ELECTROMAGNETIC FIELDS MEASUREMENTS

5G NETWORKS IN TECHNICAL TRIALS

ANACOM
AUTORIDADE NACIONAL DE COMUNICAÇÕES

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ANACOM

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LIST OF ACRONYMS AND ABBREVIATIONS

AAS	Active Antenna Systems
ANACOM	Autoridade Nacional de Comunicações
DGS	*Direção-Geral de Saúde* (Directorate-General of Health)
ECC	Electronic Communications Committee
EMF	Electromagnetic field
EU	European Union
FTP	File Transfer Protocol
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MIMO	Multiple Input Multiple Output
NR	New Radio
NRA	National Regulatory Authority
NSA	Non-Stand Alone
TDD	Time Division Duplex
TECS	Terrestrial Electronic Communications Services
WHO	World Health Organization
4G	Fourth generation of mobile technology
5G	Fifth generation of mobile technology

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EXECUTIVE SUMMARY

Autoridade Nacional de Comunicações (ANACOM) is responsible for supervising the radio spectrum in Portugal and for its efficient management. In this context, ANACOM monitors compliance with the reference levels of Electromagnetic Fields (EMF) produced by radiocommunication stations, to ensure that the general public is protected from EMF exposure.

ANACOM decided to carry out measurements of EMF levels produced by fifth generation (5G) mobile networks following authorisations issued by ANACOM to carry out technical trials of 5G technology in Portugal.

By means of Administrative Rule no. 1421/2004 of 23 November, Portugal adopted the Council Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz - 300 GHz), based on the limits defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP); these limits serve as a reference for the results of the EMF measurements carried out by ANACOM.

The results of EMF measurements carried out in Portugal during the 2000 - 2020 period, which did not include 5G networks, point to consistently safe values which are at least 50 times lower than the reference levels.

The objective of the present study is to assess the impact of 5G, in terms of the general public's exposure to EMF and to present the result of measurements taken between June and October 2020 in the vicinity of stations used to carry out 5G pilot trials in the 3.4 - 3.8 GHz (3.6 GHz) band; these stations were authorised by ANACOM, within the scope of its powers and responsibilities. EMF measurements were taken at five locations (referred to in this report as "survey sites"), in the vicinity of four different 5G networks. The main conclusions are as follows:

- The 5G networks were operating in accordance with expected requirements with respect to the 3.6 GHz band;
- Overall, the measured values were more than 50 times lower than the recommended reference levels;
- The contribution of the test 5G networks in the 3.6 GHz band to total levels of exposure was insignificant at the time of measurement when compared to the mobile networks already in operation and providing Terrestrial Electronic Communications Services (TECS).

It should be noted that EMF measurement procedures are not yet defined for 5G networks at national and international levels. While this work is essentially based on current procedures, it includes new

approaches, namely the EMF evaluation by using the extrapolation method proposed by Narda, the measuring instruments manufacturer.

In the context of the normal pursuit of its powers and responsibilities, and with a view to future actions in the area of EMF, ANACOM:

- will continue to monitor and contribute to international developments in terms of EMF measurement methods and procedures, including 5G networks and, in particular, updates to the ECC Recommendation (02)04 on "measuring non-ionising electromagnetic radiation (9 kHz-300 GHz), amended 6 February 2007"; and
- will proceed with measurement activities in public areas, assessing the general public's exposure to EMF following the deployment of public 5G networks, taking actual traffic levels into account.

1. INTRODUCTION

ANACOM is the National Regulatory Authority (NRA) in Portugal responsible for the efficient management of the radio spectrum. This work involves the planning and allocation of spectrum resources, the supervision of these resources and also coordination between civil and military radiocommunications.

ANACOM works to provide conditions which enable the development of new applications and services, contributing to national socio-economic development, including through the authorisation of technical trials prior to the introduction of specific technologies into the Portuguese market.

As part of its supervisory activities, ANACOM monitors compliance with applicable regulations and, specifically, compliance of EMF produced by radiocommunication stations with the reference levels. This important activity ensures that the general public are properly protected from EMF exposure.

Following the authorisations issued by ANACOM to carry out 5G technical tests in Portugal, and within the context of EMF, ANACOM decided to carry out measurements of EMF levels produced by 5G networks, even while EMF measurement procedures have not yet been defined at a national and international level.

Section 2 presents the framework for ANACOM's activity in terms of EMF evaluation. Section 3 gives a description of the 5G technical trials authorised in Portugal. Section 4 identifies the procedures and configurations used in EMF measurements, and also presents and analyses the results. Section 5 sets out the main conclusions. Finally, the report's Appendix presents the detailed results of the EMF measurements.

2. ANACOM'S EMF ASSESSMENT ACTIVITY

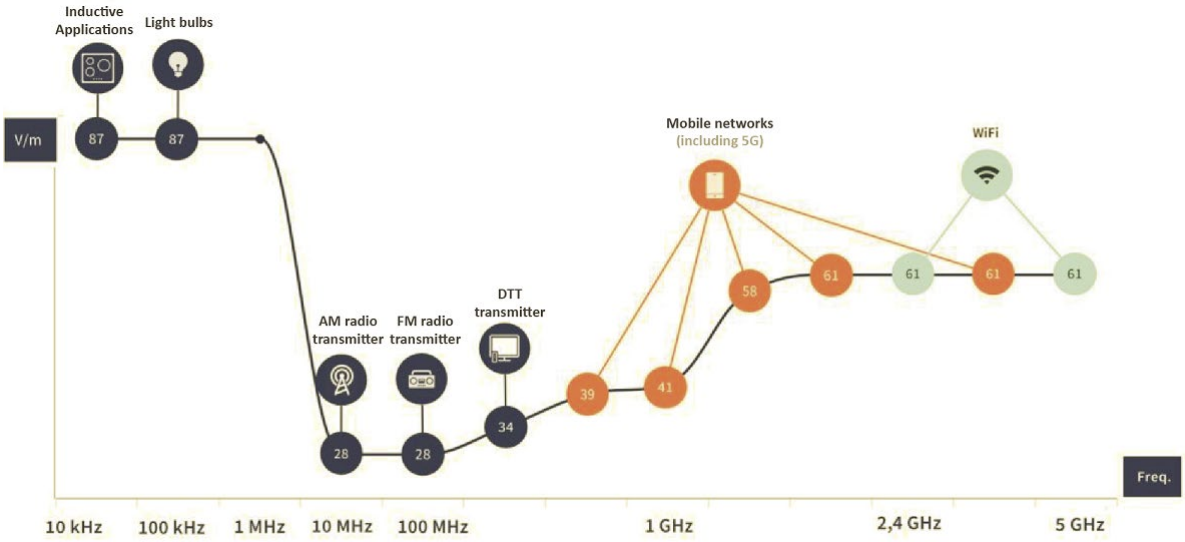
The Council of the European Union (EU) issued the Council Recommendation no. 1999/519/EC of 12 July on the limitation of exposure of the general public to electromagnetic fields (0 Hz - 300 GHz), based on the limits defined by ICNIRP, included within the framework of public health activities,

through a Decision of the European Parliament and the Council[1]. Portugal adopted the Council Recommendation by means of Administrative Rule no. 1421/2004 of 23 November. Verifying compliance with the reference levels specified in this Administrative Rule is one of the activities that constitute ANACOM's oversight work.

According to DGS - Direção-Geral de Saúde (Directorate-General for Health) [2], a leading authority in public health issues in Portugal, the reference levels for EMF exposure limits are to be determined in accordance with ICNIRP guidelines, which is formally recognised by the World Health Organization (WHO).

Figure 1 illustrates the EMF exposure limits adopted by Portugal (by frequency (MHz) and by electric field (E(V/m))).

Figure 1: EMF exposure limits



Source: ANACOM

ANACOM received 2,007 requests related to non-ionising radiation in the period from 2000 until the end of 2020, seeking analysis of specific situations. Responding to these requests, entailed taking thousands of measurements at different locations across Portugal, covering frequency bands which include mobile networks and other radiocommunication services.

