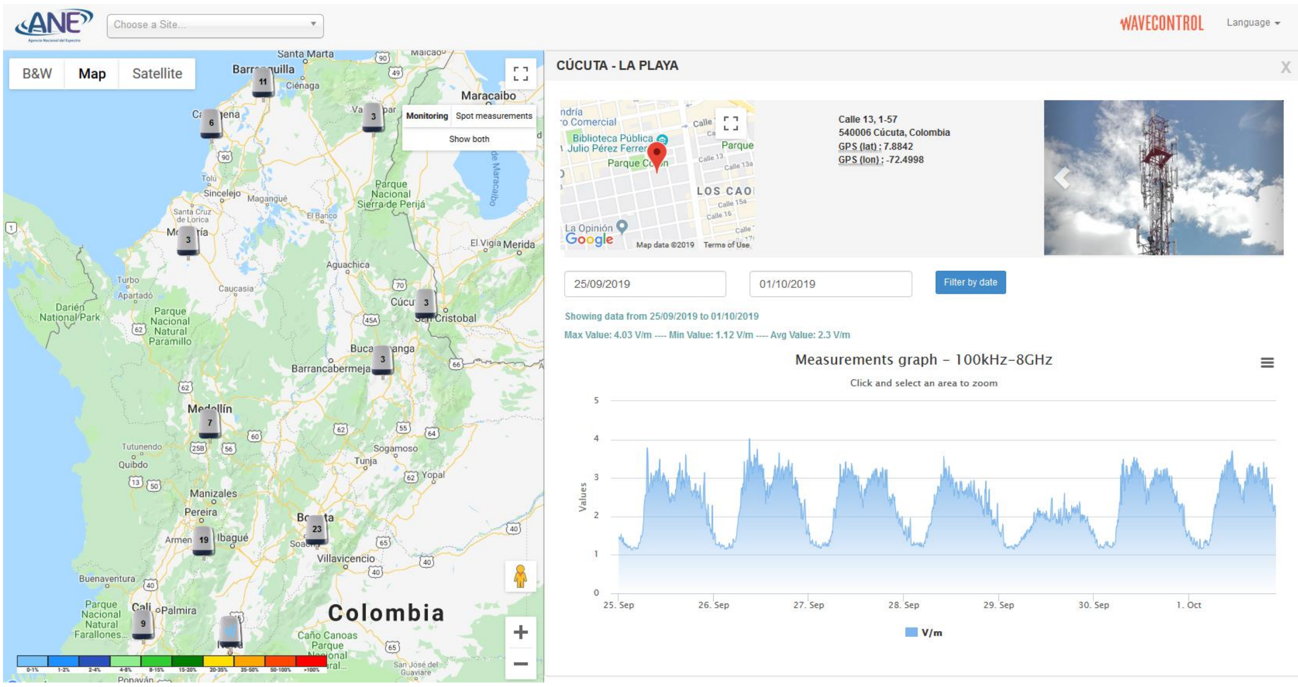



**Figure II.9 – EMF monitoring system in Colombia**

## II.6 EMF monitoring system in France

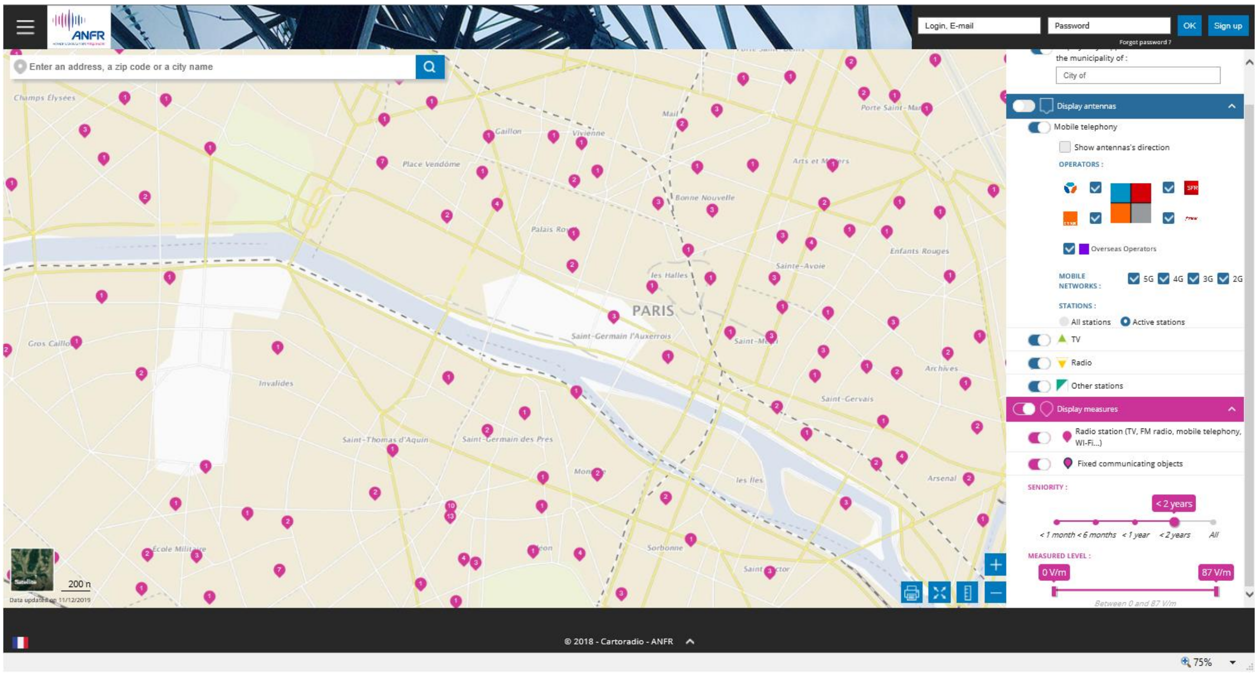



Figure II.10 – Screen with location of the mobile base stations

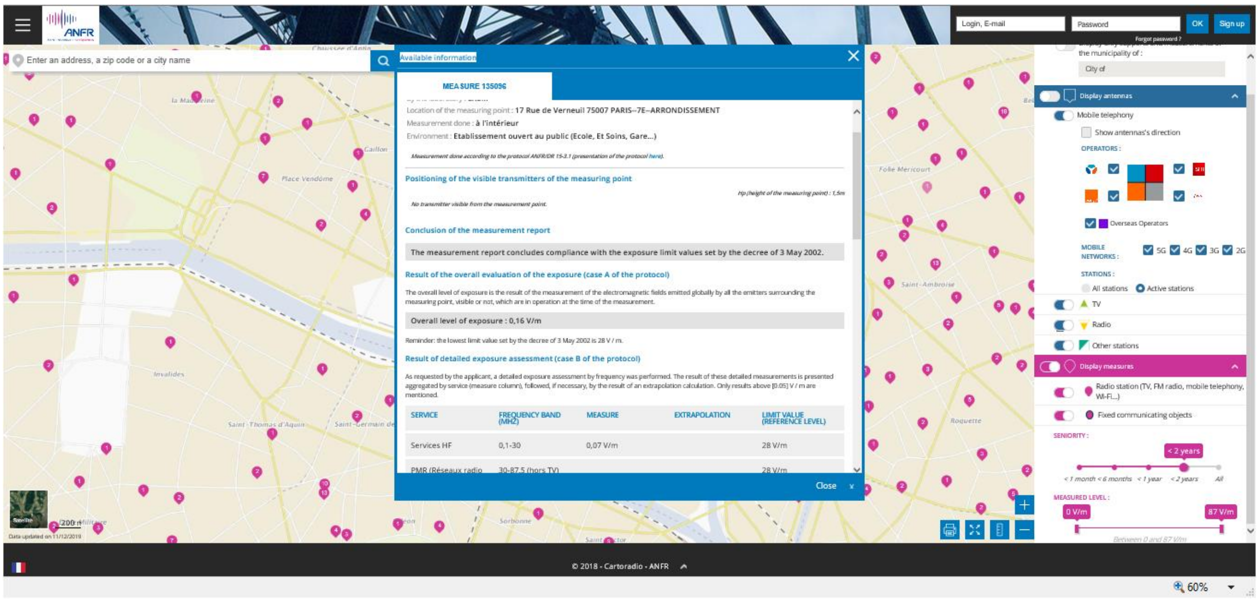



