Evaluation of electromagnetic field exposure in the vicinity of mobile phone base stations

Marius Nedelcu
Technology Department
Orange Romania
Telecommunications Department
University Politehnica of Bucharest
Bucharest, Romania
marius.nedelcu@orange.com

Teodor Petrescu
Telecommunications Department
University Politehnica of Bucharest
Bucharest, Romania
teodor.petrescu@upb.ro

Victor Nițu
Technology Department
Orange Romania
Bucharest, Romania
victor.nitu@orange.com

***Abstract*— The present paper aims to assess the level of exposure to ambient electromagnetic field, generated especially by mobile phone stations. In a first phase, before the implementation of 5G (fifth generation), the power density was measured in the vicinity of 1750 base stations of Orange Romania SA, distributed throughout the country, and was reported at the lowest reference value provided of the national legislation for the general public in the case of the mobile telephony systems in which Orange Romania's stations operate. The maximum exposure coefficient was thus obtained as a percentage value from the limits provided in ICNIRP (International Committee on Non-Ionizing Radiation Protection). In phase 2, after the development of the 5G network in Bucharest, 122 sites were re-measured, again calculating the maximum exposure coefficient as a percentage value. The results showed that regardless of the environment, over 90% of the measurements are below 0.2% of the limits provided by ICNIRP and 99% of the measurements are below 2% of the limits provided by ICNIRP.**

Keywords— EMF measurements, 5G network , ICNIRP

I. Introduction

In recent decades people's lifestyles have changed, we are exposed to a multitude of environmental factors, the effects of which are seen in the quality of life. The massive development of mobile communications equipment has increased interest in the safety of the population exposed to radio frequency radiation emitted by both base station antennas and mobile terminals.

Human exposure is quantified by Specific Absorption Rate (SAR). The standards give the maximum accepted values for this quantity, called the basic restrictions, which represent the starting point in the calculation of the reference levels set out in the standards.

The public wants to be informed about the quality of the living environment, so measuring the ambient electromagnetic field is an effective way to determine the general public exposure to electromagnetic waves. In the case of mobile networks, the main element of the network is the base station. Base stations are designed to cover an area that varies depending on the volume of traffic and the type of area. Thus, the stations are divided into several categories, the most numerous being the so-called macro station (indicates the type of coverage of the station, it serves a relatively large area). Covering a large area, macro stations must be installed on specifically design towers or on rooftops, which makes them the most visible mobile stations.

In 2018, Orange Romania launched a campaign to measure the power density near each mobile phone station (with macro or micro coverage) located within inhabited areas. Over the course of a year, the power density of 1750 sites across the country was measured. At the beginning of 2021, in Bucharest, with the development of the 5G network (fifth generation) in the frequency bands of 2100 MHz and 3500MHz, 122 power density measurements were performed in the same coordinates where the initial measurements were performed before installing 5G. The results were compared with the reference levels. The reference levels in Romania and most European countries are those provided in the limitations imposed by the ICNIRP standard (International Committee on Non-Ionizing Radiation Protection). ICNIRP is a non-governmental organization that aims to protect people against non-ionizing radiation, the main concern being to pursue studies published in the literature and, based on them, to set maximum exposure limits. The ICNIRP standard divides the limits of exposure to non-ionized radiation into two categories, these being the general public and the population working with radiant systems. The first category, of the general public, includes individuals of all ages and with different health conditions, who are not necessarily informed about the ambient electromagnetic field and therefore do not take any measures to protect against radiation. Unlike the general public, the professional working with radiant systems is aware of the effects of the electromagnetic field and ensures that radiation protection measures are taken. [1]

II. Measurement campaign methodology

A. Establishing the coordinates of the measuring points

Before starting the measurement process, a very important action was the choice of measurement points. In order to obtain relevant results, macro and micro sites were chosen, covering different living environments and sufficient population, from dense urban to rural areas.