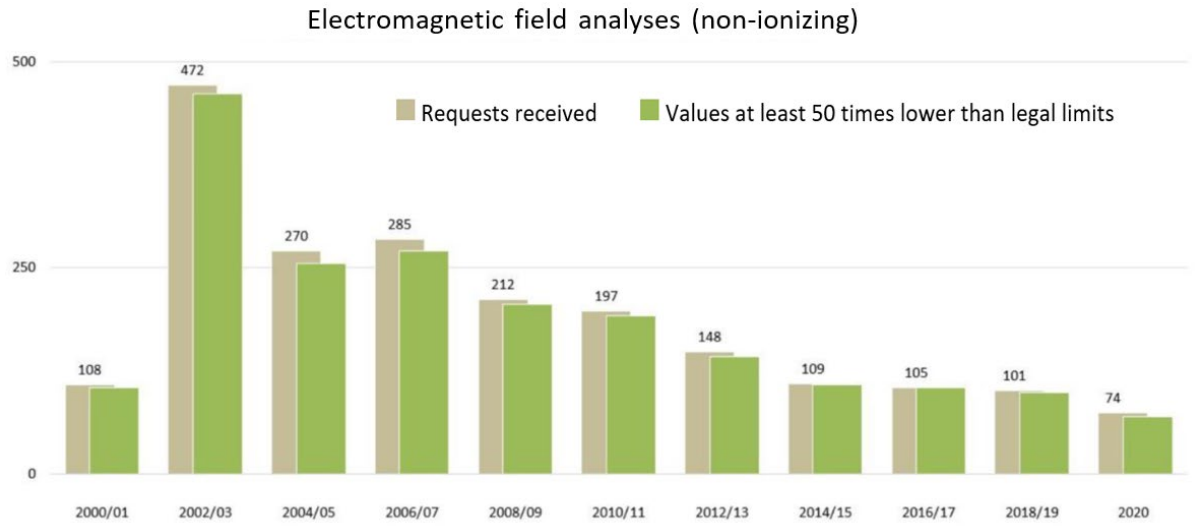
[1] ICNIRP updated its guidelines in 2020 but the Recommendation has not yet been updated at European Union level,.
[2] Further information available at https://www.dgs.pt/paginas-de-sistema/saude-de-a-a-z/radiacoes-nao-ionizantes.aspx

The results obtained over the last two decades point to consistently safe values: at least 50 times lower than the power density reference levels stipulated in Administrative Rule no. 1421/2004 of 23 November.

Out of all the requests analysed, there were only 66 situations (approximately 3% of the total) where ANACOM could not ascertain levels at least 50 times lower than the reference levels. However, in all cases, compliance with the reference levels set out in the Administrative Rule was guaranteed. All the conclusions of ANACOM's actions were brought to the attention of the parties concerned.

Figure 2 shows the analyses completed by ANACOM since 2000. It can be seen that the 66 situations noted above were concentrated in the early 2000s.

Figure 2: Trend in the number of requests received by ANACOM, 2000 to 2020



Source: ANACOM

3. TECHNICAL TRIALS OF 5G IN PORTUGAL

Since 2017, ANACOM has been providing authorisation to permit temporary use of radio spectrum in Portugal for the performance of 5G technical trials, in accordance with paragraph 3 of article 5 of Decree-Law no. 151-A/2000 of 20 July (current wording).

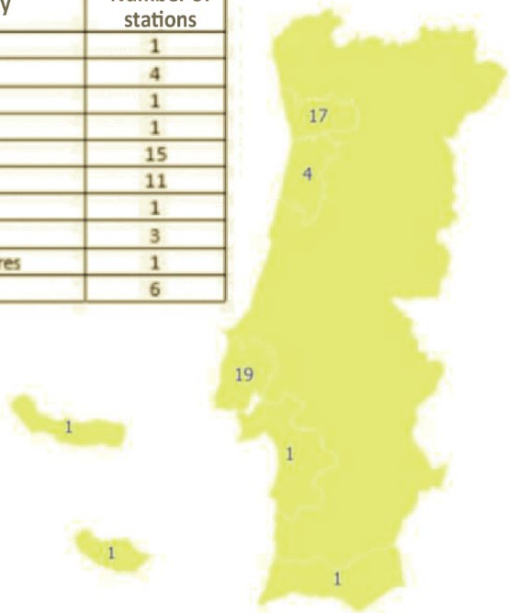
ANACOM considers these technical 5G trials and studies to be of substantial public interest and benefit, allowing researchers, manufacturers and operators of electronic communications to develop a learning process as regards the different functionalities and capabilities of the technology, and they can refine their theoretical models before taking the step towards large-scale deployment of future networks with provision of services to users.

The 3.6 GHz frequency band (3.4 - 3.8 GHz) is important for the implementation of 5G networks. The band has been used in the various technical trails that have taken place to date, in order to test its functionality.

The map in Figure 3 shows the distribution in Portugal by municipality of stations that were active on 1 July 2020 in the 3.6 GHz band, for study purposes.

Figure 3: Number of 5G stations conducting technical trials in Portugal, by municipality

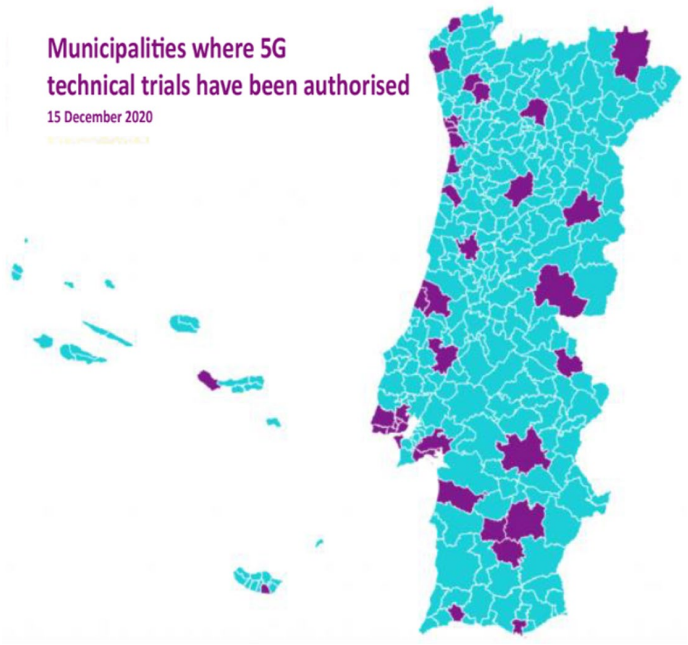
Municipality	Number of stations
Almada	1
Aveiro	4
Faro	1
Funchal - Madeira	1
Lisboa	15
Matosinhos	11
Odivelas	1
Oeiras	3
Ponta Delgada - Açores	1
Porto	6



Source: ANACOM (Reference: 01.07. **2020)**

In addition, Figure 4 shows the municipalities where 5G technical trials were authorised by ANACOM (reference date 15 December 2020).

Figure 4: Municipalities where 5G technical trials have been authorised



Source: ANACOM (Reference: 15 December 2020)

It is considered that the technical trials authorised by ANACOM have special relevance, since they allow operators to test the features and applications offered by the new mobile generation in a timely manner and in different contexts, including:

- NR (New Radio) technology;
- TDD (Time Division Duplex) access mode;
- Different TDD frame patterns;
- Bandwidths up to 100 MHz;
- Active Antenna Systems (AAS) (e.g., 64T64R);
- Multiple Input Multiple Output (MIMO);
- Beamforming;
- New handover solutions.

At the moment, 5G networks operate in non-standalone mode (NSA), so that they depend on 4G networks - in this NSA configuration, 5G is not possible without 4G.

The networks that were evaluated, although similar, have different forms of implementation depending on the manufacturer/operator, in terms of the bandwidth used, antenna configurations

with beamforming and pilot signal, as well as functionalities that allow the aggregation of 4G and 5G carriers, maximising data transfer speeds.

At the moment, the implementation of beamforming on 5G networks generates static beams only, that is, the beams are fixed in a certain direction. This creates a new challenge in 5G networks, requiring the definition of mechanisms that allow the handover between beams by the user – in practice the beam does not follow the user.

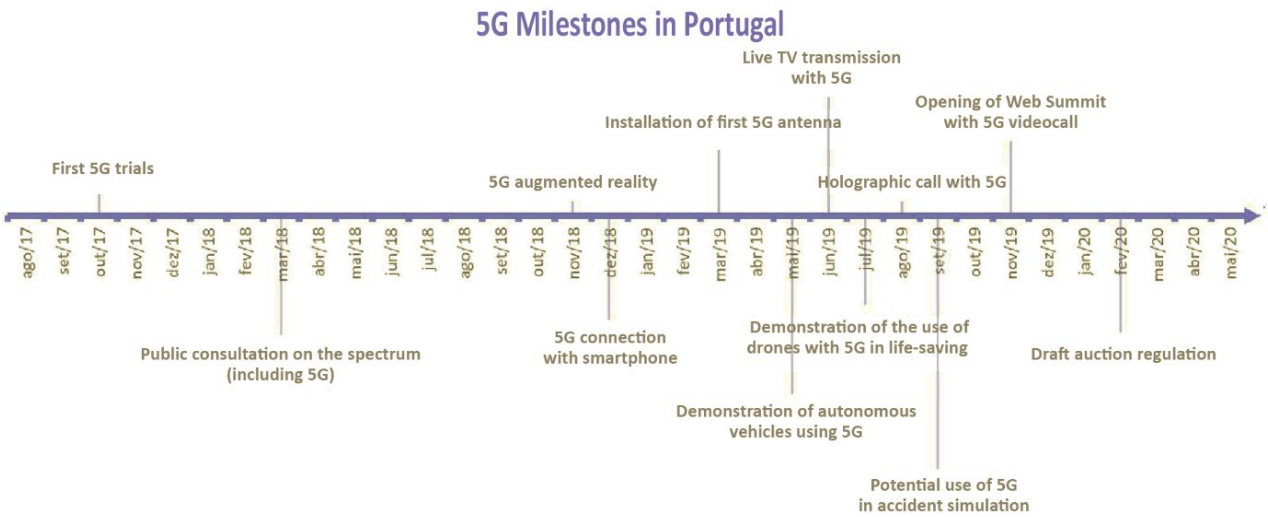
Between the authorisation of trials by ANACOM and the end of 2020, experimentation with 5G technology and with the frequency bands most suitable for its deployment allowed a set of specific steps to be taken and also meant that significant progress could be made in a number of areas. The timeline shown in Figure 5 highlights some of the main developments related to 5G in Portugal. These milestones, a number of which were highlighted in the media, include the following:

