Exposures to radiofrequency fields near Spark 5G cellsites in Palmerston North

EMF Services
Professional EMF measurement and advisory services

Report 2020/62

This report was prepared for:

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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 Spark 5G cellsites in Palmerston North. The measurements were made during the day on 16 and 17 July 2020. Exposures are shown as a percentage of the public reference level in NZS 2772.1:1999 *Radiofrequency Fields Part 1: Maximum exposure levels – 3 kHz to 300 GHz*.

Measurements were made at eight sites on the north-west side of Palmerston North. All the sites also have 3G and 4G transmitters. The 5G transmitters were set to transmit continuously at maximum power, but the 3G and 4G transmitters operated normally. (However, at a few sites, one of the 4G transmitters was also set to transmit at maximum power.) The choice of measurement locations is described in more detail in Appendix 3, but in brief they were chosen by calculating, for each sector at each site, where the highest total exposure, and the highest exposure from the 5G transmitters, were expected, and making measurements at these locations. At most sites preliminary measurements were made to confirm the choice of locations. At some sites there was limited or no access to the locations where maximum exposures were expected, in which case either no measurement was made, or a measurement was made at the closest possible alternative location. Measurements were made at a total of 32 locations, all of which had a direct line of sight back to the Spark antennas.

If nearby Vodafone and 2degrees cellsites could make a significant contribution to the total exposure, measurements were also made on these transmitters and included in the total exposure.

A summary of the results is shown in the histograms below. Figure 1 shows the distribution of the theoretical maximum possible exposures (in other words, the exposure that would occur if all transmitters at the site were to transmit simultaneously at maximum power – which in practice would never occur) and figure 2 shows the distribution of theoretical maximum possible exposures from the 5G transmitters.

For example, figure 1 shows that the theoretical maximum exposure was between 0 and 1% of the public limit at 17 of the measurement locations, and between 3 and 4% of the limit at 2 of the locations. Figure 2 shows that the theoretical maximum exposure from the 5G transmitters was between 0 and 0.1% of the public limit at 14 of the measurement locations, and between 0.3 and 0.4% of the limit at 1 of the locations.

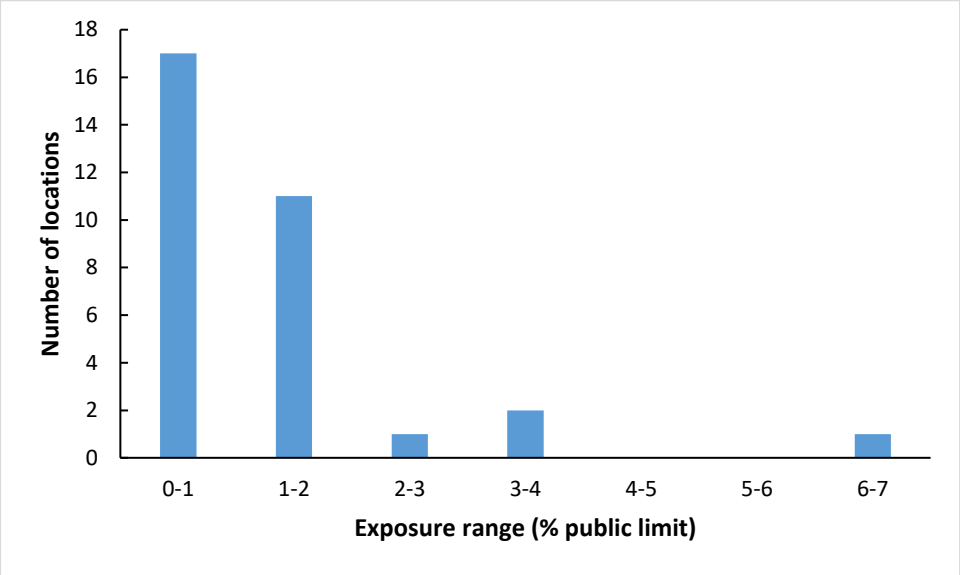

Fig 1. Histogram of the theoretical maximum exposures from all transmitters at all 32 measurement locations. Exposures shown as a percentage of the public reference level in NZS 2772.1.

