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Study of the 5G contribution to exposure of the general public to electromagnetic waves

Preliminary report
(October 2020 to October 2021)

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1. Objective

This report is part of a vast measurement program to assess public exposure to electromagnetic waves announced on 12 October 2020 by Cedric O, Secretary of State for Digital Transition and Electronic Communications, in view of the launch of the new 5G mobile technology.

5G is now being deployed in France on several frequency bands:

- the "low bands" already used for previous generations of mobile networks which can also accommodate 5G under the technological neutrality principle. French operators have deployed 5G using the 700 MHz and 2 100 MHz, bands which had already been used for 3G and 4G for many years;
- the new 3 500 MHz band which was authorised for use by Arcep in November 2020. This band is wider than the low bands, allowing higher data speeds.

The program started in October 2020: it covers about 4 800 measurements, from almost 1 650 5G sites across France, and is built around two campaigns:

- The first campaign covers almost 150 low-band sites on which 5G roll out was faster because there was no need to install new antennas. An initial measurement was made between October and December 2020, i.e. before 5G arrived at those sites, followed by a measurement after it was rolled out. About forty sites were initially measured but are still not operational for 5G.
- The second campaign covered 1 500 sites, including 140 low-band 5G sites and 1 360 sites in the 3 500 MHz band. This campaign has three phases: the first, prior to 5G roll out on the relevant bands, took place between January and May 2021; the second was initiated after 5G roll out and took place between May 2021 and September 2021; finally, the third phase started in September 2021 and will continue until the end of 2021. The objective is to monitor exposure changes as 5G is rolled out and traffic increases.

This preliminary report presents the results of both campaigns and will be completed as soon as the ongoing measurements are finished. The measurements analysed in this report are the following:

- the first 2020 campaign: 210 measurements kept out of the 298 initially launched, pending sites on which 5G is still not operational;
- the second 2021 campaign: 3 000 measurements to be completed with 1 500 measurements by the end of 2021.

The measurements were all carried out using the ANFR measurement protocol. In addition, specific measurements were made at 370 sites by downloading a 1 GB file using the 3 500 MHz band. This operating mode generates additional traffic corresponding to the exposure indicator proposed by the ANFR for mobile phone base stations with directional beam antennas[1] and makes it possible to estimate local exposure levels statistically reached over the long term with 5G.

[1] https://www.anfr.fr/fileadmin/mediatheque/documents/5G/consultation/consultation-5G-Lignes-directrices-nationales.pdf

2. Regulations

In France, decree no. 2002-775 of 3 May 2002 sets the limit values for public exposure to electromagnetic fields. It carries over the values of European Council Recommendation 1999/519/EC of 12 July 1999. Those limit values are between 28 V/m and 87 V/m depending on the frequency (SEE Figure 1).

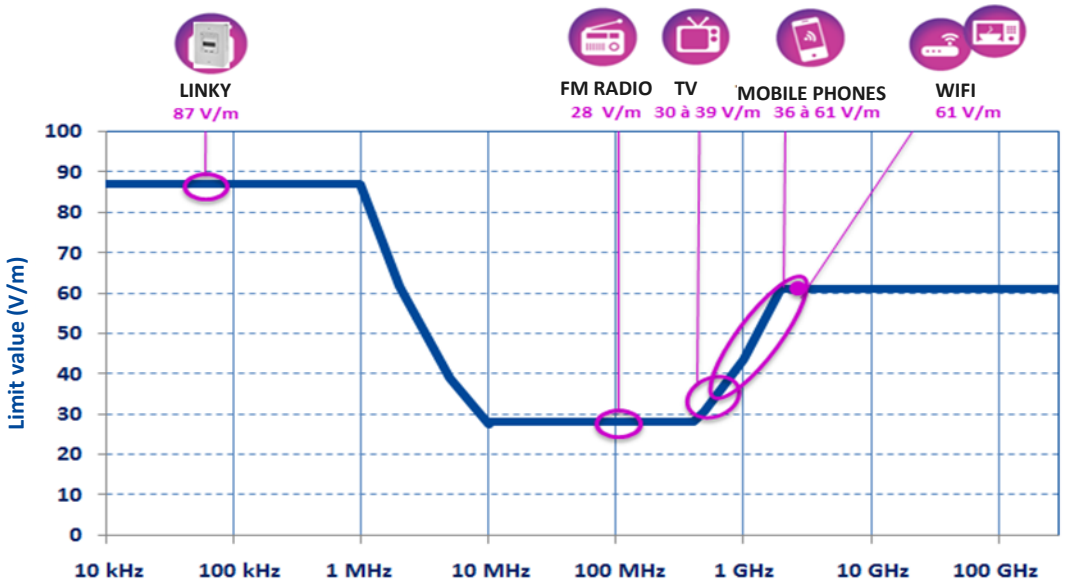

Figure 1. Regulatory limit values of public exposure defined in France by decree n° 2002-775 of 3 May 2002

FM: Analogue sound broadcasting in the 87.5 - 108 MHz band;
DTT: Digital Terrestrial Television in the 470 - 694 MHz band;
Mobile telephony and mobile broadband: 700 MHz (4G and 5G), 800 MHz (4G and 5G), 900 MHz (2G, 3G and 4G), 1 800 MHz (2G and 4G), 2 100 MHz (3G, 4G and 5G), 2 600 MHz (4G) and 3 500 MHz (5G).

3. Method

3.1. Measurement locations

The sites were selected based on COMSIS authorisation applications[2] (consultative committee for sites and easements) made by mobile phone operators. The operator's declaration of put into service then made it possible for the Agency to schedule 5G measurements on those same sites.

[2] https://www.anfr.fr/gestion-des-frequences-sites/sites-servitudes-et-assignations/sites/declarer-une-station-procedure-classique/

The distribution of 5G low-band sites selected as part of this program across the national territory is shown in Figure 2.

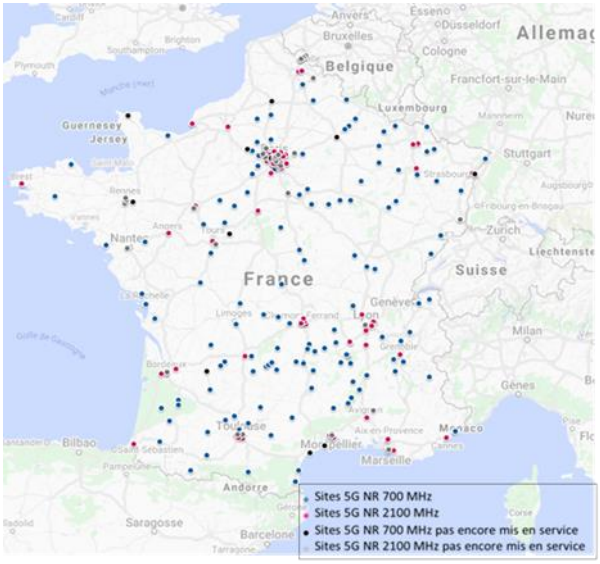

Figure 2. 5G low-band site measurement points

In the second 2021 phase, 955 sites (25 in the 700 MHz band, 323 in the 2 100 MHz band and 607 sites in the 3 500 MHz band) were initially measured but 5G was not yet operational on them when this phase ended. Those 955 sites were replaced by other 5G sites in the 3 500 MHz band that were technically operational at that time. Their pre-5G roll out exposure level was then determined by calculation by subtracting the 3 500 MHz band contribution.

Figure 3 shows the distribution of the selected 3 500 MHz band sites, the red dots indicating the 955 sites initially selected but not operational on 5G at the end of the second phase and which were therefore replaced by the 3 500 MHz sites shown by the blue dots. The green dots are the 5G sites in the 3 500 MHz band that were initially measured and were operational during the second phase of the campaign.

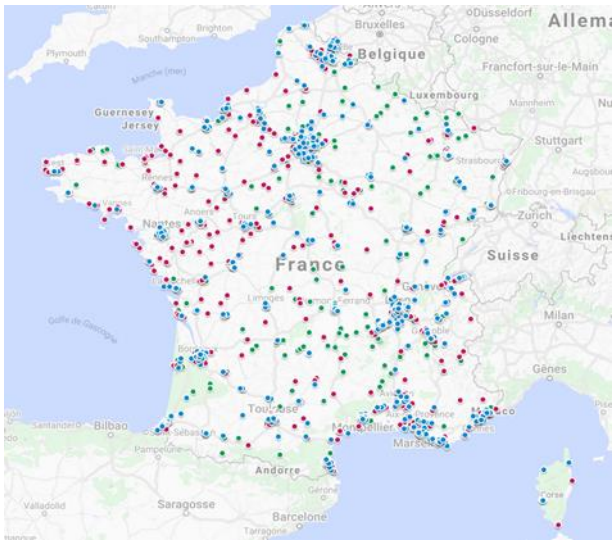

Figure 3. 5G site measurement points in continental France

3.2. Sites distribution

3.2.1. 5G sites distribution by environment type

Of the sites selected[3] as part of this program (1 649 sites) according to environment type, 85 % of them are located in urban areas and 15 % in rural areas. This distribution is close to the proportion of urban population in the total population of France (80 % in urban areas)[4]. Figure 4 shows the details of this distribution according to the frequency bands.