- October 2017: first 5G trials in Portugal;
- March 2018: Public consultation on the availability of spectrum in the 700 MHz frequency band and other relevant bands: 450 MHz, 900 MHz, 1500 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz, 3.6 GHz and 26 GHz[3];
- November 2018: demonstration of augmented reality with 5G during the Web Summit;
- December 2018: first 5G connection via smartphone;
- March 2019: first 5G antenna installation;
- May 2019: demonstration of the potential of 5G during the Portugal Smart Cities Summit, especially with regard to autonomous vehicles;
- May 2019: first 5G roaming connection between a Portuguese operator and Spanish operator;
- June 2019: live television broadcast supported by 5G technology;
- June 2019: demonstration of the use of 5G in the operation of drones to support beach life-saving (Matosinhos beach);
- August 2019: 5G Holographic call during the Paredes de Coura Festival (latency below 10 ms);
- September 2019: rescue teams use 5G to support their work in a simulated accident;
- November 2019: 5G videocall at the opening of the Web Summit;
- December 2019: connection with augmented reality device to demonstrate 5G applied to health;

[3]Available at https://www.anacom.pt/render.jsp?categoryId=406535.

- February 2020: ANACOM approved the draft auction regulation for the allocation of rights of use of frequencies in the 700 MHz, 900 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz and 3.6 GHz bands[4];
- June 2020: ANACOM publishes the Guide "Mobile networks and health - facts, data and challenges" [5];
- December 2020: start of the "5G" auction in Portugal.

Figure 5: Timeline of 5G progress in Portugal



Source: ANACOM

4. ASSESSMENT OF EMF ON 5G NETWORKS

The objective of this study is to assess the impact of 5G in terms of the general public's EMF exposure, and to present the results of analysis carried out between June and October 2020 in the vicinity of stations carrying out 5G pilot trials in the 3.4-3.8 GHz band (3.6 GHz).

While this work is essentially based on current procedures, it includes new approaches, including a new approach to the evaluation of EMF using the extrapolation method proposed by Narda (see section 4.3.4 of this report). Since the 5G trial networks were not available for public use at the time the measurements were taken, the data does not refer to an operational context.

[4]Available at https://anacom.pt/render.jsp?contentId=1502266.
[5]Available at https://www.anacom.pt/render.jsp?contentId=1540981.

In order to assess the effects of 5G on total exposure, test measurements were performed under the following conditions:

a) Absence of traffic;
b) Traffic generated by portable terminals;
c) Traffic generated by the network.

4.1 PROCEDURES

The methodology used to carry out this verification is based on the criteria defined in Regulation no. 86/2007 (this document describes the measurement method that should be used to assess electromagnetic radiation against the reference levels of human exposure to EMF (9 kHz - 300 GHz)), which includes three methods of verification:

- Case 1 - Overview;
- Case 2 - Frequency band scanning;
- Case 3 - Detailed investigation (extrapolation to theoretical maximums).

The **overview** method is applied when the purpose is to ascertain the overall level of non-ionising radiation at a given location. This method is not applicable where it is specifically necessary to ascertain the levels of non-ionising radiation by frequency (or frequency band).

The **frequency band scanning** method is applied when it is necessary to determine levels of non-ionising radiation per frequency band.

The **detailed investigation** method is applied when it is necessary to evaluate a particular emission - i.e., to investigate a specific emission independently from other emissions impacting the same location.

In accordance with Regulation no. 86/2007, the procedure used is based on the application of the three verification methods described above, whose degree of complexity and rigour gradually increases.

In this work, frequency band scanning (case 2) and detailed investigation (case 3) procedures were used to check the reference values of ICNIRP (established in Administrative Rule no. 1421/2004 of 23 November).

Given the specificities of 5G networks (for which EMF measurement procedures are not yet defined at national and international level) and the fact that the networks are not yet in operation, the following approaches were taken in evaluation:

- Extrapolation of maximum exposure from the signalling channel;
- Record of peak values in the channel in a traffic situation.

4.2 CONFIGURATION OF TESTS

The tests were carried out with the following selective analysers as shown in Figure 6: Narda SRM-3006 with an electric field probe (420 MHz to 6 GHz), and Narda SRM-3000 with an electric field probe (75 MHz to 3 GHz).

Electric field measurements were carried out in outdoor locations (referred to in this report as "survey sites") easily accessible by the general public, with the probe positioned at a height of 1.5 meters and for periods of 6 minutes, at different survey sites in relation to the 5G station (shown in Figure 7). The survey sites were previously chosen in order to assess the worst-case situation (greatest exposure to EMF).

Figure 6: Narda (SRM-3000 and SRM-3006) and probes

Source: ANACOM

Figure 7: One of the evaluated points

Source: ANACOM

4.3 RESULTS OBTAINED

The results obtained at the five survey sites where measurements were taken are presented in terms of the total exposure quotient[6]. Details of the EMF measurements are provided in the **Appendix** to this report.

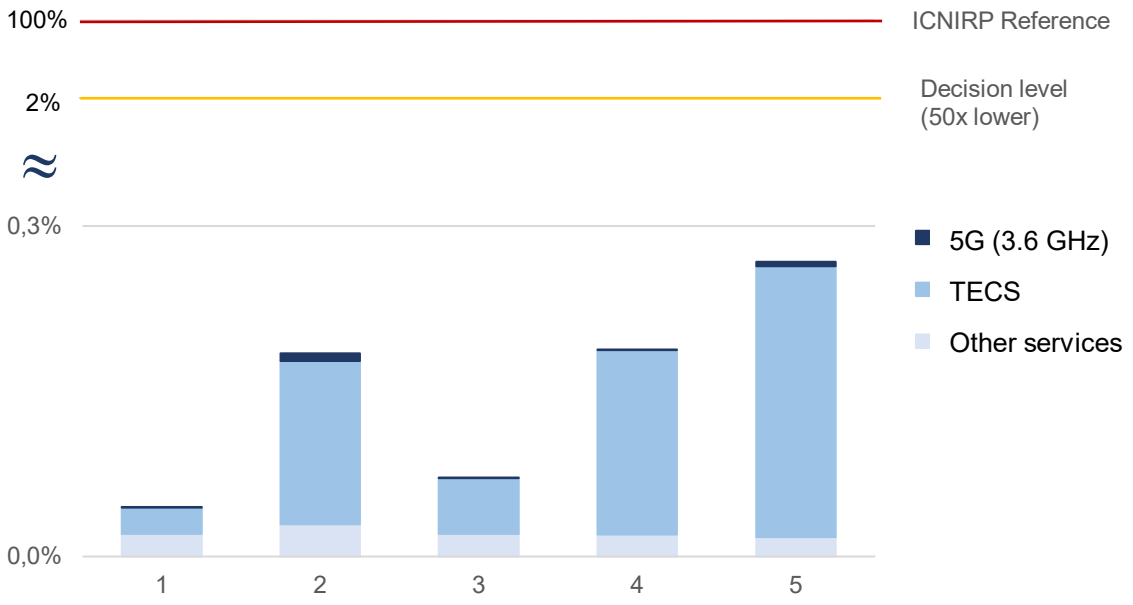
4.3.1 FREQUENCY BAND SCANNING MEASUREMENTS

The values of the total exposure quotient (75 MHz to 6 GHz), resulting from the measurements made, and in relation to the average values obtained for the sampling interval of 6 minutes, can be seen in Figure 8. For more illustrative representation, a logarithmic scale is used to compress the display of very different values[7].

[6] The total exposure quotient is the sum of all individual exposure quotients in the measured frequency range at a single location. The calculation of this value is based on the individual exposure quotients and should be defined together with the exposure limits.

[7] An arithmetic scale would give a more realistic picture of the difficulty of reaching the highest values, but would not provide a good illustration of the data.

