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# Electromagnetic Field (EMF) measurements near 5G mobile phone base stations

## Summary of results

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# Contents

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**Section**

1. Overview	1
2. Background	3
3. High-level methodology	4
4. Summary of test results	7
5. Next Steps	13
6. Glossary	14

**Annex**

A1. Version history	15
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# 1. Overview

This report is a further update to the report that was originally published on 21 February 2020 and first updated on 17 April 2020. It includes measurements at 11 additional locations that have been completed since the April 2020 update. This report now includes EMF measurements conducted at 33 locations near 5G-enabled mobile phone base stations during 2020.

The purpose of our measurements was to verify that 5G-enabled mobile base stations remained within the limits in the ICNIRP Guidelines for the protection of the general public (the ICNIRP general public limits)<sup>1</sup>.

## What we've found

In 2020 we carried out EMF measurements at 33 locations near to 5G mobile phone base stations, in 18 towns and cities across the UK, including Belfast, Cardiff, Edinburgh and London.

Measurements prior to April 2020 were targeted in busy areas where there were likely to be high levels of mobile phone use, including in and around major transport hubs and shopping centres.

Due to COVID-19 restrictions, the most recent set of measurements at 11 locations were undertaken in areas close to 5G mobile phone base stations where our measurements team were able to maintain social distancing from members of the public. They include less busy publicly accessible areas which may be physically close to the base station in question.

The results in 2020 indicate that:

- The measured EMF levels from 5G-enabled mobile phone base stations are well within the levels identified in the ICNIRP Guidelines, with the highest level being approximately 7.1% of the ICNIRP general public reference levels and the next highest level being 1.5%;
- The contribution of 5G to the total emissions level observed is currently low – the highest level we observed in the band currently used for 5G was just 0.04% of the ICNIRP general public reference levels.

1.1 Ofcom has been carrying out radio frequency electromagnetic field (EMF) measurements near mobile phone base stations for many years.<sup>2</sup> These measurements have consistently shown that EMF levels near mobile phone base stations are well within the internationally agreed levels published in the ICNIRP Guidelines.

1.2 While all the frequency bands now in use by mobile phone base stations have been used for various services for many years, our EMF measurements prior to 2020 did not include the specific frequency bands now being rolled out by the mobile operators for 5G. The

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<sup>1</sup> Guidelines for limiting EMF exposure that will provide protection against known adverse health effects are published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP is formally recognised by the World Health Organization (WHO). The measurements in this report were carried out with reference to the [1998 ICNIRP Guidelines](#).

<sup>2</sup> Ofcom inherited a programme of EMF measurements started by its predecessor, the Radiocommunications Agency (one of the five regulators whose duties were subsumed by Ofcom when it was created).

results reported here therefore concentrate on measurements near 5G-enabled mobile phone base stations.

- 1.3 The results show that, at all locations where we conducted measurements, the EMF levels are well within the ICNIRP general public limits. A detailed summary of results is presented in Section 4.
- 1.4 In the UK, Public Health England (PHE) leads on public health matters associated with radiofrequency electromagnetic fields, or radio waves, and has a statutory duty to provide advice to Government on any health effects that may be caused by EMF emissions<sup>3</sup>. On 5G, PHE's view is that *'the overall exposure is expected to remain low relative to guidelines and, as such, there should be no consequences for public health'*.<sup>4</sup>
- 1.5 The deployment of 5G networks and the take-up of 5G services is at an early stage. Once COVID-19 restrictions are lifted, we will continue to undertake EMF measurements to monitor the overall trends in the long term. This will include measurements in new areas and repeat measurements at a number of the locations which we have already visited. We will continue to publish these measurements on our website as they become available.
- 1.6 We have also published the 33 individual survey reports on our website. These form the basis of this summary report.

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<sup>3</sup> The Scottish Government set out its position on 5G and public health in a [statement](#) published alongside its [5G strategy](#) in August 2019. This noted that "the advice provided by PHE is fully endorsed by the Chief Medical Officer for Scotland". Public Health Wales notes on its [website](#) that "specialist radiation protection information and advisory services are provided in Wales by Public Health England's Centre for Radiation, Chemical and Environmental Hazards (CRCE)".

