

Exposures to radiofrequency fields near 5G cellsites

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About EMF Services and the author of this report

EMF Services is a division of Monitoring and Advisory Services NZ Ltd (MAASNZ), and provides professional measurement and advisory services related to possible health effects of electromagnetic fields (EMFs), such as the extremely low frequency (ELF) electric and magnetic fields found around any wiring, appliances or infrastructure carrying mains electricity, and the radiofrequency (RF) fields produced by radio transmitters and some industrial equipment.

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Introduction and summary

This report presents the results of measurements of exposures to radiofrequency (RF) fields near 5G cellsites in Queenstown and Auckland. The measurements were made during the day on 25 February and on 2, 3 and 4 March 2020.

Measurements were made on a total of seven sectors at five different sites. All the sites also have 2, 3 and 4G transmitters. There was a direct line of sight to the antenna at all measurement locations, and measurements were made in directions very close to the main beam azimuths. The measurement probe was mounted on an insulated stand at a height of 1.5 m above the ground.

Measurement results are presented in graphs on the following pages. The exposure to RF fields is shown as the percentage of the limit allowed for the public in the New Zealand RF field exposure Standard NZS 2772.1:1999 *Radiofrequency Fields Part 1: Maximum exposure levels – 3 kHz to 300 GHz*.

Each bar of the graphs shows the exposure at the location identified by a letter at the bottom of the bar. A table below the graphs gives information about the measurement locations. The total height of the bar shows the total exposure, as a percentage of the public limit in NZS 2772.1. The contributions of different transmitters towards that total are shown by the different coloured portions of the bar. Looking at location G in figure 1, for example, the total exposure was equivalent to 4.7% of (ie about twenty times lower than) the public limit in the New Zealand exposure Standard. Most of this was due to Vodafone 2, 3 and 4G transmitters (red portion of the bar) and the rest (about one seventh of the total) due to 5G transmitters.

Exposures during a download speed test

Measurements were made while repeatedly making a download speed test using the 5G carrier, to ensure that this carrier was highly loaded. (Note that some or all of the 4G carriers could also have been active to increase the download speed.) Results are shown in figures 1 and 2. The total exposure varied from one measurement location to another, but at most of the sites the exposure due to the 5G carrier was no more than one tenth of the total exposure due to the Vodafone site. At locations D, E and F there were also small contributions from Spark and 2degrees sites in the same area.

The highest 5G exposure, as a fraction of the total exposure due to the Vodafone site, was found at location G, where it was about one seventh of the total.

Maximum possible exposures

Cellsites transmitters adjust their power up and down so as to be just sufficient to handle traffic through the site. Additional measurements were made at all nine locations to determine the maximum possible exposures from the Vodafone sites if the transmitters (2, 3, 4 and 5G) were to operate at full power. (It should be noted that there is no chance that

this would actually happen in practice.) The results of these measurements are presented in figures 3 and 4.

Maximum possible 5G exposures, as a fraction of the total exposure from the Vodafone 5G transmitters, varied between one fiftieth and one quarter of the total, but were mostly around one tenth.