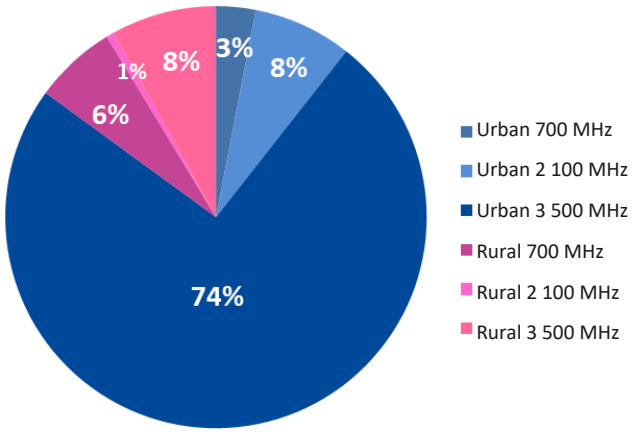

Figure 4. Distribution of sites by frequency and environment type

Figure 5 shows this distribution by frequency band:

- Out of 154 5G sites in the 700 MHz band, 50 are located in urban areas (32 %) and 104 in rural areas (68 %).
- Out of 135 5G sites in the 2 100 MHz band, 125 are in urban areas (93 %) and 10 in rural areas (7 %).
- Out of 1360 5G sites in the 3 500 MHz band, 1 227 are in urban areas (90 %) and 133 in rural areas (10 %).

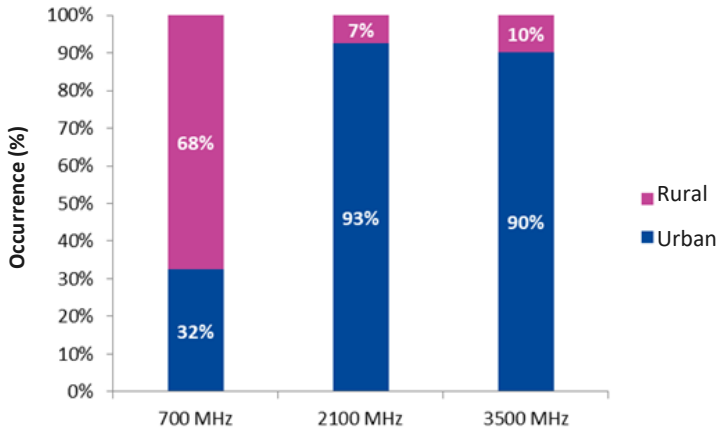

Figure 5. Distribution of sites according to technology and environment type

[3] Only selected points that were the subject of "after" measurements are taken into account in this distribution
[4] https://www.insee.fr/fr/statistiques/4806684

3.2.2. Distribution of 5G sites by operator

Figure 6 shows the distribution of 5G sites by band and by operator. The 1 649 5G sites across all bands were distributed between each operator based on the operators' initial deployment strategies, namely:

- 154 sites in the 700 MHz band for Free Mobile;
- 135 sites in the 2 100 MHz band, including, in decreasing order of number of sites, 60 from SFR, 48 from Bouygues Telecom and 27 from Orange;
- 1 360 sites in the 3 500 MHz band, including 368 from Bouygues Telecom, 360 from Orange, 348 from SFR and 284 from Free Mobile.

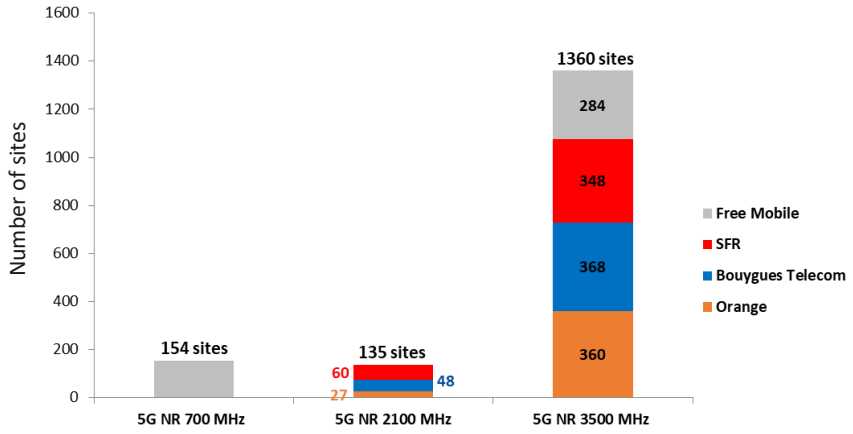

Figure 6. Distribution of sites by frequency band and by operator

3.3. Measurement protocol

The applicable version 4 of ANFR measurement protocol [5] was used. An overall exposure measurement is carried out using a broadband probe (case A). A detailed measurement (case B) can then be carried out to indicate the exposure for each frequency band and for each operator. As part of this campaign, case B was not systematically carried out at each measurement point. During the second measurement phase in 2021, it was, for the most part, only carried out for points where the initial overall level was greater than or equal to 2 V/m.

Case A takes into account all significant radio sources and frequencies. It is based on the use of a broadband probe covering the 100 kHz - 6 GHz band. This probe has a 0.38 V/m sensitivity. Case B involves the use of a spectrum analyser and provides a detailed measurement of each exposure contribution in the same frequency range. The spectrum analyser has a 0.05 V/m sensitivity depending on the frequency bands. It should also be noted that according to the ANFR protocol, emissions are only considered significant if their level is at least 0.3 V/m.

All measurements were carried out outdoors and during the daytime. On a given site, an exposure variation can be seen between two measurements, and can be explained by a difference in traffic when the measurements were taken.

[5] https://www.anfr.fr/fileadmin/mediatheque/documents/expace/2017-08-28__Protocole_de_mesure_V4.pdf

As the so-called 3 500 MHz frequency band reserved for mobile telephony (3 490 – 3 800 MHz) is only used for 5G, and as 5G traffic is still low, additional measurements (outside the protocol) have been requested from the laboratory. These were carried out by artificially generating 5G traffic using a 1 GB file download.

To facilitate the reading of this document, a measurement carried out before 5G roll out will be noted as a "before" measurement, and one carried out after the 5G roll out will be noted as an "after" measurement. A pair of measurements before and after 5G put into service will therefore be noted "before/after".

4. Analysis of exposure levels on 700 MHz 5G sites before and after 5G roll out

To study the exposure created by 5G roll out on 700 MHz sites, 154 sites were identified as part of this program, of which 11 could not be measured "after" because 5G was not yet rolled out during the measurement campaign. This report therefore covers the 143 sites for which measurements are available before and after 5G roll out. Of those 143 sites, 61 % were subject to detailed "before/after" measurements, i.e. 87 sites.

Before analysing the influence of 5G roll out on overall exposure, it seems relevant to first use the detailed frequency measurements to isolate the contribution of the mobile phone service on the 700 MHz band before and after 5G roll out. This is a possibility provided by the 87 "case B" "before/after" measurements carried out on the 700 MHz band.

4.1. Analysis of the contribution of the 700 MHz band alone

Figure 7 isolates the contribution of the 700 MHz band before and after 5G roll out for 87 sites. The histograms show the distribution of measured before/after values by 1 V/m increments. The results show that 5G roll out in the 700 MHz band did not change the distribution of levels in this band and that 99 % of the measurements (before and after) were below 2 V/m.

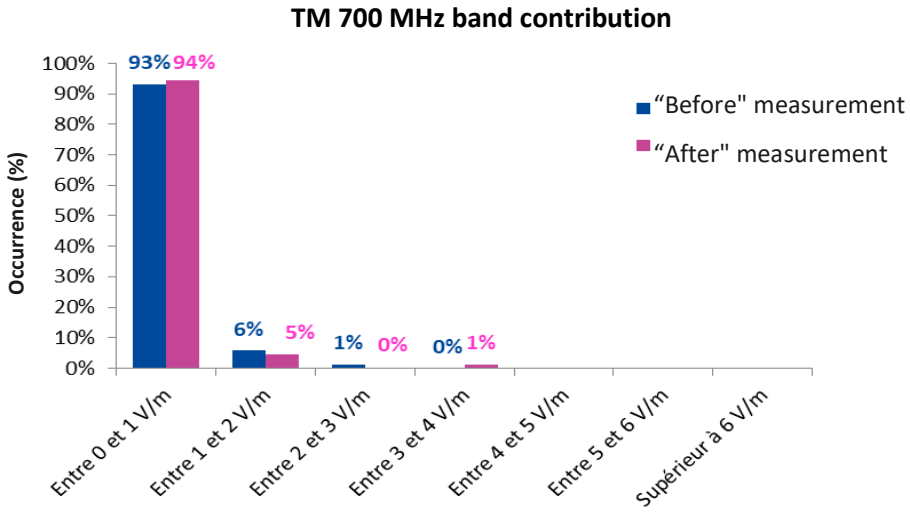

Figure 7. Distribution of exposure levels in the 700 MHz band before and after 5G roll out on 87 sites

Of the 87 measured points, a single point in the "between 0 and 1 V/ m" range before 5G roll out appears to be more exposed in the "after" measurement and moves to the "between 1 and 2 V/m" range. The contribution at this point was 0.93 V/m "before" and becomes 1.24 V/m "after".