Figure 8: Total exposure ratio from 75 MHz to 6 GHz, at each survey site



Source: ANACOM

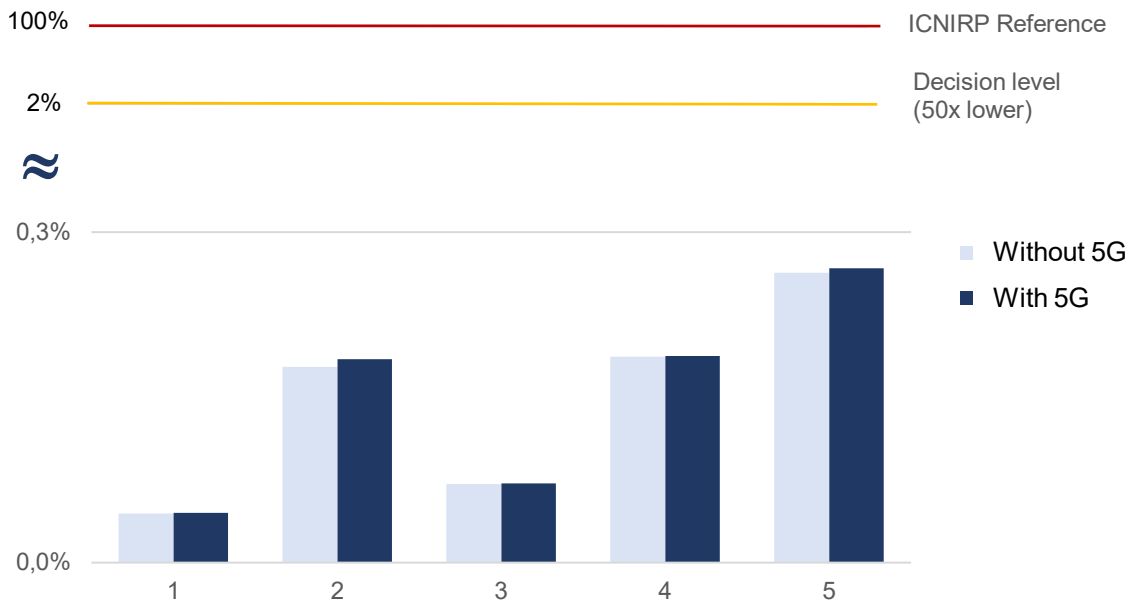
As noted in the previous Figure, the levels of total exposure at the five survey sites are less than 2% (i.e., more than 50 times lower than the reference level).

Likewise, in the 3.6 GHz band, the contribution of the trial 5G networks **was insignificant when compared to the mobile networks already in operation** and providing TECS.

In the worst situation (survey site 5), the total exposure quotient obtained was 0.27%, which corresponds to a Power Density 370 times lower than the reference value.

In Figure 9, the total exposure quotient is presented with and without 5G, in the 75 MHz to 6 GHz frequency bands. As can be seen, the contribution of 5G is insignificant.

Figure 9: Total exposure ratio without and with 5G, per point



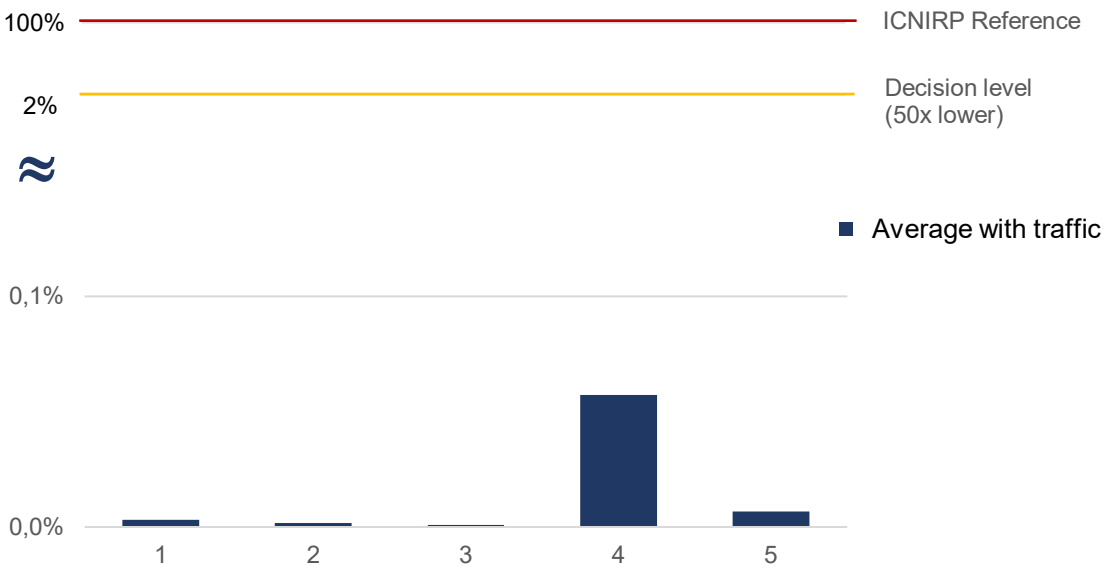
Source: ANACOM

In the previous Figures, the red line refers to the threshold in terms of electromagnetic radiation according to ICNIRP's references, which protect the public from exposure to radiation, and the yellow line represents a safety threshold to check whether the measured values are at a level 50 times lower than the thresholds recommended by ICNIRP.

4.3.2 DETAILED INVESTIGATION

Figure 10 shows the results of the measurements, with the average values obtained for the sampling interval of 6 minutes. The results at the five survey sites where measurements were made are presented in terms of the exposure quotient in the 3.6 GHz band for each of the measured channels, which considered bandwidths of 60 MHz or 100 MHz (illustrated in Figure 11).

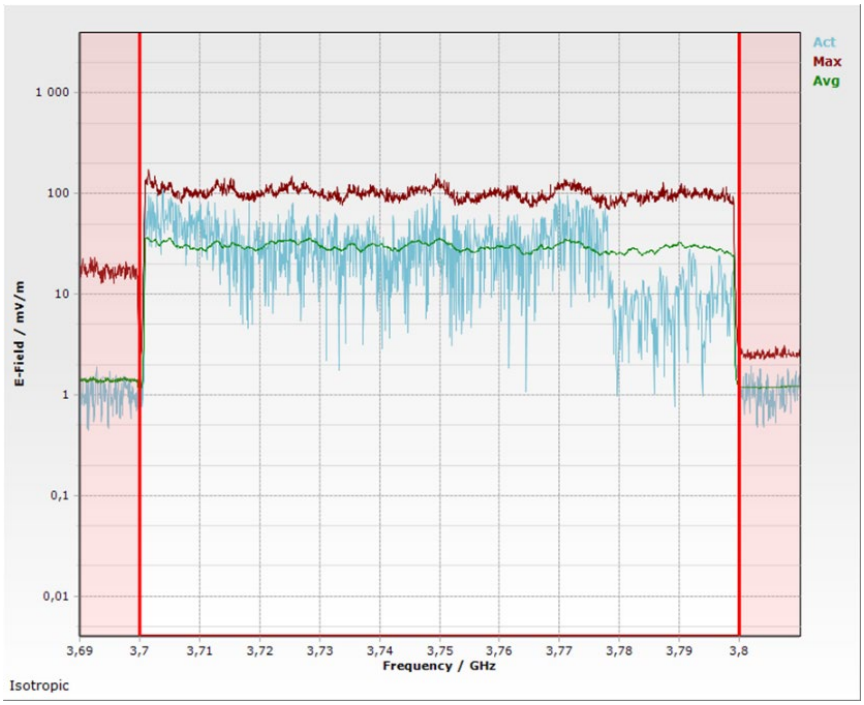
Figure 10: Total Exposure Quotient of 3.6 GHz (3400 - 3800 MHz), per survey site



Source: ANACOM

As seen in the Figure above, exposure levels in the 3.6 GHz (3400 - 3800 MHz) band of the trial 5G networks at the five survey sites are more than 50 times below the recommended reference levels.

Figure 11: 5G emission with 100 MHz bandwidth



Source: ANACOM

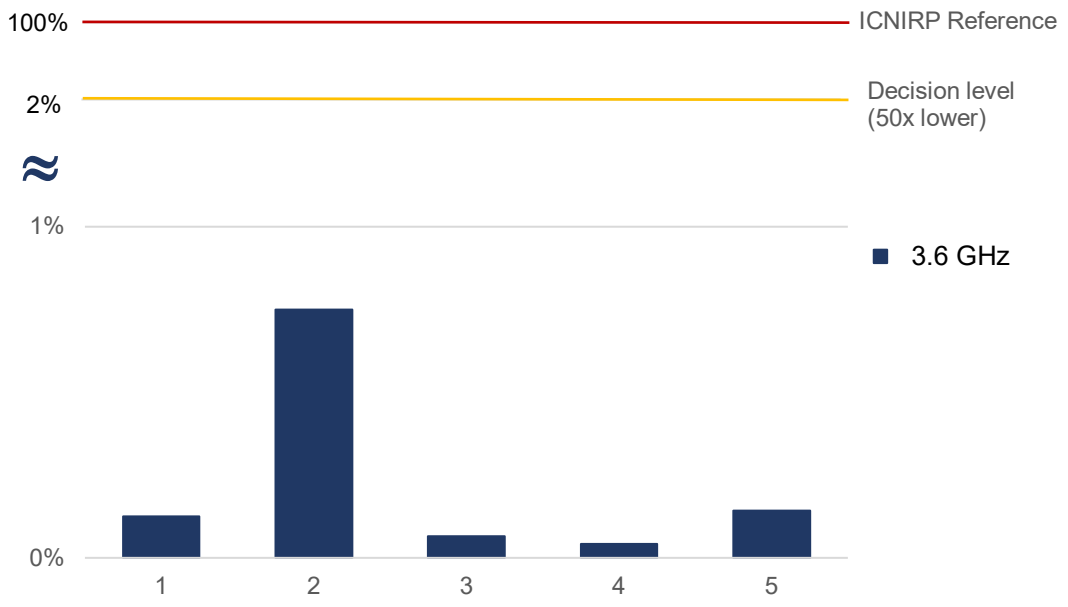
4.3.3 OTHER MEASUREMENTS (PEAK VALUES AT 3.6 GHz)

In applying the ICNIRP recommendation, it is important to consider that the established limits refer to average values for a sampling interval of 6 minutes.

