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To cite this article: Massimo Scalia *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **853** 012004

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# Electromagnetic characterization of the environment. An Italian experience and the “mapping” method

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**Abstract.** The “mapping” method is our original approach to obtain a more reliable electromagnetic characterization of the environment than the usual point-type method; and it is proposed after having tested it over time in various characterization campaigns. Specially with its improvement by resorting to GIS (Geographic Information Systems), the “mapping” method provides a more accurate report, closer to the real condition, to the Municipality committed to verifying compliance with the law of the emission exposure limits of radio transmitting stations and antennas installed in its borders, as well as to citizens concerned about this exposure; an indispensable basis for a possible more detailed health picture. In one campaign a check of the influence of electromagnetic field (EMF) on human cells has been realized. In the last campaigns a simpler representation, always of cartographic type, has been used to make easier citizens the understanding of the electromagnetic situation in their territory: the “pertinent lobes” model.

## 1. Introduction

What causes concern everywhere in the world for possible damage to health due to electromagnetic fields radiated outside by radio stations, antennas and inside by the huge number of household appliances starting from our inseparable cell phone? Has this geometric growth of artificial EMF, started after the Second World War, altered a pre-existent natural balance? Are the exposure limits proposed by international technical institutions adequate to safeguard our health? Is it true that there are no long-term risks such as leukemia or other forms of cancer?

Trying to answer these questions has led along these decades many municipalities or citizens committees to request an electromagnetic characterization of environment where they live, one of the relatively newer consequences of a scientific debate that began at the end of 19th century and is still ongoing today [1]. The request was almost always accompanied with an urgency of possible scientific explanations and of a deeper insight of EMF and their interaction with the human biology. This general framework has been the contour of each our campaign, thus we feel obliged to address those questions, even if very briefly, because they were intertwined with the measure operations and the data report on the investigated area (see below 1. and 2).

Further, the climate around our research field has been characterized by two sensational cases, of a wide resonance in Italy in the last two decades: Vatican Radio in Cesano (Rome) and MUOS in Niscemi (Caltanissetta). The story of the court case of Vatican Radio and that of the movement against MUOS, together technical profiles and scientific problems are reported in [2].



Vatican Radio is the widest installation of radio-transmissions devices of a foreign State in Italy. The judicial dispute about health impact of its emissions began at the end of the last century and was going on until few years ago. MUOS (Mobile User Objective System) is a telecommunications facility - a radar plus other antennas - serving the global satellite system of the United States of America with other three MUOS placed in other Countries to cover an overall the world surveillance.

### *1.1. Exposure limit values proposed by International Agencies, underlying models and some health consequences.*

The modeling, criteria and guidelines, which most countries refer to in formulating national standards on exposure levels and limits, have been proposed, starting from the 1960s, by ANSI (American National Standards Institute) and IEEE (Institute of Electrical and Electronics Engineers); and, subsequently, by WHO (World Health Organization) and ICNIRP (International Commission on Non-Ionizing Radiation Protection). All these criteria exclude the existence of specific effects of electromagnetic fields, the one "officially" recognized is that due to tissue heating, the "thermal" effect; so, the exposure limits are set according to the criterion that the intensity of the incident radiation should not cause, in relation to a predetermined duration of exposure, a heating of the tissue above 1°C. The health protection guaranteed by international technical standards therefore covers only the aspects resulting from the impact of radiation on body thermoregulation, the acute effects, that is, they dissolve in the absence of exposure; but it does not extend to the evaluation either of the recurrence of acute effects over time, nor, above all, of the possible damage related to specific effects, which unfold over longer times and which may concern multiple pathologies of the central and peripheral nervous system, and induction of tumors, mainly leukemia (non-thermal or long-term effects).