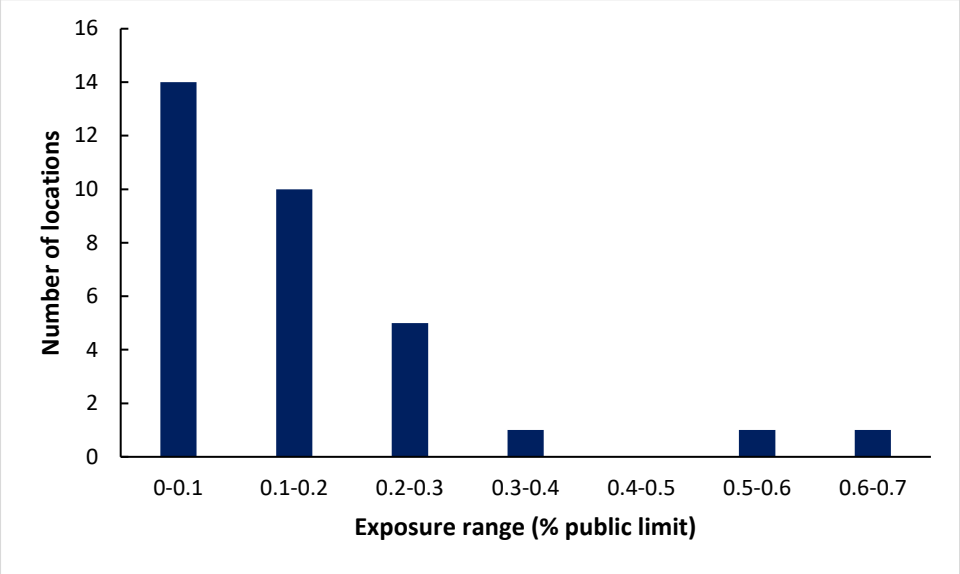

Fig 2. Histogram of the theoretical maximum exposures from Spark 5G transmitters at all 32 measurement locations. Exposures shown as a percentage of the public reference level in NZS 2772.1.

Measurement results by site

Measurement results for each site are shown on the following pages. An aerial photograph shows the location of the site, and the orientations of the antennas. Exposures are shown in two graphs. The first one shows the exposures recorded at the time the measurements were made. Cellsite transmitters adjust their power up and down so as to be just sufficient to handle traffic through the site. Additional measurements were made at each location to determine the theoretical maximum exposures if all the transmitters were to operate simultaneously at full power, and the results of these measurements are shown on the second graph. (As noted previously, there is no real chance that all transmitters would operate simultaneously at full power.)

Each bar of the graphs shows the exposure at the location identified by a letter at the bottom of the bar. The letters correspond to the measurement locations shown on the aerial photo.

The total height of the bar shows the total exposure, as a percentage of the public reference level 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 A in figure 4, for example, the total exposure was equivalent to 1.3% of (ie about seventy times lower than) the public reference level in the New Zealand exposure Standard. About a quarter of this was due to Spark 3 and 4G transmitters (bright blue portion of the bar), about a quarter due to Spark 5G transmitters (dark blue portion), just under a half from Vodafone transmitters (red portion) and there was a very small contribution from 2degrees transmitters (green portion).

The results for Takaro include some extra measurements to determine the difference between the 5G exposure with the 5G transmitter set to operate continuously at maximum power, and with the transmitter operating normally. These showed that when the 5G transmitters were operating normally the exposure was about 150 times lower than when they were operating at maximum power.

Conclusions

All exposures 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 Spark sites were to operate at their maximum power. Exposures were all less than 6.1% of the limit, and typically less than 4%.

Exposures from the 5G transmitters were all less than 0.64% of the public limit, and typically less than 0.4%.

These results give a picture of exposures found with the current deployment of 5G technology in this area. 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.

The antennas were all mounted around 20 metres above ground level, and the ground around the sites was mostly flat. All other things being equal, exposures would have been higher if the antennas were closer to the ground[1].

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

[1] For example, ground level at measurement location A at the CTER Terrace End site was about six metres higher than the base of the Spark monopole, so measurements at this location give an idea of what the exposures might be if the antennas were 14 metres above the ground.

CJAS Jasper Place

Address	21 Jasper Place, Palmerston North
Technology installed	2 x UMTS in 850 MHz band LTE in 700, and 2100 MHz bands NR in 3600 MHz band
Date and time of measurements	16 July 2020, 16:00
Weather	Cloudy, 8 °C
Maximum exposure at time of measurements	1.3% ±2.4 dB
Theoretical maximum exposure – all transmitters	3.4% ±2.0 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.50% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

Fig 3. Measurement locations near the Jasper Place site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

Measurement results are shown in the graphs below. There were no suitable measurement locations accessible on sectors 1 and 2.

Jasper Place – exposures at the time of measurement

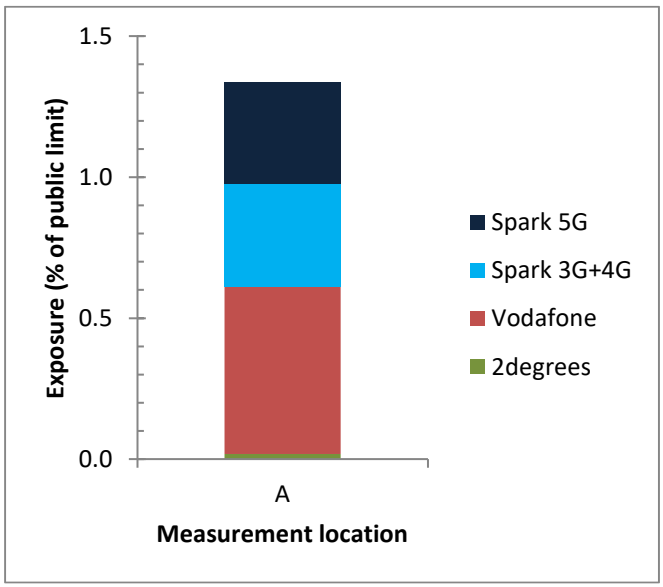

Fig 4. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 1.3% of the public reference level. Exposures from a nearby Vodafone site were taken into account when making the measurements to determine the theoretical maximum exposures.