<sup>4</sup> See: <https://www.gov.uk/government/publications/mobile-phone-base-stations-radio-waves-and-health/mobile-phone-base-stations-radio-waves-and-health>

## 2. Background

- 2.1 In March 1999, the Chairman of the National Radiological Protection Board (NRPB, now part of Public Health England) was asked by the Minister for Public Health to set up an independent expert working group to assess the current state of research into possible health risks from mobile phones. The Independent Expert Group on Mobile Phones (IEGMP) was set up in April 1999 and was chaired by Sir William Stewart.
- 2.2 The IEGMP published its report in May 2000 (the Stewart Report), recommending the establishment of an independent audit of EMF emissions from mobile base stations.<sup>5</sup> In response to this report, the Government commissioned the Radiocommunications Agency (RA) to implement a national measurement programme to ensure that emissions from mobile phone base stations did not exceed the levels identified in the ICNIRP Guidelines for general public exposure. Ofcom has continued this programme since its establishment in 2003.
- 2.3 In 2012, this activity switched from a proactive to a reactive programme. From this date onwards, Ofcom has continued to conduct EMF exposure measurements on request. This is provided as a free service to qualifying schools and hospitals (i.e. those that do not benefit financially from base stations installed on their property). Further information about Ofcom's EMF exposure measurement surveys are published on our website page: [Requesting surveys of EMF emissions from mobile base stations](#). The results of all measurements published to date are available on our website page: [Mobile phone base station audit results](#).
- 2.4 In recent years, the number of requests for EMF exposure measurements has been declining. However, the introduction of 5G has seen a renewed interest in the potential impact of radio waves on health and Ofcom has received an increasing number of queries about the safety of 5G deployments.
- 2.5 This report presents the results of proactive EMF exposure measurements undertaken by Ofcom at locations near 5G-enabled mobile phone base stations.

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<sup>5</sup> IEGMP, [Mobile Phones and Health](#), 2000 (archived 10 September 2010)

### 3. High-level methodology

- 3.1 In this section we set out the high-level methodology we have used to measure general public exposure to EMF near 5G-enabled mobile base stations.
- 3.2 We have measured the EMF exposure level at selected test locations using a field strength analyser with an isotropic probe following a procedure based on the in-situ RF exposure measurement method set out in section B.3.1.2 of IEC 62232:2017<sup>6</sup>.
- 3.3 The power density reference levels from the ICNIRP Guidelines for general public exposure (applicable to mobile phone frequencies) are as follows:

<b>Frequency range</b>	<b>Power density (<math>W m^{-2}</math>)</b>
400 – 2,000 MHz	$f/200$ *
2 – 300 GHz	10

\* Where  $f$  is the frequency in MHz

- 3.4 The measurements were conducted over the individual frequency bands used for mobile base station (downlink) transmissions as well as across all other frequency bands between 420 MHz to 6 GHz (see Tables 3.1 and 3.2 below for more details).

**Table 3.1: Frequency bands covered in reports up to April 2020**

Frequency band	Frequency range	Technology <sup>7</sup>
700 MHz	738-788 MHz	Not currently used. Spectrum award planned in 2021
800 MHz	791-821 MHz	4G
900 MHz	925-960 MHz	2G, 3G, 4G
1400 MHz	1452-1492 MHz	4G (Supplementary downlink)
1800 MHz	1805-1880 MHz	2G, 4G
1900 MHz	1900-1920 MHz	4G
2100 MHz	2110-2170 MHz	3G, 4G
2300 MHz	2350-2390 MHz	4G
2600 MHz	2570-2690 MHz	4G
3.4 GHz	3410-3680 MHz	5G, 4G
3.8 GHz	3680-4200 MHz	Various
Others <sup>8</sup>		

<sup>6</sup> International Electrotechnical Commission, *IEC 62232:2017: Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*, 23 August 2017

<sup>7</sup> Note: this is an indication of the type of technologies typically deployed in these bands. Not all frequency bands and technologies will be in use in any one location.

<sup>8</sup> All other frequencies between 420 MHz and 6 GHz

**Table 3.2: Frequency bands covered in reports from August 2020 onwards**

Frequency band	Frequency range	Technology <sup>9</sup>
700 MHz	738-788 MHz	Not currently used. Spectrum award planned in 2021
800 MHz	791-821 MHz	4G
900 MHz	925-960 MHz	2G, 3G, 4G
1400 MHz	1452-1492 MHz	4G (Supplementary downlink)
1800 MHz	1805-1880 MHz	2G, 4G
1900 MHz	1900-1920 MHz	4G
2100 MHz	2110-2170 MHz	3G, 4G
2300 MHz	2350-2390 MHz	4G
2600 MHz TDD	2570-2620 MHz	4G
2600 MHz FDD	2620-2690 MHz	4G
3.4 GHz	3410-3680 MHz	5G, 4G
3.8 GHz	3680-4200 MHz	Various
Others <sup>10</sup>		

- 3.5 We used a field strength analyser (Narda SRM-3006),<sup>11</sup> connected to an isotropic electric field (E-field) probe, to carry out the measurements. As illustrated in Figure 3.1 below, the probe is mounted on a tripod at a height of 1.5m above ground level. The use of an isotropic probe means that the measurement result is not affected by the direction of signal arrival and the polarisation of the measured field.