The measurements were performed for each site, but in addition to the direct wave and its reflections from the measured site, there are also contributions from other neighboring sites, which does not constitute a problem, as the purpose of the investigation is the environmental field, not just the field produced by a single site.

To obtain relevant results, the field measurement requires that the measuring installation be positioned in the direction of the main lobe of the measured antenna and the space between the transmitter and the probe with which the field is evaluated is not obstructed. The choice of each measurement point followed the steps below :

1) Calculation of the distance at which the main direction of radiation of the antenna reaches the probe 1.5 meters above the ground. The distance was calculated based on information about the heights at which the antennas are located, the vertical characteristics of the antenna pattern and the tilt of the antennas. Fig. 1 shows the vertical coverage, based on the notions of vertical opening and main direction of radiation of the main lobe of the antenna.

2) Search for a suitable measuring point, based on the distance calculated previously, the azimuths emitted by the base station antennas and the horizontal characteristics of the antenna pattern. Fig.2 shows the vertical and horizontal antenna pattern diagrams of the AQU4518R4v06 antenna at the frequency of 900 MHz; this antenna, with an horizontal directivity of 65° and 4-6° vertically being the most common on the measured sites. There are also sites that are equipped with antennas whose horizontal beamwidth is 33° or 90°.

The calculated distances are between 30 and 50 meters in front of the building or tower, in the main direction of radiation of one of the radio antennas. In the cases in which no accessible measuring point was identified, a measuring point in the immediate vicinity was chosen.

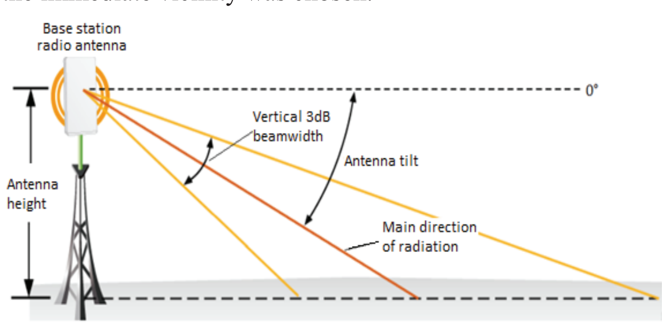

Fig. 1. Vertical coverage of the main lobe

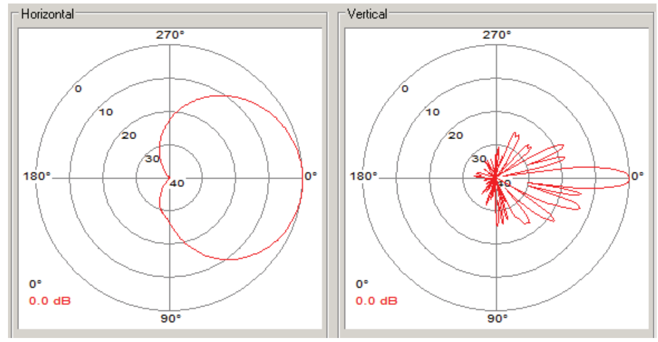

Fig. 2. Vertical and horizontal antenna pattern diagrams of the AQU4518R4v06 antenna at 900 MHz

B. The measurement process

Due to the nature of their magnetic and electrical properties, metals can interact with the electromagnetic field and can immediately couple to the probe we use. Consequently, a minimum distance from metal surfaces must be maintained. The measuring instruments must be located on a non-conductive surface and the person performing the measurements must be at a distance of at least 3 meters from the instrument. [2]

In 2002, Recommendation ECC (02) 04 was published, prepared by the Electronic Communications Commission of the European Postal and Telecommunications Conference (Conférence Européenne des Administrations des Postes et des Télécommunications - CEPT) [3], which presents the measurement of electromagnetic fields. Non-ionizing in the 9 KHz - 300 GHz frequency range in order to validate compliance with the available limits. The recommendation does not impose a certain limit, but only ways to measure the general public's exposure to electromagnetic fields.