## **2. EMF don't stop themselves, respectfully, outside our skull**

The "thermal" model and the dosimetric approach, based on the SAR (Specific Absorption Rate), constitute the phenomenological and "theoretical" corpus on which the still dominant philosophy and protectionist criteria are based (ANSI, IEEE, WHO, ICNIRP). A different modeling is in fact possible, at the same time more realistic and more rigorous from the physical-mathematical point of view, up to the correct boundary conditions to be set for Maxwell's equations. Several models of the latter kind have been advanced by Ronold King (1981, 1995, 2000) [3, 4, 5, 6], Niels Kuster and Quirino Balzano (1992) [7] and other authors [1].

The difference with the model values underlying the limits proposed by the WHO and ICNIRP is striking and very relevant from the point of view of health, just one example: while the models adopted by the health protection agencies do not foresee that the radiofrequency EMF ( $\approx 1\text{GHz}$ ) can pass through the skin and bones of the skull, the value of 6 V/m, the one that the Italian legislation establishes outside the human body as an attention value, is still found, in the estimates of the aforementioned and much more accurate models, 5 cm. inside the brain! [3, 4, 5, 6, 7].

### *2.1. RF are possible carcinogens*

In a 2013 monograph, the IARC assessed that there was a sufficient evidence to classify electromagnetic fields at radio frequencies (RF) in group B2, i.e., as possible carcinogens; "limited" evidence among mobile phone users in relation to the onset of gliomas and acoustic neuromas, "inadequate" instead to draw conclusions on other types of cancer. In the press release presenting the monograph, the IARC working group recalled that over the last ten years, since 2004, there had been.

It is worth noting that the position that for brevity we have defined as "official", contrary to what is often stated in the press and on TV, is by no means "universal". The exposure limits for radiofrequency and microwave radiation in Russia and other Eastern European countries are much more restrictive than both the United States and Western European countries; this has been going on for 50 years, mainly due to the difference in views on what exposure standards should protect. In addition to Russia, the states that do not recognize themselves in the ICNIRP guidelines are Italy,

Switzerland, Belgium (Walloon region), Liechtenstein, Austria (city of Vienna), Luxembourg, Spain (Castile), Canada, Poland, Bulgaria, Chile.

A 40% increase in the risk of glioma in the category of users who use the mobile phone the most (30 minutes a day for a period of 10 years).

If the damage is “possible”, this only implies an alert and a continuation of studies and research; if the damage is probable, this obliges public health managers to set up adequate health protection measures. The results of several other researches, after carried out, have motivated sectors of scientific community to appeal for recognizing as “probable” the RF risk evidence.

## 2.2. Natural fields and artificial fields

The inevitable question arises: “Are electromagnetic fields bad for your health?” The question can be better articulated by referring to the distance from the source of the fields, their intensity, the duration of exposure and better defining that “bad”. However, the attempt to formulate an answer must be preceded by a fundamental reflection regarding the evolution that the natural environment has undergone due to electromagnetic fields artificially produced by electronic devices, whose diffusion has proceeded in geometric progression since the Second World War.

Over millions of years, and as far as we - homo sapiens - the last two hundred thousand are concerned, living beings have established a balance with the natural electromagnetic environment, the values of which we report in Table 1a). The Earth, as we know, has its own electrostatic field and its own magnetostatic field and then with time-varying fields over a wide band of frequencies, due to natural phenomena.

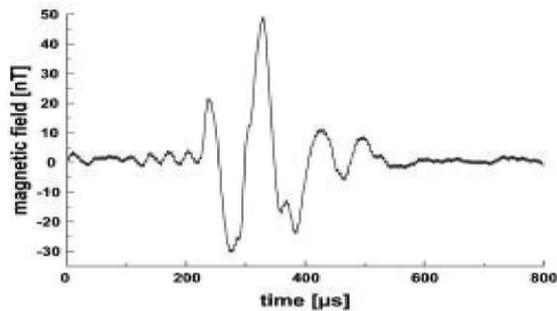
**Table 1.** Natural background (effective value).

