

Non Ionizing Radiation: Development of fixed stations that allow their monitoring through the Internet Network Monitors

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Abstract. The present work aims to describe the development of a fixed station to monitor NIR. Using Internet access, this monitoring detection service enables public display of the location of the station, the radiation level, and its evolution throughout the day. The design takes into account availability, accessibility, and feasibility of the technological and human resources in our country.

Key Words: NIR, Microcontroller, Current Legislation, Probe, GPS.

1. Introduction

An electromagnetic signal transports energy from one point to another in space, as a result of a composition between the magnetic and electric field. Transmitting devices of this type of energy can be artificial, whenever its presence is the product of human intervention, or natural, whenever human action does not take place.

Natural fields originate from atmospheric discharges and from cosmic and solar noise. Their levels are normally less than those from artificial fields. Living organisms can tolerate them perfectly because, since the beginning of life, their evolution has taken place in the presence of such fields.

In recent decades, as a result of technological development in communication and electronics, the emission of electromagnetic radiation has increased considerably.

These emissions originate mainly from transmitters used in radio electric communications, tools and machinery which produces sparks or can generate electric signals, starter systems in engines, and devices used in industry, science, and medicine, as well as in our homes.

Receivers may be communication or navigations systems, different types of devices (industrial, scientific or medical), computers, or engines. In addition, living organisms (animals or plants) can also behave as a receptor antenna, depending on their geometry (size) and the elements in their composition.

With IONIZING RADIATION (IR), the most important effect is the ionization of matter molecules; for instance: X-Rays, Gamma radiation, and cosmic radiation. Risks associated with the use of X-Rays and Gamma radiation has been thoroughly studied in medical, nuclear, and industrial applications. Their effects are widely known, possibly leading to severe consequences.

Therefore, IR has been the focus of special consideration, developing safety regulations and establishing exposure limits to protect people who suffer from exposition in their daily labor, as well as the public in general [1].

The term NON IONIZING RADIATION (NIR) is applied to a group of radiation which shares the electromagnetic spectrum with IR. NIR, as opposed to IR, does not have enough energy associated to alter molecular structures or break chemical bonds, and hence to originate the process of cellular ionization.

NIR comprise a large part of the electromagnetic spectrum. Such radiation cannot be perceived by human senses unless its intensity reaches values large enough to manifest itself through thermal effects. The exception corresponds to a very narrow band within the spectrum, visible light, which is detected by the eye.

In recent years, research has focused attention on the possible non thermal or biological effects of NIR generated at low levels and under prolonged exposure [2]. The results obtained so far do not permit neither assure nor deny damaging effects on human health. Thus, the World Health Organization (WHO) recommends the use of *the Principle of Caution*.

The principle, of difficult application, has been somewhat quantified by Swiss authorities with the development of Installation Limit Values (ILV) [3]. These values were implemented in Switzerland in the year 2000 and cover different bandwidths, ranging from the electric network to cellular phones, AM and FM stations, TV signals, and even radar.

General exposure to artificial sources of radiofrequencies and microwaves has increased exponentially in the last decades. Among the most common sources, the following are worth noting: the wide range of telecommunications, Internet use (Wi-Fi, Wi-Max), radio and TV stations, electric energy generation and distribution, industry, medicine, research, education, and home appliances.

NIR exposure and its possible effects concern not only authorities, but also workers suffering from exposure, as well as the general public.

When dealing with radio electric emissions, such as those originated in communication systems, public and private concerns meet on the same ground, coming from such different fields like health, the environment, urbanism, and economics. Thus, appropriate regulation becomes necessary to reduce uncertainty and to allow, at the same time, the adequate development of the interests and the protection of the rights of the parties involved.

The unification of criteria for NIR measurement and the interpretation of the results have become necessary. Currently, great concern in the international community on these parameters has given place to the development of a set of standards called Standard Harmonization or Regulation Harmonization.

2. State of the Matter

2.1 Standards Organizations and their Measurements.

The World Health Organization (WHO) has taken great effort in this issue. The International Commission for Non-Ionizing Radiation Protection (ICNIRP) is part of the WHO system devoted to assess and inform international organizations, national governments, local communities, and society in general. It develops recommendations regarding NIR and health, including optic radiation, ultrasound, and infrasound.

