POWER DENSITY MEASUREMENTS ON SHARED SITES

Marius-Nicușor NEDELCU[1], Teodor PETRESCU[2]

A special case of sites, highly visible, are the sites where several types of transmission or transmission-reception equipment are installed. This paper presents a series of power density measurements on such a site in order to verify compliance with the norms in force. The results showed that the exposure is only a few percent, never exceeding 10% of the legal limits. The exposure on the top floor, immediately below the terrace where the antennas were installed, was evaluated. The field level is reduced compared to the one recorded on the terrace.

Keywords: electromagnetic field measurements, ICNIRP, human exposure.

1. Introduction

One of the first attempts to measure the electromagnetic field in free space was made at Bell Laboratories. The measurement was made in the frequency range of 600 kHz - 1200 kHz, using a very sensitive detector. This type of instrument has been used for a long time and has had many adjustments, mainly to get rid of noise [1].

In the campaign carried out by Orange Romania to assess exposure to the ambient electromagnetic field in the vicinity of mobile phone base stations, in 2018 the power density was measured near 1750 sites where 5G (fifth generation) technology had not yet been installed, and in 2021, once with the start of the development of the 5G network in the 2100 MHz and 3500 MHz frequency bands, 122 power density measurements were performed in the same coordinates where the initial measurements were performed. The obtained results showed that the exposure is reduced compared to the reference limits imposed by the ICNIRP standard (International Committee on Non-Ionizing Radiation Protection) [2]. ICNIRP is a non-governmental organization whose objective is to protect people against non-ionizing radiation, it follows the studies published in the specialized literature and, based on them, establishes the maximum exposure limits. The ICNIRP standard divides exposure limits to non-ionizing radiation into two categories, limits for the general public and limits for the population working with radiant systems. The category of the general public includes individuals of all

[1] PhD Student, Telecommunications Dpt., University POLITEHNICA of Bucharest, Romania, e-mail: marius.nedelcu@orange.com
[2] Prof., Telecommunications Dpt., University POLITEHNICA of Bucharest, Romania, e-mail: teodor.petrescu@upb.ro

ages, with different health conditions, who are not necessarily informed about the ambient magnetic field and do not necessarily take any measures to protect against radiation [3].

A special case is represented by the sites where several transmission or transmission-reception equipment are installed. At the national level, more and more such sites are appearing. In 2018, in order to choose such a site in order to carry out electromagnetic field measurements, in addition to the visual choice, the electromagnetic field values measured by the 150 fixed sensors within the network developed and made available to the general public by the National Authority for Administration and Regulation were analyzed in Communications (ANCOM), arranged in 104 localities in the country, located in the vicinity of educational institutions, hospitals, public institutions, congested areas or public areas in the vicinity of which there are agglomerations from the point of view of electromagnetic field sources [4]. The sensor that recorded some of the highest values of the field was the one located on the terrace of building A of the Faculty of Electronics, Telecommunications and Information Technology, from Iuliu Maniu Boulevard 1-3, Bucharest; values reconfirmed by the analysis from the year 2022 when the Executive Directorate of Monitoring and Control within ANCOM facilitated our access to the data measured by 150 fixed sensors during one year, between August 1, 2021 and July 31, 2022. Then, for each sensor, the annual average of the maximum values of the electric field measured at the hourly level was calculated, as well as the annual average of the average values of the electric field measured at the hourly level. The sensor in Bucharest that recorded the highest values of the field was the one mounted on the terrace of building A of the Faculty of Electronics, Telecommunications and Information Technology, from Iuliu Maniu Boulevard 1-3, Bucharest, where there are several broadcast stations for radio broadcasting, telephony mobiles, data transmissions, radio relays, etc. [5]

Although it was the highest annual average value, the highest value of the electromagnetic field in the 100 kHz - 7 GHz band recorded during the analyzed year was 12.24 V/m, being below 45% of the reference level. For this value, the maximum exposure coefficient of the general public, considering the most restrictive reference level, is approximately 20%. [5]

2. Measurements, results and their interpretations

In Fig. 1 we have the plan of the terrace of building A of the Faculty of Electronics, Telecommunications and Information Technology.