Jasper Place – theoretical maximum exposures

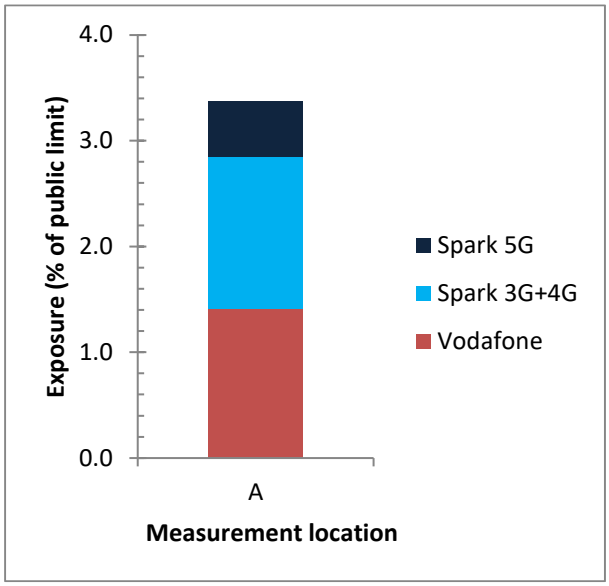

Fig 5. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Jasper Place site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark and Vodafone sites operate at maximum power would be 3.4% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.50% of the reference level.

CKVG Kelvin Grove

Address	Mihaere Drive, Palmerston North
Technology installed	2 x UMTS in 850 MHz band LTE in 700 and 2100 MHz bands NR in 3600 MHz band
Date and time of measurements	17 July 2020, 11:45
Weather	Sunny, 9 °C
Maximum exposure at time of measurements	0.49% ±2.4 dB
Theoretical maximum exposure – all transmitters	1.1% ±2.0 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.23% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