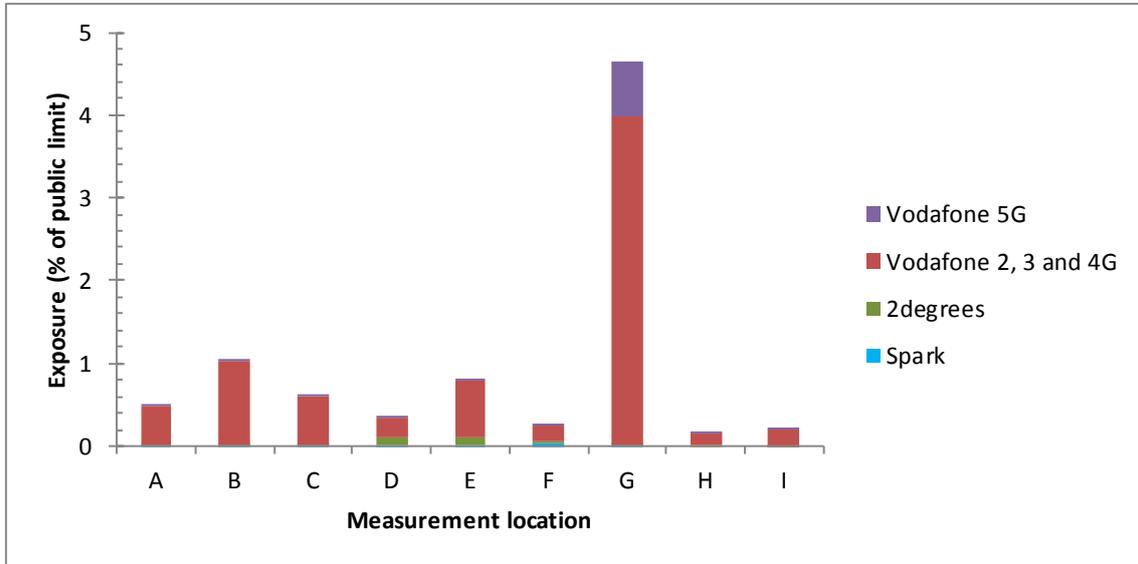


Fig 1. Exposures from 5G-equipped sites during a download speed test, shown as a percentage of the public limit in NZS 2772.1.

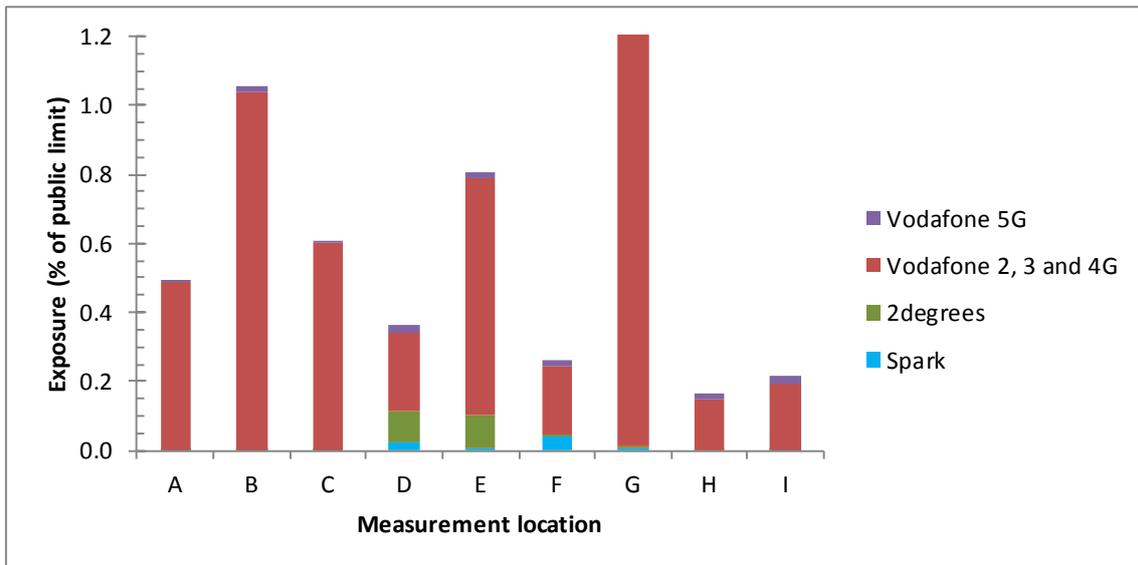


Fig 2. As figure 1, shown on an expanded scale. The results for location G are off scale and should be read from figure 1.