Vecchia in the year 2008 in a lecture at the COPITEC commented that the process of electromagnetic energy absorption depends on the frequency, height, and mass of the person acting as a receiving antenna, as well as on the energy involved. Thus, *specific absorption rates* (SAR) have been defined and they have been established at 0.4 W/kg for workers and 0.08 W/kg for the general public [2].

In this framework, defining parameters to measure and establish the concept of risk or radiation threshold becomes relevant.

In the case of thermal effects, threshold values are based on the SAR, which is the potency absorption capacity per unit of mass. Considering the difficulties in measuring this parameter in practice, values are stated in units of electric and magnetic fields and the potency density equivalent to the plane wave.

Under low frequency rates, the magnetic field becomes significant because the electric field attenuates rapidly. The variable magnetic field, due to the Law of Faraday, induces currents in the human body which may affect the person. For instance, the magnetic field at 30 meters from a high voltage tower is $0.8 \mu\text{T}^1$, while a hair drier ranges from 0.01 to $7 \mu\text{T}$ at a distance of 30 centimeters. A microwave oven ranges from 4 to $8 \mu\text{T}$.

In the case of cellular communications, working at high frequencies, the electric and/or magnetic field is measured, expressing it as potency density equivalent to the plane wave. For example, an FM station emits from 10 to 100 times more potency than a cellular communications station.

¹ μT : micro Tesla: Tesla = weber/m², Unit of Magnetic Induction or Magnetic Flux Density (Vector B)

In our country, standards are based on Resolution 202/95 from the Ministry of Health, resulting from studies dated back to 1988 [4, 5]. These standards also follow the recommendations of the ICNIRP [2], except for those in the frequency range lower than 10 MHz.

The SAR is proportionate to the square of the intensity of the internal electric field and is measured in watts per kilogram for the body. Thermal imaging is used to determine distribution. Local measurements are carried out with probes.

With these methods, the energy absorbed can be determined, as well as the time of exposure and the internal distribution of energy. It depends on: a) the parameters of the field; b) the characteristics of the body exposed; and c) the effects of the land and the reflection of other objects.

The response to exposure depends on the average SAR in the entire body and its distribution. This response varies in different species and, within the same species, with the genetic variability of each individual. Same SAR values in animals and humans do not necessarily produce the same biological responses.

The following graph shows maximum threshold levels in potency density equivalent to the plane wave for Argentine general population (Curve C) and work related exposure (Curve A).

Note that of the three curves in the general population (B, C, and D), even when C was selected and is currently the standard, curve D is the one that matches ICNIRP recommendations.

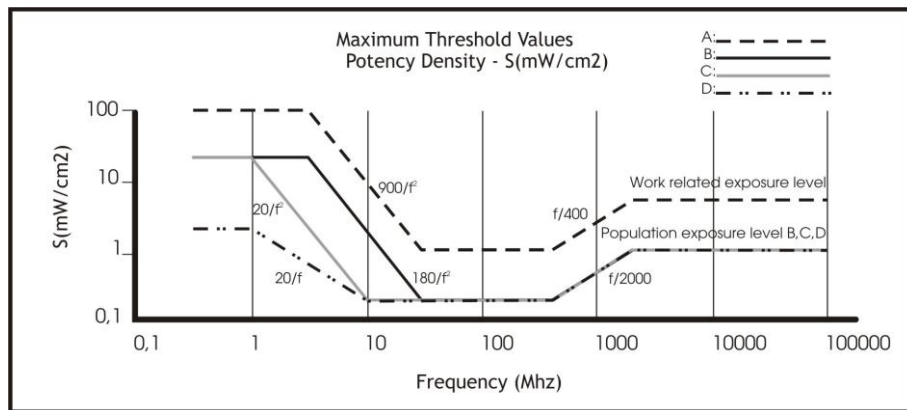


Figure 1: Threshold Limit Values – Potency Density [4, 5]

2.2 Standards

Setting standards can be tackled from different viewpoints, which are not necessarily incompatible:

1. From the standpoint of the general public who dreads the consequences of the lack of control.
2. From the point of view of service providing companies that aim to provide a service at a profit, but avoiding environmental conflicts.
3. From local government concerns in which the state needs to play social and auditing roles without entering into additional costs.
4. From the professional point of view, requiring clear, simple, uniform, and appropriate regulations.