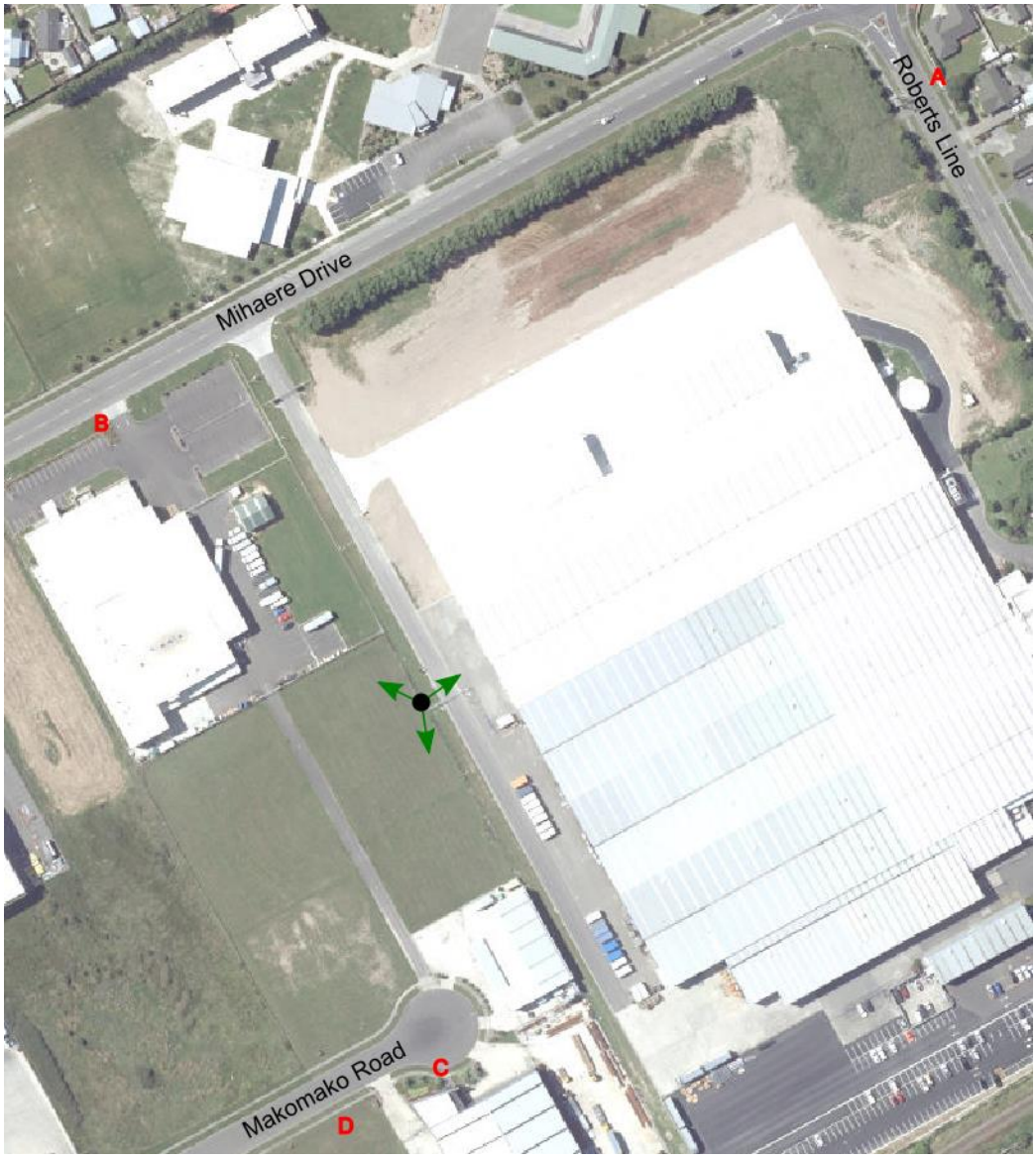

Fig 6. Measurement locations near the Kelvin Grove site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

Measurement results are shown in the graphs below.

Kelvin Grove – exposures at the time of measurement

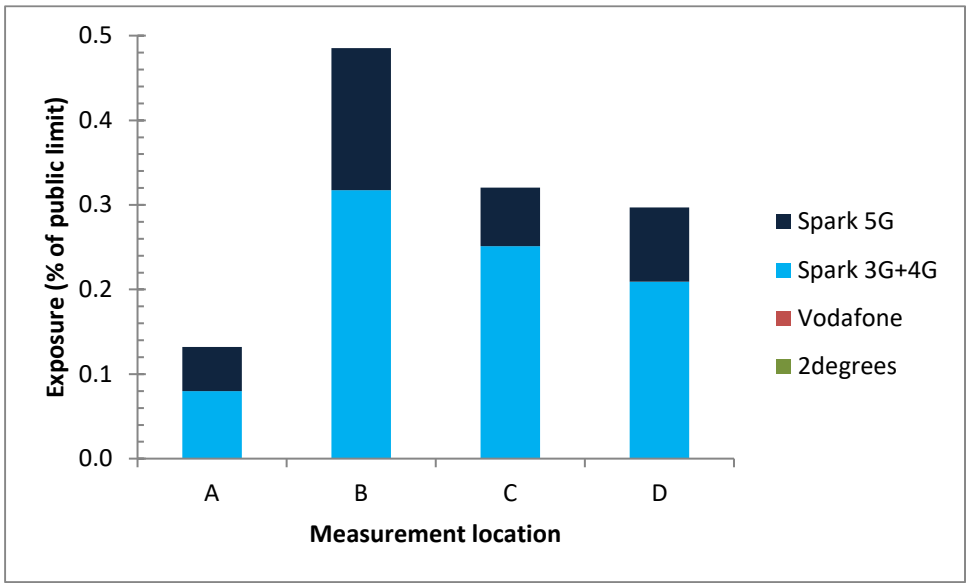

Fig 7. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 0.49% of the public reference level. Almost all of the exposures at all four locations were attributable to the Spark site.

Kelvin Grove – theoretical maximum exposures

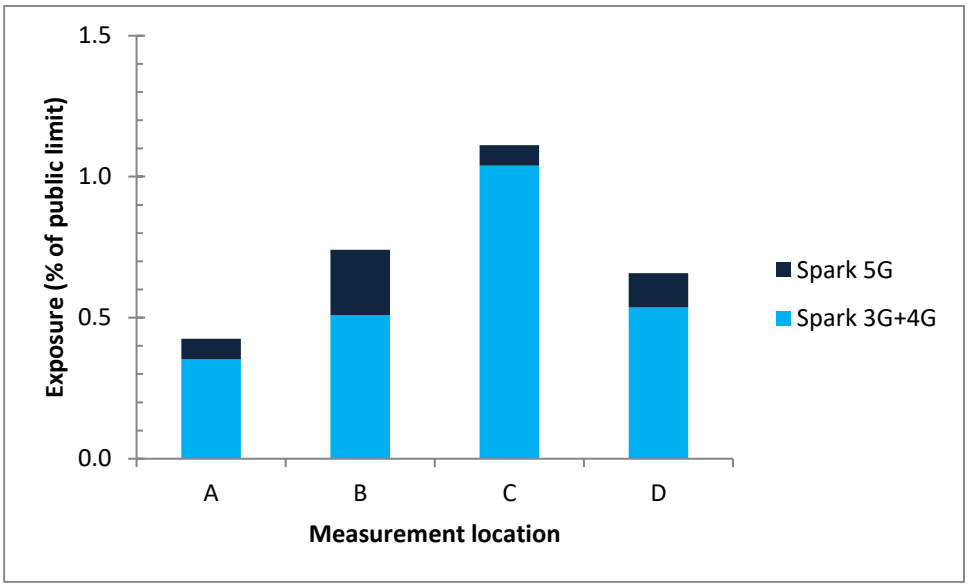

Fig 8. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Kelvin Grove site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark site operate at maximum power would be 1.1% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.23% of the reference level.

