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Assessment of a non-ionizing radiation measuring system to be used by the Ecuadorian Agency for Regulation and Control of Telecommunications

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Abstract. The Ecuadorian Agency for Regulation and Control of Telecommunications (ARCOTEL) is a public entity in charge of supervision of telecommunications in Ecuador. One of its main duties is to assess the non-ionizing radiation compliance. In that regard, ARCOTEL counts on a legal instrument called "Regulation for human protection against non-ionizing radiation caused by the use of the radioelectric spectrum" that states an EMF measurement procedure to be followed in order to evaluate electromagnetic emissions. The paper presents a study of the basic requirements to measure the electromagnetic fields focusing on the 850 MHz and 1900 MHz cellular bands and 2.4 and 5 GHz IEEE 802.11 bands, and evaluates and compares three different commercially available non-ionizing radiation measurement systems. Finally, it recommends selection of a system assessed to best fit the scope of the ARCOTEL's regulation.

Keywords: ARCOTEL, non-ionizing radiation, compliance, electromagnetic field strength measurement

Ocena merilnih sistemov za merjenje neionizirnega sevanja pri Agenciji za regulacijo in nadzor telekomunikacij v Ekvadorju

Agencija za regulacijo in nadzor telekomunikacij v Ekvadorju (ARCOTEL) je pravna oseba, pooblaščena za nadzor telekomunikacij. Ena njenih nalog je tudi ocena, ali je neionizirno sevanje skladno s predpisi. Jakost sevanja ugotavljamo s predpisanim merilnim postopkom elektromagnetnega polja. V članku je predstavljena študija meritve elektromagnetnega polja s poudarkom na mobilnem omrežju na frekvenčnem območju 850 MHz 1900 MHz, 2.4 GHz in 5 GHz IEEE 802.11. Ocenili in primerjali smo tri različne merilne sisteme za merjenje neionizirnega sevanja in predlagali sistem, ki najbolj ustreza namenu.

1 INTRODUCTION

Telecommunications constitute one of the most dynamic sectors of modern economies. The services provided are widely varied and their accessibility is of a great importance in the development of a country [1], all of that being reflected in industry, education and social matters [2], [3].

The increasing use of the wireless technologies as a means of transporting information allows to deliver different services to final consumers, being the reason that the electromagnetic spectrum and the way it is managed is becoming a key factor of the information society [4]. As an unavoidable consequence, the entire population is always exposed to a complex mix of the electromagnetic fields (EMF) of a diverse frequency content [5].

Despite all the advantages the technological progress bears, it is necessary to consider that the telecommunications equipment and any electrical equipment emitting non-ionizing radiation (NIR) may cause various effects in the body tissues depending on the time of exposure, transmitting power and propagation frequency [6], [7].

The Agency for Regulation and Control of Telecommunications (ARCOTEL) is the entity responsible for administration, regulation and control of telecommunications systems and services in Ecuador. This includes radio spectrum management and all the technical aspects regarding the media using frequencies within the spectrum or operating data networks. ARCOTEL counts on a legal instrument called "Regulation for human protection against non-ionizing radiation caused by the use of the radioelectric spectrum" [8]. This regulation states an EMF measurement procedure to be followed to evaluate the electromagnetic emissions. The ARCOTEL's measuring method is the one recommended by the International Telecommunications Union (ITU) and the reference levels are those set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and supported by the International EMF Project [9] of the World Health Organization (WHO).

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The paper starts with a brief review of the EMF assessment methods followed by a summary of international recommendations and guidelines for the human exposure limits and measurements. Then it evaluates and compares three different commercially available NIR measurement systems: SRM3006 by NARDA, Field Nose by ARC and FieldFox by KEYSIGHT. Finally, it draws out some recommendations and conclusions about the measurement system best fitting the ARCOTEL's purpose.

2 EMF ASSESSMENT

The exposure in the proximity of telecommunication facilities has to be assessed based on the EMF calculation and the conditions of accessibility to the emitting sources [10].