The measurements were performed with the "rapid assessment" method [3], this method being the most appropriate in remote field situations. Rapid assessment is performed with a broadband device and is a method that is applied in the first phase to determine whether the total level is close to the decision threshold.

C. Measuring system

Electromagnetic field measuring devices fall into 2 broad categories: broadband measuring devices and selective frequency and narrowband code measuring devices.

The devices of the first category have a simple mode of operation, the measuring device indicating the magnitude of the electric or magnetic field integrated in the whole frequency band for which the probe was designed. Usually, this band ranges from a few hundred KHz to 40-60 GHz. Broadband measurements are general measurements, and when their purpose is to validate compliance with the standards, the measured value must be related to the minimum limit defined for the frequency range in which the device measures. The advantages of broadband devices include portability, built-in power supply and ease of use. However, the disadvantage of such a device is that with only the overall result, the contribution of a single field source cannot be estimated. Due to the wide range of frequencies it can measure, the calibration of the device is not as accurate as that of narrowband devices.[2]

Devices in the second category can select a narrow band convenient for field measurements. They are in fact spectral analyzers that process the signal received from the electric or magnetic field probe and extract the values corresponding to each frequency from the analyzed band. The working band of these devices is much smaller than in the case of devices of the first category, usually, this band extends from a few hundred KHz to 3-6 GHz. Narrowband instruments are used when greater sensitivity is required.

These devices, whether narrowband or broadband, generally consist of 2 main components: a probe, which converts electromagnetic energy into an electrical signal, which is then used to assess the intensity of the electric field or magnetic field and an electronic module for processing and displaying data received from the probe. Depending on the component of the electromagnetic field they measure, in addition to the detector, the probes are composed of an antenna, if it evaluates the electric field, respectively an inductive loop if the magnetic field is evaluated. The need for the detector is to convert electromagnetic energy into electrical signal using diodes or thermocouples.

Although selective frequency measurement solves many of the problems of broadband measurements, it is still extremely difficult to clearly identify the share of exposure caused by different transmitters for the same frequency.

Selective measurements in code are particularly useful for systems where all base stations emit in the same frequency band and selective frequency receivers cannot identify energy from different base stations. Selective receivers in code are able to decode the signal emitted by each source and separate the signal of interest from the rest of the sources.

If two measurements made in the same place, one in broadband and the other in narrowband, have different results, the narrowband measurement is always taken into account. [2]

The measuring installation used in this study was of the first category, being composed of: a probe, which converts electromagnetic energy into electrical signal, then used to assess the intensity of the electric field or magnetic field and an electronic module for processing and displaying received data from the probe. A Narda NBM-520 electronic broadband module was used to which a Narda RF 1891 triaxial electric field probe with 3MHz - 18 GHz band was connected. Because the probe is triaxial, the measurement is made independently of the polarization of the transmitter, which makes the measurements easier. The mediation time was considered, according to ICNIRP requirements, 6 minutes, and the physical quantity in which the field value was expressed is the power density. The measurement analyzer has been set to measure the average of the maximum values recorded in the measurement time interval.

In order not to disturb the measurement of the electromagnetic field and so that the measuring probe is at a height of about 1.5 meters from the ground, the measuring installation was mounted on a non-conductive tripod. A GPS device was mounted on the tripod in order to have the exact coordinates of the measurement points. In Fig. 3, two images from the measurement campaign are presented, in which the measuring installation is highlighted and its positioning relative to the measured site.

The existence in the vicinity of the measuring installation of a large number of objects that bring a scattering or absorption of energy, leads to an uneven distribution of the field.

The measurements were centralized in a report containing the measured value for each site, the geographical coordinates of the point where the measurement was made, temperature, humidity and calendar date.

Fig. 3. Measuring system

III. Results and Their Interpretation

The physical quantity in which the measured value of the field was expressed is the power density [W/m^2]. Romanian legislation through the Order of the Minister of Public Health 1007/2002, then supplemented by Order 1193/2006, took over in full the recommendation 519/1999 drafted by the Council of Europe, which is based on the document [1], published by ICNIRP, which established for the first time the basic restrictions governing exposure to electromagnetic wave emissions for frequencies up to 300 GHz. The maximum permissible power density limit varies with frequency, as can be seen in Table 1.

