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Human exposure in a 5G cellular base station environment in residential districts of Iasi city

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***Abstract* – The paper presents a pilot study over human exposure to radiofrequency (RF) electromagnetic field (EMFs) levels generated by the 5G cellular base stations installed in different residential district in city of Iasi, Romania.Also, a comparison with different EMFs levels generated by different mobile phonetechnologies, from our national operators, have been done. Measurement of electromagnetic field levels (instantaneous exposure) expressed in terms of power density levels has been performed in city of Iasi, fom March to November 2021, in nine locations with a high density of cellular base stations. The EMF exposure levels for different mobile communications standards have been measured with an up to date calibrated NARDA SRM 3006 field strength analyser system connected to an isotropic electric field probe.The methodology for measuring the non-ionising electromagnetic radiation levels described by ECC RECOMMENDATION (02)04have been respected.**

I. INTRODUCTION

As the world continues to embrace new technology in various aspect of our lives, from phones to smart devices, there is growing attention and concerns around the world over the effects of EMFs on human health.Without EMF, the everyday life as we know it would not exist.

We are surrounded by a complex mixture of a large number of RF EMF sources and questions and public discussions about the exposure have been raised more and more in the last decade, especially with the development of the new 5G mobile network. The rollout of the new 5G cellular base stations in the sub-6 GHz band is already in progress in many countries.

For human protection against electromagnetic radiation, different organizations like ICNIRP (International Commission on Non-ionizing Radiation Protection, FCC (Federal Communication Commission) and IARC (International Agency on Research on Cancer) are recognized by WHO forvarious studies over EMF biological effects over the human body.

EMF exposure regulation according the ICNIRP have been adopted in many contries all over Europe. But there are some countries in Europe not follow exactly the ICNIRP guidelines and they defined and adopted own national legislations with restrictiv values of limits for the protection of general public against exposure at EMF levels.Countries like Poland, Bulgaria, Lithuania and Italy, because of theri national legislation have already problems in past with migration from 3G to 4G. This restrictive limitation could have now in 2022 a real negative impact over the future deploy of 5G network infrastructure in theses countries.. This problem raise the question of whether it is not necessary for these restrictive limits imposed by these countries to be relaxed and possibly harmonized with the other countries from Europe.

ICNIRP guidelines identify basic limits and reference levels.

In Romania, the exposure of the population to electromagnetic fields (also including the range of frequencies used for nw 5G NR technology) is regulated by the Order of the Minister of Public Health no. 1193 from 29.09.2006, [1]. Romania approved norms regarding the limitation of the exposure of the general population to electromagnetic fields from 0 Hz to 300 GHz, described by the Romanian National Ministry Order 1193/2006 integral transposition for 519/1999 Recommendation of the Council of the European Union, [2].The EU Council Recommendation 1999/519/EC, which is the reference document in the Europe Union, is based on the emission limits set out by the new ICNIRP's 2020 guidelines, [3], who is an updated version of ICNIRP 1998 guidelines. The 5G NR mobile communication technology was take into account when the new version of ICNIRP guidelines was developed.

In addition to determining the maximum exposure for verifying the compliance with the exposure limits using different extrapolation methods, [4], [5],could be also of interest to determine the instantaneous exposure, [6].

The instantaneous exposure can reflect the actual exposure of a person and depend over the actual traffic demand in a cellular base station, demand who can varying over time.

The present paper is focused mainly on the 5G human exposure, EMF levels monitoring beeing investigated with a mobile equipment in the vicinity of such cellular base stations.

We here present the measurement of electromagnetic field levels (in terms of power density values) performed in 2021 form March to November in Iasi city. For the assessment of human exposure to RF EMF generated by cellular base stations was take into consideration nine residentialareas in the city with high density of mobile phone base stations sites, covering a wide range of mobile phone communications standards– 2G, 3G, 4G and the new 5G. For each location we investigated the EMF exposure level from all mobile services taking in consideration for the 5G mobile telephony service two situations – without or with generated data traffic.

In the final a comparison between instantanoeusmeasured fields values data and limits imposed by international organizations and national regulatory bodies has been performed. Also, a compliance check was performed and a set of preliminary conclusions have been taken.

II. MATERIAL AND METHODS

According to ICNIRP guidelines, the reference levels for public exposure in frequency range of mobile phone communications standards, included also the new 5G are presented in Table 1, where f is the frequency expressed in MHz.