Figure II.11 – Example of the menu

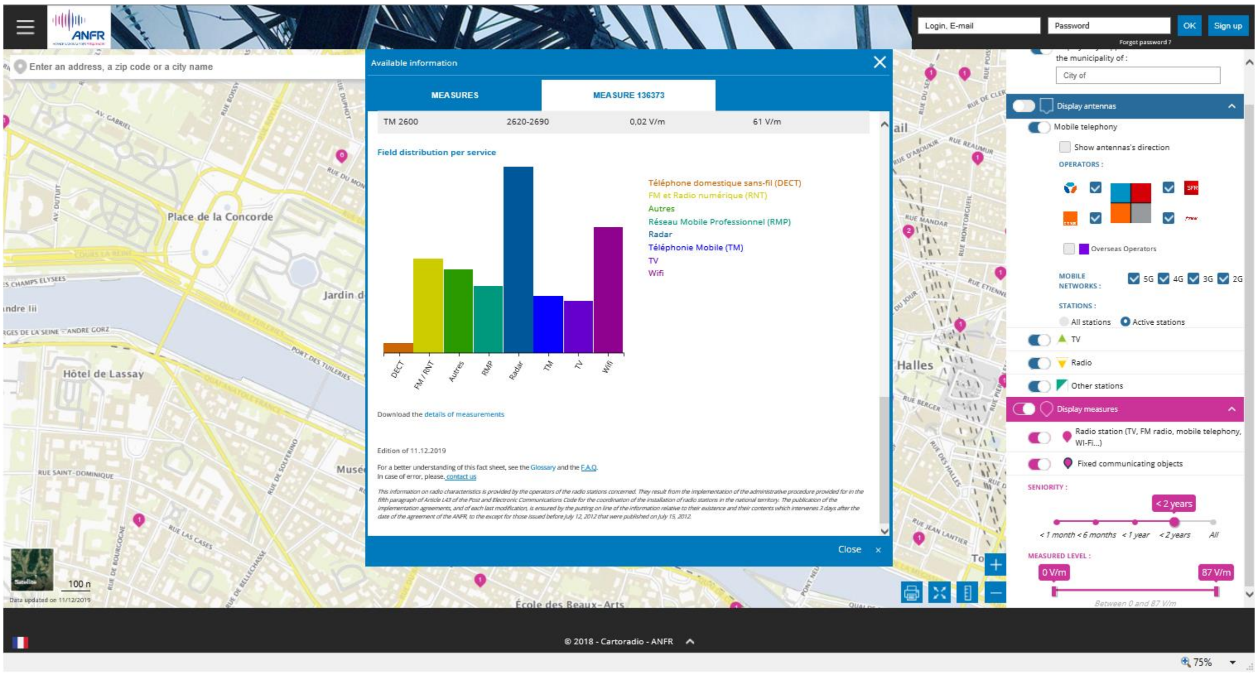



**Figure II.12 – Example of the results of the EMF monitoring**

## II.7 EMF monitoring system in Greece

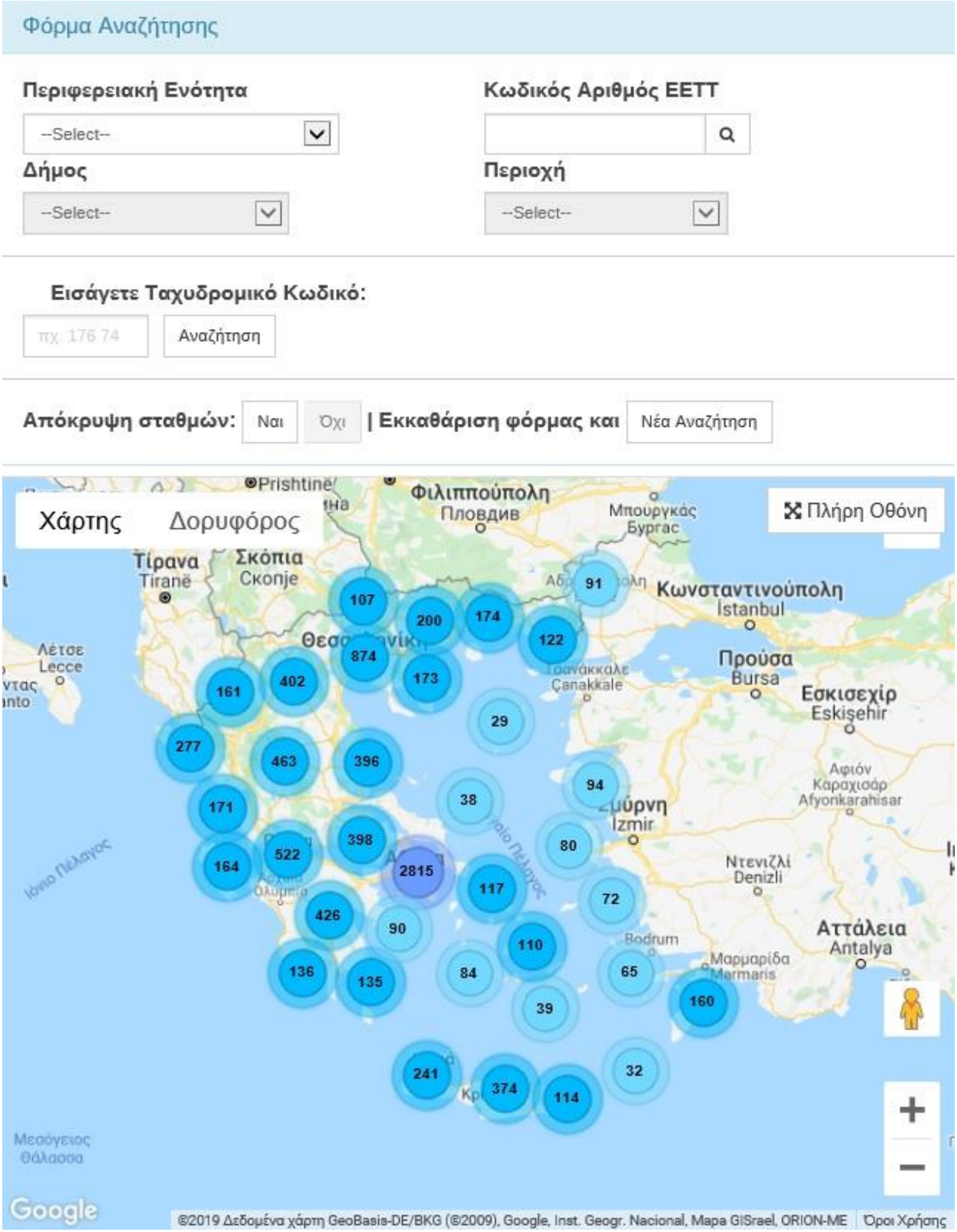



**Figure II.13 – In situ measurements results available to the public**

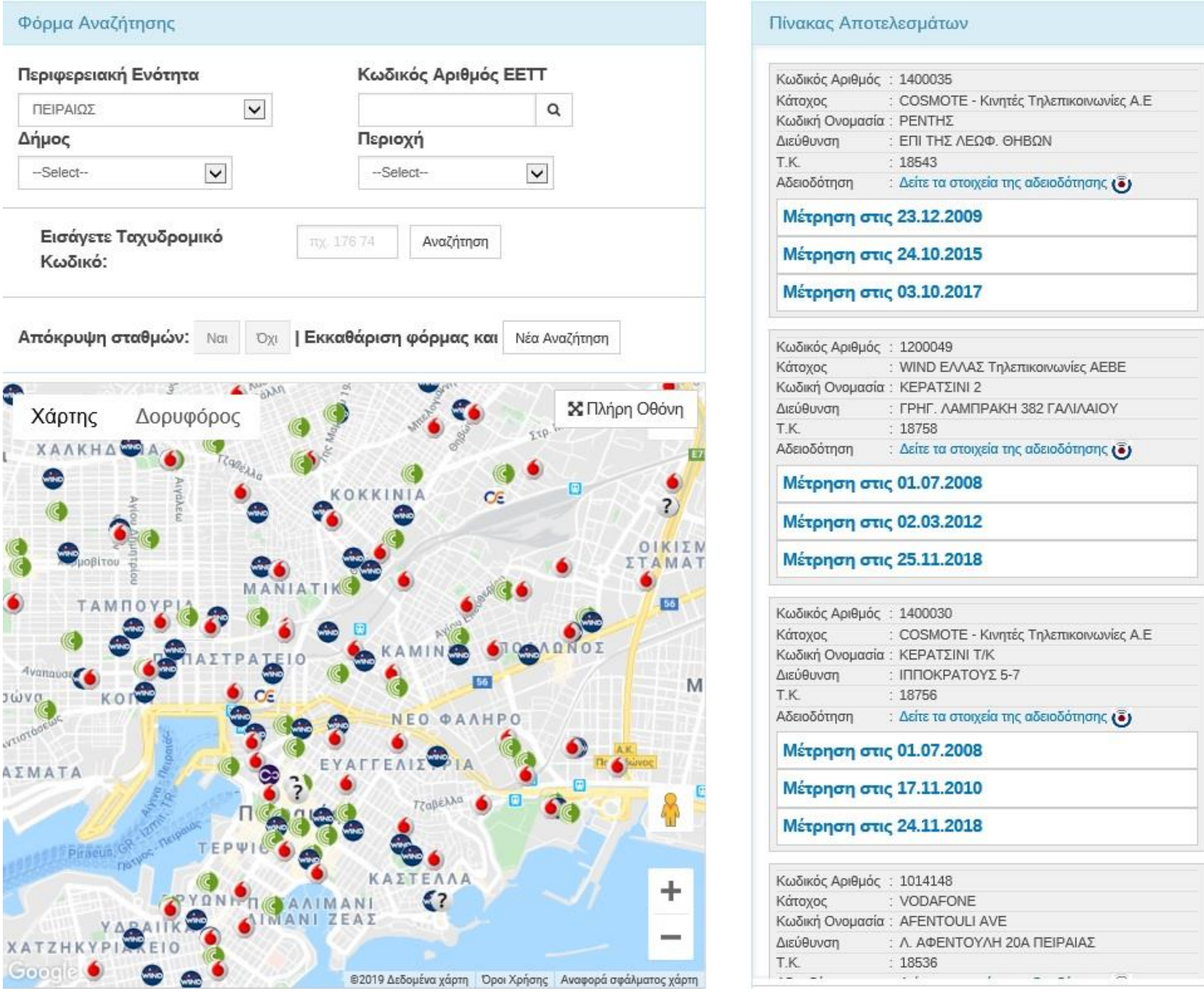