2.3 Comments on Resolution Number 3690

In 1995, with Resolution 202/95 [6], the Ministry of Health and Social Action agreed “to approve the National Safety Standard for radio frequency exposure in the range of 100 KHz and 300 GHz, according to the safety standards manual for radio frequency exposure.” [4, 5].

Later, in the year 2000, the Secretary of Communications, with Resolution N° 530 [7], ratified the standard and established that “...the National Communications Commission (CNC) shall report in its due time the findings of new research which may require updating to what is established hereinto, to ensure the wellbeing of the population subject to such radiation exposure.”

Finally, the CNC, with Resolution 3690 in 2004 [8], set the norms that regulated sites emitting radio frequencies and determined the application of such regulation, requiring the intervention of a professional certified by the Professional Council of Telecommunication Engineering, Electronics and Computer Science (COPITEC), with national jurisdiction.

2.4 NIR Measurements

Growing social concern has forced local governments to carry out radiation measurement on their own, purchasing imported devices without the services of specialized professionals, and, commonly, without following the periodical protocols to calibrate the equipment. In other cases, local governments have required service providers to record radiation measurements occasionally (once or twice a year).

Regularly, the results of such measurements are not clearly presented to the population; hence, an increase of social concern has resulted.

Experiences in other countries regarding this problem reveal the joint actions taken by the public and private sector. In our country, a *Code of Good Practice* is under

development between the Argentine Federation of Local Governments and the companies which operate cellular communications.

In addition, the Foundation for the Development of Telecommunications, Electronics and Computer Science (FUNDETEC), under the wing of COPITEC and working with a consulting organization from FAM, has developed a NIR fixed monitoring device whose results are published at <http://rni.copitec.org.ar>.

Thus, using Internet, anybody can access remotely and review the existing levels of NIR (compared to the maximum threshold) in the area where the measuring device is set, upon request from a local government. The equipment has been developed by Argentine professionals, and their performance match imported equipment at a cost significantly lower and with additional features.

2.5 Comparison of Standards

Given the diversity of criteria regarding our regulation when dealing with NIR at the high frequency range, i.e. cellular communication, FM, AM, open TV, a suitable approach is perform a comparative analysis with other standards such as those recommended by the ICNIRP [2] (in use in the European Community) and those adopted in other countries.

The following graph compares the Argentine standards to the ICNIRP recommendation and the regulation standards of Canada and the United States, for the general population.

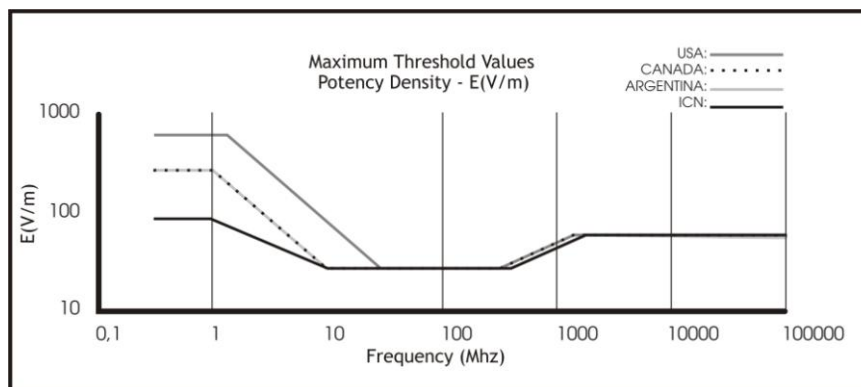


Figure 2: Threshold Limit Values – Electric Field

The graph shows that our standards, for frequencies higher to 10 MHz are equivalent to the ICNIRP recommendation and similar to Canada; while the United States begins to match Argentina at 30 MHz.