CLOV Cloverlea

Address	291 Tremaine Avenue, Palmerston North
Technology installed	3 x UMTS in 850 MHz band LTE in 700, 1800, 2100 and 2600 MHz bands NR in 3600 MHz band
Date and time of measurements	16 July 2020, 13:10
Weather	Cloudy, 9 °C
Maximum exposure at time of measurements	0.65% ±2.4 dB
Theoretical maximum exposure – all transmitters	1.7% ±2.0 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.30% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

Fig 9. Measurement locations near the Cloverlea site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

Measurement results are shown in the graphs below.

Cloverlea – exposures at the time of measurement

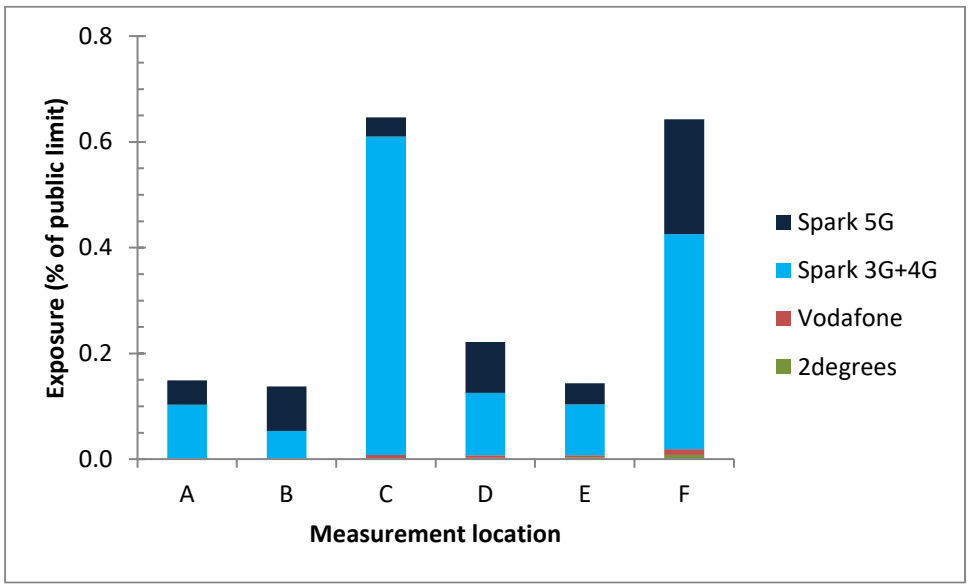

Fig 10. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 0.65% of the public reference level. Almost all of the exposures at all six locations were attributable to the Spark site.

Cloverlea – theoretical maximum exposures

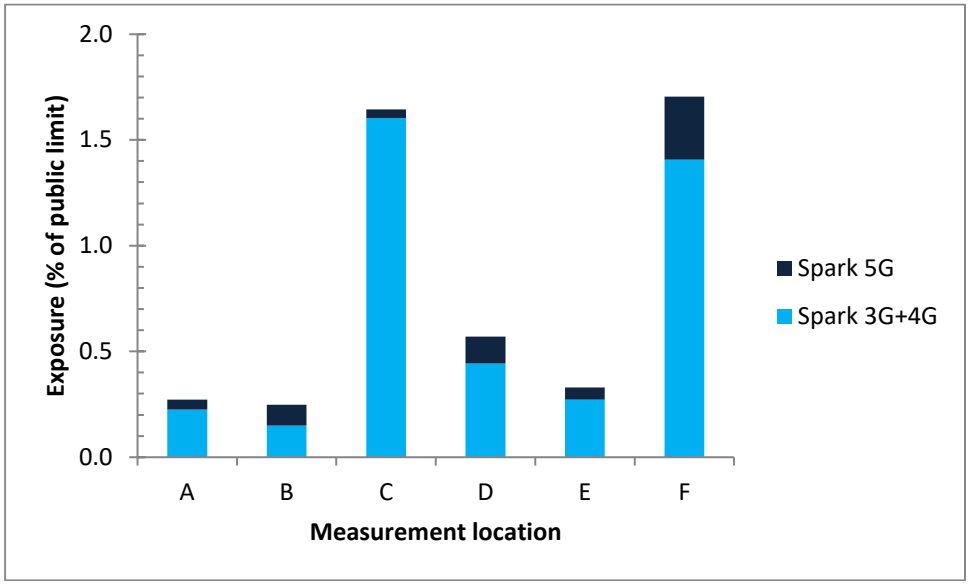

Fig 11. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Cloverlea site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark site operate at maximum power would be 1.7% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.30% of the reference level.