**Figure II.14 – Map with location of EMF sources**

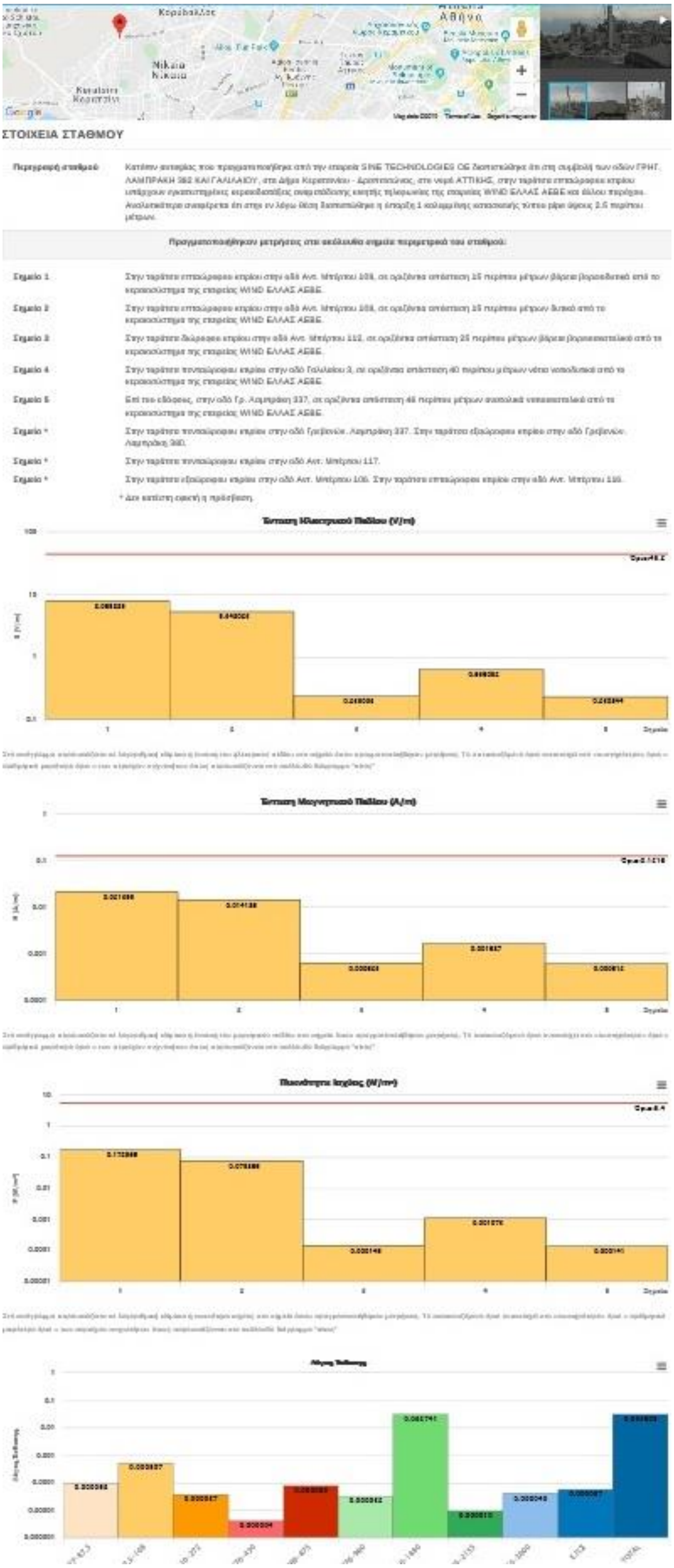



**Figure II.15 – Results of EMF monitoring**

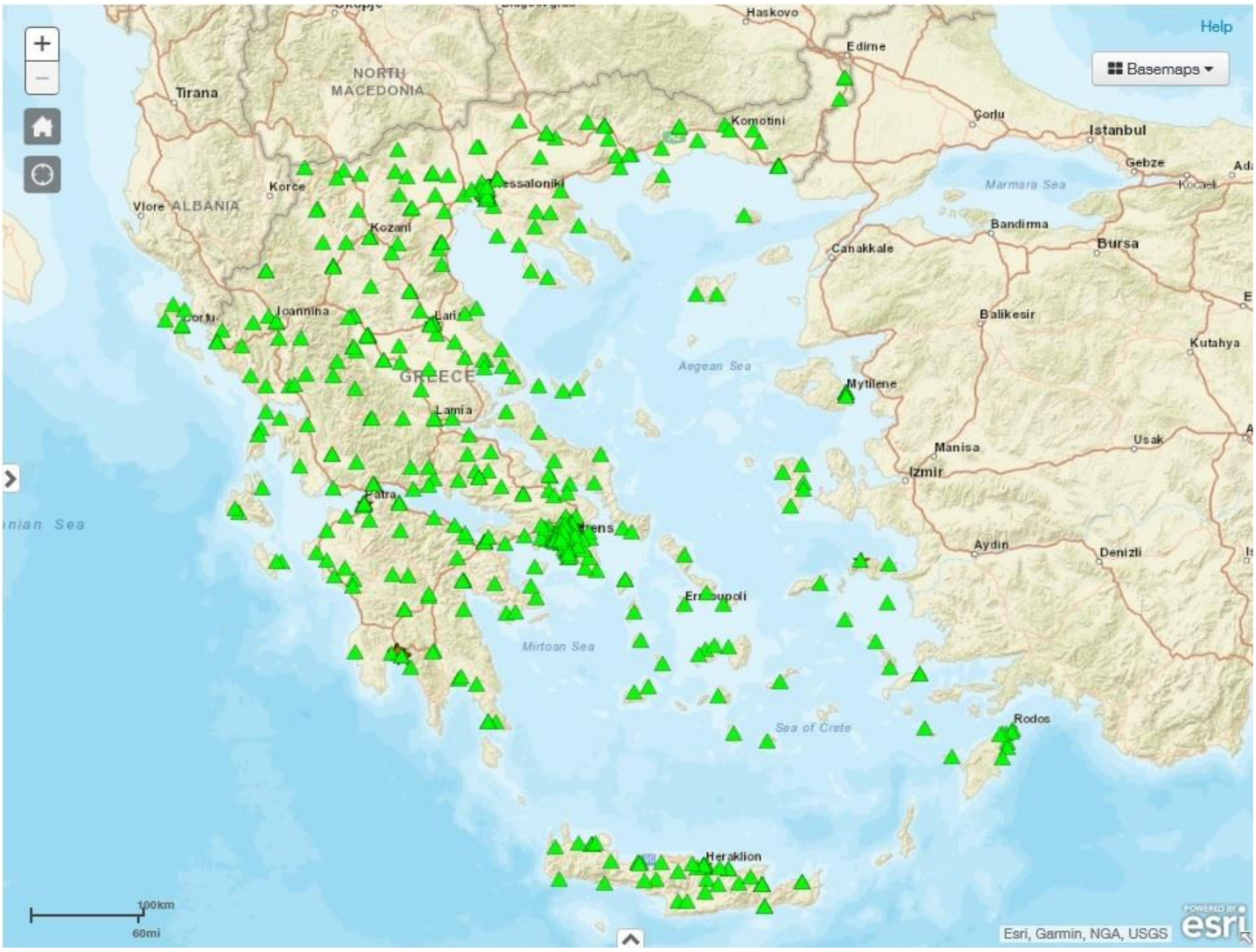



**Figure II.16 – Location of the EMF measurement points**

## Depot of Palaio Faliro Municipality

**Station Location**


**Station Photos**

| Station Information | |
|---|---|
| Address | Sokratous kai Ag. Petrou |
| Municipality | Palaiou Falirou |
| Prefecture | Notiou Tomea Athinon |
| Active since | 22-09-2015 08:02:30 |
| Last update | 12-12-2019 |
| Measurement files captured by handheld device | Click here |

**Electric Field Strength**

| Frequency Bands (MHz) | Frequency Band Limit (V/m)* | Average Value (V/m) | Peak Value (V/m) |
|---|---|---|---|
| Broadband Zone | 21.7 | 0.69 | 0.77 |
| EGSM-900 | 31.8 | 0.11 | 0.12 |
| EGSM-1800 | 45.1 | 0.14 | 0.17 |
| UMTS | 47.2 | 0.13 | 0.16 |