The EMF levels are determined by numerical prediction and measurements [11]. The first [12] is used before installation of a telecommunication facility to determine theoretical EMF values that can be used as a reference and to decide if it is necessary to take certain considerations and precautions, such as delimitating the areas of accessibility. Upon the facility installation completion, the radiation levels are measured [13] to comply with the international regulations for human exposure.

Compliance with the international standards is assessed by measuring the EMF strength [14] by using properly calibrated measurement instruments and their uncertainty specified [15].

It is also important to understand the mitigation techniques to reduce the human-exposure levels in the surroundings of multiple EMF sources [16] and how to apply these techniques especially in developing countries like Ecuador where not much research has been done on NIR.

3 RECOMMENDATIONS ON HUMAN EXPOSURE LIMITS TO EMF AND EMF MEASURING METHODS

Many attempts to reach a global agreement on the limits of the human exposure to EMF as well as numerical prediction methods and measuring techniques of these fields have been made with no positive outcome. On one hand there are countries using limits set by ICNIRP [17], and on the other there are countries using limits set by their national regulatory agencies through research [18].

The recommendations of the ITU-T K series (Protection against interference) propose the basic limits and reference levels for assessing the EMF exposure defined in the "Guidelines for limiting exposure to electric, magnetic and time-varying electromagnetic fields (up to 300 GHz)" [17] by ICNIRP. However, each country is free to define its own limits. Entities responsible for protection of persons in presence of NIR have set human exposure limits compliably with the physiological response [19] of people exposed to EMF:

- Basic limits for Specific Absorption Rate (SAR), Specific Absorption (SA) or Current Density.
- Derived levels (a.k.a. reference levels) for power density, electric fields and magnetic fields.

The Institute of Electrical and Electronics Engineers (IEEE) defines safety levels for the human exposure in the C95.1-2005 recommendation [20] and good practices for the RF safety in the C95.7-2014 recommendation [21]. The International Electrotechnical Commission (IEC) presented in its IEC 62209-1:2005 [22] and IEC 62209-2:2010 [23] recommendations procedures to determine SAR for hand-held devices used in a close proximity to the ear and for the wireless communication devices used in a close proximity to the human body, respectively.

By adopting different NIR human-exposure limits, different measuring techniques should be developed as well.

ITU, the global body responsible for coordination of radiocommunications and for standardization and development of telecommunications [24] has published a NIR measuring method to assess the telecommunication facilities in the ITU-T K.52 recommendation [10].

Other regulatory bodies have carried out studies on human exposure to NIR and measurement procedures achieving their own recommendations and guidelines. The European Committee for Electrotechnical Standardization (CENELEC) [25] has adopted a measuring method in its EN50383 recommendation.

An overview of the main measuring methods is given later in this paper.

4 MEASURING INSTRUMENTS AND APPLICATIONS

Within the electromagnetic spectrum, the range attributed to the radio waves, specifically the ultra and super high frequencies (300MHz – 30GHz), is home to the technologies under study: the cellular and Wi-Fi transceivers.

When selecting a measuring system [10], it is important to remember to comply with the imposed standards, taking into consideration the number of the EMF sources and their characteristics, and to identify the measuring field regions.

A measuring equipment [12] must be calibrated correctly and at least have a measuring receiver or spectrum analyzer and a right antenna to fulfil its purpose.

Some characteristics must be considered before selecting a measuring system. For instance, the spectrum analyzer to be chosen must allow the field-strength measurements with the frequency selectivity and must offer the possibility of the bandwidth selection between 800MHz to 5.5GHz, comprising the cellular and Wi-Fi spectra. It must also be capable of in-situ measurements [26] to give an assessment at the site under study, particularly in sensitive areas such as schools or hospitals as well as accessible locations to the public in the vicinity of transmitters. The isotropic measuring instruments with a root mean-square detection and time average are the best choice. For the added spatial average, a sensor can be located as required.