Source	Magnetic induction	Electric Field	Frequency
Atmospheric electric field		80-150 V/m	0 Hz
Unperturbed field *		<0.5 V/m	0 Hz
Geomagnetic field	Equator ~ 20 $\mu$ T Poles ~ 70 $\mu$ T Italy ~ 40 $\mu$ T		0 Hz
Schumann's resonances	3 pT		8 Hz
Thunderstorm activity	< 0.1 nT	max 0.5 V/m	5 Hz - 1 kHz
Thunderstorm activity	0,05 nT	0,01 V/m	50 Hz
Thunderstorm activity	Max 50 nT	max 50 $\mu$ V/m	1 kHz - 10 MHz
Natural background (cosmic noise)		194 $\mu$ V/m	10 MHz – 30 GHz

Notes:

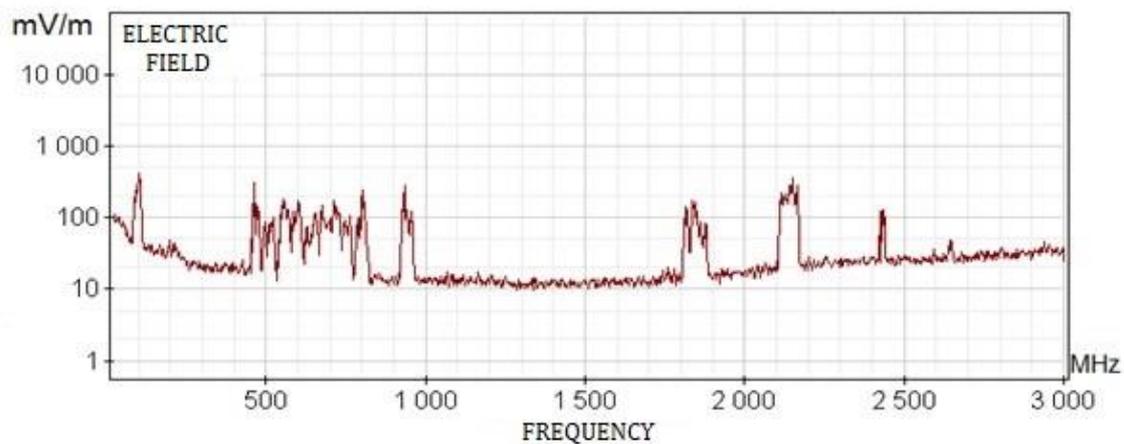
\*It is the “background”, that is the natural electric field present in environments shielded from the atmospheric electric field such as under trees, inside a cave or in buildings in general.

The characteristic of this natural electromagnetic activity is that it is generally produced, as regards the variability over time that is the frequency, in the form of spikes, of impulses distributed over time in a random and non-continuous way. The graphical representation as a function of time of this situation, which is the electromagnetic natural background, would correspond to short sections of curves that describe irregular oscillations, randomly present in the different frequency regions. In short, the spectrum would be essentially “empty” if not for some bands; a possible model is the one represented in Figure 1 for magnetic field in the band around 10 MHz.