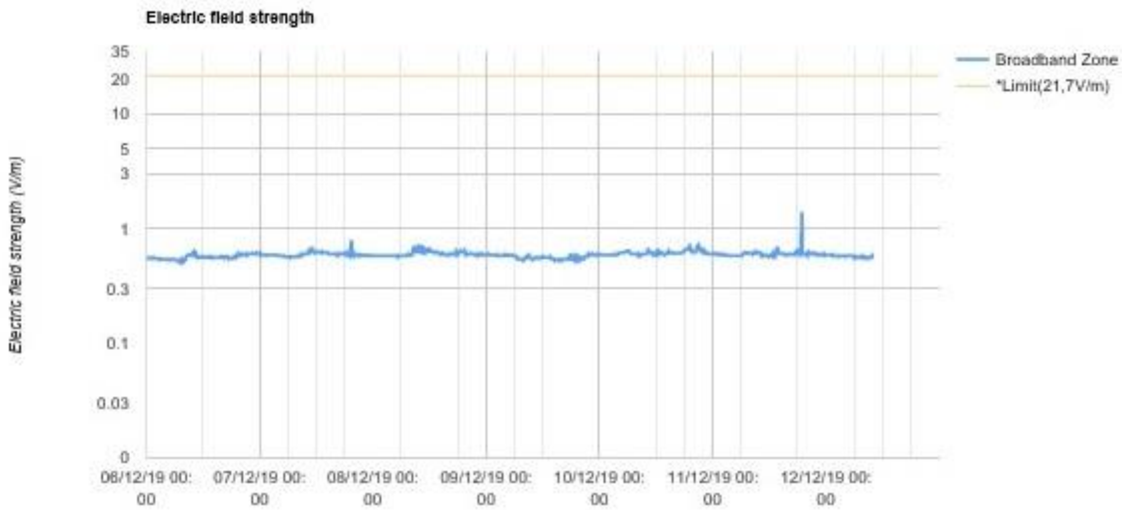
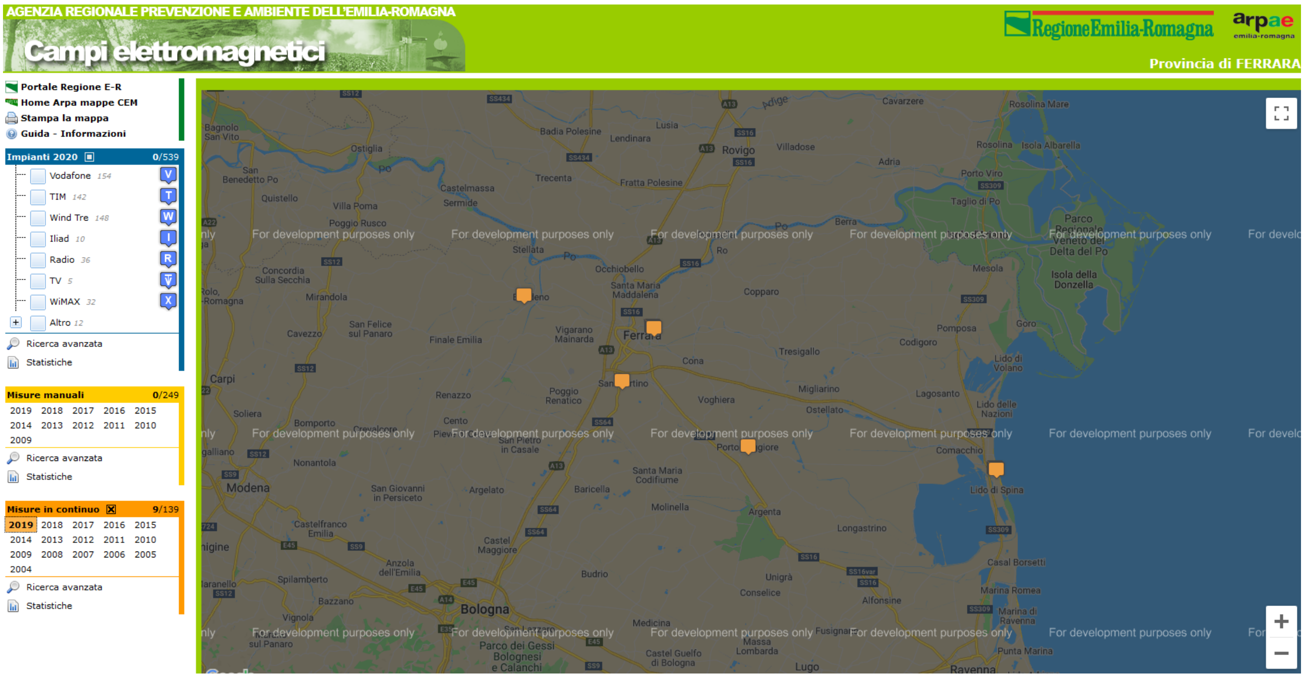