Another point that was initially in the "between 2 and 3 V/m" range is now in the "between 3 and 4 V/m" range: it thus increases from 2.09 V/m to 3.14 V/m.

On the other hand, one point appears to be less exposed and moves from the "between 1 and 2 V/m" range to the "between 0 and 1 V/m" range (from 1.13 V/m to 0.97 V/m).

Table 1 summarises the measured field level statistics for the 700 MHz band. The mean, median and standard deviation remain equivalent before and after 5G roll out.

	Number of measurements	Mean (V/m)	Median (V/m)	Standard-deviation	Max (V/m)
Contribution of the 700 MHz band "before"	87	0.30	0.16	0.41	2.09
Contribution of the 700 MHz band "after"	87	0.31	0.19	0.43	3.14
"Before/after" variation (V/m)		0.01	0.03	0.02	1.05

Table 1. Comparison of measured field level statistics in the 700 MHz band before and after 5G roll out on 87 sites

To more accurately analyse field level distribution due to the 700 MHz band, it is proposed to study the local variation, i.e. the calculated difference for a pair of "before/after" measurement points for the same site. The histograms in Figure 8 show the distribution of the differences between the "before" and "after" measurements in 0.2 V/m intervals.

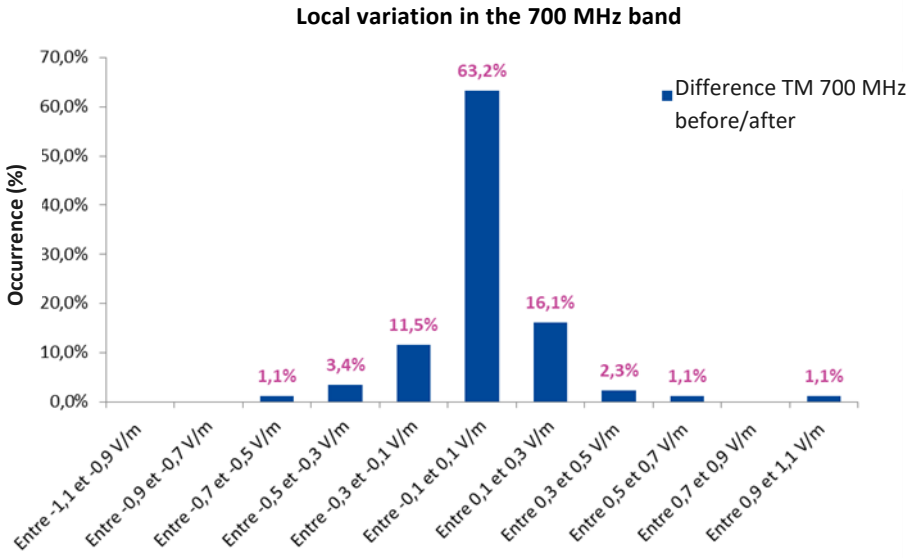

Figure 8. Distribution of differences between 700 MHz band contribution before and after 5G roll out on 87 700 MHz 5G sites

The figure shows that almost 91 % of the differences are between -0.3 and 0.3 V/m, which represents a very low variation (remember that emissions are considered significant starting from 0.3 V/m). In the remaining 9 % of cases, for half of them there is either an increase or a decrease: in 4.5 % of cases, there is an average increase of 0.6 V/m, and in the remaining 4.5 %, there is a decrease of 0.5 V/m. These variations may be assimilated to the variations due to traffic between two measurements.

Furthermore, the average standard deviation is 0.01 V/m, which is very close to zero. Statistically, and considering the measurement tool performances, this means that the differences are centred around 0 V/m. At this stage of the study, it is therefore reasonable to conclude that the contribution of the 700 MHz band after 5G roll out remains comparable to the contribution before the roll out, as shown by the level averages before and after the introduction of 5G.

4.2. Analysis of overall exposure levels

In this section, an overall analysis is carried out of the levels measured using the broadband probe according to protocol case A on 143 sites before and after the 5G roll out on the 700 MHz band. It should be kept in mind that the broadband probe has a sensitivity of 0.38 V/m.

The statistical analysis of overall exposure shown in Figure 9 in 1 V/m steps shows that 93 % of the measurements made before and after 5G roll out remain below 2 V/m.

3 measurement points which were in the "between 0 and 1 V/m" range appear to be more exposed.

When analysing the upper "between 4 and 5 V/m" range, one measuring point has moved from the "between 3 and 4 V/m" to the "between 4 and 5 V/m" range, its exposure having increased from 3.4 V/m to 4.5 V/m.

On the other hand, one measurement point appears to be less exposed, initially in the "between 2 and 3 V/m" range it has moved to the "between 1 and 2 V/m" range (from 2.04 V/m to 1.91 V/m).

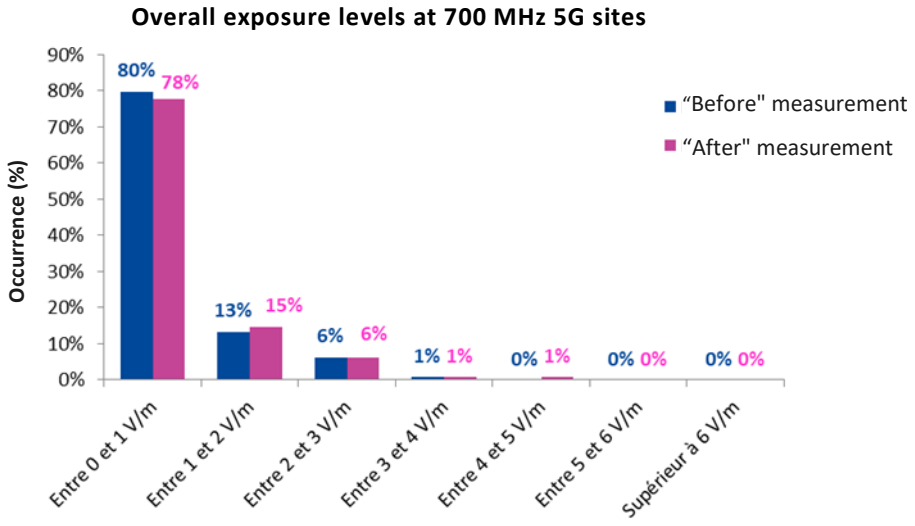

Figure 9. Distribution of overall exposure levels before and after 5G roll out on 143 700 MHz sites

Table 2 gives the overall exposure field level statistics measured at the 143 NR 700 MHz 5G sites before and after they were technically operational. These values are equivalent in terms of mean, median and standard deviation.

	Number of measurements	Average (V/m)	Median (V/m)	Standard-deviation	Max (V/m)
Overall NR 700 MHz 5G exposure "before"	143	0.69	0.46	0.65	3.40
Overall NR 700 MHz 5G exposure "after"	143	0.76	0.51	0.73	4.50
Before/after" variation (V/m)		0.07	0.05	0.08	1.10

Table 2. Comparison of overall exposure field level statistics before and after 5G roll out at 143 700 MHz sites

To further assess the differences between the points measured before and after 5G roll out, Figure 10 shows the distribution of differences between each pair of points measured before and after, in 0.2 V/m steps.

On this figure, it can be seen that more than 92 % of the differences are between -0.4 and 0.4 V/m (remember that the probe sensitivity is close to 0.4 V/m and that differences are only considered significant from 0.3 V/m). In about 8 % of the cases, an average increase of about 0.9 V/m is seen. Variations of this order may be due to the variation in traffic between two measurements.