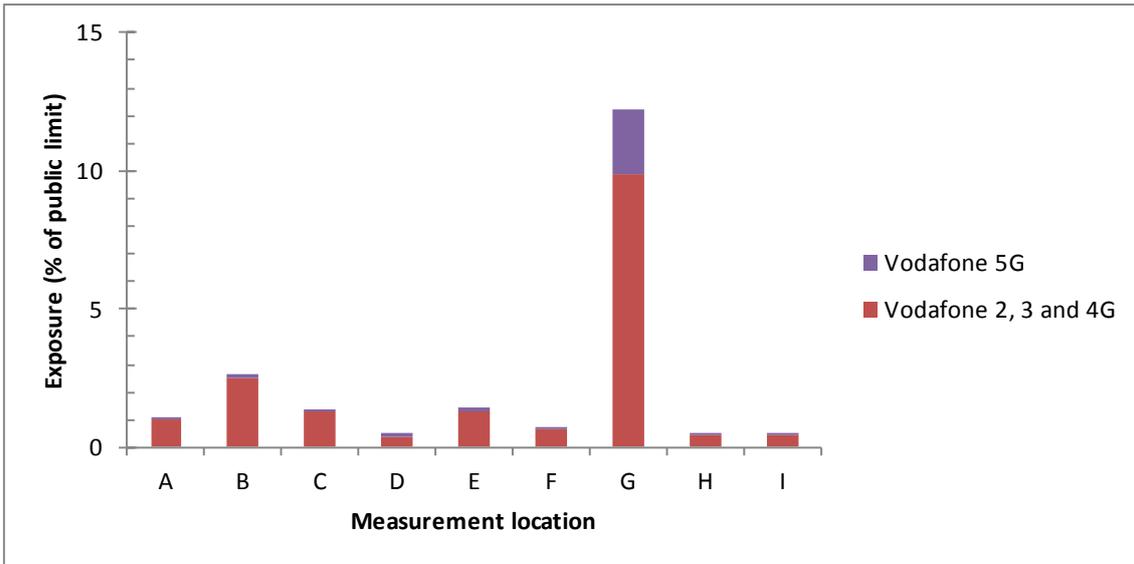


Fig 3. Maximum possible exposures from 5G-equipped sites, shown as a percentage of the public limit in NZS 2772.1.

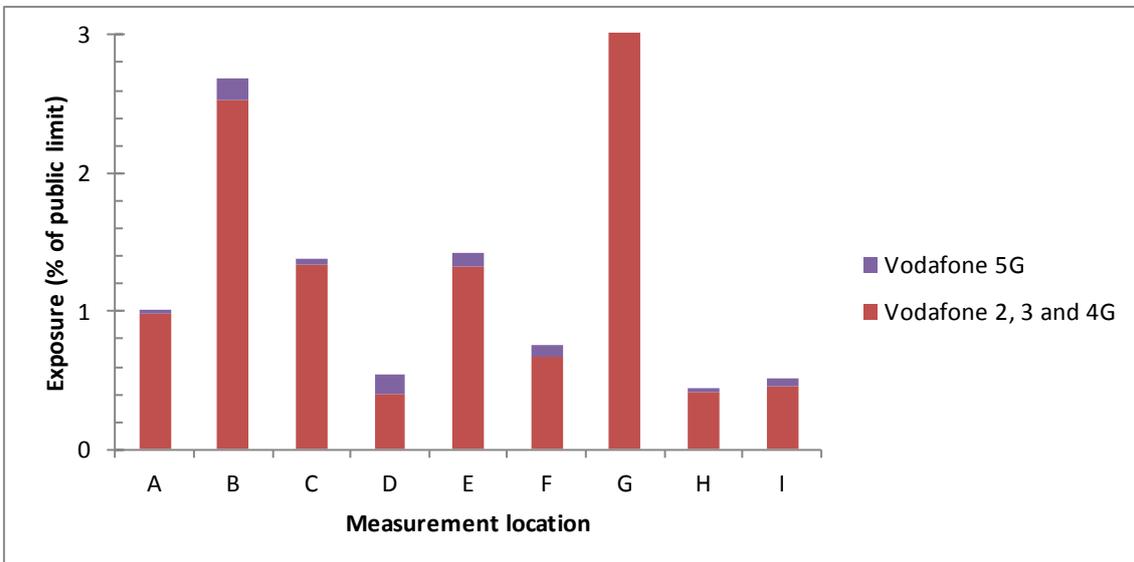


Fig 4. As figure 3, shown on an expanded scale. The results for location G are off scale and should be read from figure 3.