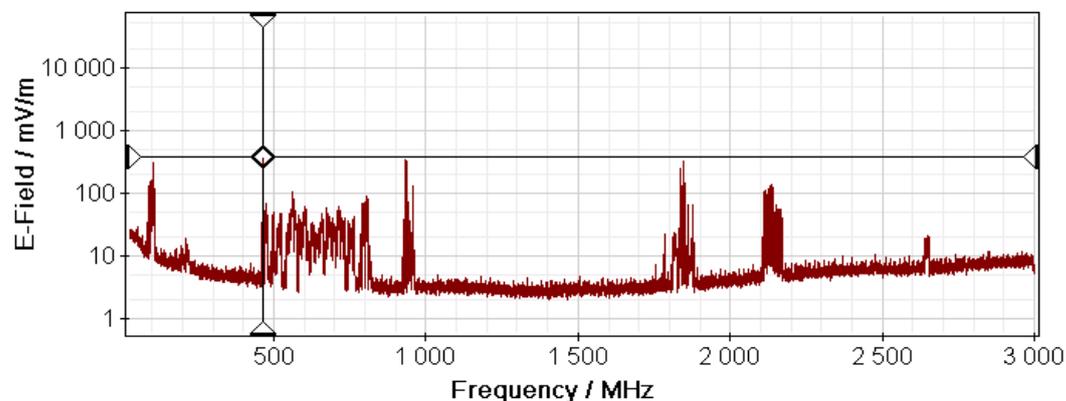


**Figure 1.** The figure shows the typical trend of the magnetic component of a natural EMF due to thunderstorm activity. The time interval in which the magnetic field remains appreciably different from zero is only about 0.3 ms, the peak value is 50 nanoTesla [1].

On the contrary, the presence of artificial fields has progressively invaded the entire electromagnetic spectrum with continuity, at least up to 3 GHz, justifying the concept of “electromagnetic pollution”, or “electro-smog”, and producing a situation such as those represented in Figure 2a and 2b).



**Figure 2a.** The spectrum, measured in an unconfined air environment in an area of Rome (Cinecittà Est), extends from 26 MHz to 3 GHz. The first peak on the left indicates FM radio broadcasts. Digital TV broadcasts begin immediately after the 400 MHz frequency. Around 900 MHz there is GSM telephony and the two peaks centered at 1.9 GHz and 2.2 GHz are the emissions of the UMTS system [1].



**Figure 2b.** The spectrum in the frequency range of Fig. 10 b), recorded indoors in the premises of the University of Tor Vergata in Rome, shows the same peaks in the same bands, but the background is about half (10 mV). This applies in general to housing [1].

The comparison between the two situations, natural background/artificial background, would require a spectrum analysis similar to that of Figure 2b, but for an uncontaminated environment. Since such a complete survey is not available at the moment, reference can be made to the effective peak value of the natural background, which in the high frequency region (10 MHz, 3000 MHz) is equal to 194  $\mu\text{V/m}$  (0.2 mV/m); assuming it as an average value, the extent of the natural field is strongly overestimated, but nevertheless the average value of the artificial background, equal to about 20 mV/m as can be deduced from Figure 2b), is at least one hundred times higher than the natural one, as we have approximated it upwards. If we then look at field measurements carried out immediately outside or even inside homes and schools, with values from 2V/m to 20 V/m, in areas exposed to radiofrequency antennas, in these "hot spots" the mean value of the field is ten thousand to one hundred thousand times higher than that of the natural background in the same frequency region.

### 2.3. *The evolutionary balance*

These considerations make it clear, first of all, that the comparison between artificial fields and natural fields must be made with the values of the different frequency bands, which are very different, and not with the static case. And how completely misleading certain public statements are, let's think of those made by Umberto Veronesi in his dual role as doctor and Minister of Health precisely at the time of the Vatican Radio issue in the spring of 2001: "... we are therefore suitable, evolutionarily speaking, to the terrestrial electromagnetic field, as if to say that our cells are naturally compatible with this kind of radiation." Of course, an evolutionary balance has been established for our cells and our bodies with the electromagnetic fields present on earth, but over two hundred thousand years and with the natural values of the fields!

It is therefore more than understandable that not only the man in the street asks himself the question of what happens to an equilibrium disturbed by such a strong shock: an exponential increase in the values of the artificial fields achieved in the last sixty years, i.e., a very short time, less than a thousandth of the time duration over which the evolutionary history of homo sapiens unfolded.

## 3. Methods and tools for the electromagnetic monitoring of the environment

### The "mapping" method

As stated in the title of this paper, and underlined in the Introduction, the core of this research is to apply a method of electromagnetic characterization of the environment different from the usual ones in order to obtain a more faithful and precise information to better enlighten health problems, possibly due to EMF exposure in the different frequency band.