In order to be easier to understand and identify in the field, the aedicula and portions of the terrace were highlighted on the plan. The points where the electromagnetic field measurements were made were marked with Arabic

numerals, and the main and most visible electromagnetic field sources were highlighted with “X”.

Most of the existing antennas on the terrace operate at frequencies exceeding 23 GHz and are used for point-to-point communications. Regarding the antennas used for mobile telephony, this site accommodates all technologies (GSM, UMTS, LTE, NR). According to the information related to the location of radio stations [6], in “Lion Student Campus”, there are 2 FM radio stations, one for “Naţional FM” and the other for “Radio RFI”. On building 3 there is a TV transmitter, deactivated for several years.

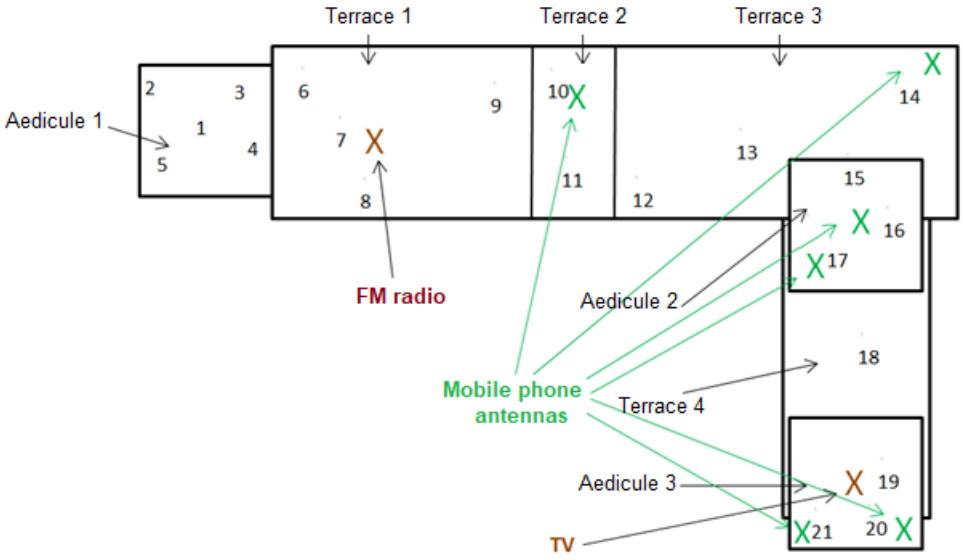

Fig. 1. Terrace plan building A of the Faculty of Electronics, Telecommunications and Information Technology

For the measurements in this work, a Narda NBM-520 broadband electronic module was used to which a Narda RF 1891 triaxial electric field probe with the 3 MHz - 18 GHz band was connected. The measurement process followed the "quick assessment" method detailed in ECC/REC (02)04 [7], with the probe located 1.5 meters above the terrace and approximately 0.5 meters from the antenna.

As stipulated by the requirements of the ICNIRP standard, the averaging time considered was 6 minutes, and the physical quantity chosen to express the measured value of the field is the power density.

For each measuring point, 2 measurements were made, the first time the average value of the power density in the 6 minutes was kept, and the second time the maximum value was kept. Table 1 includes all measured values.

Fig. 2 shows the measurement points on the aedicule 1, as well as the antennas near them.