<sup>9</sup> Note: this is an indication of the type of technologies typically deployed in these bands. Not all frequency bands and technologies will be in use in any one location.

<sup>10</sup> All other frequencies between 420 MHz and 6 GHz

<sup>11</sup> <https://www.narda-sts.com/en/products/selective-emf/srm-3006-field-strength-analyzer/>

**Figure 3.1: Narda SRM-3006 field strength analyser connected to an isotropic E-field probe mounted on a tripod 1.5m above ground level**

- 3.6 The SRM-3006 analyser together with the probe has an overall operating frequency range from 420 MHz to 6 GHz. This is sufficient to cover all the frequency bands currently used for mobile phone base station transmissions.
- 3.7 For the measurements reported here, the SRM-3006 was set to its Safety Evaluation mode. In this mode, the analyser automatically adjusts its resolution bandwidth to 5 MHz and its frequency step size to 2.5 MHz and repeatedly sweeps across all frequencies from 420 MHz to 6 GHz at a rate of approximately 1 sweep per second. At each frequency step the analyser measures the root mean square (rms) field strength. As specified in the 1998 ICNIRP Guidelines, the measurements at each location are averaged over a six minute period.
- 3.8 The SRM-3006 reports the exposure level as a percentage of a selected safety standard limit (e.g. the levels from the ICNIRP Guidelines). Exposure levels are reported for each individual frequency band and the total EMF emission level across all bands measured (420 MHz – 6 GHz) is also reported.



## 4. Summary of test results

- 4.1 At the time of publication, we have carried out measurements close to known 5G-enabled mobile phone base stations in 33 locations<sup>12</sup> across England, Scotland, Wales and Northern Ireland. We have published individual measurement test reports for each location on our website. This section provides a high-level summary of the results for all locations visited.
- 4.2 The map below shows the towns and cities where we have conducted measurements to date.

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<sup>12</sup> The original version of this report, published on 21 February, included measurements at 16 locations. We updated the report on 17 April 2020 to include 6 additional locations and in this update to include a further 11 locations.

Figure 4.1: Towns and cities where we have conducted measurements



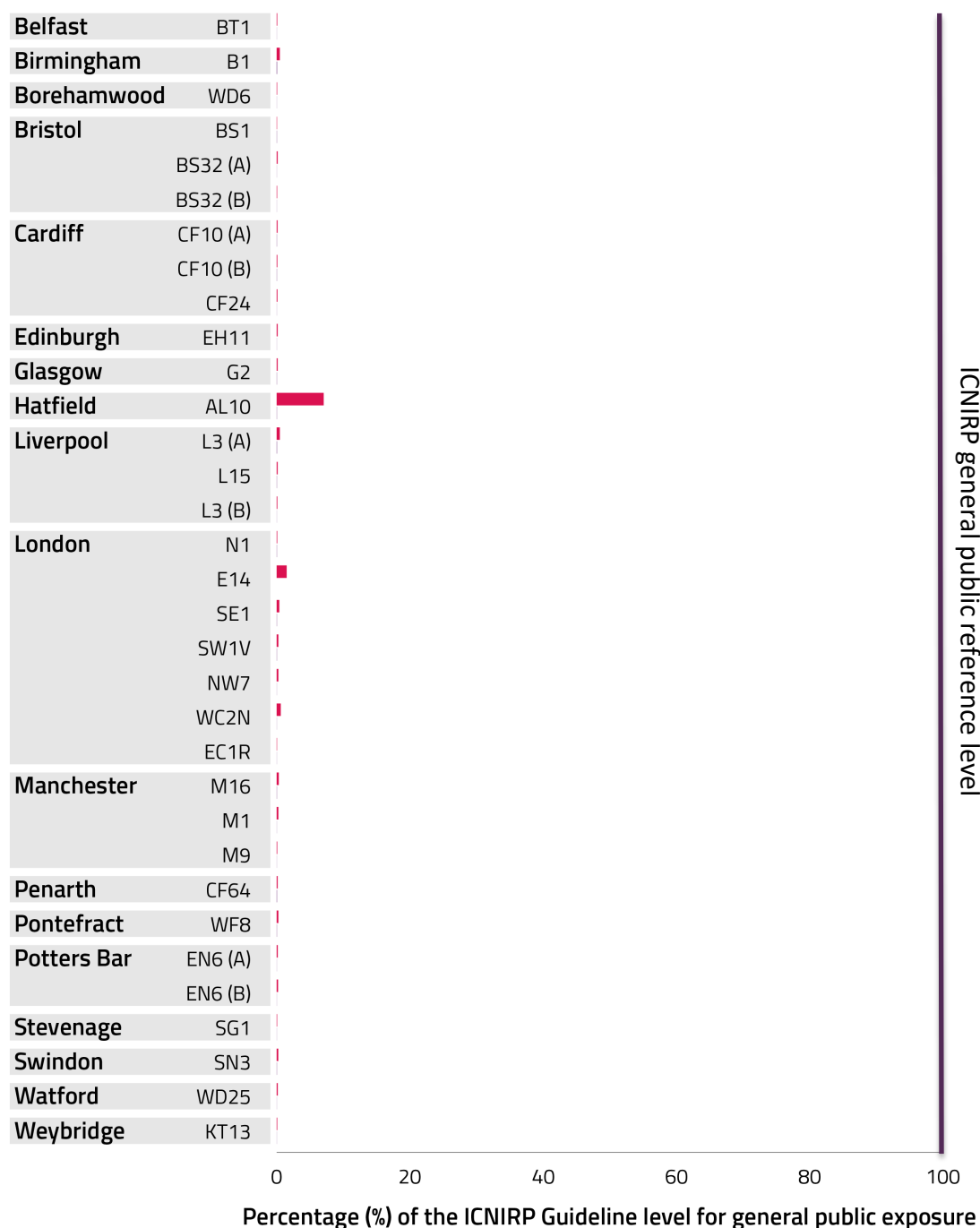
4.3 Figure 4.2 on the following page shows the highest average exposure level that we recorded at each location. Table 4.1 on page 10 shows the same data in tabular form. The exposure levels are expressed as a percentage of the reference levels for general public exposure in the 1998 ICNIRP Guidelines<sup>13</sup>. The chart presents two measured levels:

- a) the exposure level measured across all mobile frequency bands; and
- b) the exposure level for the 5G frequency band (currently, 5G is deployed in the 3.4-3.6 GHz band).

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<sup>13</sup> All figures below (or equal to) 100% are considered as being within the recommended exposure limits.

Figure 4.2: Highest recorded average exposure levels at all 5G-enabled sites visited<sup>14</sup>



<sup>14</sup> 11 new locations were added in our update on 26 February 2021 and are Bristol BS32 (B), Watford WD25, Weybridge KT13, Borehamwood WD6, Hatfield AL10, Pontefract WF8, London NW7, Swindon SN3, Penarth CF64 and two locations in Potters Bar EN6.

Table 4.1: Highest average exposure levels at all locations visited<sup>15</sup>

City	Location	Highest All Band Value [%]*	Highest 5G Band Value [%]*
Belfast	<a href="#">BT1</a>	0.0807	0.0006
Birmingham	<a href="#">B1</a>	0.4688	0.0386
Borehamwood	<a href="#">WD6</a>	0.0525	0.0018
Bristol	<a href="#">BS1</a>	0.0460	0.0068
	<a href="#">BS32 (A)</a>	0.1431	0.0010
	<a href="#">BS32 (B)</a>	0.0582	0.0007
Cardiff	<a href="#">CF10 (A)</a>	0.1195	0.0060
	<a href="#">CF10 (B)</a>	0.0823	0.0041
	<a href="#">CF24</a>	0.0978	0.0016
Edinburgh	<a href="#">EH11</a>	0.1419	0.0004
Glasgow	<a href="#">G2</a>	0.1399	0.0044
Hatfield	<a href="#">AL10</a>	7.0510	0.0081
Liverpool	<a href="#">L3 (A)</a>	0.4608	0.0239
	<a href="#">L15</a>	0.1371	0.0069
	<a href="#">L3 (B)</a>	0.0894	0.0011
London	<a href="#">N1</a>	0.0711	0.0117
	<a href="#">E14</a>	1.4960	-
	<a href="#">SE1</a>	0.3828	0.0065
	<a href="#">SW1V</a>	0.2483	0.0042
	<a href="#">NW7</a>	0.2521	0.0021
	<a href="#">WC2N</a>	0.5970	0.0014
	<a href="#">EC1R</a>	0.0420	0.0013
Manchester	<a href="#">M16</a>	0.3017	0.0053
	<a href="#">M1</a>	0.2460	0.0019
	<a href="#">M9</a>	0.0736	0.0016
Penarth	<a href="#">CF64</a>	0.1343	0.0290
Pontefract	<a href="#">WF8</a>	0.2487	0.0058
Potters Bar	<a href="#">EN6 (A)</a>	0.1528	0.0017
	<a href="#">EN6 (B)</a>	0.2029	0.0020
Stevenage	<a href="#">SG1</a>	0.0654	0.0008
Swindon	<a href="#">SN3</a>	0.2253	0.0115
Watford	<a href="#">WD25</a>	0.1524	0.0022
Weybridge	<a href="#">KT13</a>	0.0663	0.0004