#### 3.1. *EMF "mapping"*

The detection of the electromagnetic field of low and high frequency in environmental surveys is usually of the punctual type: through qualitative tests, the sites where the field has the maximum intensity, or power density, are determined, and then we proceed to the rigorous measurement of value. The idea behind this operating mode is the model according to which the only biological effects due to the interaction of the electromagnetic field are acute: thermal, for high frequency fields (> 10 MHz), stimulation of nerve receptors, for those of low frequency. In this perspective, the only significant protectionist element is the determination, both in urban and rural environments, of the points in which there is a "dose" of the field capable of triggering such acute effects in exposed subjects.

To take into account the long-term or chronic effects, we proposed, starting from 1997, to substitute a "mapping" of the electromagnetic field for the punctual type of monitoring.

For the first campaigns, no tools were available that linked the rigorously measured data in the field, and in any case many more than in usual punctual-type survey, with a digital representation of objects on a map; nevertheless, it was possible to provide the data with a mathematical "metric" to "spread" them on areas of different electric field intensities. This is the sense of "mapping", and the method became more complete and suitable to its purpose when it was possible to resort to GIS (Geographic

Information Systems), as we were able to put into practice in the campaigns for Rocca di Papa (Rome) and Guadagnolo (Rome), described below.

In general, following the “mapping” method, the territory is divided into colored areas or zones, each indicating specific ranges of electromagnetic field. By adopting this method, it is possible:

- obtain qualitative information on the chronic exposure of living beings (man, fauna and vegetation) to artificial EMF;
- study the trend, over the years, of the electromagnetic pollution of a given area;
- correlate clinical and epidemiological data with the real values of the electromagnetic field.

In the following cases, Rocca di Papa and Guadagnolo, for the realization of the mapping we could use a program and as basic cartography (ArcGIS 9.3), regional technical maps (scale 1: 10000), aerial photos and orthophotos.

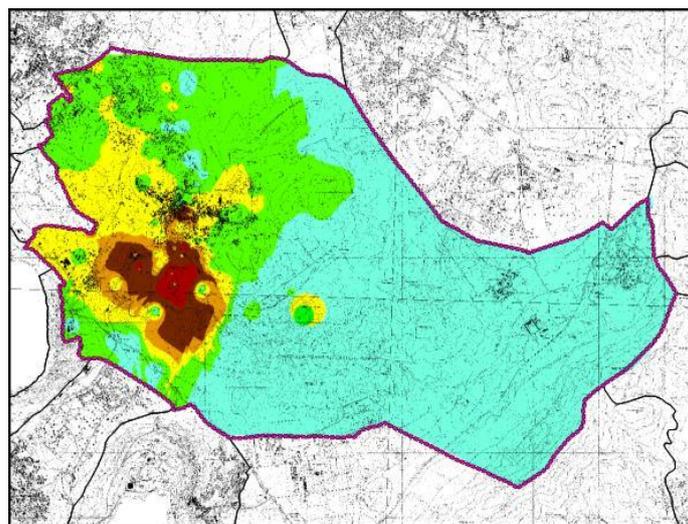
### 3.2. Interpolation of points

Environmental data is collected as discrete observations, as points. Thus, arises the need to convert discrete data into continuous data. The derivation of continuous surfaces starting from point-type data is an analysis method with numerous applications, ranging from the creation of maps of environmental parameters (temperature, humidity, precipitation, etc.) to, in more recent times, the generation of Digital Terrain Models (DTM) and the representation of other physical or geographical variables [8]. GIS allow digital representations of objects on a map to be connected with a database that describes that object, a true revolution in cartography. Because the element that more than any other influences the interpolating surface is the algorithm to which one can resort, we have preferred the Inverse Distance Weighted (IDW), using the ArcGIS Geostatistical Analyst extension.