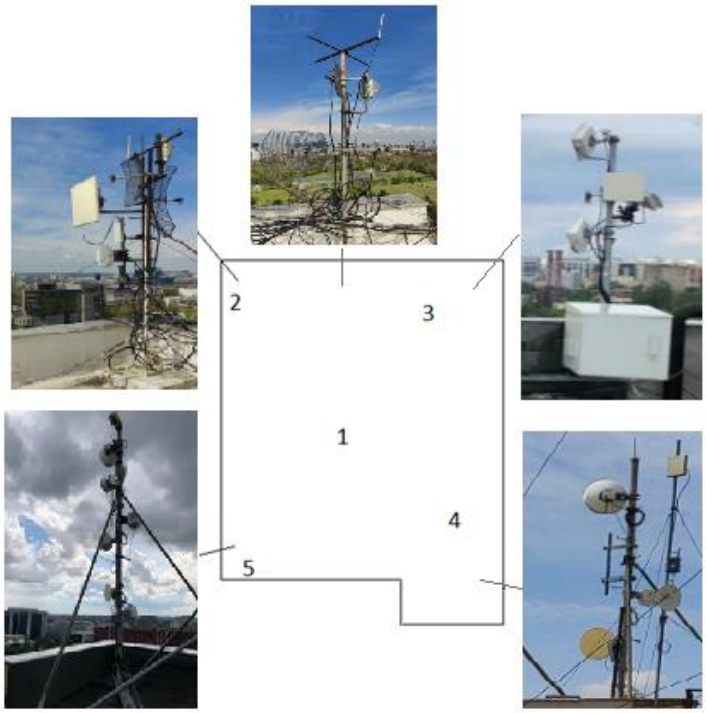

Fig. 2. Aedicule 1 plan

The first measurement point was chosen in the center of the aedicule, where we have no field source in the immediate vicinity, in an area easily accessible to those who climb the terrace. Among the five measurement points on the aedicule, here we obtained the lowest value of the field.

The second point was chosen near the mat on which there are several antennas, in front of the white, square antenna, which emits along the terrace, in an accessible area. The maximum measured value for the power density was 0.2713 W/m^2, almost 4 times higher than in the center of the aedicule but well below the decision threshold considering that the emission frequency is several GHz and the limit for this band is 10 W/m^2.

In point 3 there are two antennas used for data transmissions in the unlicensed 2.4 - 2.5 GHz band. The area being accessible, even to pass by other structures, the public gets very close to the antennas, in addition to the probe measurement at 0.5 m from the antennas, 2 measurements were made at 0.3 m and 0.15 m, respectively. These two new measurement points were marked with 3' and 3", respectively. For the measurement from point 3", with the probe placed 0.15 m from the antenna, we applied, at the limit, the plane wave model where it is sufficient to measure only one component of the electromagnetic field.

Similar to point 3, also in point 4 an additional measurement at 0.15 m was necessary, the audience having to pass close to the antennas. The measurements made 15 cm in front of the antennas revealed maximum values below 3% of the ICNIRP limits corresponding to the frequency band 2.4 – 2.5 GHz.

Point 5 is near the mast on which there is an antenna that operates in the 3500 MHz band plus other antennas for point-to-point communications. As the antennas on this pillar are oriented towards the outside of the building, the dominant field in this measurement point is also generated by the square antenna from point 2 that emits along the terrace.

Fig. 3 shows the measurement points on terraces 2 and 3, as well as the antennas near them.

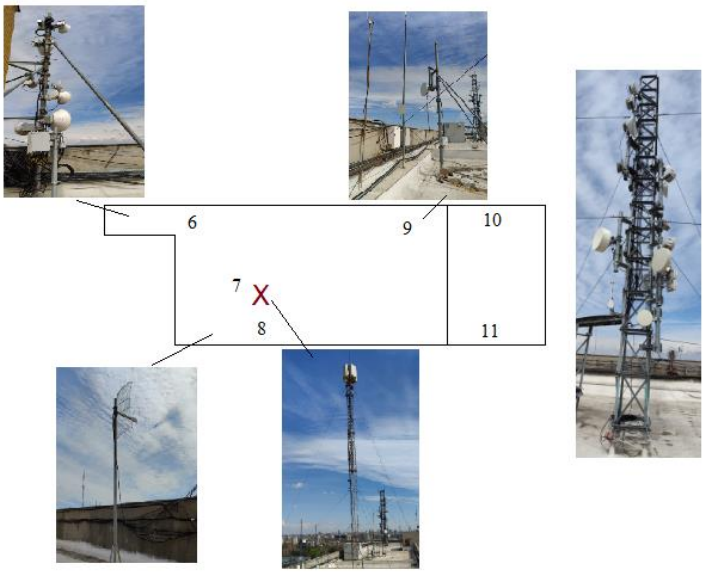

Fig. 3. Terrace 1 and Terrace 2 plan

On the “Lion Student Campus” there are two FM radio transmitters for "National FM", respectively for "Radio RFI", the measurement from point 7 being in close proximity.