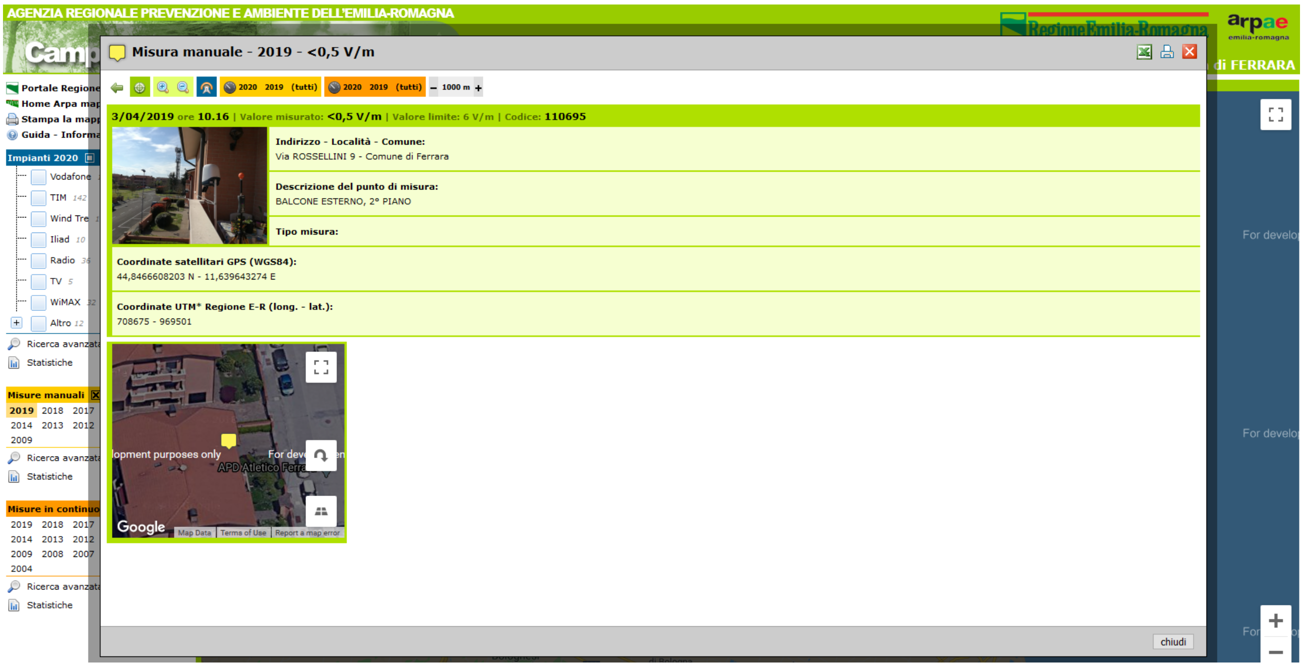