CMIL Milson

Address	49 Malden Street, Palmerston North
Technology installed	2 x UMTS in 850 MHz band LTE in 700, 1800, 2100 and 2300 MHz bands NR in 3600 MHz band
Date and time of measurements	16 July 2020, 17:00 and 17 July 2020 at 08:30
Weather	Cloudy, 9 °C
Maximum exposure at time of measurements	0.65% ±2.4 dB
Theoretical maximum exposure – all transmitters	3.1% ±2.1 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.18% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

Fig 12. Measurement locations near the Milson site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

There were no accessible locations suitable for measurements on sector 1 of the site. Measurement results are shown in the graphs below.

Milson – exposures at the time of measurement

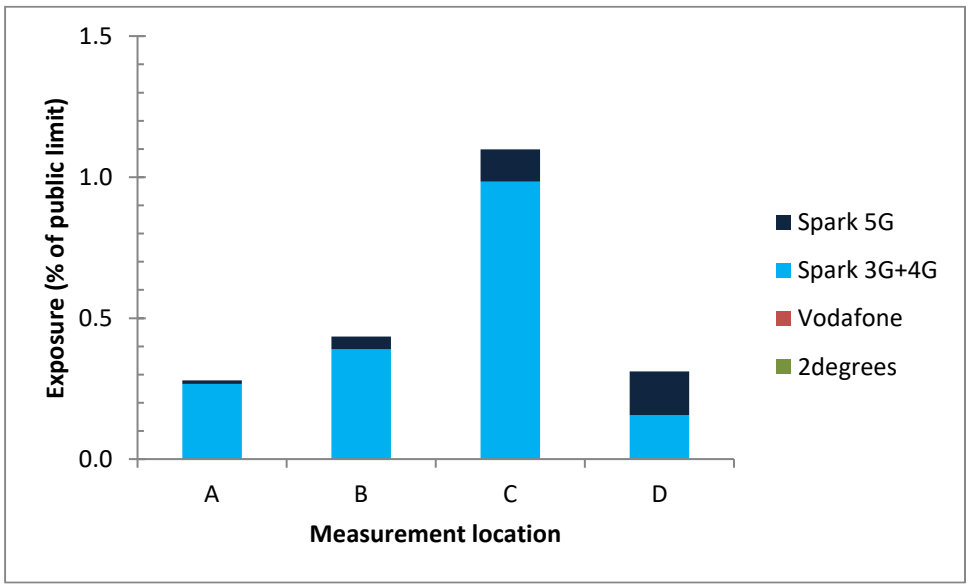

Fig 13. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 1.1% of the public reference level. Almost all of the exposures at all four locations were attributable to the Spark site.

Milson – theoretical maximum exposures

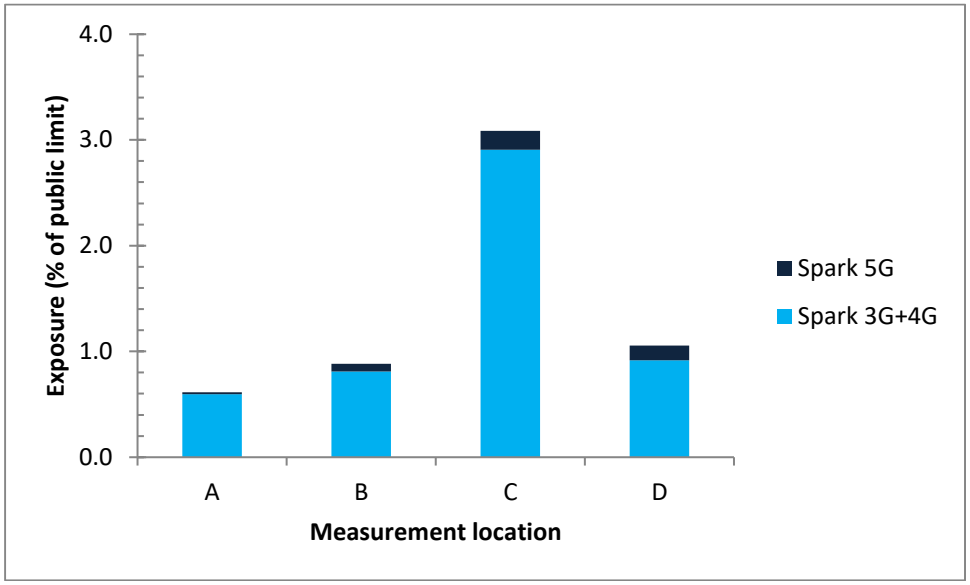

Fig 14. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Milson site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark site operate at maximum power would be 3.1% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.18% of the reference level.