From the pictures it can be seen that in addition to being directive and oriented towards the outside of the building, almost all the antennas are over 2 m high. This makes the measured values very low, well below the permissible limits.

Fig. 4 shows the measurement points on Terrace 3, as well as the antennas near them. Cell phone station and point-to-point links are noted here.

In point 12 there are two antennas for data transmissions. Compared to the measurements on aedicule 1, the exposure near these antennas is negligible because the orientation of these antennas is towards the outside of the building in a hard-to-reach area.

In point 13, several measurements were made because one of the microwave antennas is at a height comparable to the height of a human. Thus, one measurement was made at 50 cm from the antenna, and the second at 10 cm, in both situations being at a greater distance than lambda, and therefore, being able to use the far field probe. During the measurement at a distance of 10 cm, in the radiant near field, high field values were recorded, reaching values of almost 1 W/m^2, i.e. 10% of the maximum limit allowed at frequencies higher than 2 GHz.

Point 14 was chosen due to the distance from the pylon and the orientation of the radio antenna, the position being on the main radiation direction of an antenna. Although measurement was attempted in the main lobe of the antenna, due to the high height of the pylon and the small vertical opening of the antenna feature, the measured values are low, below 0.2 W/m^2, i.e. around 4% of the regulated limits for the GSM band.

Table 1

Measurement results

Measuring point	Average power density value [W/m^2]	Maximum power density value [W/m^2]
Point 1	0.0475	0.0712
Point 2	0.1754	0.2713
Point 3	0.1024	0.1563
Point 3’	0.1221	0.1912
Point 3”	0.2174	0.2823
Point 4	0.0845	0.1309
Point 4’	0.1692	0.2281
Point 5	0.0251	0.0502
Point 6	0.0063	0.0107
Point 7	0.018	0.0303
Point 8	0.0216	0.0352
Point 9	0.0174	0.0291
Point 10	0.0285	0.043
Point 11	0.0206	0.0283
Point 12	0.0213	0.031
Point 13	0.0383	0.6072
Point 13’	0.0628	0.9747
Point 14	0.102	0.1917
Point 15	0.0565	0.0925
Point 16	0.0552	0.1012
Point 17	0.0684	0.122
Point 18	0.0083	0.0095
Point 19	0.0764	0.1527
Point 20	0.0739	0.1588
Point 21	0.0884	0.1925