The theoretical exercise of considering the maximum value obtained at any instant as the average value (the value that should be compared with the ICNIRP limits), providing a "worst case" view, show that the limits are not exceeded even under these conditions.

Figure 12 shows the result of the quotient in the 3.6 GHz band for each of the measured channels, which considered bandwidths of 60 MHz or 100 MHz.

Figure 12: 3.6 GHz exposure quotient (peak values), per survey site



Source: ANACOM

4.3.4 CALCULATION OF EXTREME NETWORK CONDITIONS

The scenario of extreme network conditions assumes that the network is being used constantly under conditions of maximum power with all carriers included.

In order to carry out the analysis of the network under extreme conditions, the **5G signalling block (with 8 MHz bandwidth)** was measured; in particular, measurements were taken of recorded peak values with the generation of 5G traffic during at least 50% of the measurement time.

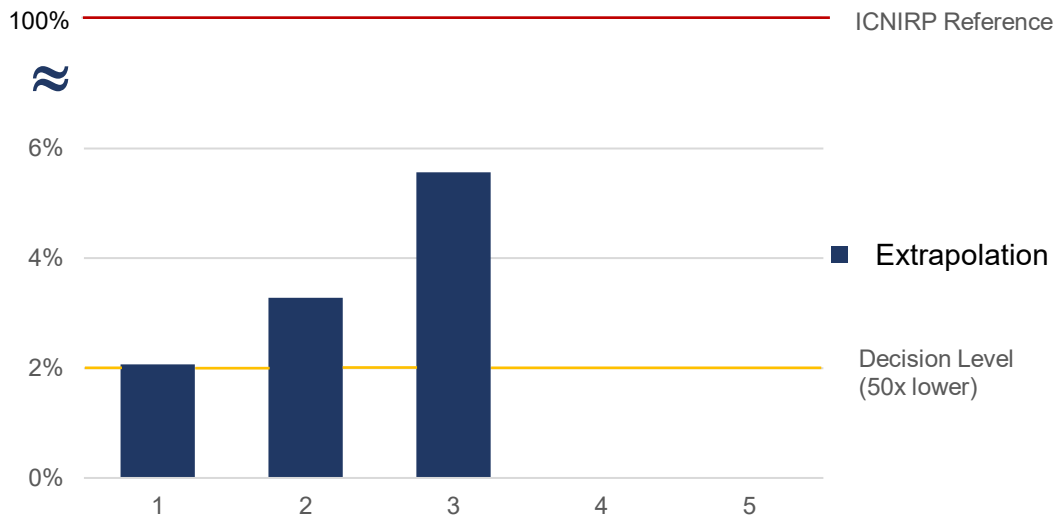
On two of the 5G networks analysed, the signalling block is fixed in terms of frequency and occupied bandwidth, while on the other two 5G networks, the frequency is variable. This is due to the option implemented by the manufacturer in their equipment.

Using the "extrapolation method", the maximum theoretical level of exposure is inferred, obtaining a perception of the EMF that is produced in a situation of maximum power emission on the 5G network.

The extrapolation method used was the one proposed by Narda[8], which is only applicable to 5G networks with a fixed signalling block. Figure 13 shows the results obtained.

This approach, as well as the approach described in 4.3.3., provides a means of estimating a "worst case" situation, since the networks are not designed to work within this limit (given the need to protect the constituent equipment and preserve its durability) and will rarely be used in these scenarios. It is a theoretical exercise (in the sense that it will have little relevance to everyday reality) that will only be justified in very specific situations.

Figure 13: Extrapolated exposure quotient, per survey site



Source: ANACOM

[8]Available at https://journals.lww.com/health-physics/fulltext/2019/11000/on_the_assessment_of_human_exposure_to.7.aspx.

From the analysis of the above Figure, it appears that at two of the survey sites, according to the extrapolation carried out, a level 50 times lower than the reference level is not guaranteed, however, it is ensured that the reference levels are met with significant margin.

5. CONCLUSIONS

Following the authorisations issued by ANACOM to carry out 5G technical trials in Portugal, and in the context of EMF, ANACOM carried out measurements of EMF levels produced by 5G networks.

The objective of this study is to assess the impact of 5G in terms of the general public's exposure to EMF, and to present the results of analyses carried out between June and October 2020 in the vicinity of stations carrying out 5G pilot trials in the 3.6 GHz band.

EMF measurements were made at 5 survey sites, in the vicinity of four different 5G networks. The main conclusions are as follows:

- The 5G networks were operating in accordance with expected requirements with respect to the 3.6 GHz band;
- Overall, the measured values were more than 50 times lower than the recommended reference levels;
- The contribution of the trial 5G networks in the 3.6 GHz band to total levels of exposure was insignificant at the time of measurement when compared to the mobile networks already in operation and providing Terrestrial Electronic Communications Services.

It should be noted that the procedures for EMF measurements are not yet defined for 5G networks at national and international levels. While this work is essentially based on current procedures, it includes new approaches, namely the EMF evaluation by using the extrapolation method proposed by Narda.

In the context of the normal pursuit of its powers and responsibilities, and with a view to future actions in the area of EMF, ANACOM:

- will continue to monitor and contribute to international developments in terms of EMF measurement methods and procedures, including 5G networks and, in particular, updates to

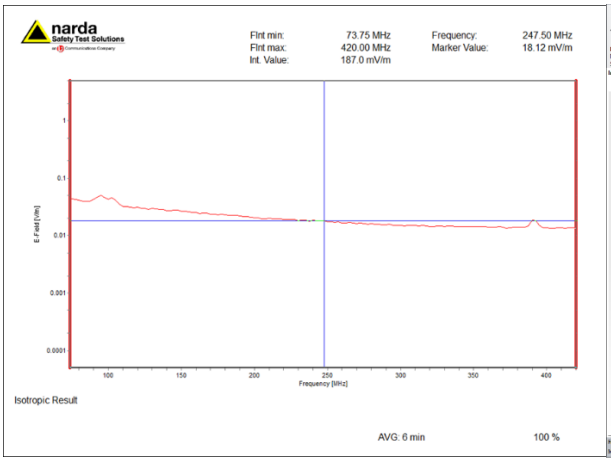
the ECC Recommendation (02)04 on “measuring non-ionising electromagnetic radiation (9 kHz-300 GHz), amended 6 February 2007”; and

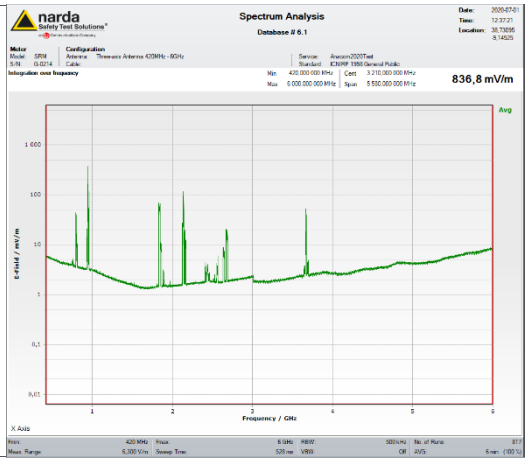
- will proceed with measurement activities in public areas, assessing the general public’s exposure to EMF following deployment of public 5G networks, taking actual traffic levels into account.

APPENDIX

Operator 1 - Survey site 1: Measurements made on a public road about 100 meters from the 5G station

Evaluation of exposure 75 MHz - 6000 MHz





According to the current procedure, in terms of power density (average values over 6 minutes), the total exposure quotient is 0.05% (2,217 times lower than the applicable reference values).