CPAE Papaioea

Address	690 Tremaine Avenue, Palmerston North
Technology installed	2 x UMTS in 850 MHz band LTE in 700 and 2100 MHz bands NR in 3600 MHz band
Date and time of measurements	17 July 2020, 09:30
Weather	Sunny, 10 °C
Maximum exposure at time of measurements	0.77% ±2.4 dB
Theoretical maximum exposure – all transmitters	1.6% ±2.0 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.22% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

Fig 15. Measurement locations near the Papaioea site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

Measurement results are shown in the graphs below.

Papaioea – exposures at the time of measurement

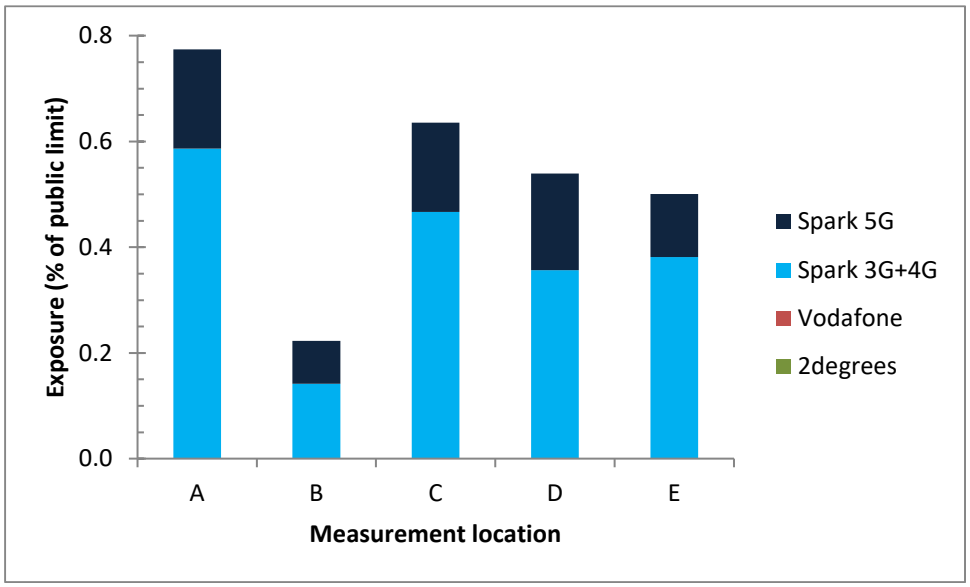

Fig 16. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 0.77% of the public reference level. Almost all of the exposures at all five locations were attributable to the Spark site.

Papaioea – theoretical maximum exposures

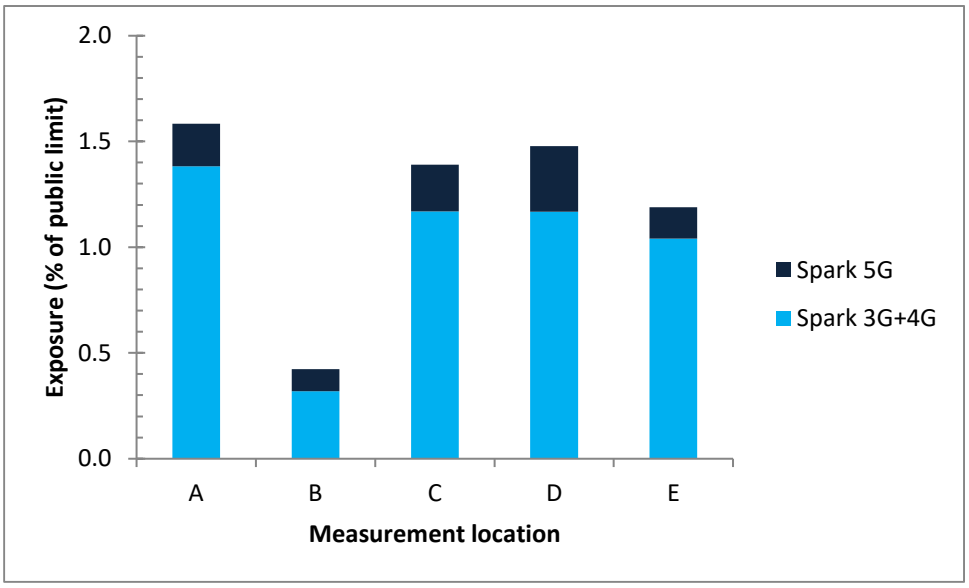

Fig 17. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Papaioea site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark site operate at maximum power would be 1.6% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.22% of the reference level.