Table 1. ICNIRP reference levels for public exposure

Frequency f [Mhz]	E [V/m]	S [W/m^2]
400 – 2000 MHz	$1.375 \times \sqrt{f}$	f/200
2000 – 300 000	61	10

All measurements have been performed indaytime during the peak hours of a working day and the total measurement time was6 minutes.

For determining the EMF levels, we used a mobile equipment from Narda, Narda SRM 3006 spectrum analyzer. The device is set to work in Safety Evaluation mode. This mode was developby Narda for a fast overview of the exposure levelsdue to individually definable frequency ranges (for a single or multi frequency environment), services and providers as absolute values or automatically evaluated according to common human safety standards, [7].

Using the SRM-3006 Tools software associated with device, we have created a special service table called Mobile Phone Operators. The service table contain six individual frequency bands used for different telephony services of our national operators between 790 MHz and 3.8 GHz. The all six frequency bands range assigned for Mobile Phone Operators service table is presented in Table 2.

In theory to avoid underestimation of the immission, it is important that the resolution bandwidth (RBW) to not be set less than the bandwidth of the signal to be measured. For example, for GSM service, GSM frequency spacing / signal channel width is 200 kHz, this value can be set for RBW for this service, [8].

Table 2. Mobile Phone Operators service table

Index	Cellular Service Name	F start [Mhz]	F stop [Mhz]	RBW
1	MOBIL 800 DL	791	821	200 kHz
2	MOBIL 900 DL	925	960	200 kHz
3	MOBIL 1800 DL	1805	1880	200 kHz
4	MOBIL 2100 DL	2110	2170	5 MHz
5	MOBIL 2600 DL	2570	2690	5 MHz
6	MOBIL 3500-3700	3400	3800	20 MHz

As a part of measurement procedure descbribed in ECC (02)04, for spectrum analysers it is recommended for 300 MHz – 3 GHz frequency band a value of 100 kHz for bandwidth, [9].

Also, NARDA SRM 3006 automatically sets the RBW if the user don't set an individual RBW, so that four spectral lines cand still be detected in the narrowest band.

As a particularity,wedon't use the automatically setting of the RBWby Narda,and individual values for RBW has been assignedby user for every cellular service created.We set the RBW value as the lowest value based on the presence of a specific mobile communication standard in the frequency band corresponding toeverycellular service defined.

The measurement points of EMF exposure levels generated by cellular base stations in city of Iasi are presented in Table 3. Each location have a 5G-enable mobile base station.

Table 3. EMF measurement point locations

Measure ment Location	Adress	Cellular base station ground level height (m)	Distance to cellular base station (m)
MP1	Metalurgiei street	~70	~300
MP2	Ciornei street	~55	~100
MP3	Tudor Vladimirescu Boulevard	~45	~200/110
MP4	Socola Boulevard	~55	~95
MP5	Graniceri street	~30	~80
MP6	Ciric street	~40	~210
MP7	Prof. Dimitrie Mangeron Boulevard	~55	~300
MP8	Titu Maiorescu street	~57	~120
MP9	Anastasie Panu street (Palace of Culture Square)	~60	~190/190

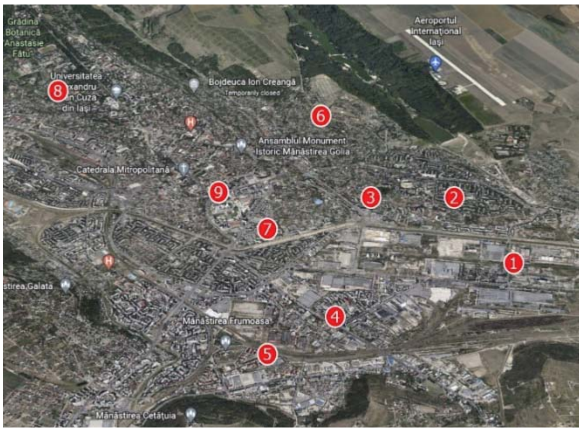


Fig.1 Location of EMF measurement points

On a detailed Iasi city map, all three locations can be visualized in Figure 1.