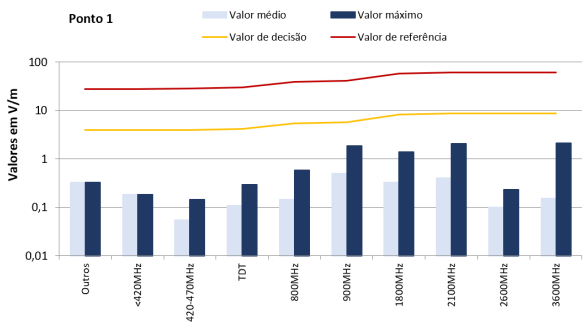
Average values (6 minutes)

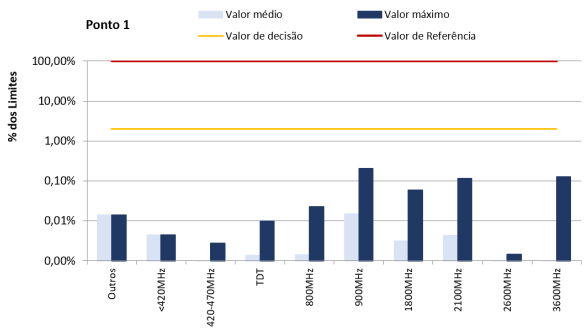
Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,332	0,187	0,055	0,110	0,146	0,501	0,328	0,402	0,101	0,152	0,857
Contribution										
15,0%	4,8%	0,4%	1,6%	2,9%	34,2%	14,6%	22,0%	1,4%	3,1%	100,0%
Exposure quotient										
0,0141%	0,0045%	0,0004%	0,0013%	0,0014%	0,0150%	0,0032%	0,0043%	0,0003%	0,0006%	0,05%

If maximum values are considered, in terms of power density, the total exposure quotient is 0.56% (179 times lower than the applicable reference values).

Maximum values (for 6-minute intervals, with 5G tests at random times)

Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,332	0,187	0,147	0,296	0,581	1,850	1,404	2,066	0,234	2,162	3,871
Contribution										
0,7%	0,2%	0,1%	0,6%	2,3%	22,8%	13,2%	28,5%	0,4%	31,2%	100,0%
Exposure quotient										
0,014%	0,004%	0,003%	0,010%	0,023%	0,205%	0,058%	0,115%	0,001%	0,126%	0,56%

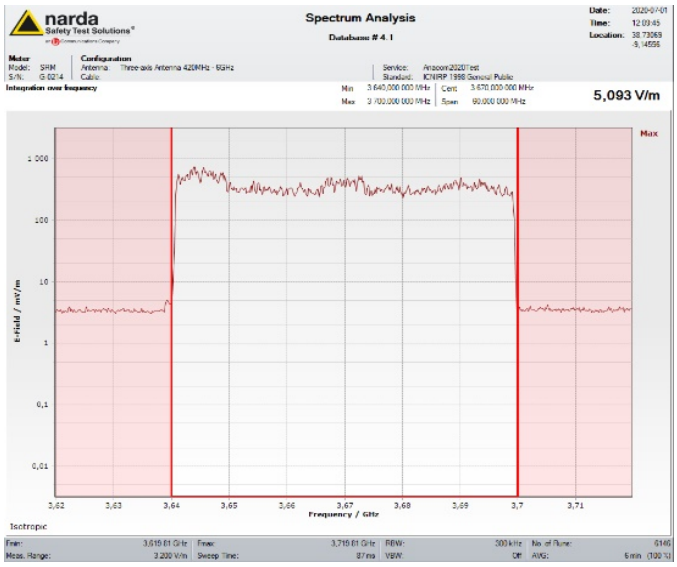




From analysis of these Figures, it can be concluded that all emissions are below the decision value (50 times lower than the reference value).

<u>Detailed 5G signal analysis</u>

Maximum value obtained in a traffic test situation:



Field Value for 5G channel:

Survey Site 1	Maximum value			*Average value 6 minutes*
	Signalling only	Traffic	Extrapolated Maximum (*)	
V/m	1.015	5.09	8.78	*0.34* [(2)]
Exposure Ratio (%)	0.03	0.7	2.07	*0.003*

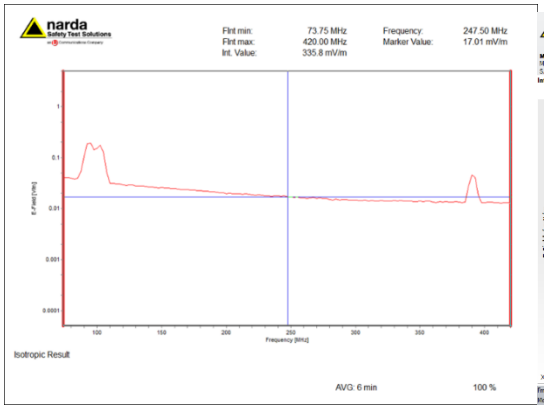
(*) value obtained using the calculation formula proposed by Narda based on the "pilot" level.

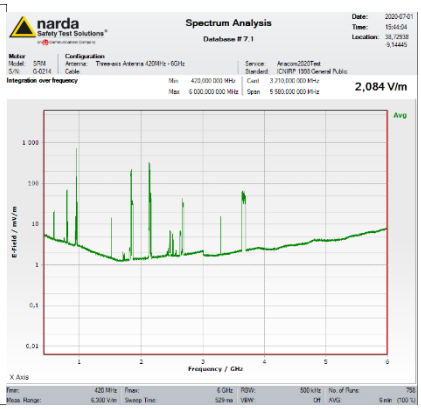
[(2)] Value obtained with Speedtest tests about 60% of the time.

Note: the value used for extrapolation is still under discussion, and the value used may be excessive. In addition, the methodology for measuring electromagnetic fields produced by the 5G network is still being defined.

Operator 1 - Survey Site 2: Building terrace about 230 meters from the station, with stations of other operators in the vicinity

Evaluation of exposure 75 MHz - 6000 MHz





According to the current procedure, in terms of power density, the total exposure quotient is 0.19% (537 times lower than the applicable reference values).

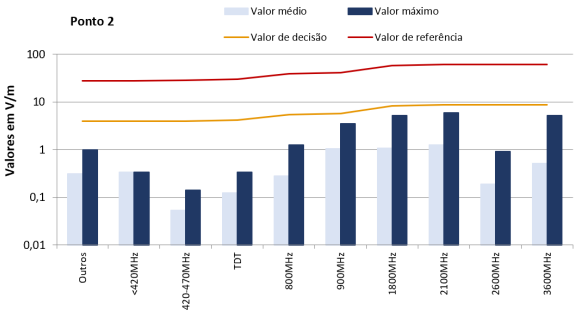
Average values (6 minutes)

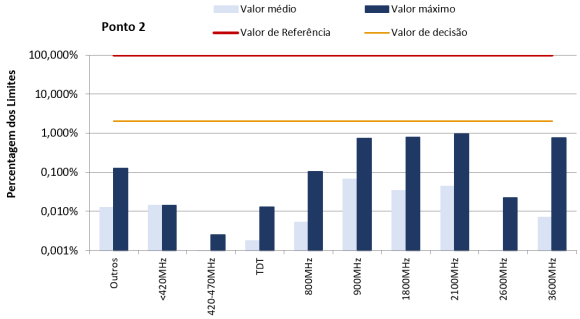
Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,315	0,336	0,053	0,125	0,280	1,046	1,066	1,272	0,190	0,511	2,111
Contribution										
2,2%	2,5%	0,1%	0,4%	1,8%	24,6%	25,5%	36,3%	0,8%	5,9%	100,0%
Exposure quotient										
0,0127%	0,0144%	0,0004%	0,0018%	0,0052%	0,0654%	0,0334%	0,0435%	0,0010%	0,0070%	0,18%

If maximum values are considered, in terms of power density, the total exposure quotient is 3.52% (28 times lower than the applicable reference values).

Maximum values (for 6-minute intervals, with 5G tests at random times)

Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,999	0,336	0,141	0,339	1,245	3,522	5,186	5,962	0,908	5,285	10,315
Contribution										
0,9%	0,1%	0,0%	0,1%	1,5%	11,7%	25,3%	33,4%	0,8%	26,3%	100,0%
Exposure quotient										
0,127%	0,014%	0,003%	0,013%	0,104%	0,742%	0,790%	0,955%	0,022%	0,751%	3,52%

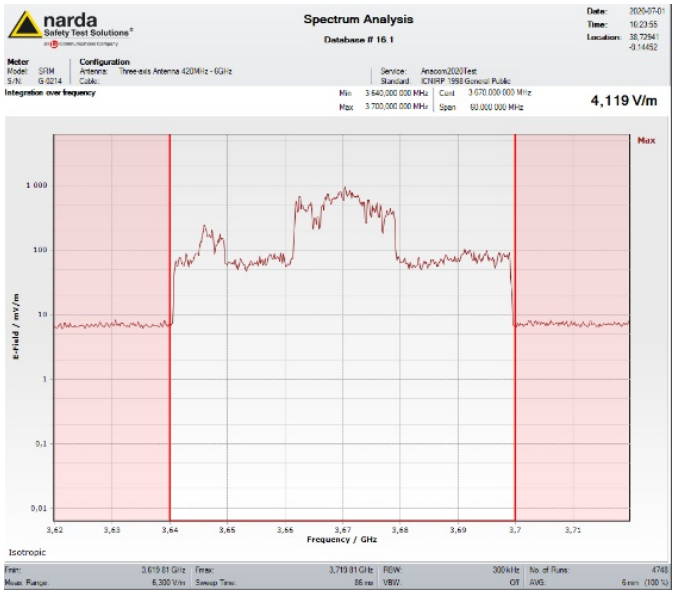




From analysis of these Figures, it can be concluded that all emissions are below the decision value (50 times lower than the reference value).