\*Results which are not sufficiently above the system noise floor to record as a valid measurement are shown as a dash (-)

4.4 As can be seen from Figure 4.2 and Table 4.1 above, EMF emission levels from 5G-enabled mobile phone base stations remain well within the reference levels for general public exposure in the ICNIRP Guidelines, with the highest level recorded being approximately 7.1% of the reference levels, and the next highest level being 1.5%.

<sup>15</sup> The location names in this table contain links to the detailed measurement reports for each location which are published separately on our website. The Annex shows the results published in each update.

- 4.5 Our measurements also show that the contribution of 5G to the total emissions level observed is currently low – the highest level we observed in the band used for 5G was just 0.04% of the reference levels.
- 4.6 We note that the measurement results presented in this report are not directly comparable with previous EMF measurement surveys, i.e. those conducted before 2020, for several reasons. For example, whilst previous measurements were largely focused on schools, hospitals or residential areas, many of our 2020 measurements were focused on busy areas where we could expect to see the highest levels of mobile phone use<sup>16</sup>. In addition, our latest measurements include a larger number of frequency bands, including frequencies recently made available for 5G.
- 4.7 As can be seen from Figure 4.2 and Table 4.1 above, the measurements presented in this report show some variation between the exposure levels measured at each location. This is likely to be due, at least in part, to differences in the position of the measurement probe relative to the base station at each location. We took all measurements in publicly accessible areas, and these areas were at varying distances to the mobile phone base station serving the area. In all cases however, we sought to take measurements at locations with the highest signal strength near the base station.
- 4.8 The highest level recorded during the most recent set of 11 measurements (7.1%) was significantly higher than the levels recorded at any other site (with the next highest level recorded being 1.5%). The main reason for this was likely that, at this measurement location, the mobile base station was closer to the publicly accessible area than at other sites. Despite this, the recorded levels remained well within the ICNIRP general public limits.

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<sup>16</sup> Due to COVID-19 restrictions, the most recent set of measurements at 11 locations were undertaken in areas close to 5G mobile phone base stations where our measurements team were able to maintain social distancing from members of the public, including less busy publicly accessible areas which were physically close to the mobile base station..

## 5. Next Steps

- 5.1 The deployment of 5G networks and the take-up of 5G services in the UK is still at an early stage. We will therefore continue to undertake EMF measurements to monitor the overall trends in the long term.
- 5.2 This will include repeat measurements at a number of the locations which we have already visited as well as measurements in new areas.
- 5.3 We will continue to publish the results of these measurements on our website as they become available.

## 6. Glossary

### List of acronyms and units

5G	The fifth generation of mobile telecommunications technology
Base station	Radio transmitter infrastructure that controls and communicates to mobile phones
Downlink	In mobile communication, a downlink refers to the transmission link from the base stations to the mobile devices such as mobile phones or tablets.
E-field strength	Electric field strength
EMF	Electromagnetic fields
Far field	Regions where the distance from the measurement point to the source is greater than $D^2/\lambda$ where D is the diameter of the source antenna and $\lambda$ is the wavelength of the frequency.
GHz	Gigahertz (1 GHz is equivalent to 1000 MHz)
ICNIRP	The International Commission on Non-Ionizing Radiation Protection
IEC	The International Electrotechnical Commission
IEGMP	The Independent Expert Group on Mobile Phones
kHz	Kilohertz (1 kHz is equivalent to 1000 Hz)
MHz	Megahertz (1 MHz is equivalent to 1000 KHz)
NRPB	The National Radiological Protection Board, now part of Public Health England
Ofcom	The Office of Communications
RA	The Radiocommunications Agency
rms	The root mean square (rms) is defined as the square root of the arithmetic mean of the squares of a set of numbers
W m <sup>-2</sup>	Watts per square metre, a measure of radiated power density.



## A1. Version history

Version	Date published	Comments
1	<a href="#"><u>21 February 2020</u></a>	Measurements at 16 locations
2	<a href="#"><u>17 April 2020</u></a>	Measurements at a further 6 locations added
3	1 March 2021	Measurements at a further 11 locations added