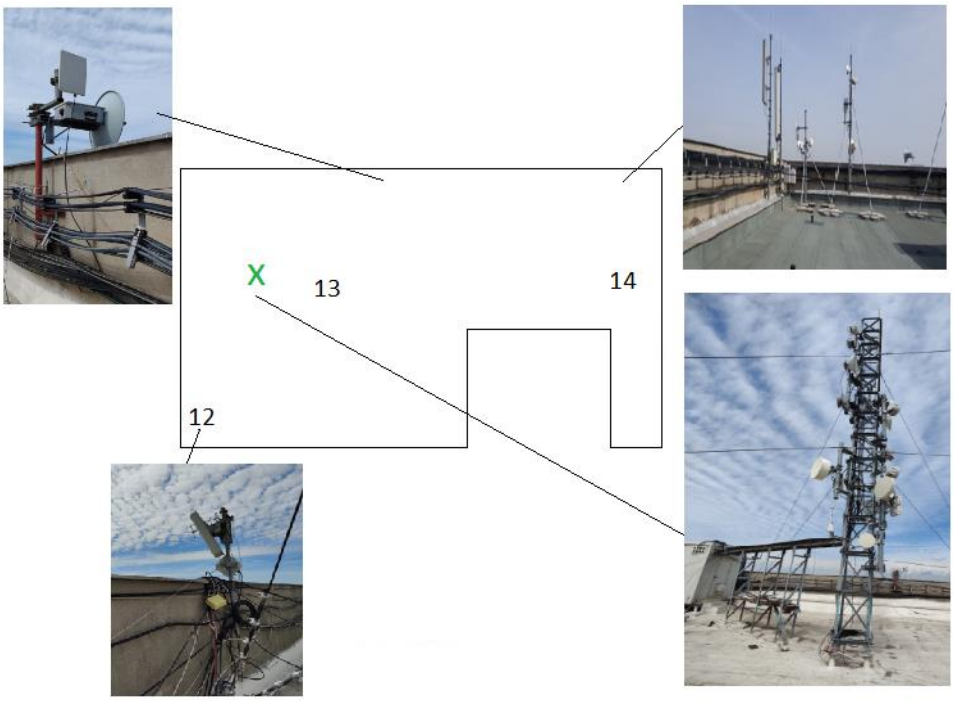

Fig. 4. Terrace 3 plan

Measurements were also taken on the side of the building consisting of 2 aedicula and the terrace between them. Fig. 5 shows the measurement points on aedicule 2, Terrace 4, respectively aedicule 3 as well as the antennas near them. Cell phone antennas and point-to-point links stand out here. There is a TV station on aedicule 3, but it no longer broadcasts.

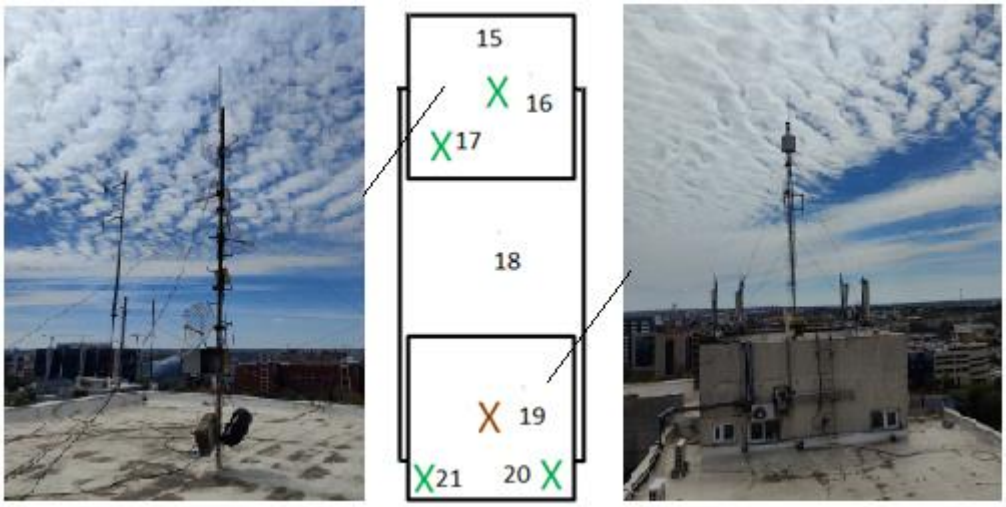

Fig. 5. Rooftop plan of the side formed by Terrace 4 and aedicules 2 and 3

In the center of the aedicule 2 is a structure that supports several antennas for data transmissions and a sector of the mobile phone station. In the vicinity of this support, the measurements from points 15 and 16 were carried out. Point 15 is in front of some antennas used for data transmission, located at an accessible height, and point 17 corresponds to the support on which the other two antennas of the mobile phone base station are located.

No antennas are installed on Terrace 4. The maximum value recorded at point 18 was 0.0095 W/m^2, the lowest recorded during the measurements. This is explained by the fact that the terrace is a few meters lower than the two aedicula, with reduced visibility towards the electromagnetic field sources.

The points on the aedicule 3 were chosen near the mobile phone antennas and the TV transmitter which is currently out of service.

In Fig. 6 and Fig. 7, respectively, the maximum values and average values measured of the power density are represented. In order to observe the difference compared to the reference levels established by law, we have also represented the reference limits specific to the public for the power density for each frequency band. In the case of the frequency band 400 MHz - 2 GHz, where the limit is given as the frequency expressed in MHz weighted by 200, we took the worst case, considering the power density limit of 2 W/m^2.