Ref	Site	Sector	Distance from antenna (m)	Antenna height (m)	Comments
A	1	1	30	9	Residential street
B	1	2	40	9	Residential street
C	1	2	100	9	Residential street
D	2	3	130	11	Public park. Spark and 2degrees sites in the area.
E	2	3	100	11	
F	3	3	130	9	Shopping centre. Spark site in the area
G	4	3	37	8.5	Rooftop car park
H	5	1	30	9	Residential street
I	5	2	35	9	Residential street

Conclusions

All exposures during the download speed test were well below the limit allowed for the public in the New Zealand RF field exposure Standard, and would continue to be so if all transmitters currently installed at the Vodafone site were to operate at their maximum power. During the speed test the exposure from the 5G transmitters was typically no more than one tenth of the total exposure from the Vodafone site.

These results give a picture of exposures found with the current deployment of 5G technology. It should be noted that the sites have passive antennas (in other words, they are not beam-forming antennas that form more tightly focussed radio beams directed towards individual users), and results obtained in the future with beam-forming antennas could be different.

Full details of the measurement equipment and procedures, and the New Zealand RF field exposure Standard, are presented in appendices to this report.

Appendix 1 Site description

Each of the sites had transmitters operating in all of Vodafone's frequency bands (700, 900, 1800, 2100, 2600 and 3500 MHz) using 2, 3, 4 and 5G technologies. Each sector has two antennas, one transmitting the 2, 3 and 4G signals, and the other the 3500 MHz 5G signal.

Characteristics of the four technologies are summarised below.

1.1 2G (GSM)

GSM components are configured to transmit on one Control (BCCH) channel, and one or more Traffic (TCH) channels on each sector. The control channels transmit continuously at constant power, and the traffic channel power is adjusted as necessary to handle additional traffic. The maximum power of the traffic channels in each frequency band is the same as that of the control channel in the same band.

1.2 3G (UMTS)

The power of UMTS carriers is adjusted up and down depending on the amount of traffic passing through the site. Each carrier includes a primary common pilot channel (P-CPICH) which is always transmitted, even if no calls are going through the site, at a constant fraction of the maximum carrier power.

1.3 4G (LTE)

Like UMTS, the power of the LTE carriers is varied up and down so as to be just sufficient to handle traffic passing through the site. Reference signals, whose power is constant and bears a fixed relationship to the maximum carrier power, are transmitted regularly across the LTE carrier.

1.4 5G (NR)

5G sites currently implemented by Vodafone use passive (non-beamforming) antennas. Synchronisation signals are transmitted periodically at constant power in the central portion of the carrier spectrum. There is a fixed ratio between the power of the synchronisation signals and the power of the data signals.

Appendix 2 Exposure Standards

The New Zealand Ministry of Health recommends using NZS 2772.1:1999 *Radiofrequency Fields Part 1: Maximum exposure levels – 3 kHz to 300 GHz* to manage exposure to RF fields. This Standard is based closely on Guidelines published by the International Commission on Non-Ionising Radiation Protection (ICNIRP). ICNIRP is an independent scientific body recognised by the World Health Organisation for its independence and expertise in this area. Their exposure Guidelines, which are based on a careful review of the health effects research, were first published in 1998¹, and reaffirmed in 2009² following a review of more recent research in this area³, and again in 2017⁴. Research published since 2009 has been reviewed by a number of other health and scientific bodies⁵, none of which has questioned the underlying basis of the limits used in New Zealand.

NZS 2772.1 sets limits for exposure to the RF fields produced by all types of transmitters, and covers both public and occupational exposures. Occupational limits should normally be applied only to people who are expected to work on RF sources (eg radio technicians and engineers, riggers, RF welder operators etc), who have received training about potential hazards and precautions which should be taken to avoid them. Their exposures to occupational levels would normally be limited to the working day and over their working lifetime. Occupational exposure limits are set at levels 10 times lower than the threshold at which adverse health effects might occur. Members of the public, on the other hand, includes people of all ages who could be in any state of health, and whose exposures could be of unlimited duration. For these reasons, public limits have a safety factor of 50.