<u>Detailed 5G signal analysis</u>

Maximum value obtained in a traffic test situation:



Field Value for 5G channel:

Survey Site 2	Maximum value			*Average value 6 minutes*
	Signalling only	Traffic	Extrapolated Maximum (*)	
V/m	1,487	4,12	11,1	*0,25* [(2)]
Exposure Ratio (%)	0,06	0,46	3,28	*0,002*

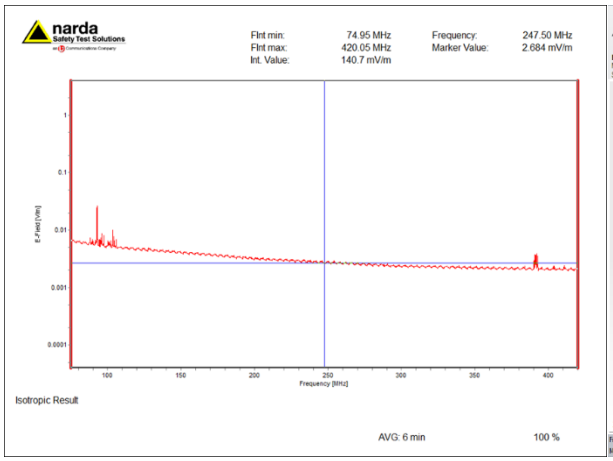
(*) value obtained using the calculation formula proposed by Narda based on the "pilot" level.

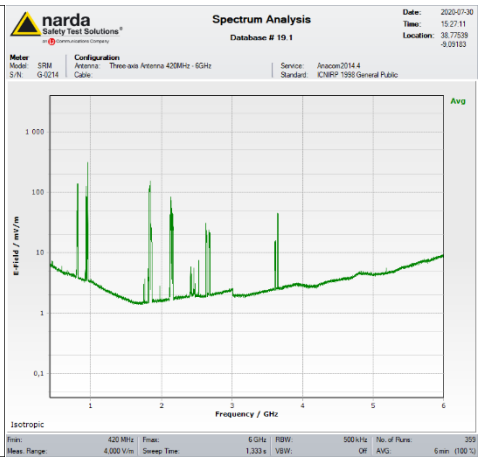
[(2)] Value obtained with Speedtest tests about 60% of the time.

Note: the value used for extrapolation is still under discussion, and the value used may be excessive. In addition, the methodology for measuring electromagnetic fields produced by the 5G network is still being defined.

Operator 2 - Survey Site 3: Public road about 80 meters from the station

<u>Evaluation of exposure (75 MHz - 6000 MHz)</u>





According to the current procedure, in terms of power density the total exposure quotient is 0.07% (1,393 times lower than the applicable reference values).

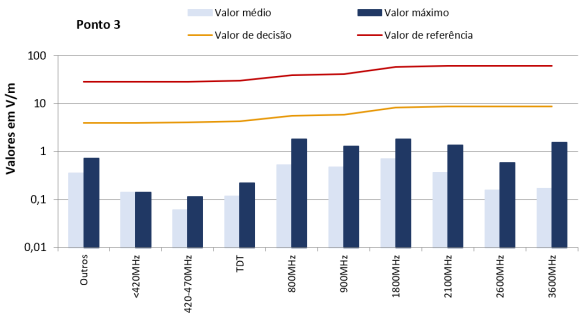
Average values (6 minutes)

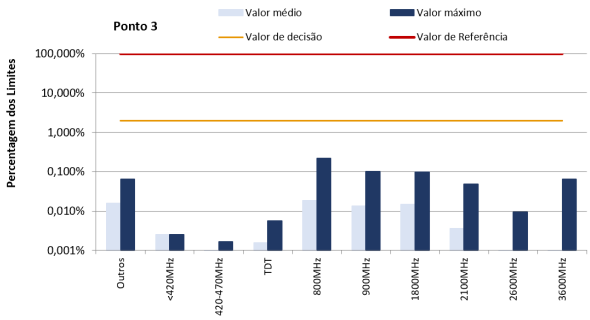
Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,353	0,14	0,060	0,118	0,523	0,475	0,705	0,364	0,158	0,168	1,159
Contribution										
9,3%	1,5%	0,3%	1,0%	20,4%	16,8%	37,0%	9,9%	1,9%	2,1%	100,0%
Exposure quotient										
0,0159%	0,0025%	0,0005%	0,0016%	0,0183%	0,0135%	0,0146%	0,0036%	0,0007%	0,0008%	0,07%

If maximum values are considered, in terms of power density, the total exposure quotient is 0.61% (163 times lower than the applicable reference values).

Maximum values (for 6-minute intervals, with 5G tests at random times)

Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,712	0,14	0,115	0,222	1,803	1,299	1,824	1,346	0,590	1,551	3,663
Contribution										
3,8%	0,1%	0,1%	0,4%	24,2%	12,6%	24,8%	13,5%	2,6%	17,9%	100,0%
Exposure quotient										
0,065%	0,003%	0,002%	0,006%	0,218%	0,101%	0,098%	0,049%	0,009%	0,065%	0,61%

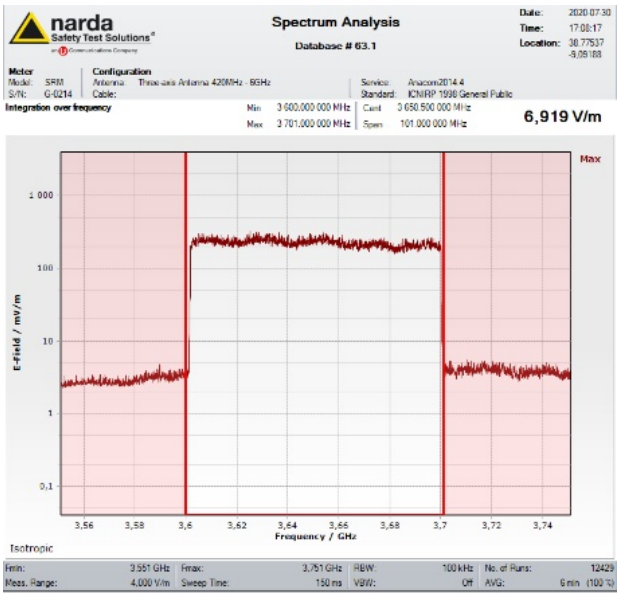




From analysis of these Figures, it can be concluded that all emissions are below the decision value (50 times lower than the reference value).

<u>Detailed 5G signal analysis</u>

Maximum value obtained in a traffic test situation:



Field Value for 5G channel:

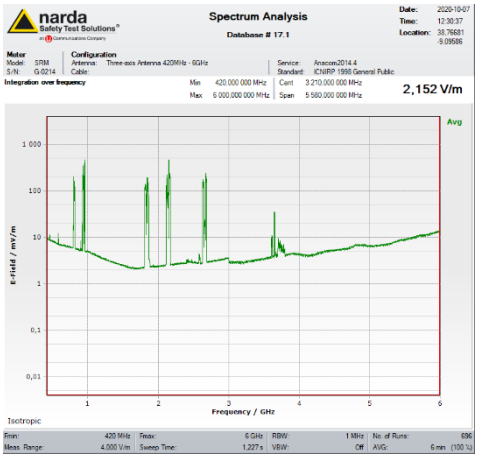
Point 3	Maximum value			*Average value 6 minutes*
	Signalling only	Traffic	Extrapolated Maximum (*)	
V/m	1.21	6.92	14.39	*0.18* [(2)]
Exposure Ratio (%)	0.04	1.29	5.57	*0.001*

(*) value obtained using the calculation formula proposed by Narda based on the "pilot" level.

[(2)] Value obtained with YouTube content tests for about 60% of the time.

Operator 3 - Survey Site 4: Public road about 50 meters from the station

Exposure evaluation 420 MHz - 6000 MHz (value from 75 - 420 MHz band are residual and negligible)



According to the current procedure, in terms of power density the total exposure quotient is 0.19% (533 times lower than the applicable reference values).