Hence, Argentina has a regulatory framework more rigorous than its equivalent in the United States in the range below 30 MHz, but less than the recommended ICNIRP standard. Furthermore, the standards are practically equivalent to the case of Canada.

Note that standards are based only on energy and thermal issues and not on biological effects.

3. Development of a NIR Remote Measuring Unit.

3.1 Conceptual Diagram of the Measuring Process

Conceptually, the system can be visualized as follows:

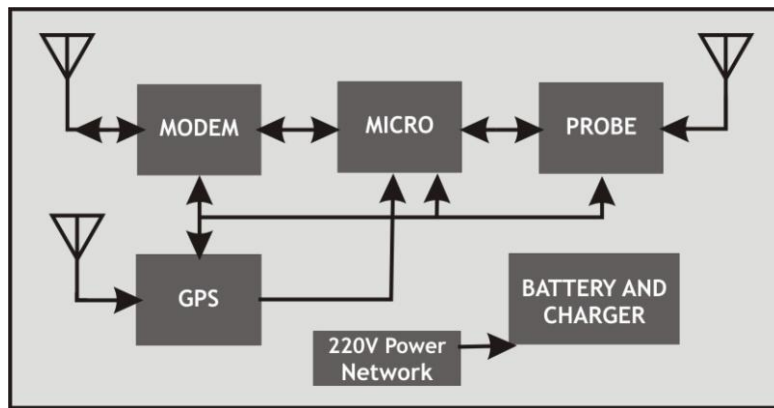


Figure 3: Conceptual Diagram

For our system, it developed into the following electric diagram:

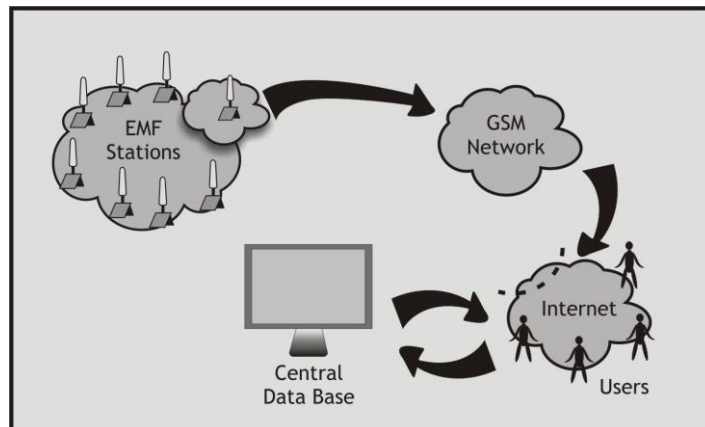


Figure 4: Electric Diagram

The measuring device is a calibrated PROBE (antenna) which translates into electrical values the intensity of electromagnetic radiation interacting with it.

Such values are registered by a MICRO block (microcontroller), establishing communications and operating the whole system.

A GPS device can determine the geographical location of the system with great precision, as well as the location registered by the MICRO.

For GPS outgoing messages, a protocol NMEA [9] is used, filtering through software only the GGA output. Considering that this event occurs once every second synchronized with UTC time, it was used as time set. In other words, MICRO obtains time, latitude, longitude, and bit data, validating the recorded data every time the GPS delivers it.

For example, the following GGA chain might be delivered by the GPS:

```
$GPGGA,002153.000,3342.6618,N,11751.3858,W,1,10,1.2,27.0,M,-4.2,M,,0000*5E
```

The location, along with the PROBE data, is sent to the MODEM block. Based on the GPRS/GSM standard for cellular communications, the device connects to a remote server wirelessly, via Internet. The server stores the measurements and presents the recorded values of all remote devices on a webpage, available to the general public.

The PROBE is an active device which generally includes a display and is battery operated. It may have an RS232 interface for initialization and operates under a licensed protocol. The prototype includes a battery charger. The device charges from 00:00 a.m. to 06:00 a.m. to avoid interference; during this period the equipment remains inactive.

The MODEM, with TCP/IP protocol included, solves any access conflict between the remote units and the server. A Motorola G24 MODEM is used in this case, based on an AT licensed command set [10].