At the frequencies of interest for this survey, the Standard sets fundamental limits, called *basic restrictions*, on the amount of RF power absorbed in the body. As absorption of RF power is difficult to measure, the Standard also specifies *reference levels* in terms of the more readily measured (or calculated) electric and magnetic field strengths, and plane wave equivalent power density. Compliance with the reference levels ensures compliance with the basic restrictions, and in many situations they can effectively be regarded as the NZS 2772.1 “exposure limits”, although this term is not used as such in the Standard. If exposures exceed the reference levels, this does not necessarily mean that the basic restriction has also been exceeded. However, a more comprehensive analysis is required before compliance can be verified.

The exposure limit, in watts per square metre (W/m²) depends on the frequency of the RF field as shown in the table below.

¹<http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf>.

² <http://www.icnirp.org/cms/upload/publications/ICNIRPStatementEMF.pdf>

³ ICNIRP. Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz) - Review of the Scientific Evidence and Health Consequences. Munich: International Commission on Non-Ionizing Radiation Protection; 2009. ISBN 978-3-934994-10-2.

⁴ <http://www.icnirp.org/en/activities/news/news-article/revision-of-hf-guidelines-2017.html>

⁵ Links to recent reviews can be found at <http://www.health.govt.nz/our-work/radiation-safety/non-ionising-radiation/research-non-ionising-radiation>.

Frequency band	Public limit
10 MHz – 400 MHz	2W/m ²
400 MHz – 2000 MHz	f/200 W/m ² (f = frequency in MHz)
>2000 MHz	10 W/m ²

At the frequencies of interest in this survey, the limits prescribed in the Standard are average values over six minutes. Spatial averaging, at the four corners and centre of a 30 cm square whose sides are between 4.5 and 30 cm long, depending on the transmitter frequency, is also permitted. Apart from the time averaging noted in Appendix 3.2, no other averaging was carried out in this survey.

ICNIRP published revised Guidelines in April 2020. The reference levels relevant to this survey are the same as those in the table above. However, the averaging time is increased to 30 minutes.

Appendix 3 Measurement equipment and techniques

The planning, execution and reporting of the measurement survey followed the procedures recommended in AS/NZS 2772.2:2016 *Radiofrequency fields Part 2: Principles and methods of measurement and computation – 3 kHz to 300 GHz*.

The weather was sunny or cloudy at the times the measurements were made, with temperatures in the range 17-22°C

3.1 Measuring equipment

RF fields were measured with a Narda SRM-3006 Selective Radiation Meter and three-axis electric field probe connected by a 1.5 m cable. Full specifications are presented in Annexe A.

The meter and probe combination measures electric field strength, which is expressed in units of volts per metre (V/m). For ease of comparison with the exposure limits recommended in NZS 2772.1:1999, the meter was set to record data as the equivalent power density of a plane wave, and results in this report are presented as a percentage of the power density reference level recommended in the NZ RF field exposure Standard.

The probe was mounted on an insulated stand 1.5 m above the ground.

3.2 Measurement technique

3.2.1 Exposures during a download speed test

Exposures during the download speed test were measured with the meter in safety evaluation mode. In this mode, the meter measures the power density in each of a number of preset frequency bands (called “services” in the instrument terminology), plus the total power density of signals which fall outside these bands. The preset frequency bands used, and their approximate detection thresholds (or noise levels) are summarised in Annexe B. The preset frequency bands were set up to cover the downlink frequencies used by Vodafone, as well as the downlink frequencies used by the other mobile phone operators.