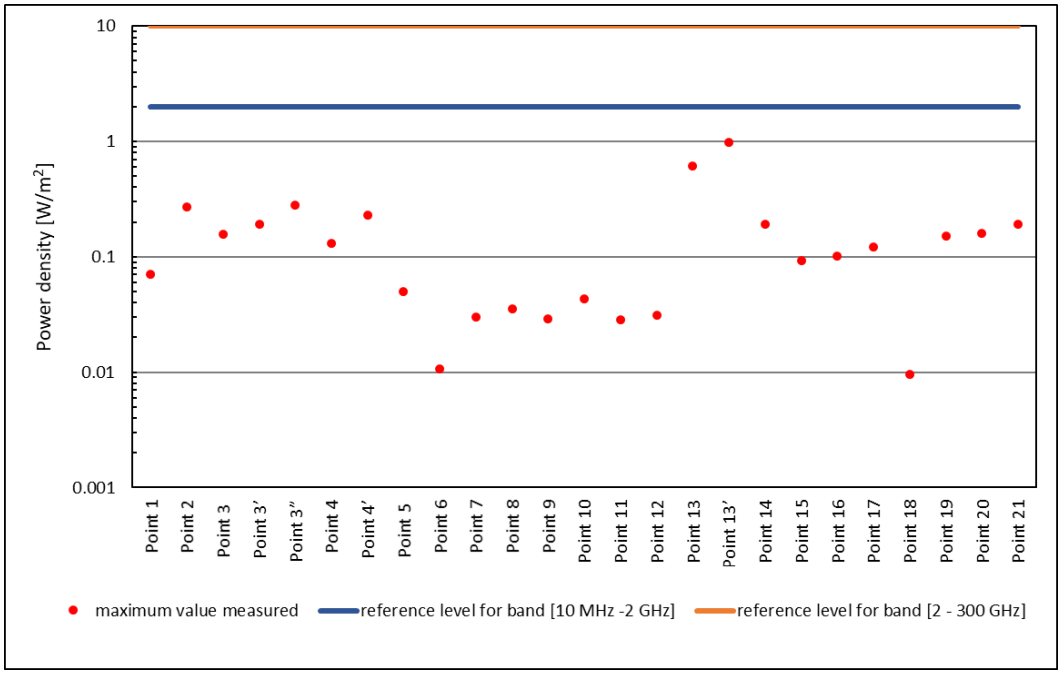

Fig. 6. Maximum power density values measured

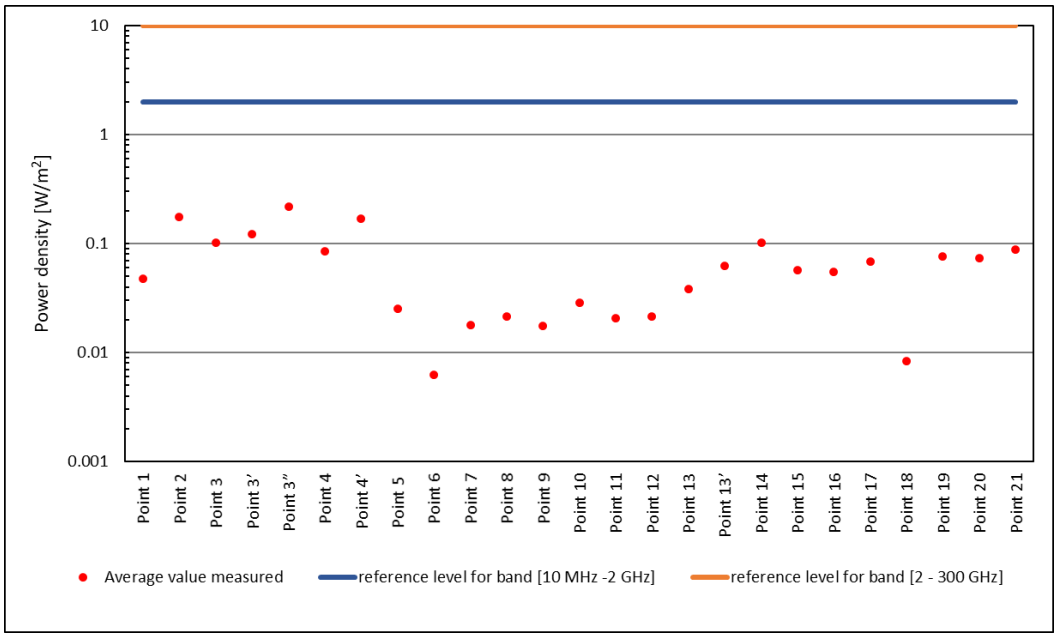

Fig. 7. Average power density values measured

Although the measurements show that there are no reasons for concern, we considered it useful to see the values of the field on the last floor of the building, in the hallway just below the terrace where the initial measurements were made. For these measurements, we kept only the maximum values, their centralization being presented in table 2.

Table 2

Measurement results at 8th floor

Measuring point	Maximum power density value [W/m^2]
"Apaca lifts"	0.0081
Office A802	0.0052
Office A804	0.0048
Office A808	0.0049
Office A810	0.0058
Office A814	0.0061
"LEU lifts"	0.0078

As expected, due to the propagation losses and attenuations introduced by the obstacles between the field sources and the measurement location, the field level is reduced compared to the one to be recorded on the terrace. It would have been even lower if a Wi-Fi router had not been placed on the 8th floor.

3. Conclusions

The conclusion is that the values measured at any point on the terrace are below the reference levels for the general public specified by the ICNIRP standard. With the exception of the area in front of the microwave antenna related to measuring point 13, the higher values are recorded on the aedicules, especially on the 1st aedicule, where the visibility with the emission antennas is higher than in the case of the terraces.

The difference between the obtained values of the maximum exposure coefficients, 10% based on the measurements made by the author and 20% the measurements made by the ANCOM sensor, is explained by the fact that the ANCOM measurements were reported at 27.5 V/m which is the minimum reference threshold in the band 100 kHz – 7 GHz, although most terrace antennas emit in bands above 2 GHz, where the reference level is 61 V/m, which would result in maximum exposure coefficients not exceeding 5% of the norm.