TABLE I. Power density reference levels

Frequency	Power density [W/m^2]
10 – 400 MHz	2
400 – 2000 MHz	f/200
2 – 300 GHz	10

In order to obtain the maximum exposure coefficient as a percentage value from the regulated limits, the measured values were reported to the lowest reference value provided by the national legislation for the general public in the case of mobile telephony systems in which Orange Romania stations operate. Based on the data in Table 1, the 800 MHz LTE system operating on the downlink in the 806-816 MHz frequency band determines 4.03 W/m^2 as the lowest power density reference value and the limit used to calculate the maximum exposure coefficient.

Fig. 4 illustrates the cumulative distribution function (CDF) of the 1750 values of the maximum exposure coefficients measured. As can be seen, over 90% of the coefficients are below 0.2% of the limits provided by ICNIRP (where 100% is equivalent to reaching the power density value of 4.03 W/m^2, meaning over 500 times lower. The average of the values of the coefficients is approximately 0.11% and 99% of the measurements are below 1.05% of the reference value. The maximum level recorded was 6.667%, which is more than 15 times lower than the minimum reference level.

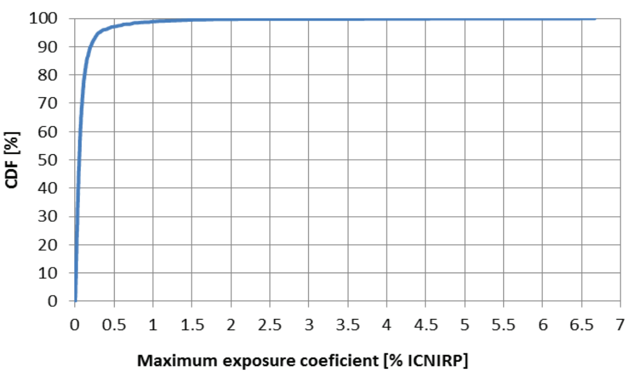

Fig. 4. Cumulative distribution function of all measurements

Based on the coordinates of the sites, they were classified into 1190 urban sites and 560 rural sites. In Fig. 5, respectively Fig. 6, there are presented the cumulative distribution functions of the maximum exposure coefficients measured for the sites in the urban area, respectively the rural area.

Regardless of the environment, the cumulative distribution shows that over 90% of the coefficients are below 0.2% of the limits provided by ICNIRP. In the case of urban measurements there were 4 maximum exposure coefficients which had values between 4.2% and 6.67%, while over 99% of the values were below 2%. Following the punctual analysis of the 4 values, it was found that near the measuring points there were buildings where indoor mobile phone sites were in operation.