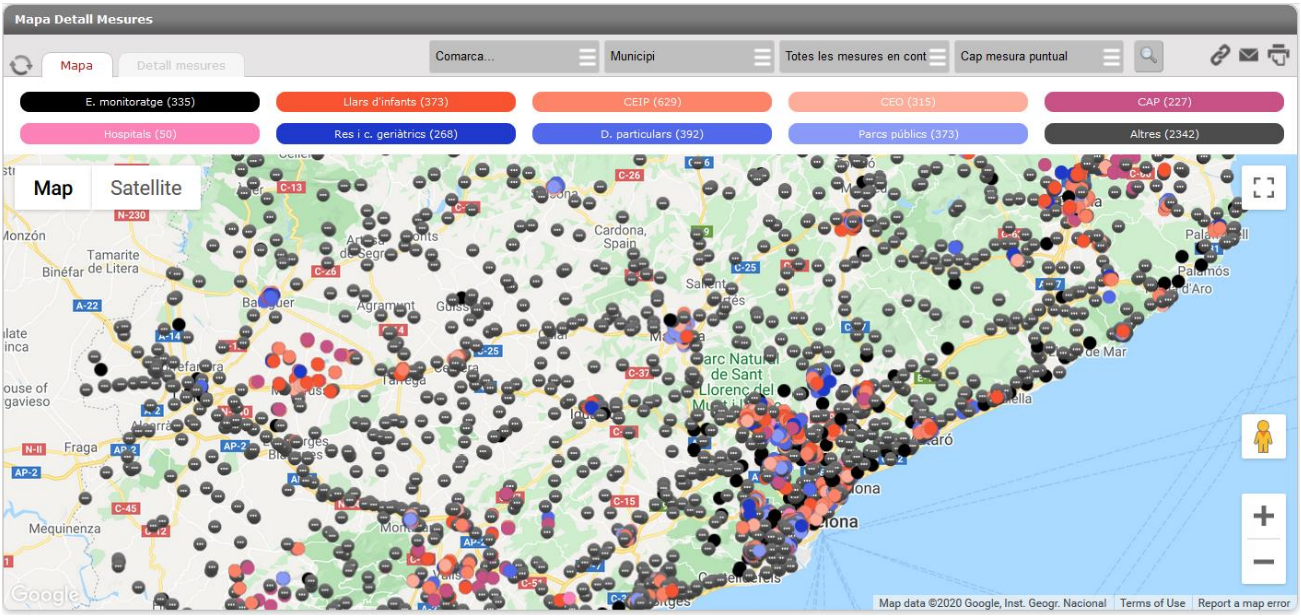

**Figure II.17 – Results of the EMF measurement**

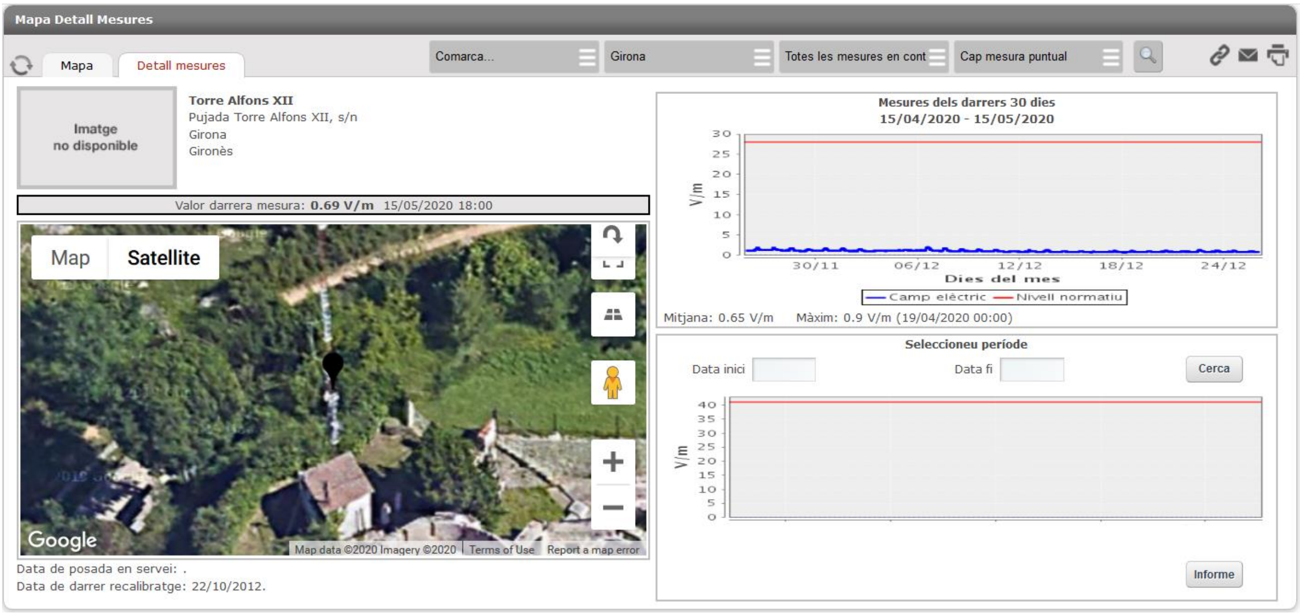
## II.8 EMF monitoring system in Italy






## II.9 EMF monitoring system in Catalonia (Spain)

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Comarca...
Girona
Totes les mesures en cont
Cap mesura puntual
Imatge
no disponible
Torre Alfons XII
Pujada Torre Alfons XII, s/n
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Data de darrer recalibratge: 22/10/2012.
Mesures dels darrers 30 dies
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