The EMF exposure levels generated by investigated cellular base stations in all selected location have been measured using a calibrated up to date Narda SRM 3006 field strength analyzer connected to an isotropic probe as presented in Figure 2, for MP9 EMF measurement point location.The electric field probe [10] is designed to measure to electric field in frequency range domain from 420 MHz to 6 GHz. This frequency domainwill cover very well all of the frequency bands for all mobile communications standards used for cellular base stations transmissions.

According to the manufacturer's specifications, the measurement uncertainty of the level measured by the Narda SRM 3006 is + 2.7 / -3.8 dB.

The measurements were performed with a good visibility to the cellular base station with no obstacles between measurement system and antennas.

The measurements have been performed in accordance with by integrating signals into specified frequency bands corresponding to the cellular services createdover a 6 (six) minute time frame (averaged value), with an electrical probe rising to a ground height of 1,5 m, [9].

Fig.2 Narda SRM 3006 field strenght analyzer

Using an isotropic probe denote the fact that the measurement results is not affected by the direction of the arrived signal. The result is not also affected by the polarization of the measured field.

The value of the total resultant electric field measured in one location is given by the equation (1):

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2} \quad (1)$$

where Ex, Ey and Ez are the electric field components measured on the perpendicular axes of the 3D coordinate system.

Before starting the evaluation of EMF levels using Safety Evaluation mode, we take a short and rapid view over the presence or not of cellular telephony services in all measurement point locations, setting the Narda to work in Spectrum Analyzer mode.A synthetic and suggestive image acquired by Narda software, regarding the presence of cellular telephony services (Actual values) in the spectrum in MP9 location is represented by Figure 3.

The sensitivity of anequipment in signal detection depends on the input attenuator setting. In Narda SRM 3006 spectrum analyzer this setting is determined by the Measurement Range (MR) parameter, [10].

In case of measuring signals with different power from a cellular telephone base station it is important to not overload the device. Also choosing a correct MR the situation of having false measured results is prevented.

After some preliminary tests, for each EMF measurement point location, the MR value was setting manually depending on the strength of the signals in the area.

In each from all nine measurement points, a 5G cellular base stations were present in the area. Because we assumed that the presence of 5G terminals with 5G services active in the area will be very reduce, we force the appearance of a traffic beam in the measurement point for 5G telephony service. With a 5G mobile phone terminal placed next to the measurement device we simulate a downlink using the Netograf application developed internaly by ANCOM, [11]. This could be called a**single user exposure scenario**.

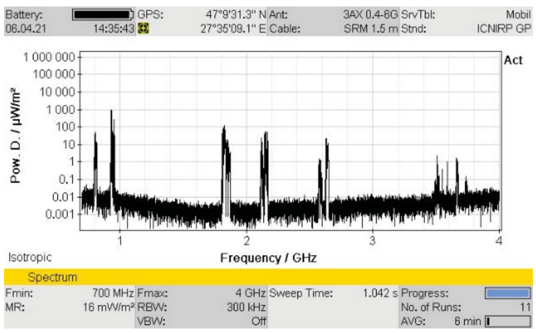


Fig.3 Spectral distribution of cellular telephony services

For each location where the assessment of human exposure to cellular base stations was performed, we measured the instantaneous (Avg values) and maximal (Max values) possible exposure for a perioad of time of 6 minutes.

In a multi frequency exposure scenario, the contribution of all individual frequencies can be express by the total EMF immission level across all bands measured in terms of total power density, [8]its value being given by the equation (2):

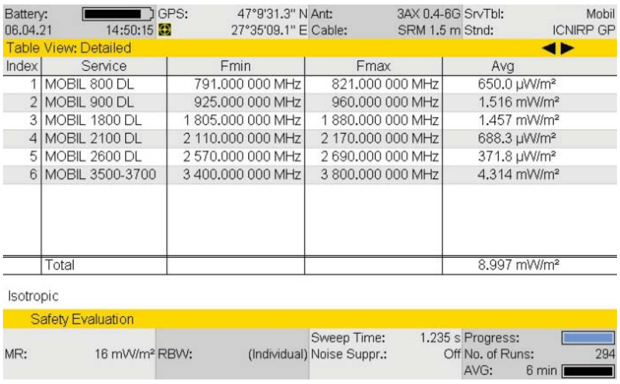
$$S_{tot} = \sum_{i=1}^{N} S_i \qquad (2)$$

where:

S_{tot} is the total immission level expressed in terms of total power densityfor all cellular services

S_i is the immission level expreesed in term of power density corresponding to a specific cellular service from service table created.