### 3.3. It represents that interpolation method in which each measured point has an influence that decreases with distance

The simplest weighted interpolation formula for IDW is called the “Shepard method” [9], based on relatively simple mathematical equations. The obtained results are represented in Figure 3 and 4.

After the results of the two mappings of Rocca di Papa and Guadagnolo, a test was performed on human cells as “spot” measurements in the areas already characterized, observing cellular apoptosis. The complex biophysical and biochemical procedures followed, and the tools used were described in a valuable doctoral thesis and reported to a public scientific conference [10]. Different colours represent, with an obvious graduation, the RMS (Root Mean Square) values of the field strength RMS values of the field strength.



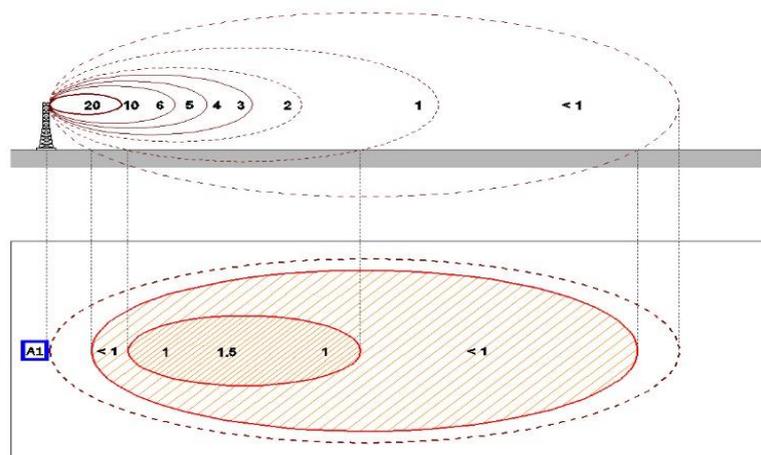
**Figure 3.** Characterization of the electromagnetic environment of the municipality of Rocca di Papa (1: 50,000) [10].



**Figure 4.** Characterization of the electromagnetic environment of Guadagnolo, a fraction of Capranica Prenestina (Rome) (orthophoto, 1: 2000) [10].

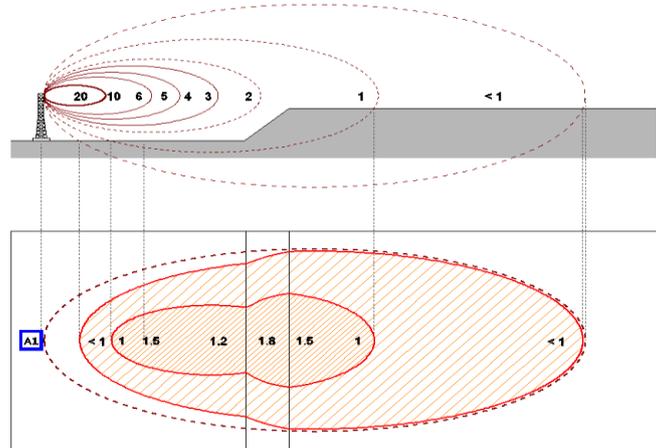
### 3.4. "Pertinent lobes" model

The "mapping" method, which we introduced as an original contribution to account the EMF characterization of environment, is the best we know for this purpose and represents a necessary premise to give precise answers to health issues (for instance, beginning from biological tests on human cells). The method is truly demanding in terms of time and, consequently, of costs for measure operations and data elaborations such as we have above explained. A simpler method, even if not as rigorous as the "mapping" one, aimed at facilitating, again in terms of cartography, the understanding of the levels and places of greatest exposure, can be achieved with the "pertinent lobes" model, that we have used first time in a campaign requested by the municipality of Castelnuovo di Porto (Rome) (2015); and we are using in an ongoing campaign in Fara Sabina (Rome). Without going into details, we can give an idea of how it works by showing the diagrams in Figure 5, 6 and 7.