The battery permits operation during power shortages. It lasts for 24 hours.

The prototype is set up on a 10 x 20 centimeter base and has five RS232 interfaces: for the MODEM, the GPS, and the PROBE (with galvanic insulation to avoid errors), and two interfaces for general use and future applications.

The equipment is set up with a 12V 7AH battery of free maintenance in a plastic waterproof cabinet.

3.2 A few Considerations about Design

An **Atmel** microcontroller was chosen for this system: the **ATmega 162** [11, 12], programmed in “C” Language with a third part IDE, on a PC with Atmel’s kit

STK500. However, similar software could have been used, such as **Microchip** or **Freescale**.

The size of executable code is approximately 5 KB. Special attention was paid to situations that could freeze the system; for instance when waiting for a MODEM response that never reaches the server due to a malfunction or excessive delay (non operative network), or other problems with the service.

The basic steps for a successful link are:

- a) Modem initialization and logging into the GSM network.
- b) ISP connection request. The network assigns a dynamic IP.
- c) Server remote port access.
- d) Data transmission, when the previous steps have been successfully fulfilled.
- e) Port closed and MODEM turned off.

During this procedure, PROBE measurements are not recorded, because the intense and proximate signal from the MODEM could interfere with them. Measurement registration resumes once the MODEM is turned off. In addition, the PROBE does not have a galvanic connection with the rest of the equipment to avoid altering the results.

Measurement criteria are based on recommendations requiring a series of samples – in this case 36 values are taken at 10 seconds intervals – during 6 minutes. Later the average is calculated and the maximum is recorded. This method yields results which represent the effects on human exposure to NIR.

Given the type of PROBE selected, which is wide bandwidth, the Argentine norm determines that the maximum threshold levels shall not exceed $200 \mu\text{W}/\text{cm}^2$, either on average nor maximum levels.

The equivalence relationship between units is:

$$\frac{\left(\frac{V}{m}\right)^2}{Z_0} = \frac{W}{m^2} \quad \frac{W}{m^2} = 100 \frac{\mu W}{\text{cm}^2}$$

Where Z_0 : vacuum impedance = $120 \text{ PI} \sim 377 \text{ ohms}$

3.3 Operation

The remote station sends information of radio frequency electric field and location determined by the GPS with the GPRS module. Then, it logs into a web server at the processing center, storing the data in an SQL database.

Stored data is then inputted to the graphing software to locate the remote station on a city map. Google Maps are used to locate the monitoring station, as shown in the following graph:



Figure 4: Map with station locations

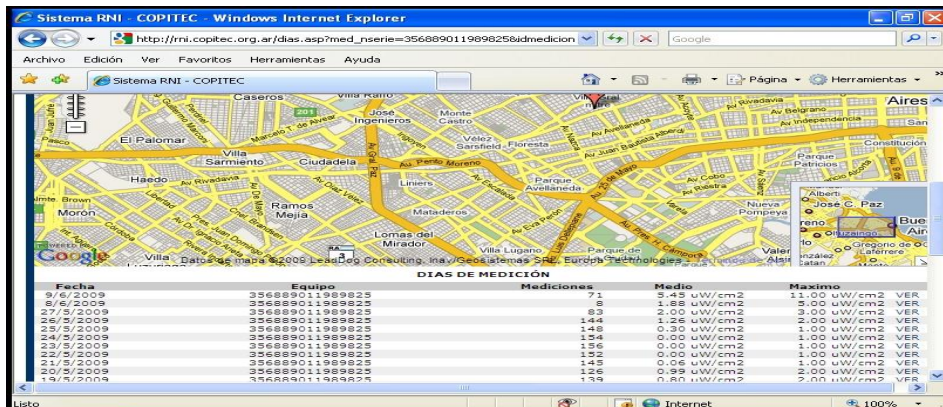


Figure 5: Daily Records

The software shows, on a webpage, the last average value measured with an icon indicating the monitoring station. It also displays the maximum peak registered (MPR) and the limit established by regulation.

When clicking over *See Days*, the daily evolution of electromagnetic radiation is shown. In this case, a window opens with daily records, allowing the user to select the desired days.