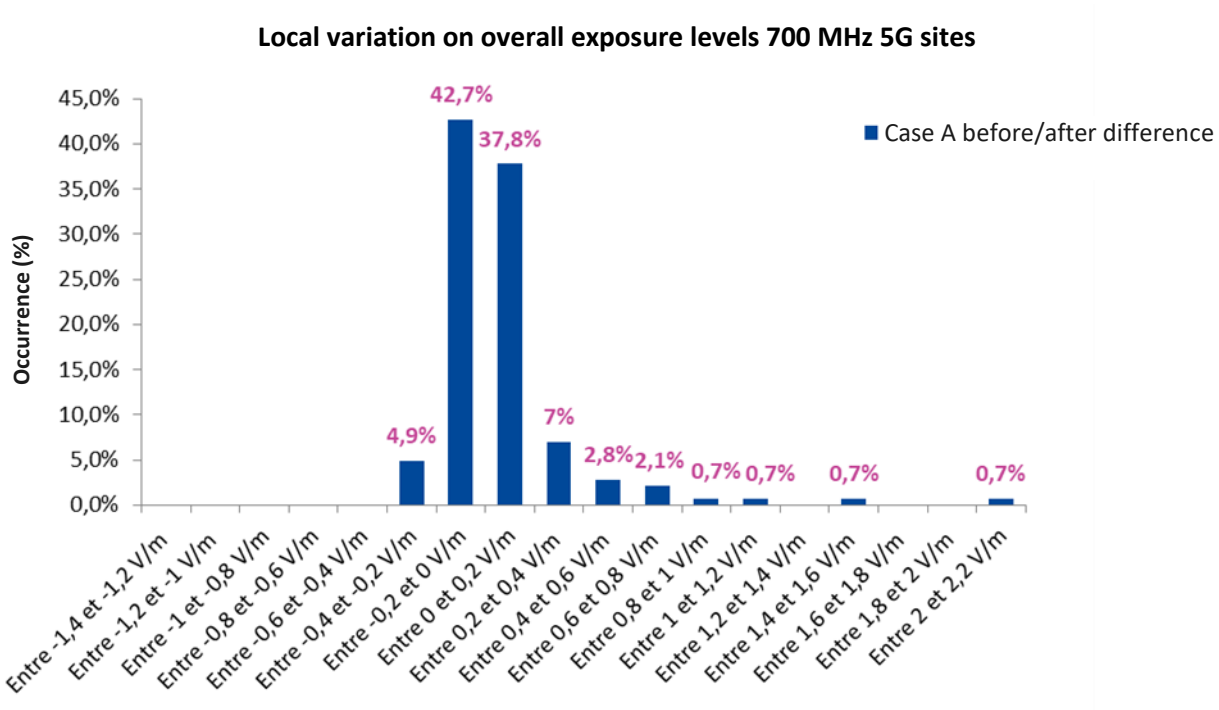

Figure 10. Distribution of differences between overall exposure levels before and after 5G roll out on 143 700 MHz sites

The average difference in overall exposure before and after 5G roll out is 0.07 V/m, a very low value close to 0 V/m. Considering the accuracy of the instruments, this value also leads to consider that the overall exposure generated after 5G roll out in the 700 MHz band remains comparable to that seen before the roll out.

To conclude, using detailed measurements at 87 sites hosting 5G in the 700 MHz band, the analysis showed that the field levels measured on the 700 MHz band contribution after 5G roll out remain comparable to those seen prior to the roll out. The overall exposure analysis on a bigger sample (143 5G sites in the 700 MHz band) did not challenge this conclusion.

5. Analysis of exposure levels on2 100 MHz 5G sites before and after 5G roll out

To study the exposure created by the 5G roll out at the 2 100 MHz 5G sites, 135 were identified as part of this program, of which 33 could not be measured "after" because 5G was not yet rolled out during the measurement campaign. This analysis therefore covers 102 sites in the 2 100 MHz band. Of those 102 sites, 75 % were subject to detailed "case B" measurements, i.e. 77 sites.

As in the study on 700 MHz sites presented above, the field levels measured on the 2 100 MHz band alone will be analysed in a first step for 77 sites using detailed frequency measurements (protocol case B). In a second step, the analysis will focus on the overall exposure levels at 102 sites (protocol case A).

5.1. Analysis of the contribution levels from the 2 100 MHz band alone

Figure 11 shows the contribution of the 2 100 MHz band alone before and after 5G roll out in that band at 77 sites. The histograms show the distribution of measured before/after values by 1 V/m increments.

It shows that 5G roll out in the 2 100 MHz band has not changed the level distribution in the band and that 100 % of the "before" measurements are below 2 V/m and almost 99 % of the "after" measurements are also below 2 V/m.

Of the 77 measured points, one point that was in the "between 0 and 1 V/ m" range before 5G roll out appears more exposed in the "after" measurement and moves to the "between 1 and 2 V/m" range: the contribution on this point was 0.70 V/m and reached 1.13 V/m for the second measurement. Another point initially in the "between 1 and 2 V/m" range moved to the higher "between 2 and 3 V/m" range (from 1.75 V/m to 2.58 V/m).

In contrast, a point that was initially in the "between 1 and 2 V/m" range is in the lower "between 0 and 1 V/m" range in the "after" measurement, passing from 1.09 V/m to 0.66 V/m.

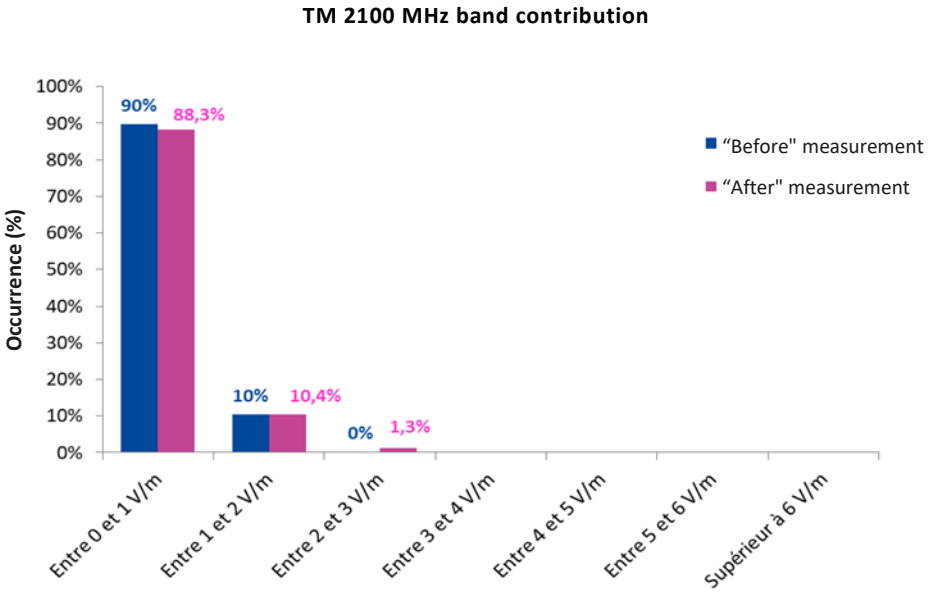

Figure 11. Distribution of exposure levels in the2 100 MHz band before and after 5G roll out at 77 2 100 MHz sites

Table 3 summarises the measured field level statistics for the2 100 MHz band alone. The mean, median and standard deviation remain equivalent before and after 5G roll out (there is a non-significant mean decrease).

	Number of measurements	Average (V/m)	Median (V/m)	Standard-deviation	Max (V/m)
Contribution of the2 100 MHz band "before"	77	0.46	0.30	0.42	1.83
Contribution of the 2100 MHz band "after"	77	0.45	0.33	0.40	2.58
"Before/after" variation (V/m)		-0.01	0.03	-0.02	0.75

Table 3. Comparison of field level statistics measured in the2 100 MHz band before and after 5G roll out at 77 sites

To characterise the variation in the contribution of the 2 100 MHz band before and after 5G roll out in this band, the differences are calculated for each before/after measurement pair. The histograms in Figure 12 show the distribution of the differences between the "before" and "after" measurements in 0.2 V/m intervals.

82 % of the differences are between -0.3 and 0.3 V/m. In 7 % of the cases, there is an increase of 0.6 V/m on the band and in 11 % a decrease of 0.6 V/m. As explained above, variation in traffic between two measurements can explain this.

Local variation in the 2 100 MHz band

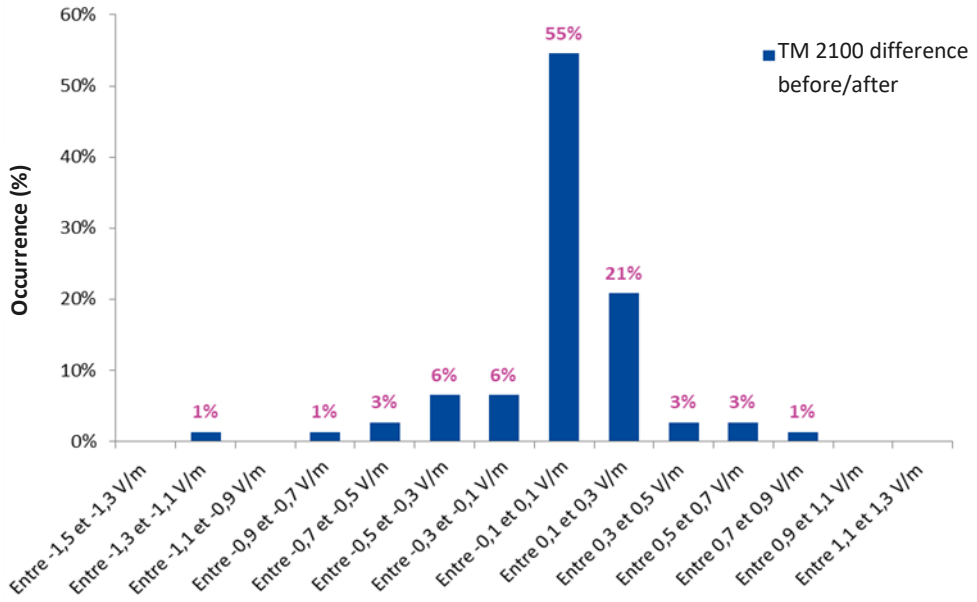

Figure 12. Distribution of differences between2 100 MHz band contribution before and after 5G roll out at 772 100 MHz sites

The average difference is -0.01 V/m, close to zero, which, considering the sensitivity of the measuring instruments, means that the differences are centred on 0 V/m. At this stage of the study, it is reasonable to infer that the contribution of the 2 100 MHz band after 5G roll out remains comparable to that before the roll out.