The meter was set to average the readings from 16 successive sweeps through the frequencies of interest. Each sweep took approximately 2.2 seconds. As noted in Appendix 1, the power of the Vodafone transmitters is adjusted up and down depending on the voice and data traffic through the site. To take account of this, and obtain a reading that is representative of the transmitters operating at the upper end of their power, the exposure was monitored for three minutes in each location and the maximum 16-sweep average recorded every minute. The highest of these 16-sweep averages is presented in this report.

3.2.2 Maximum possible exposures

Additional measurements were made in order to determine the maximum possible exposure if the Vodafone transmitters were to operate at their full output powers.

2G transmitters

The exposure from the BCCH control channel, which transmits at constant power, was measured in level recorder mode, and multiplied by the total number of 2G carriers on the sector.

3G transmitters

Measurements were made in the meter's UMTS (pilot channel demodulation) mode. In this mode the meter demodulates the pilot channel from the 3G signal and measures its power. From the known ratio between the pilot channel power and maximum transmitter power the value of the pilot channel power can be scaled to show the theoretical maximum exposure when the carrier operates at full power.

4G transmitters

Measurements were made in the meter's LTE-FDD (frequency division duplex) demodulation mode. In this mode the meter measures the power in reference signals transmitted at constant power that are distributed throughout the 4G waveform. The reference signal measurement can be scaled to provide the theoretical maximum exposure using the known ratio of the reference signal power to the total carrier power.

5G transmitters

Measurements were made in Level Recorder mode using measurement parameters recommended by Narda⁶. The technique measures the exposure from the PSS and SSS signals present in the signal spectrum (usually in the central block), which can then be extrapolated to give the maximum exposure from the whole carrier when it is operating at full power (taking into account differences in the power of the synchronisation and data resource blocks, and the number of MIMO carriers).

It should be noted that in practice there is no real possibility that all carriers on all technologies will operate simultaneously at their maximum possible power. Data from cellphone networks overseas suggests that the average power of 3G carriers during the day, for example, is typically between about 30 and 45% of the maximum possible, and the highest power is less than 76% of the maximum possible^{7,8}.

⁶ The approach is described in Keller (2019). On the assessment of human exposure to electromagnetic fields transmitted by 5G NR base stations. *Health Physics* 117(5):541-545.

⁷ Burgi A et al. Time Averaged Transmitter Power and Exposure to Electromagnetic Fields from Mobile Phone Base Stations. *Int. J. Environ. Res. Public Health* 2014, 11, 8025-8037.

⁸ Mahfouz Z et al. Influence of Traffic Variations on Exposure to Wireless Signals in Realistic Environments. *Bioelectromagnetics* 33:288-297, 2012.

Annexe A Measuring equipment specifications and uncertainty

A1 Meter specifications

Manufacturer	Narda Safety Test Solutions GmbH, Pfullingen, Germany
Meter	SRM-3006 s/n H-0010, firmware v 1.5.2
Probe	3-axis electric field probe 3502/01 s/n G-0224
Coaxial cable	1.5 m cable 3602/01 s/n AA-0565
Measurement range	Lower detection threshold: dependent on measurement parameters (see Annexe B). Upper limit 160 V/m (68 W/m ²)
Frequency range	420 MHz – 6 GHz
Calibration	By the manufacturer, October 2018
Recommended calibration interval	2 years

Full specifications are available at:

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

A2 Measurement uncertainty

The principal interest in the uncertainty assessment for these measurements is to determine the upper bound of the uncertainty. For that reason, if quantities have an asymmetrical uncertainty distribution (eg +a/-b dB), they are treated as having an uncertainty of $\pm a$ dB.

A.2.1 Overall uncertainty assessment – exposures during download speed test

Parameter	Uncertainty data source	Standard uncertainty <i>u</i> (dB)
Meter and probe	Data sheet*	± 1.15
Transmitter power	Manufacturer data	± 0.41
Combined standard uncertainty		± 1.22
Coverage factor		1.96
Expanded uncertainty		± 2.4

* This includes all uncertainties associated with the meter, calibration, probe isotropy and connection mismatches at the frequencies of principal interest for this survey.