By selecting a day on the open table and clicking on *See*, a new window opens with a graph displaying the daily record of electromagnetic radiation, showing the evolution of the average value of potency density equivalent to the flat wave (averaged every 6 minutes) and the peak value, registered 24 hours a day.

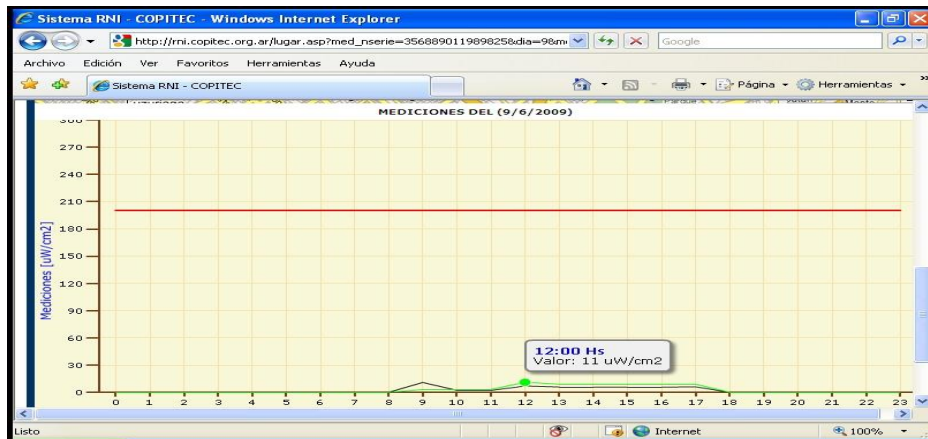


Figure 6: Evolution of the radiation level

4. Preliminary Conclusions

A significant strength of this system is its local design, components, and associated services which are easily found in the domestic market at a reduced cost

On the other hand, the imported sensor or probe might constitute a weakness of the system. Its value could turn the system expensive, depending on the bandwidth to cover. For the range used by cellular communications only, the cost is moderate. In the case that a wider range is desired, for instance from 0,5 to 5 GHz, the cost increases significantly.

Consequently, agreements have been pursued with technological development organizations with transference capabilities to assess the implementation. The model in use currently is loaned to the “Environmental Protection Agency” of Buenos Aires.

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References

1. ICRP, 1991b. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60, Ann. ICRP 21 (1–3).
2. International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz). Health Physics, Vol. 74, No. 4, pp. 494-522, April 1998.
3. Swiss Agency for the Environment, Forests and Landscape (SAELF) “Regulation for Protection of the General Population in Switzerland”, Suiza 2000.
4. A. Portela, J.J. Skvarca, E.B. Matute Bravo and L.A. Loureiro, “Prospección de radiación electromagnética ambiental no ionizante”. Volume I: “Manual de estándares de seguridad para la exposición a radiofrecuencias comprendidas entre 100 kHz y 300 GHz”, Ministerio de Salud y Acción Social de la Nación. República Argentina, 1988
5. A. Portela, J.J. Skvarca, E.B. Matute Bravo and L.A. Loureiro, “Prospección de radiación electromagnética ambiental no ionizante”. Volumen I: “Radiación de radiofrecuencias, consideraciones biofísicas, biomédicas y criterios para el establecimiento de estándares de exposición”, Ministerio de Salud y Acción Social de la Nación. República Argentina, 1988
6. Resolución N° 202/95 – Ministerio de Salud y Acción Social de la Nación, República Argentina, 1995.
7. Resolución N° 530/00 – Secretaría de Comunicaciones de la Nación, República Argentina, 2000.
8. Resolución N° 3690/04 – Comisión Nacional de Comunicaciones, República Argentina, 2004.
9. Protocolo de salida para GPS: NMEA Reference Manual Rev. 2.1, December 2007.
10. Motorola G24 Developer Guide, AT Commands Reference Manual, May 31, 2007. www.motorola.com
11. Atmel AVR Microcontroller ATmega162 Datasheet, 2513I-AVR02/07.
12. Atmel AVR Application Notes. www.atmel.com.