Even if we have a high number of antennas on this site, the exposure is reduced due to the use of directional antennas with a small vertical opening of the main lobe, thus ensuring a sufficient vertical clearance between the accessible areas on the surface of the terrace and the radiation direction of the lobes of 3 dB.

Antennas mounted at heights accessible to people or emitting to accessible areas lead to the emergence of more intense fields, but even in these cases the measurements did not exceed the regulated values.

The measurements carried out inside, on the top floor, located immediately below the floor where the radiation sources are installed on the building, revealed much better values than outside, which is easy to intuit due to the attenuation brought by the walls and ceiling of the building.

R E F E R E N C E S

[1]. *Mohamed Shalaby, Mona Shokair, Nagy W. Messiha.* "Electromagnetic Field Measurement Instruments: Survey", Shiraz University, 2018. https://doi.org/10.1007/s40998-018-0116-y

[2]. *Marius Nedelcu, Teodor Petrescu, Victor Nițu,* "Evaluation of electromagnetic field exposure in the vicinity of mobile phone base stations," 2021 IEEE International Black Sea Conference on Communications and Networking, Bucharest, Romania, 2021, pp. 1-5, doi: 10.1109/BlackSeaCom52164.2021.9527794.

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

[4]. *** *https://www.monitor-emf.ro/*

[5]. *Marius NEDELCU, Teodor PETRESCU,* "Evaluation of human exposure to electromagnetic field using data provided by the National Autonomous Electromagnetic Field Monitor system", U.P.B. Sci. Bull., Series C, Vol. 85, Iss. 2, 2023, pp. 175-184, ISSN 2286-354

[6]. *** http://radiomap.eu/ro/bucuresti

[7]. *** CEPT general/REC (02)04, Measuring non-ionising electromagnetic radiation (9 kHz–300 GHz), 2004