A.2.2 Overall uncertainty assessment – maximum possible exposures

Parameter	Uncertainty data source	Standard uncertainty <i>u</i> (dB)
Meter and probe	Data sheet*	± 1.15
Transmitter power	Manufacturer data	± 0.41
Combined standard uncertainty		± 1.22
Coverage factor		1.64
Expanded uncertainty		2.0

* This includes all uncertainties associated with the meter, calibration, probe isotropy and connection mismatches at the frequencies of principal interest for this survey.

Note that as the main purpose of the determination of maximum possible exposures is to check compliance with the limits in NZS 2772.1:1999, a one-sided 95% coverage interval with a coverage factor of 1.64 is used, as recommended in section 6.1 of AS/NZS 2772.2:2016.

No allowance has been made for the following potential sources of uncertainty:

Potential source	Comment
Probe position in high field gradients	Measurements made sufficiently far from the transmitters for this to be negligible.
Variations in transmitter power due to transmitter power control	Recording maximum 16-sweep average values will tend to show exposures at the upper end of the possible range.
Signal reflection off operator	Reflections can produce increases and decreases in measured PFD over distances of 100 – 250 mm. Operator stood in positions so as to minimise potential effect and magnitude of reflections.
Errors reading fluctuating meter readings	Results stored by the meter, so uncertainty source eliminated.
RF propagation, environmental clutter and reflections	Exposures at individual frequencies could be higher or lower than measured, but as effects of reflections would be uncorrelated the effects will tend to balance out.
Reflections from movable large objects near source or probe	Reflections from large metal objects may affect readings. Results presented show exposures at the time of measurement, and may vary, for example, if nearby parked vehicles move.

Annexe B SRM-3006 preset frequency bands and settings

Service name (preset frequency band)	Explanation	Lower frequency (MHz)	Upper frequency (MHz)	Detection threshold (mW/m ²)*
Spark 4G 700 do	Spark cellsites in their 700 MHz band	758	778	0.00041
Vf 4G 700 do	Vodafone cellsites in their 700 MHz band	778	793	0.00030
2deg 4G 700 do	2degrees cellsites in their 700 MHz band	793	803	0.00020
Spark 900	Spark cellsites in their 900 MHz band	870	885	0.00025
2deg 900	2degrees cellsites in their 900 MHz band	935	944.8	0.00015
Vod 900	Vodafone cellsites in their 900 MHz band	944.8	960	0.00023
2deg 1800	2degrees cellsites in their 1800 MHz band	1805	1830	0.00007
Spark 1800	Vodafone cellsites in their 1800 MHz band	1830	1855	0.00007
Vod 1800	Vodafone cellsites in their 1800 MHz band	1855	1880	0.00007
Vod 2100	Vodafone cellsites in their 2100 MHz band	2110	2135	0.00008
Spark 2100	Spark cellsites in their 2100 MHz band	2140	2155	0.00005
2deg 2100	2degrees cellsites in their 2100 MHz band	2155	2170	0.00006
Spark 2300	Spark cellsites in their 2300 MHz band	2300	2370	0.00029
Spark 2600	Spark cellsites in their 2600 MHz band	2640	2660	0.00009
Vf 2600	Vodafone cellsites in their 2600 MHz band	2675	2690	0.00007
Vf 5G	Vodafone 5G	3528	3548	0.00016

*On 10 mW/m² measurement range.

Settings – Safety evaluation mode

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Maximum 16-sweep average
RBW	50 kHz

Settings – Level Recorder mode – 2G

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Maximum RMS
Averaging time	0.48 seconds
Centre frequency:	Set for the 2G BCCH

Settings – UMTS mode – 3G

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Maximum
Centre frequency:	Set for each 3G transmitter

Settings – LTE-FDD mode – 4G FDD transmitters

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Maximum
Centre frequency:	Set for each 4G FDD transmitter
CBW	3 MHz
Parameter extrapolated	RS Sum

Settings – Level Recorder mode – 5G

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Peak
Centre frequency:	3538 MHz
RBW	4 MHz
VBW	3.2 kHz