For the antenna, it is necessary to consider [12]:

- Its directivity; the antenna can be either isotropic or directive.
- Its frequency range; if wideband, it gives no information about the frequency spectrum and uses more sophisticated devices, or if narrowband, it has a plain antenna factor in a limited spectrum range and is used for the frequency selective measurements.
- Its measuring units; it is recommended to use electric field measuring devices for the frequencies in study and if necessary, considering the field region, the magnetic field and the power density may be calculated.

The accuracy of the results depends on the measurement procedures and characteristics of the instruments used. The calibration factor, antenna factor, isotropy, linearity, impulsive signal, axial rejection and integration of multiple signals are some of the main requirements to be met by measuring instruments [12]. Before measuring it is necessary to set up some important parameters such as the frequency, amplitude, measurement method, noise processing and periodicity. Setting up the time and frequency filters could be useful as well.

5 EMF MEASUREMENT METHODS

The following electric field strength measuring methods [27] are used by the systems surveyed and are the most relevant in the bands of interest:

The RF field probes allow easy measuring with results obtained quickly and satisfactorily. They have excellent isotropic radiation properties and a wide frequency operating range but usually with no or limited frequency selectivity, so measurements do not help identify the specific emitters.

The method with an addition of three-dimensional field components, the Add3D [28] method, combines the advantages of frequency-selective measuring with the properties of an isotropic field probe. It is similar to the isotropic spatial averaging method but it associates three-dimensional field components in a single measurement.

Both EMF measuring methods have their own strengths and weaknesses and the selection of the system and method depends merely on which one best suits the requirements.

A part of the scope of this work it is to analyze three commercial measurement systems: Narda SRM 3006 (RF field probe), Austrian Research Centre Seibersdorf Field Nose (Add3D) and Keysight Technology Field Fox (RF field probe), in order to assess compliance with the international standards and guidelines for the human-exposure safety limits to NIR sources like cellular radio base stations and Wi-Fi routers. It is found useful to start this analysis by stating that ARCOTEL currently uses Narda SRM 3006 to evaluate EMF in Ecuador and we begin the assessment using this instrument.

References [29] and [30] explain some procedures and results taken under consideration before measuring and interpreting data. Evaluation of the measurement systems selected was done as follows.

The selective radiation meter for EMFs of up to 6GHz (SRM 3006) [31] achieves a great combination of a spectrum analyzer with a wideband measuring set. Developed to address safety concerns in EMF, it provides its users with measuring methods capable to read different services and even specific channels, like those for the cellular and wireless communications. It is possible to make selective EMF measurements between 9 KHz to 6 GHz. Its operating modes are safety evaluation, spectrum analysis, level recorder, scope, UMTS and LTE. The results can be displayed as individual values in tables and as an overall total value. A three-axis measuring antenna is used, which gives isotropic measurements automatically.

In order to process data, it is necessary to export and compile it with a spreadsheet program. Figure 1 shows the compilation of data for an 850 cellular band, i.e. the frequency range from 869 MHz to 894 MHz.

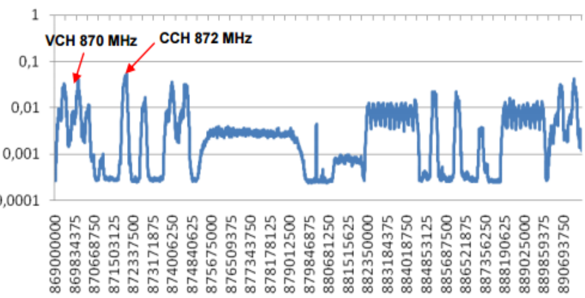

Figure 1. Spectrum for the 850 MHz cellular band.

SRM 3006 is an easy-to-use system, its spectrum analyzer presents data in a comprehensible way but it is not very efficient while processing it in a computer. It may be considered time consuming, making this system not very efficient.

The Field Nose system [32] is based on the Add3D measuring method, executed by antenna rotations of 120° on a platform to achieve three orthogonal positions, and mainly formed of a spectrum analyzer and a shortened precision omnidirectional dipole (sPOD16) antenna [33] working in the frequency range from 800 MHz to 6 GHz, a rotor for antenna positioning to calculate the isotropic magnitude (ARCS Rotator) and a data-collector software (NOSE PRO 3.1.2) [34] that is a flexible tool that provides a convenient way to visualize and evaluate the EMF measurements.