5.2. Analysis of overall exposure levels

The analysis of overall exposure levels (protocol case A) is studied in this section on 102 5G sites in the 2 100 MHz band.

The statistical analysis of overall exposure shown in Figure 13 in 1 V/m steps shows that 70 % of the measurements made before and after 5G roll out remain below 2 V/m.

4 measurement points which were in the "between 0 and 1 V/m" range, appear to be more exposed.

An analysis of the highest "between 4 and 5 V/m" range shows that one measurement point has moved from the "between 3 and 4 V/m" range to the "between 4 and 5 V/m" range (from 3.28 V/m to 4.33 V/m).

On the other hand, several measuring points change from higher to lower intervals, for example from 2.70 V/m to 0.41 V/m or from 2.59 V/m to 0.62 V/m.

A closer look at these points shows that the contribution of the other mobile phone frequency bands has decreased, especially in the 800 MHz and 900 MHz bands.

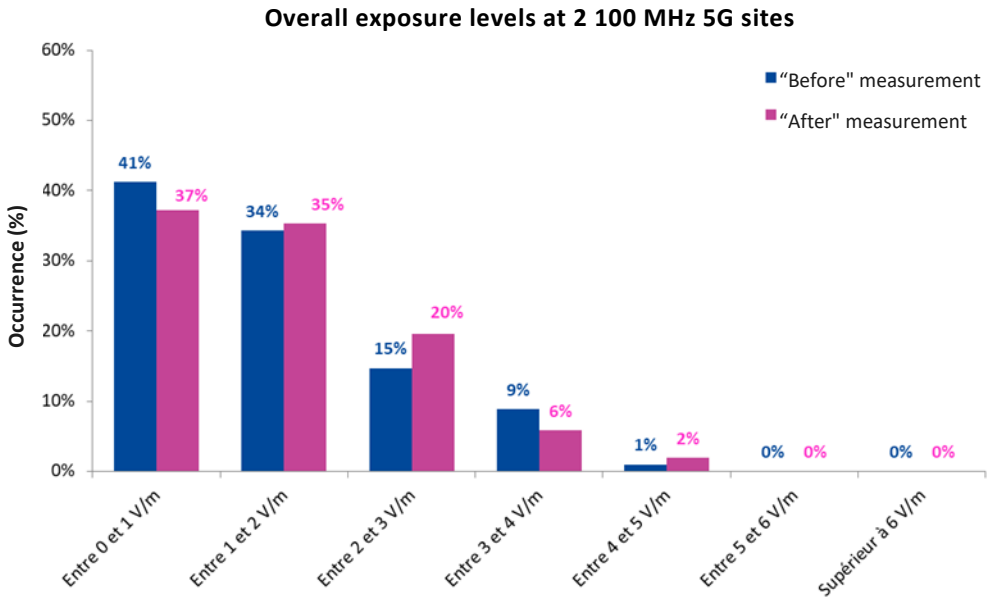

Figure 13. Distribution of overall exposure levels before and after 5G roll out at 102 2 100 MHz sites

The measured field level statistics in the2 100 MHz band are given in Table 4. The mean, median and standard deviation remain equivalent for the overall exposure at the2 100 MHz 5G sites (there is also a non-significant mean decrease in overall exposure).

	Number of measurements	Average (V/m)	Median (V/m)	Standard-deviation	Max (V/m)
Overall 2 100 MHz 5G exposure “before”	102	1.52	1.16	0.96	4.98
Overall 2 100 MHz 5G exposure “after”	102	1.50	1.18	0.94	4.33
“Before/after" variation (V/m)		-0.02	0.03	-0.03	-0.65

Table 4. Comparison of overall exposure field level statistics before and after 5G roll out on 102 2 100 MHz sites

To further assess the differences between the overall exposure levels before and after the 5G roll out in the 2 100 MHz band, Figure 14 shows the distribution of differences between each pair of points measured before/after, in 0.2 V/m intervals.

In over 77 % of cases, the differences are between -0.4 and 0.4 V/m, which is close to the probe sensitivity (0.38 V/m). In about 15 % of cases, there is an increase of 0.6 V/m and in about 12 % of cases, an average decrease of 0.9 V/m is seen. As in the previous cases, these variations can be explained by variation in traffic between two measurements.

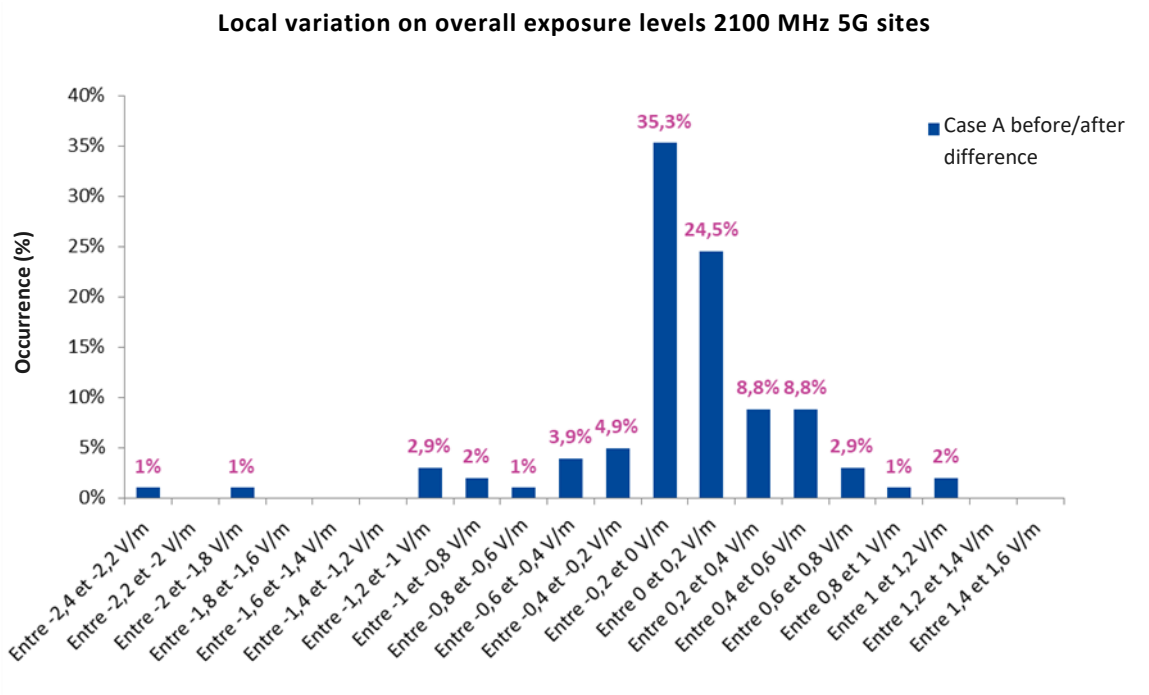

Figure 14. Distribution of differences between overall exposure levels before and after 5G roll out on 102 5G sites in the 2 100 MHz band

The average differences in overall exposure before and after 5G roll out in the 2 100 MHz band is -0.02 V/m, close to zero. One can therefore conclude that the overall exposure measured after 5G roll out in the 2 100 MHz band is very similar to that found before its roll out.

To conclude, by analysing the selective detailed frequency measurements at 77 sites hosting 5G in the 2 100 MHz band on the one hand, the findings show that the contribution of the 2 100 MHz band before and after 5G roll out produces field levels that are very similar to those found before its introduction. On the other hand, the analysis of overall exposure at 143 5G sites in the 2 100 MHz band also showed that the levels measured before 5G roll out are similar to those after its roll out.

6. Analysis of exposure levels on3 500 MHz 5G sites before and after 5G roll out

The 3 500 MHz band has been the subject of major reworking for 5G. In France in 2020, this band was still used by wireless local loop (WLL) networks using WiMax *(Worldwide Interoperability for Microwave Access)* technology. At the end of 2020, before 5G was put into service, emissions were no longer authorised in the band assigned to mobile telephony, so the expected exposure levels corresponded to the residual noise level in this band.

Out of the 1 360 sites hosting 5G selected as part of this program in the 3 500 MHz band, nearly 80 % (1 063 sites) have been the subject of detailed measurements after their operational 5G deployment. 112 of those sites also have a detailed frequency measurement prior to the 5G roll out.

As previously mentioned, in addition to the standard measurements under the applicable protocol, additional measurements specific to 5G in the 3 500 MHz band were carried out at 370 sites. Those measurements were made by generating traffic from a 1 GB file download to direct the 5G antenna's variable beam towards the measurement point and thus create exposure more representative of what might be reached in the future, when 5G-enabled terminals become more widespread.