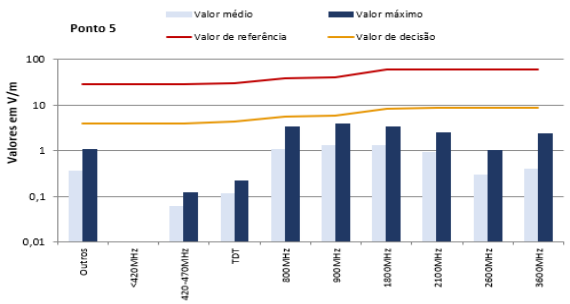
Average values (6 minutes)

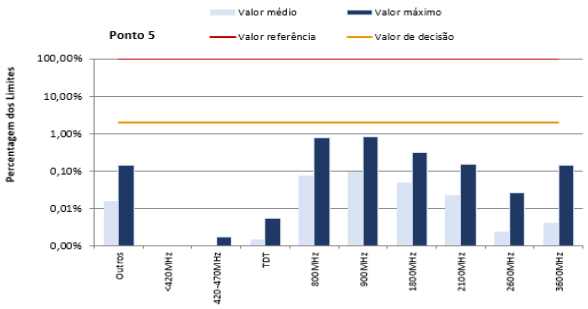
Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,375	0	0,064	0,124	0,562	1,003	0,768	1,266	0,970	0,123	2,152
Contribution										
3,0%	0,0%	0,1%	0,3%	6,8%	21,7%	12,7%	34,6%	20,3%	0,3%	100,0%
Exposure quotient										
0,0179%	0,0000%	0,0005%	0,0017%	0,0211%	0,0601%	0,0173%	0,0431%	0,0253%	0,0004%	0,19%

If maximum values are considered, in terms of power density, the total exposure quotient is 2.4% (42 times lower than the applicable reference values).

Maximum values (for 6-minute intervals, with 5G tests at random times)

Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,755	0	0,136	0,243	2,043	3,114	3,300	4,648	4,365	1,262	8,225
Contribution										
0,8%	0,0%	0,0%	0,1%	6,2%	14,3%	16,1%	31,9%	28,2%	2,4%	100,0%
Exposure quotient										
0,073%	0,000%	0,002%	0,007%	0,279%	0,580%	0,320%	0,581%	0,512%	0,043%	2,40%

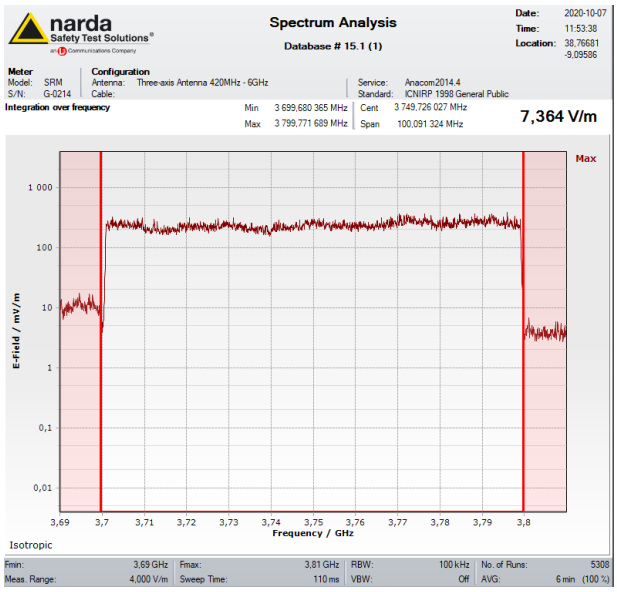




From analysis of these Figures, it can be concluded that all emissions are below the decision value (50 times lower than the reference value).

<u>Detailed 5G signal analysis</u>

Maximum value obtained in a traffic test situation:



Field Value for 5G channel:

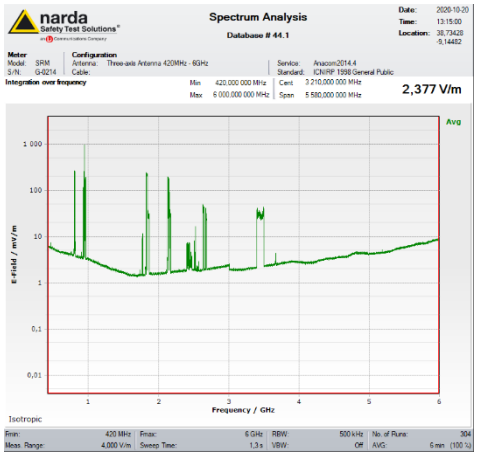
Survey Site 4	Maximum value			*Average value 6 minutes*
	Signalling only	Traffic	Extrapolated Maximum (*)	
V/m	1.32	7.36	NA	*1.46* [(2)]
Exposure Ratio (%)	0.05	1.46	-	*0.057*

(*) value obtained using the calculation formula proposed by Narda based on the "pilot" level.

[(2)] Value obtained with FTP/Speedtest tests about 80% of the time.

Operator 4 – Survey Site 5: Public road about 200 meters from the station

<u>Exposure evaluation 420 MHz - 6000 MHz (value from 75 - 420 MHz band are residual and negligible)</u>



According to the current procedure, in terms of power density the total exposure quotient is 0.27% (374 times lower than the applicable reference values).

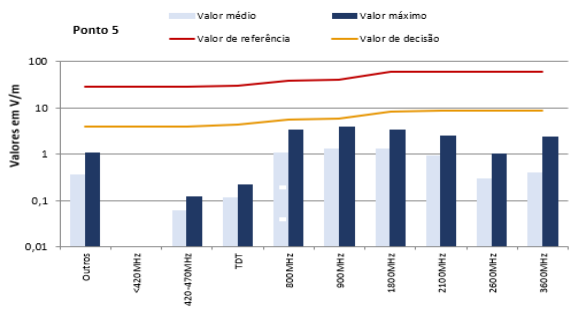
Average values (6 minutes)

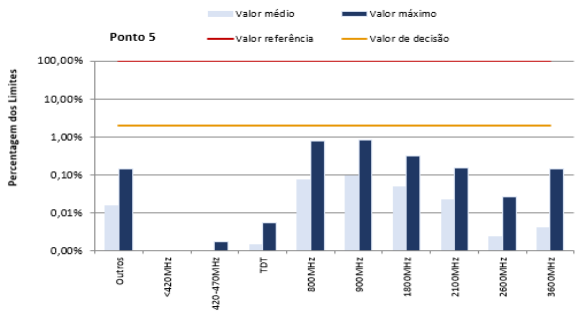
Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
0,348	0	0,059	0,115	1,052	1,278	1,303	0,903	0,296	0,394	2,374
Contribution										
2,1%	0,0%	0,1%	0,2%	19,6%	29,0%	30,1%	14,5%	1,6%	2,8%	100,0%
Exposure quotient										
0,0154%	0,0000%	0,0004%	0,0015%	0,0741%	0,0976%	0,0499%	0,0219%	0,0024%	0,0042%	0,27%

If maximum values are considered, in terms of power density, the total exposure quotient is 2.32% (43 times lower than the applicable reference values).

Maximum values (for 6-minute intervals, with 5G tests at random times)

Bands										TOTAL
Others	<420MHz	420-470MHz	DTT	800MHz	900MHz	1800MHz	2100MHz	2600MHz	3600MHz	
Values (V/m)										
1,040	0	0,118	0,218	3,354	3,729	3,264	2,402	0,998	2,311	7,004
Contribution										
2,2%	0,0%	0,0%	0,1%	22,9%	28,3%	21,7%	11,8%	2,0%	10,9%	100,0%
Exposure quotient										
0,138%	0,000%	0,002%	0,005%	0,753%	0,831%	0,313%	0,155%	0,027%	0,144%	2,37%

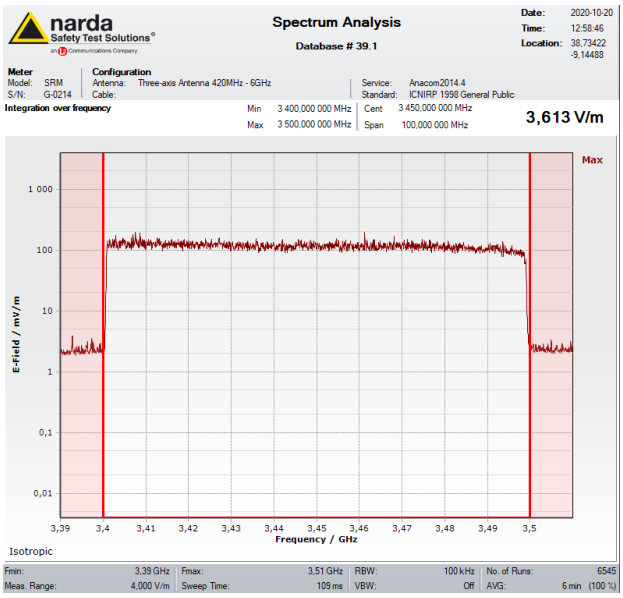




From analysis of these Figures, it can be concluded that all emissions are below the decision value (which is defined at 50 times below the reference value).

Detailed 5G signal analysis

Maximum value obtained in a traffic test situation:



Field value for 5G channel at **Survey Site 5**:

Survey Site 5	Maximum value			*Average value 6 minutes*
	Signalling only	Traffic	Extrapolated Maximum (*)	
V/m	1.45	3.61	NA	*0.5* [(2)]
Exposure Ratio (%)	0.06	0.35	-	*0.007*

(*) value obtained using the calculation formula proposed by Narda based on the "pilot" level.

[(2)] Value obtained with load tests 70% of the time.

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