Selective frequency measurements can be done using the Field Nose system. It is also possible to study the UMTS technology, used for the third-generation mobile telephony in Ecuador, allowing to assign certain properties of this type of technology that other systems do not. Emissions can be assigned to their respective sources, accurate enough to measure the spectrum allocated to forward channels in cellular communications, as seen in Figure 2, as well as the spectrum allocated in a data channel, shown in Figure 3 (the data channel at 872.0 MHz).

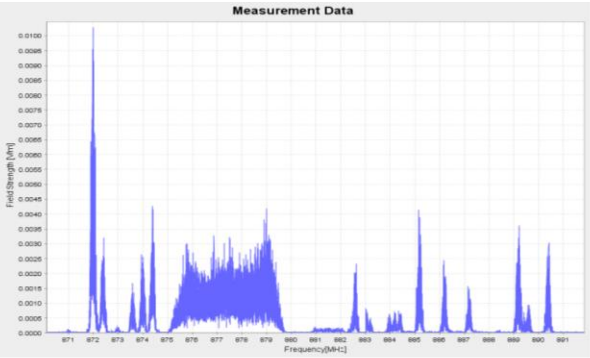

Figure 2. Spectrum for the 850 MHz cellular band.

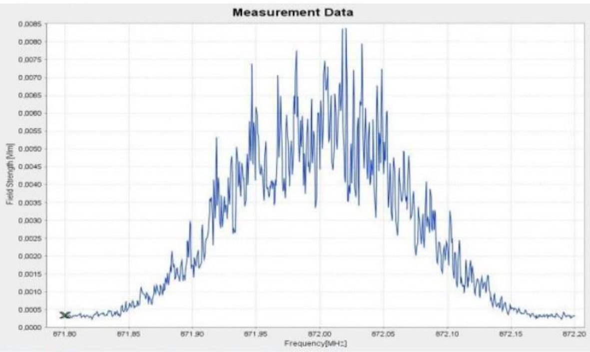

Figure 3. Data channel at 872.0 MHz.

FieldFox N9962A [35] is a convenient device with several operating modes, from cable testing to vector analyzer. It will be used as the third measuring system to get accurate measurements in a frequency range from 9 kHz to 50 GHz. In the spectrum analyzer mode, the channel and adjacent channel power, occupied bandwidth, extended range transmission analysis and interference analysis will be used. This device allows remote control with several types of devices.

Aaronia HyperLOG7060 [36] will be used with the FieldFox for the EMF measurements. This is a logarithmic-periodic pre-compliance test antenna in the range from 700MHz to 6GHz suitable for interference field strength measurements. Its specialized broadband characteristics allow measurements to be taken in the complete specified frequency range.

A measurement in the 850 MHz cellular band using this system is shown in Figure 4.

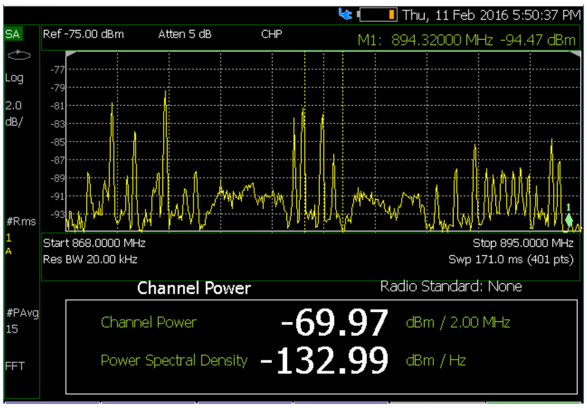

Figure 4. Spectrum for the 850 MHz cellular band.

As noticed, the UMTS spectra are approximately located at the frequency ranges from 874MHz to 880 MHz and from 882MHz to 887 MHz. Both spectra can be studied zooming on that ranges.