Only one site with before/after and specific measurements will be removed from this study. Indeed, the "after" measurement showed that the initial site had been dismantled and moved about fifteen metres, which prevents reliable comparisons.

This part is organised as follows:

- first, the contribution of the 3 500 MHz band will be analysed at 1 062 sites after 5G roll out, followed by a comparative study of the contribution of the 3 500 MHz band at 111 sites for which detailed measurement data is available before and after 5G roll out;
- secondly, overall exposure levels will be studied at 1 359 sites before and after 5G roll out (of which 955 will be determined by calculation);
- and finally, specific measurements in the presence of traffic will be used to estimate future exposure in the presence of a majority of terminals with 5G subscriptions.

6.1. Analysis of the contribution levels from the 3 500 MHz band alone

Figure 15 shows the distribution of field levels measured in the 3 500 MHz band at 1 062 operational 5G sites. The results show that almost 100 % of the measured levels are below 1 V/m.

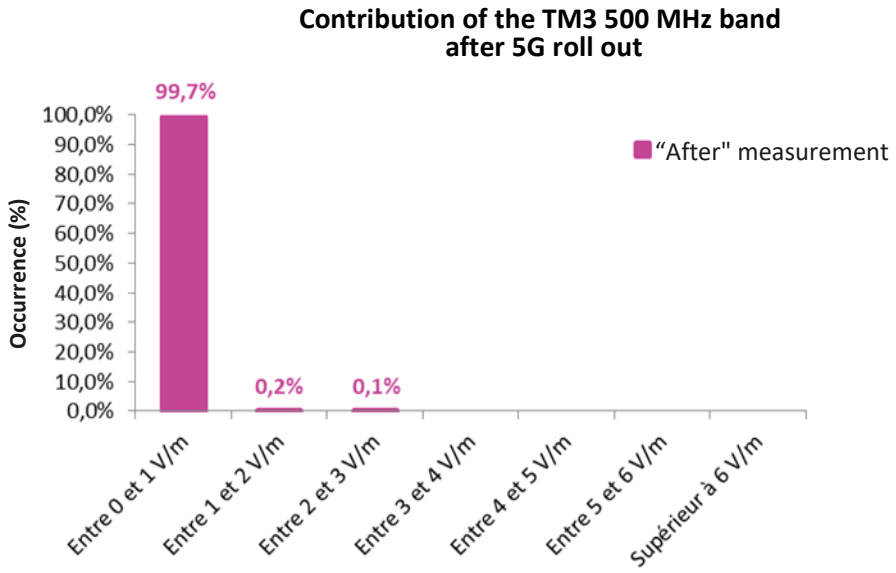

Figure 15. Contribution of the3 500 MHz band after 5G roll out estimated from 1 062 measurements

As shown in Table 5, the average contribution from the 3 500 MHz band across these 1 062 sites is 0.11 V/m. This level seems very low compared to the reference level (limit value) in the band in question (61 V/m).

	Number of measurements	Average (V/m)	Median (V/m)	Standard-deviation	Max (V/m)
Contribution of the 3 500 MHz band	1 062	0.11	0.07	0.16	2.1

Table 5. Statistics for field levels measured on the contribution of the 3 500 MHz band after 5G roll out at 1 062 sites

Table 6 summarises the the measured field level statistics in the 3 500 MHz band, where an increase in the average of 0.13 V/m can be seen.

Prior to roll out, there was no significant transmission in the band, which was freed up to host 5G. The measured levels are therefore very low (0.02 V/m on average) and show the noise level in the band.

	Number of measurements	Average (V/m)	Median (V/m)	Standard-deviation	Max (V/m)
Contribution of the 3 500 MHz band	111	0.02	0	0.13	0.28
Contribution of the 3500 MHz band	111	0.15	0.09	0.21	1.25
“Before/after" variation (V/m)		0.13	0.09	0.08	0.97

Table 6. Comparison of measured field level statistics in the 3 500 MHz band before and after 5G roll out at 111 3 500 MHz 5G sites

To observe the variation between the levels measured before and after roll out in the3 500 MHz band, Figure 16 shows the distribution of the differences between each pair of before/after points in 0.2 V/m intervals.

83 % of the differences are between -0.3 V/m and 0.3 V/m. In 16 % of cases an average increase of 0.5 V/m is seen, and in 1 % an average decrease of 0.4 V/m.

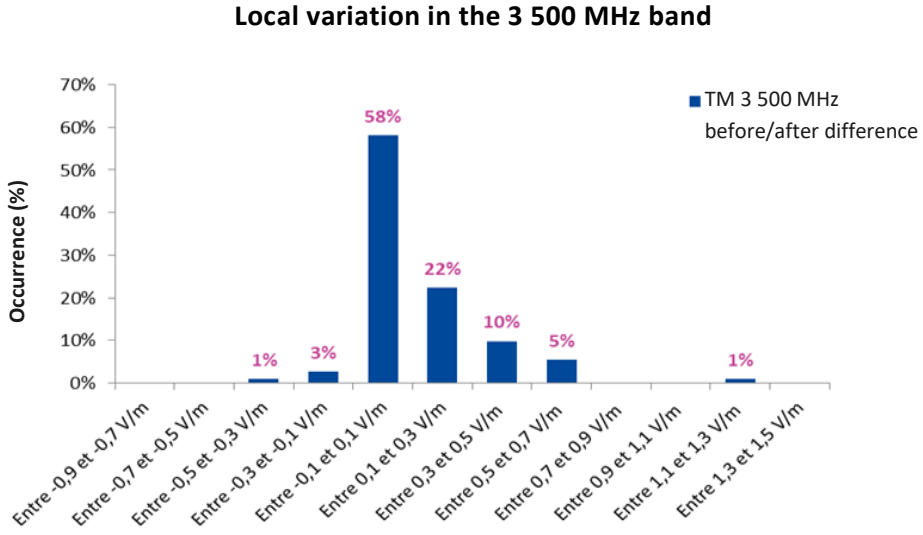

Figure 16. Distribution of differences between 3 500 MHz band contribution before and after 5G roll out at 1113 500 MHz sites

The average difference in overall exposure before and after 5G roll out in the 3 500 MHz band is 0.13 V/m. This value is still low, but is significantly higher than those observed for the low-bands, which are 0.01 V/m for the 700 MHz band and -0.01 V/m for the 2 100 MHz band. The distribution is no longer centred around 0 V/m: the vast majority of differences are positive and show an increase in exposure which seems low since it remains non-significant for the majority of cases.

6.2. Analysis of overall exposure levels

Figure 17 shows the distribution of measurements in 1 V/m intervals on the overall exposure levels observed before and after 5G roll out in the 3 500 MHz band.

1.5 % of the points (20 points) that were in the "between 0 and 1 V/m" range move out of this range as they become more exposed. Similarly, 1 % (14 points) of the points that were initially in the "between 1 and 2 V/m" range saw their exposure increase.

Overall, over 88 % of the 1 359 "before" measurements carried out (or calculated) on 3 500 MHz 5G sites stay below 2 V/m. Analysis of the "after" measurements shows that almost 88 % of the measurements are also below 2 V/m. The distribution is therefore almost equivalent in the extended 0 to 2 V/m range.

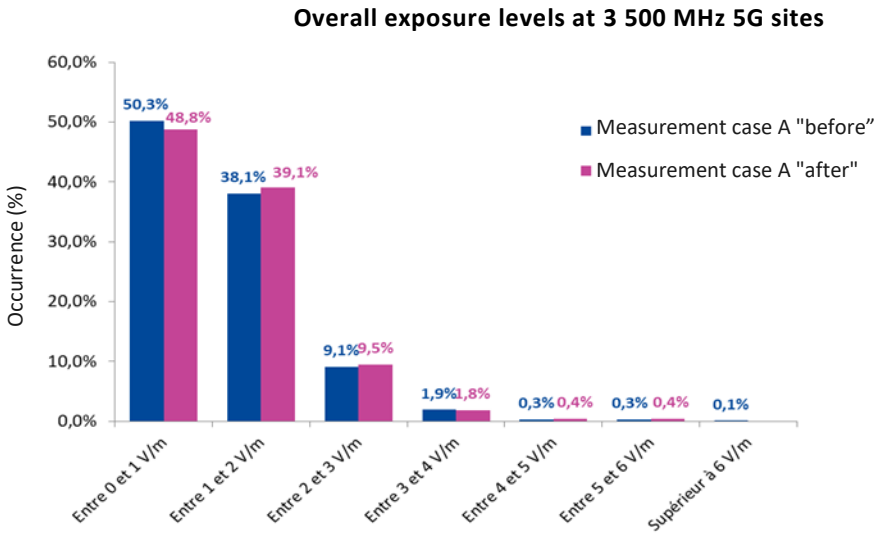

Figure 17. Distribution of overall exposure levels before and after 5G roll out on 1359 3 500 MHz sites

These bar graphs show that the two "before" and "after" measurements are comparable. The average exposure level confirms this: it is 1.16 V/m for the "before" measurement and 1.17 V/m for the "after" measurement, i.e. a non-significant increase of 0.01 V/m.