On the spectrum analyzer display exposure levels are reported in real time both for a single cellular service and the sum of all services,as presented in Figure 4.


Battery: | GPS: 47°9'31.3" N | Ant: 3AX 0.4-6G | SrvTbl: Mobil
06.04.21 14:50:15 | 27°35'09.1" E | Cable: SRM 1.5 m | Stnd: ICNIRP GP
Table View: Detailed

Index	Service	Fmin	Fmax	Avg
1	MOBIL 800 DL	791.000 000 MHz	821.000 000 MHz	650.0 µW/m²
2	MOBIL 900 DL	925.000 000 MHz	960.000 000 MHz	1.516 mW/m²
3	MOBIL 1800 DL	1 805.000 000 MHz	1 880.000 000 MHz	1.457 mW/m²
4	MOBIL 2100 DL	2 110.000 000 MHz	2 170.000 000 MHz	688.3 µW/m²
5	MOBIL 2600 DL	2 570.000 000 MHz	2 690.000 000 MHz	371.8 µW/m²
6	MOBIL 3500-3700	3 400.000 000 MHz	3 800.000 000 MHz	4.314 mW/m²
	Total			8.997 mW/m²

Isotropic
Safety Evaluation
MR: 16 mW/m² | RBW: (Individual) | Sweep Time: 1.235 s | Noise Suppr.: Off | Progress: | No. of Runs: 294 | AVG: 6 min

Fig.4Avg values of EMF level strength in MP9 location with 5G cellular service activated

III. RESULTS AND DISCUSSION

The instantaneous exposure can reflect the actual exposure of a person and depend over the actual traffic demand in a cellular base station, demand who can varying over time.

The instantaneous and maximal possible exposure in terms of field strength values, expressed by power density (S) values, maximum (Max) and averaged (Avg) values over a 6-minute time interval are presented in Table 4 for all nine EMF measurement points.

The values of interest for the assessment of human exposure to electromagnetic fields generated by mobile base stations according to ICNIRP guidelines isAvg value of power density which must be compared with the limit value imposed by ICNIRP guidelines.

From the results presented in Table 4 we can observe that for each locationwhere the assessment of exposure was investigated, the S Avg values are very well below with those limit values imposed by ICNIRP guidelines, especially for the case when data traffic was generated for 5G telephony services.

The highest values of S Avg was recorded in MP3 and MP9 measurement point locations. Both locations are representative for the city of Iasi in terms of urban agglomeration and cellular base stations density. This locations could be marked like being a hot spot areas.

Graphically, a comparison between instantaneous S Avg and maximum S Max values for all telephony services identified in MP3 location, for a 5G single user exposure scenario, is presented in Figure 5.

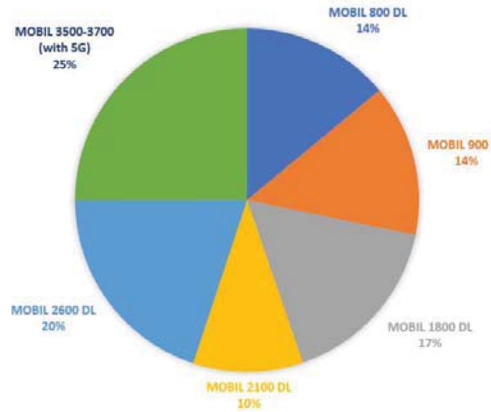


Fig.5 Quantitative and comparative S Avg values, for the identified cellular services in MP3 location

A comparison between maximum values of power density (S Max)field strength levels for all telephony services identified in MP3 location, for a forecd 5G traffic beam, is presented in Figure 6.

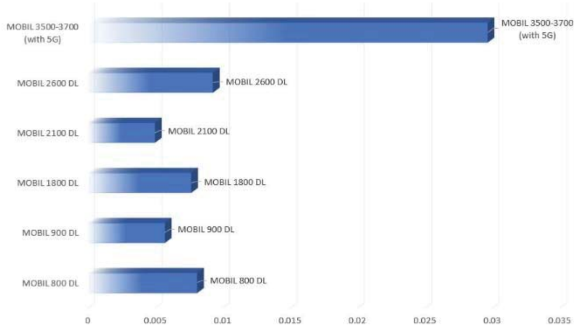


Fig.6 S Max values comparison, for the identified cellular services in MP3 location

The highest S Avg and S Max values for 5G cellular service with forced traffic beam have been measured in MP5 location.This fact correspond to the fact that the measurements were performed at the smallest distance from the site compared to the rest of the measurements performed.