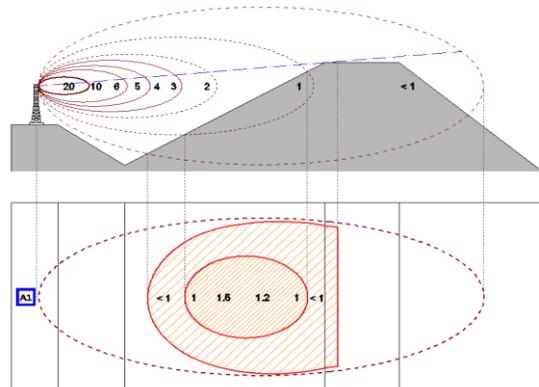
**Figure 5.** Intersection with the ground surface. The numbers represent the electric field intensity in V/m.

A source placed over a flat stretch generates a long intersection with the ground, so even a considerable distance continues to record field values, albeit low. The volt/meter values indicated in figures translate those detectable experimentally.



**Figure 6.** Intersection with ground reliefs (like a hillock).

In the case of a source with reliefs facing, in addition to a longer projection of the presence of the field, still high values are usually recorded even at medium distance, even if the ground can reach the height of the source.



**Figure 7.** Front-valley case.

In Figure 7, the model has no intersections with the ground in the hollow part. On the other hand, on the relief facing the installation, although distant, non-negligible values can be measured also at altitudes higher than the installation height of the support. If these are inaccessible or difficult to access, so that it is not possible to carry out an instrumental measurement, it may be useful to adopt the trend of the model.

To define the mapping, the analysis is conducted both in high and low frequency in all open environments, but also in some closed environments of public importance (schools, hospitals, shopping centers, etc.).

#### 4. Instruments for measuring field intensity

The two instruments mainly used for measuring artificial electromagnetic fields are: PMM 8053B, which is a versatile and expandable system, with EHP-50C PROBE and EP 745PROBE, suitable for measuring the intensity of fields - electric, magnetic and electromagnetic - as a function of frequency, both in a confined and outdoor environment; SRM-3006, a compact measurement system, which allows to carry out environmental measurements of electromagnetic fields by highlighting the spectral

components of the field in a given frequency range (See Figure 8). The measurements that can be carried out with this instrument are the following:

#### **PMM 8053 - EHP-50C PROBE**

Electric fields from 5 Hz to 100 kHz, minimum value 10 mV/m;

Magnetic fields from 5 Hz to 100 kHz, minimum value 10 nT;

Electromagnetic spectrum from 5 Hz to 100 kHz (minimum values 10 mV/m and 10 nT)

#### **PMM 8053 - EP 745 PROBE**

Electric field component of electromagnetic fields from 100 kHz - 7 GHz, minimum value 0.35 V/m

#### **SRM - 3600**

Electromagnetic spectrum from 27 MHz to 3 GHz (minimum value 25  $\mu$ V/m)

Time course of radar signals and pulsed fields from 27 MHz to 3 GHz



**Figure 8.** Instrumentation for the characterization of the electromagnetic environment.

## **5. Conclusions**

The idea of a “mapping” method to substitute punctual-type measurements, the latter aimed to catch “hot spots” of electric field intensity, has been confirmed as the best to obtain necessary and reliable information for assessing, after the characterization, the possible health impacts. Its development along twenty and more years has arrived to the top when it has become possible to resort to GIS and interpolations methods we have used in the above illustrated cases. Accompanying the electromagnetic characterization with an analysis of the variations in human cell cultures exposed in a well determined site of the “mapping”, it is the first signifying step to assess possible health harms.

The method we have carried out and its applications are the core of our research, but as we have emphasized its effectiveness, we have at the same time remembered its costs, also in terms of the requested time. To manage a less demanding method than the “mapping” one, we introduced and still use a simpler, even if reliable and satisfying, method: the “pertinent lobes” model, which we have presented here.

All the results provided in this article have not yet been published in scientific journals.

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