The comparison of the statistical parameters from the overall exposure data before and after 5G roll out in the 3 500 MHz band shown in Table 7 confirms this first trend.

	Number of measurements	Average (V/m)	Median (V/m)	Standard-deviation	Max (V/m)
Overall 3 500 MHz 5G exposure “before”	1,359	1.16	1.00	0.75	6.19
Overall 3 500 MHz 5G exposure "after”	1,359	1.17	1.01	0.74	5.41
Variation (V/m)		0.01	0.01	-0.01	-0.78

Table 7. Comparison of field level statistics for overall exposure before and after 5G roll out at 1359 3 500 MHz 5G sites

To better characterise the variation between the "before" and "after" measurements, the local variation is studied to see how the field levels are distributed.

For this purpose, the statistical distribution of the differences between the pairs of before/after measurements is characterised in Figure 18.

In more than 93 % of cases, the variation is between -0.4 and 0.4 V/m, thus close to the probe sensitivity. In almost 4 % of cases, an average increase of 0.6 V/m is seen, whereas in almost 3 % of cases, an average drop of 0.7 V/m can be seen.

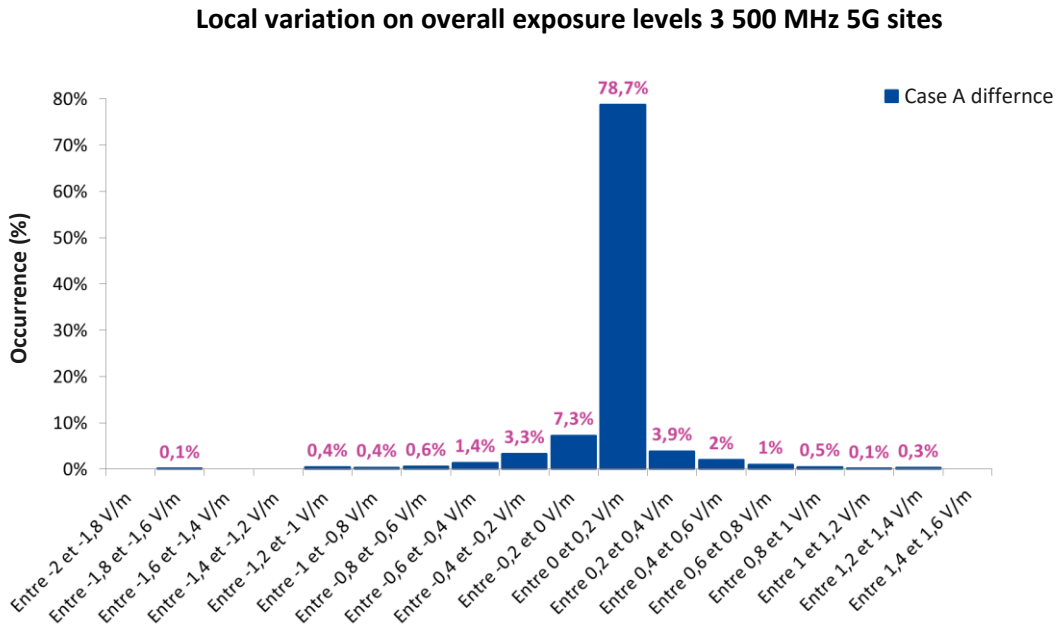

Figure 18. Distribution of differences between overall exposure levels before and after 5G roll out on 1359 5G 3 500 MHz sites

The average of the differences between the overall exposure levels before the operational 5G deployment in the 3 500 MHz band and after its roll out is 0.01 V/m. This difference is very low, close to 0 V/m.

At this stage of the study one can therefore conclude that overall exposure to electromagnetic waves generated by sites hosting 5G in the 3 500 MHz band is comparable to the exposure on the same sites generated by previous generations of mobile telephony (2G/3G/4G) in the low-bands.

To conclude, at this stage of deployment in which 5G traffic remains low, the exposure level in the 3 500 MHz band after roll out is low with an average additional contribution of 0.11 V/m, a value obtained from the detailed measurements. The arrival of 5G in this band has resulted in only a very low increase in the overall exposure level.

6.3. Specific measurements with 5G data download

As seen in the previous paragraph, the contribution of the 3 500 MHz band seemed low.

At the current stage of deployment, few users are soliciting 5G antennas, which is why there was an interest in artificially creating traffic to study the effect of 5G on overall exposure by simulating higher use in this band.

Additional measurements specific to 5G in the 3 500 MHz band were therefore requested from the laboratory. These measurements were carried out outside the protocol. They consisted in soliciting the 5G antenna from the measurement location using a 5G phone and at the height where the measured field level was found to be the highest during the spatial averaging of case A[6]. The traffic is then generated by downloading 1 GB of data, which corresponds to the exposure indicator proposed by the ANFR[7]. The average field level during the download is then assessed. The field levels are then averaged over 6 minutes.

Almost 370 5G 3 500 MHz sites have been the subject of these specific measurements making it possible to solicit the 5G network.

Figure 19 shows the average field level during the download of the 1 GB file on the3 500 MHz band (in blue) as well as the average field level without the download (in pink).

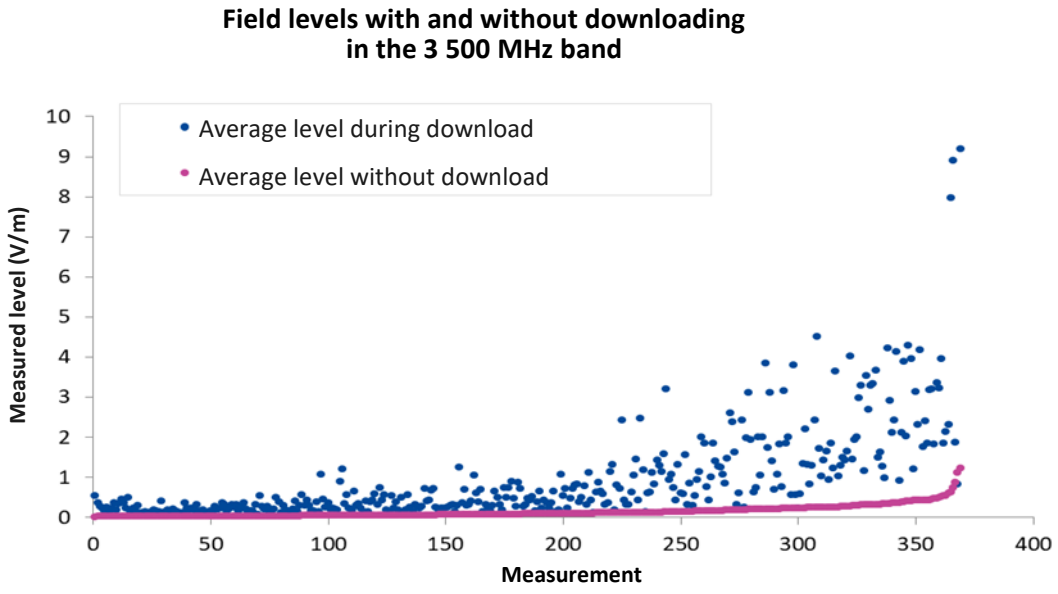

Figure 19. Average field level during a 1 GB file download compared to the average level without downloading

[6] A spatial average is taken at three measuring points at 1m10, 1m50 and 1m70

[7] https://www.anfr.fr/toutes-les-actualites/actualites/lanfr-publie-un-rapport-de-mesures-sur-lexposition-aux-ondes-des-experimentations-5g-et-presente-un-nouvel-indicateur-de-mesure-de-lexposition/

Figure 20 shows the average field level over 6 minutes with download (in blue) and without download (in pink).

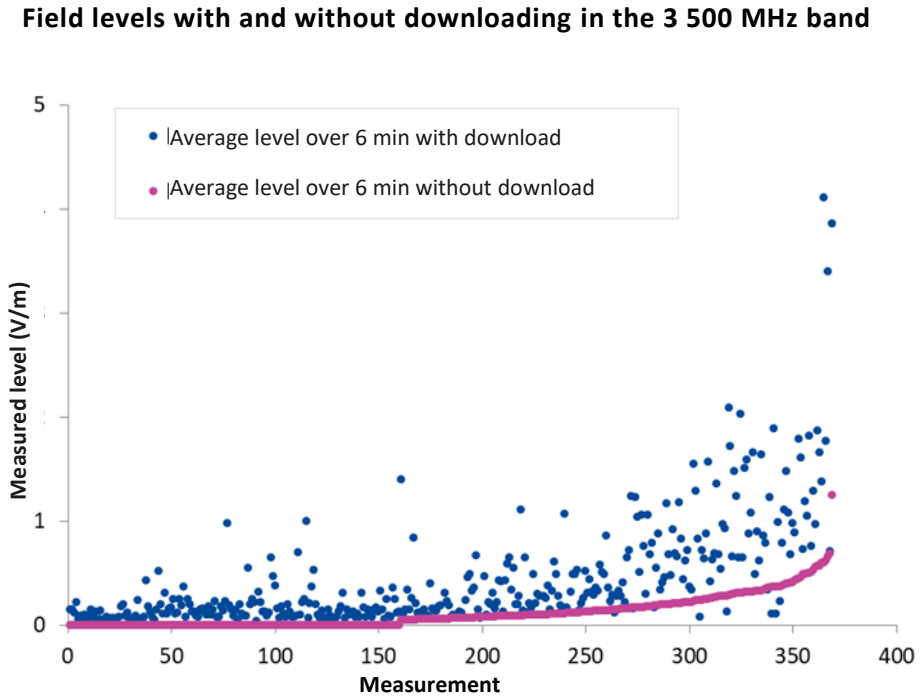

Figure 20. Average field level over 6 minutes while downloading a 1 Gb file compared with the average level over 6 minutes without downloading

Both figures show an increase in exposure due to the file download.