This system does not allow to analyze the spectrum allocated in a specific data channel since the narrowest permissible bandwidth is 2 MHz for the FieldFox, but for this research, it is necessary to evaluate a data channel with a bandwidth of 400KHz. Figure 5 shows the spectrum for the frequency range from 870.2MHz to 872.2MHz, i.e. a bandwidth of 2MHz.

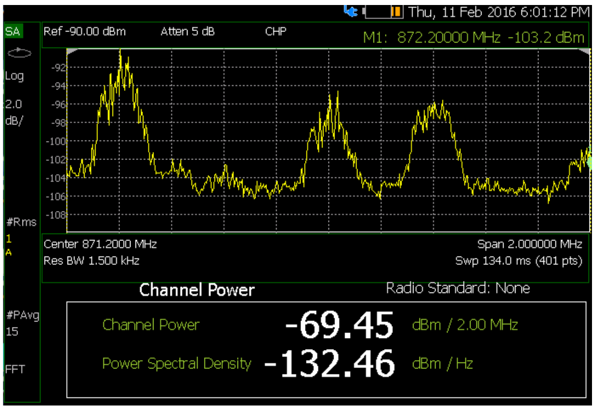

Figure 5. Data channels at the frequency range from 870.2 to 872.2 MHz.

6 Conclusion

Since the potential harmful health effects of the NIR exposure are of public interest, each country is responsible for regulating its telecommunication companies and for informing its people about the latest study results and any research under development on these electromagnetic emissions.

At the moment of choosing a measuring method, some considerations must be taken. The RF field probes have a high isotropic behavior but are not frequency selective and the NIR sources cannot be determined but the total field strength at the site of measurement, so it must be determined whether it is possible to conduct the study using this method or not. The sweeping methods are less optimal than other probes but allow frequency selective measurements efficiently. As measured, the isotropic spatial average method has more advantages than others, however, it is not so easy to carry it out and takes much longer. The monitoring method is very efficient but does not allow a good spatial average and its costs are higher.

In order to get the most accurate measurements, it is vital to keep any conductive and dielectric elements away from the antenna, particularly at high frequencies. Also, as recommended by ITU and ICNIRP, measurements should be done at rush hours since the values will be under maximum traffic conditions.

SRM 3006 is an easy-to-use system. Its spectrum analyzer presents data in a comprehensible way but it is not very efficient because it is necessary to export and compile it with a spreadsheet program in a computer. Hence, it may be considered time consuming, making it not the best option.

The Field Nose measurement procedure is simple and time-efficient as may be controlled by software. The rotor positions the antenna in three different directions. The software designates the receiver bandwidth and frequency range and stores the measured data. Mobility is a big adversity for this system since it is necessary to keep it connected to a laptop and the rotor must be positioned in a steady surface.

FieldFox is a spectrum analyzer with many advantages. Its operation modes are very intuitive. Measurements can be done easily and time-efficiently. It is frequency selective but the narrowest bandwidth could not be narrow enough to measure specific channels, which is a disadvantage for this powerful system.

Even though, each EMF measurement method has its own strengths and weaknesses. It depends merely on the needs of selecting the system and method that suits best. Due to all its benefits, and for this case, FieldFox is the best option. It fits the requirements set by the international regulation bodies. It is light-weighted and portable so the measurements are carried out with no trouble. The results are obtained in a user-friendly way and data can be effortlessly compiled and processed. Although no results have linked the cellular and Wi-Fi transceivers with the human health risks (according to the latest WHO researches), it is better to take preventive measures such as periodic assessments of the electromagnetic emissions and even, if possible, try to mitigate the radiation levels to provide greater protection to general public.

ARCOTEL should consider this study and international recommendations, guidelines and reports, especially those published by ICNIRP and WHO and ITU, in order to assess different equipment and systems to measure NIR for human health protection and to keep the operation of transceivers in compliance with regulations.

In developing countries, as Ecuador, where scarce or no research on NIR has been performed, the governments should motivate the NIR research at universities and the creation of specialized centers. Also, they should encourage an active participation of ARCOTEL and cellular operators in these matters and keep the public always informed.

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