Table 4. Electromagnetic field power density measured values in MP1 – MP9 locations

Location	Cellular Service Name	F start [MHz]	F stop [MHz]	S Max [W/m^2]	S Avg [W/m^2]	S Std [W/m^2]
MP1 - no 5G *(Metalurgiei street)*	MOBIL 800 DL	791	821	0.0002122	0.0000811	3.95
	MOBIL 900 DL	925	960	0.0007103	0.0003492	4.62
	MOBIL 1800 DL	1805	1880	0.0006903	0.0002996	9.02
	MOBIL 2100 DL	2110	2170	0.0003991	0.0002116	10
	MOBIL 2600 DL	2570	2690	0.0007978	0.0003124	10
	MOBIL 3500-3700	3400	3800	0.0001118	0.0000192	10
MP1 - with 5G	MOBIL 3500-3700	3400	3800	**0.0195500**	**0.0017400**	10
MP2 - no 5G *(Ciornei street)*	MOBIL 800 DL	791	821	0.0003178	0.0001973	3.95
	MOBIL 900 DL	925	960	0.0006241	0.0002991	4.62
	MOBIL 1800 DL	1805	1880	0.0000817	0.0000267	9.02
	MOBIL 2100 DL	2110	2170	0.0007138	0.0002911	10
	MOBIL 2600 DL	2570	2690	0.0008813	0.0001967	10
	MOBIL 3500-3700	3400	3800	0.0003180	0.0000333	10
MP2 - with 5G	MOBIL 3500-3700	3400	3800	**0.0227200**	**0.0046100**	10
MP3 - no 5G *(Tudor Vladimirescu Boulevard)*	MOBIL 800 DL	791	821	0.0081100	0.0028880	3.95
	MOBIL 900 DL	925	960	0.0057170	0.0029560	4.62
	MOBIL 1800 DL	1805	1880	0.0076700	0.0034070	9.02
	MOBIL 2100 DL	2110	2170	0.0049880	0.0021340	10
	MOBIL 2600 DL	2570	2690	0.0092800	0.0041110	10
	MOBIL 3500-3700	3400	3800	0.0002192	0.0000303	10
MP3 - with 5G	MOBIL 3500-3700	3400	3800	**0.0296500**	**0.0051760**	10
MP4 - no 5G (*Socola Boulevard)*	MOBIL 800 DL	791	821	0.0009110	0.0003710	3.95
	MOBIL 900 DL	925	960	0.0027170	0.0009330	4.62
	MOBIL 1800 DL	1805	1880	0.0008230	0.0003170	9.02
	MOBIL 2100 DL	2110	2170	0.0019880	0.0009340	10
	MOBIL 2600 DL	2570	2690	0.0062800	0.0023210	10
	MOBIL 3500-3700	3400	3800	0.0003112	0.0000701	10
MP4 - with 5G	MOBIL 3500-3700	3400	3800	**0.0336500**	**0.0057130**	10
MP5 - no 5G (*Graniceri street)*	MOBIL 800 DL	791	821	0.0003338	0.0002113	3.95
	MOBIL 900 DL	925	960	0.0008141	0.0003751	4.62
	MOBIL 1800 DL	1805	1880	0.0001915	0.0003667	9.02
	MOBIL 2100 DL	2110	2170	0.0005134	0.0001131	10
	MOBIL 2600 DL	2570	2690	0.0003813	0.0011354	10
	MOBIL 3500-3700	3400	3800	0.0001170	0.0000491	10
MP5 - with 5G	MOBIL 3500-3700	3400	3800	**0.0516500**	**0.0074960**	10
MP6 - no 5G (*Ciric street)*	MOBIL 800 DL	791	821	0.0003719	0.0000957	3.95
	MOBIL 900 DL	925	960	0.0006129	0.0002976	4.62
	MOBIL 1800 DL	1805	1880	0.0027120	0.0009918	9.02
	MOBIL 2100 DL	2110	2170	0.0008204	0.0003860	10
	MOBIL 2600 DL	2570	2690	0.0005641	0.0001731	10
	MOBIL 3500-3700	3400	3800	0.0000991	0.0000381	10
MP6 - with 5G	MOBIL 3500-3700	3400	3800	**0.0217100**	**0.0019220**	10
MP7 - no 5G *(Prof. Dimitrie Mangeron Boulevard)*	MOBIL 800 DL	791	821	0.0003953	0.0000891	3.95
	MOBIL 900 DL	925	960	0.0005941	0.0004010	4.62
	MOBIL 1800 DL	1805	1880	0.0000584	0.0000211	9.02
	MOBIL 2100 DL	2110	2170	0.0031179	0.0009870	10
	MOBIL 2600 DL	2570	2690	0.0002013	0.0001172	10
	MOBIL 3500-3700	3400	3800	0.0003180	0.0000981	10
MP7 - with 5G	MOBIL 3500-3700	3400	3800	**0.0198600**	**0.0025710**	10
MP8 - no 5G *(Titu Maiorescu street)*	MOBIL 800 DL	791	821	0.0021490	0.0008201	3.95
	MOBIL 900 DL	925	960	0.0004117	0.0001140	4.62
	MOBIL 1800 DL	1805	1880	0.0007210	0.0005250	9.02
	MOBIL 2100 DL	2110	2170	0.0048520	0.0017540	10
	MOBIL 2600 DL	2570	2690	0.0002130	0.0001150	10
	MOBIL 3500-3700	3400	3800	0.0002100	0.0000980	10
MP8 - with 5G	MOBIL 3500-3700	3400	3800	**0.0161100**	**0.0037450**	10
MP9- no 5G *(Anastasie Panu street)*	MOBIL 800 DL	791	821	0.0014840	0.0007437	3.95
	MOBIL 900 DL	925	960	0.0031660	0.0026000	4.62
	MOBIL 1800 DL	1805	1880	0.0093880	0.0029000	9.02
	MOBIL 2100 DL	2110	2170	0.0036170	0.0015900	10
	MOBIL 2600 DL	2570	2690	0.0024850	0.0008950	10
	MOBIL 3500-3700	3400	3800	0.0003668	0.0001132	10
MP9 - with 5G	MOBIL 3500-3700	3400	3800	**0.0244900**	**0.0043140**	10