The average increase calculated between the measurement with download averaged over 6 minutes (in blue) onthe 3 500 MHz band and the average level without download (in pink) is 0.3 V/m.

The purpose of this additional measurement is to simulate a possible increase in traffic by specifically soliciting the 5G antenna.

To assess the impact on the overall exposure level, the 6-minute average strength from the specific measurement with 5G solicitation is included in the overall exposure for case A and case B by calculation, and then compared to the case A "after" and case B "after" measurement without specific network solicitation. Figure 21 shows the distribution of the "Case A" overall exposure levels with and without downloading. Figure 22 shows the overall exposure levels for "Case B" with and without downloading.

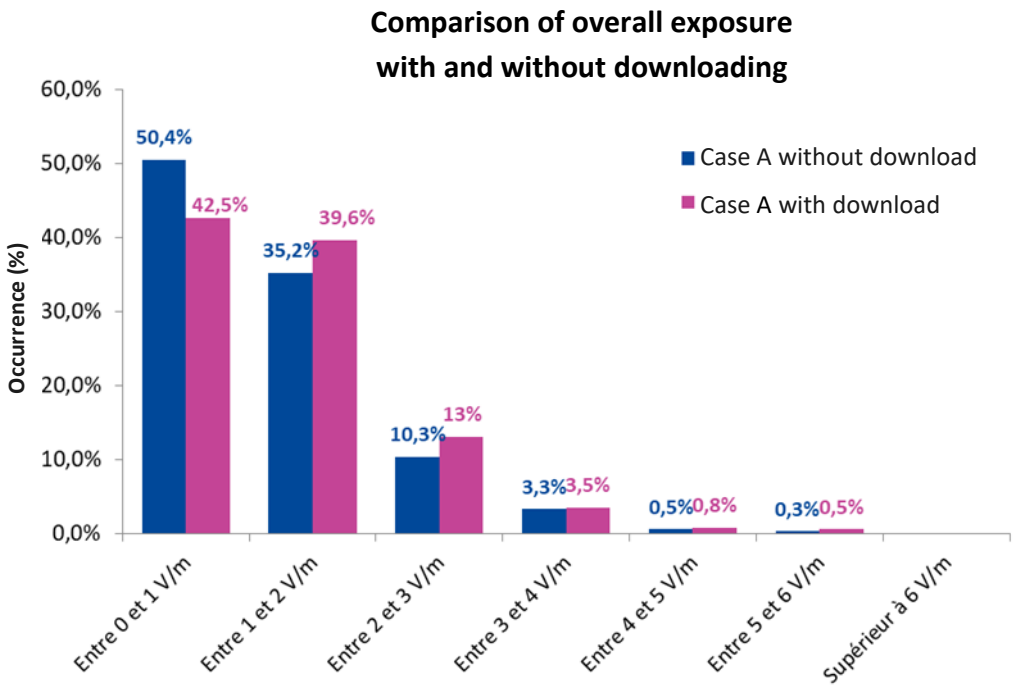

Figure 21. Distribution of the average level over 6 minutes from the specific measurement with 5G solicitation included in case A global exposure by calculation, and compared to the case A measurement "after" without specific network solicitation

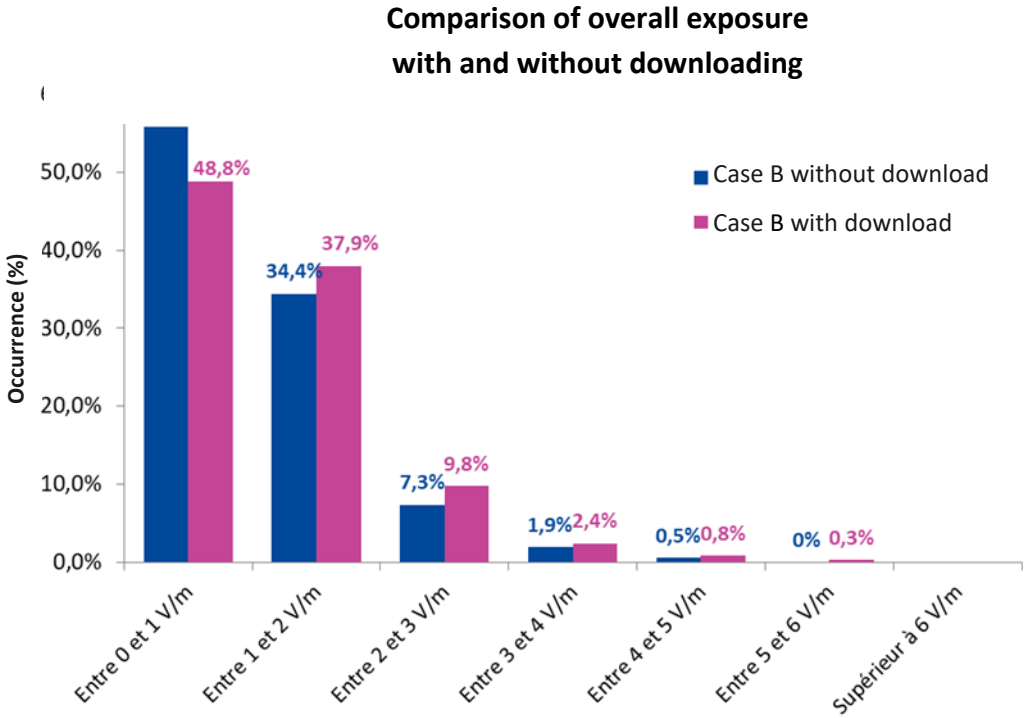

Figure 22. Distribution of the average level over 6 minutes from the specific measurement with 5G solicitation included in the case B overall exposure by calculation, and compared to the case B measurement "after" without specific network solicitation

The comparison between the statistical parameters from the overall exposure data (Case A and Case B) with and without downloading in the 3 500 MHz band is shown in Table 8.

	Number of measurements	Average (V/m)	Median (V/m)	Standard-deviation
Case A overall exposure without download	369	1.21	0.99	0.78
Case A overall exposure with download	369	1.34	1.13	0.84
Variation (V/m)		0.13	0.14	0.06
Case B overall exposure without download	369	1.08	0.91	0.70
Case B overall exposure with download	369	1.22	1.02	0.77
Variation (V/m)		0.14	0.11	0.07

Table 8. Comparison of overall exposure field level statistics with and without download on 369 5G 3 500 MHz sites

The average increase between the two levels is 0.13 V/m for case A and 0.14 V/m for case B, i.e. an average increase of 14 % and 16 % respectively. One can therefore consider that an increase in 5G traffic in line with the exposure indicator introduced by the ANFR should lead to an increase of around 20 % in the overall exposure level.

7. Conclusions

This preliminary study is based on the analysis of more than 3 000 measurements carried out as part of an extensive campaign on the evolution of exposure related to the deployment of 5G in the 700 MHz and 2 100 MHz low frequency bands already used for 3G and 4G networks, as well as in the new 3 500 MHz band which was authorised for use by ARCEP in November 2020.

Initial results show that exposure remains very similar after 5G is rolled out on the low bands, which also continue to be used for previous generations of 3G and 4G. For the most part, the variation is less than 0.3 V/m with an average value very close to 0 V/m.

The 3 500 MHz band is reserved for 5G and was previously cleared of other transmission sources. The first results show that the overall exposure also varies very little. In almost 93 % of cases, the variation does not exceed +/- 0.4 V/m, which is close to the probe sensitivity. The average difference between the overall exposure measurements before and after 5G roll out is close to zero (0.01 V/m). The contribution of the 3 500 MHz band alone on operational 5G sites is 0.11 V/m.

Few users are currently using the network compared to its potential, which may explain the very low increase in exposure in the 3 500 MHz band. Measurements will therefore continue to monitor the evolution of exposure according to the expected increase in traffic in the coming years. This provisional report will then be completed, initially by including the supplement to the first campaign study and the third phase of the second campaign which continues until the end of 2021.

As 5G traffic is still low at this stage of deployment, additional measurements specific to 5G in the 3 500 MHz band were carried out in the presence of artificially generated traffic to solicit the 5G antenna by downloading a 1 GB file using a 5G phone. Initial results suggest an eventual increase of about 20 % in overall exposure.