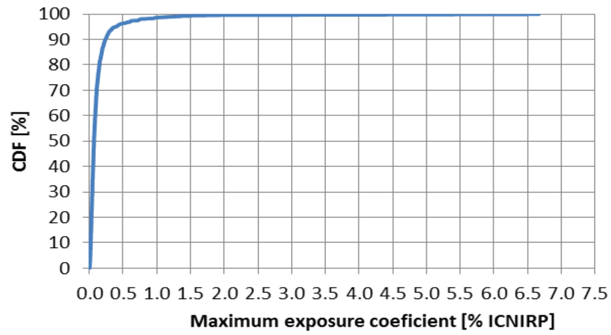

Fig. 5. Cumulative distribution function of urban measurements

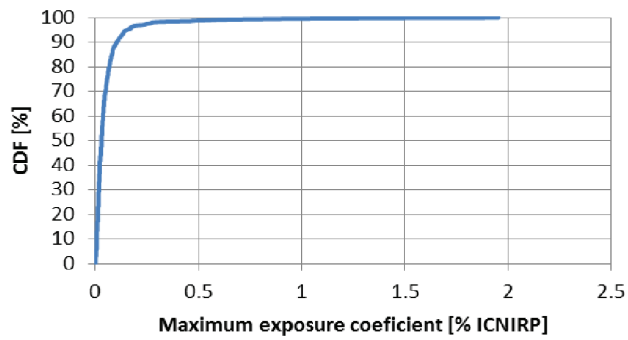

Fig. 6. Cumulative distribution function of rural measurements

For the values measured after starting the 5G network, the same maximum exposure coefficient was calculated, by reporting the measured value to the lowest reference value provided by the national legislation for the general public in the case of mobile telephony systems operating Orange Romania stations, namely 4.03 W/m^2 corresponding to the LTE system 800 MHz (806 - 816 MHz). The cumulative distribution shown in Fig. 7 shows that 90% of the coefficients are below 0.2% of the limits provided by ICNIRP, while over 99% of the values are below 1%, a single measured value being 2.4% of the limit provided by ICNIRP.

For the 122 measurements, the average value of the maximum exposure coefficient before and after 5G was calculated. The average value of the maximum exposure coefficient before 5G was 0.47% of the lowest reference value provided by the national legislation for the general public in the case of mobile telephony systems in which Orange Romania stations operate and, after the installation of the 5G network, this value increased to 0.55%, a value almost 200 times lower than the legal limit.

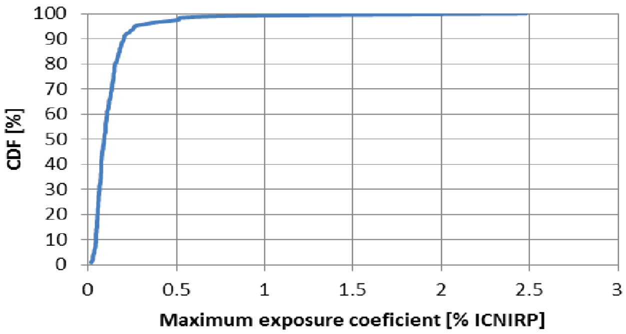

Fig. 7. Cumulative distribution function of measurements after 5G deployment

IV. Conclusions

The measurements show that the exposure of the general public to the electromagnetic field produced by macro mobile base stations is low. Except for 4 values, the maximum exposure coefficients measured being less than 2%. Having the 4 values obtained in the vicinity of some of the stations that operate inside the buildings, we can think that in the case of some measurements inside the buildings we could obtain higher values of the power density.

The measurements performed after the installation of the 5G network led to the same conclusions, average exposure increased by only 17%, in some cases the measured values being even lower due to the fact that the traffic of the 5G network is still low.

This paperwork brings clarifications for the future 5G developments and evolution in radio access network part to support the challenging use cases and further 5G Network Applications.

Acknowledgment

The scientific, technical, and academic activities and the testing and validation of the results of the research disseminated in this article have been performed in the Orange 5G Lab, an advanced experimental facility in Bucharest, created with the CAMPUS Research Center of UPB – University POLITEHNICA of Bucharest. The Orange 5G Lab supports the prototyping, testing, and validation of 5G Use-Cases, new applications, and new equipment within a team of Industry-leading experts and academics.

This work was partly funded by the European Commission under the European Union’s Horizon 2020 program - grant agreement number 101016448 (5GASP project) and 101016567 (VITAL-5G). The paper solely reflects the views of the authors. The Commission is not responsible for the contents of this paper or any use made thereof.

References

[1] ICNIRP GUIDELINES for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz). 1998, HEALTH PHYSICS.

[2] General Overview on methods for monitoring environmental electromagnetic fields (emf). G. d'Amore Environmental Protection Agency of Piedmont Region (ARPA Piemonte).

[3] Measuring Non-Ionizing Electromagnetic Radiation (9 kHz - 300 GHz). Administrations, Electronic Communication Committee (ECC) within the European Conference of Postal and Telecommunications. Vol. ECC RECOMMENDATION.