IV. CONCLUSIONS

This paper provides an overview on the assessment of human exposure to RF EMF generated by different types of cellular base stations in nine residential district locations from city of Iasi, Romania. The selected locations are public with a high density of cellular base stations sites, covering a wide range of mobile phone communications standards, from 2G to 5G NR.

This is the first major public study from Romania over the assessment of human exposure to EMF fields generated by the 5G cellular base station, even the 5G traffic beam was forced to be generated in a so called 5G single user exposure scenario.

The assessment was realized from the point of view of the instantaneous and maximal possible exposure in term of field values, expressed in maximum and averaged values of power density (S) over a 6-minute measurement time interval.

The instantaneous exposure can reflect the actual exposure of a person and depend over the actual traffic demand in a cellular base station, demand who can varying over time.

For each frequency band associated with defined cellular services the measurement equipment was set accordingly in accordance with actul standard and recommended guidelines.

All power density averaged values measured, were very well below with those limit values imposed by international organizations and national regulatory bodies, even for a 5G single user exposure scenario when traffic beam was forced to be generated.

The highest S Avg values was measured in MP5 location for forced 5G cellular service, this value representing0,07 %from standard value.

For every location investigated, will notice that the measurements values for forced 5G cellular service show some variations between the exposure levels measured at each location. This is likely to be due, by the difference in the position of the measurement electric field probe against the position of cellular base station.This behaviorcan be checked in detail in a future study.

The measurement method proposed in this study can be used successfully when the instantaneous field strength values (averaged values over a 6-minutes period of time) would be enough for an assessment of human exposure to electromagnetic fields generated by various telephony services at an aleatory moment of time. If the measured averaged field values are well below those impose by limits, then the maximum field strength values can be used for a better accurate assessment of the reality of exposure.Without exception, the measured values of the electric field strength must be extrapolated to the maximum load of the cellular networkfor an accurate and precise assessment of human exposure.

Also, as a future research, the assessmenet of human exposure needs to be extendedin a 5G multi-exposure scenario to be more relevant for everyday life.

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