CPNX Palmerston North

Address	486-498 Main Street, Palmerston North
Technology installed	3 x UMTS in 850 MHz band LTE in 700, 1800, 2100 and 2600 MHz bands NR in 3600 MHz band
Date and time of measurements	17 July 2020, 15:00
Weather	Cloudy, 9 °C
Maximum exposure at time of measurements	0.27% ±2.4 dB
Theoretical maximum exposure – all transmitters	0.59% ±2.0 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.091% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

Fig 18. Measurement locations near the Palmerston North site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

Measurement results are shown in the graphs below. There were no suitable measurement locations on sector 3.

Palmerston North – exposures at the time of measurement

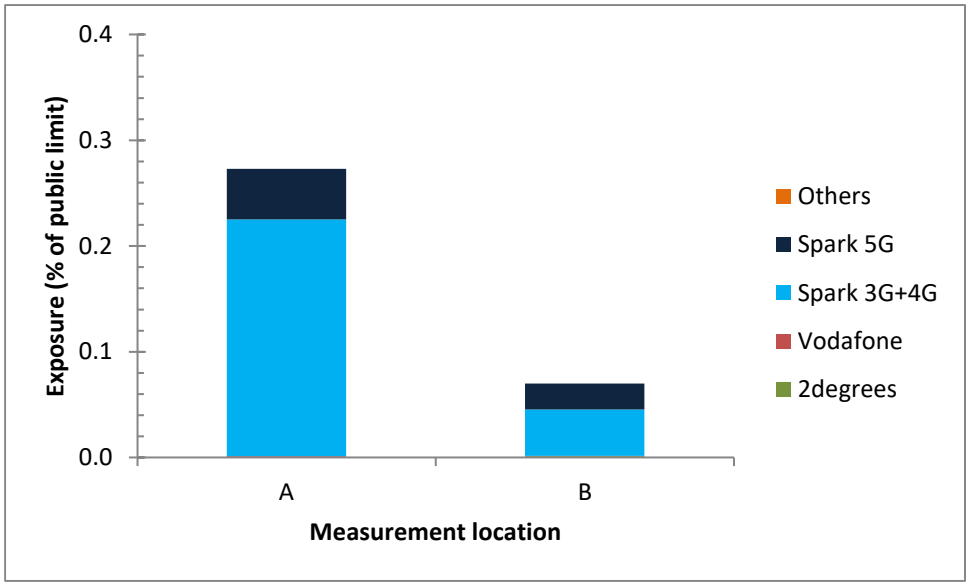

Fig 19. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 0.27% of the public reference level. Almost all of the exposures at all five locations were attributable to the Spark site.

Palmerston North – theoretical maximum exposures

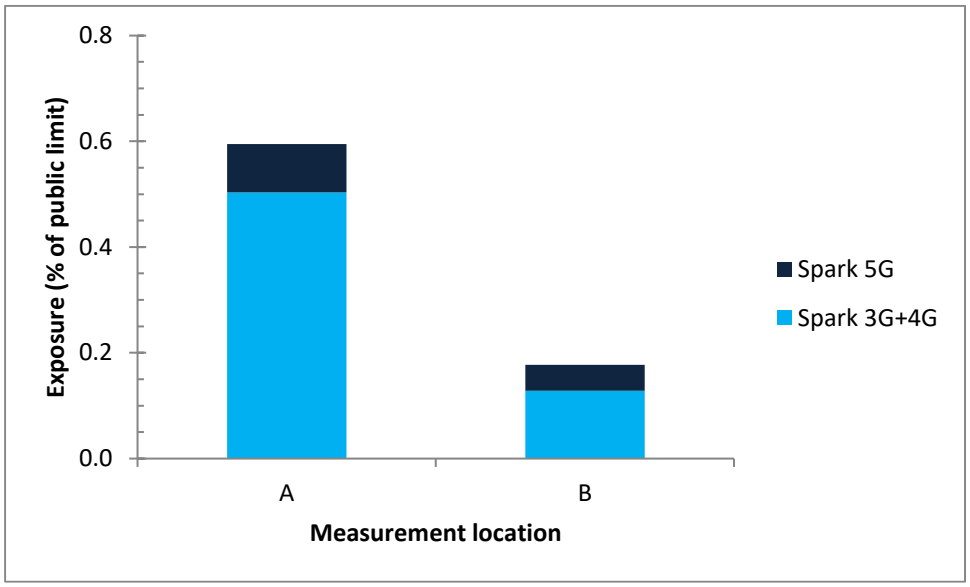

Fig 20. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Palmerston North site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark site operate at maximum power would be 0.59% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.091% of the reference level.

CTAK Takaro

Address	Waldegrave Street, Palmerston North
Technology installed	2 x UMTS in 850 MHz band LTE in 700, 1800, 2100 and 2600 MHz bands NR in 3600 MHz band
Date and time of measurements	16 July 2020, 09:00
Weather	Cloudy, 8 °C
Maximum exposure at time of measurements	0.54% ±2.4 dB
Theoretical maximum exposure – all transmitters	1.3% ±2.0 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.19% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

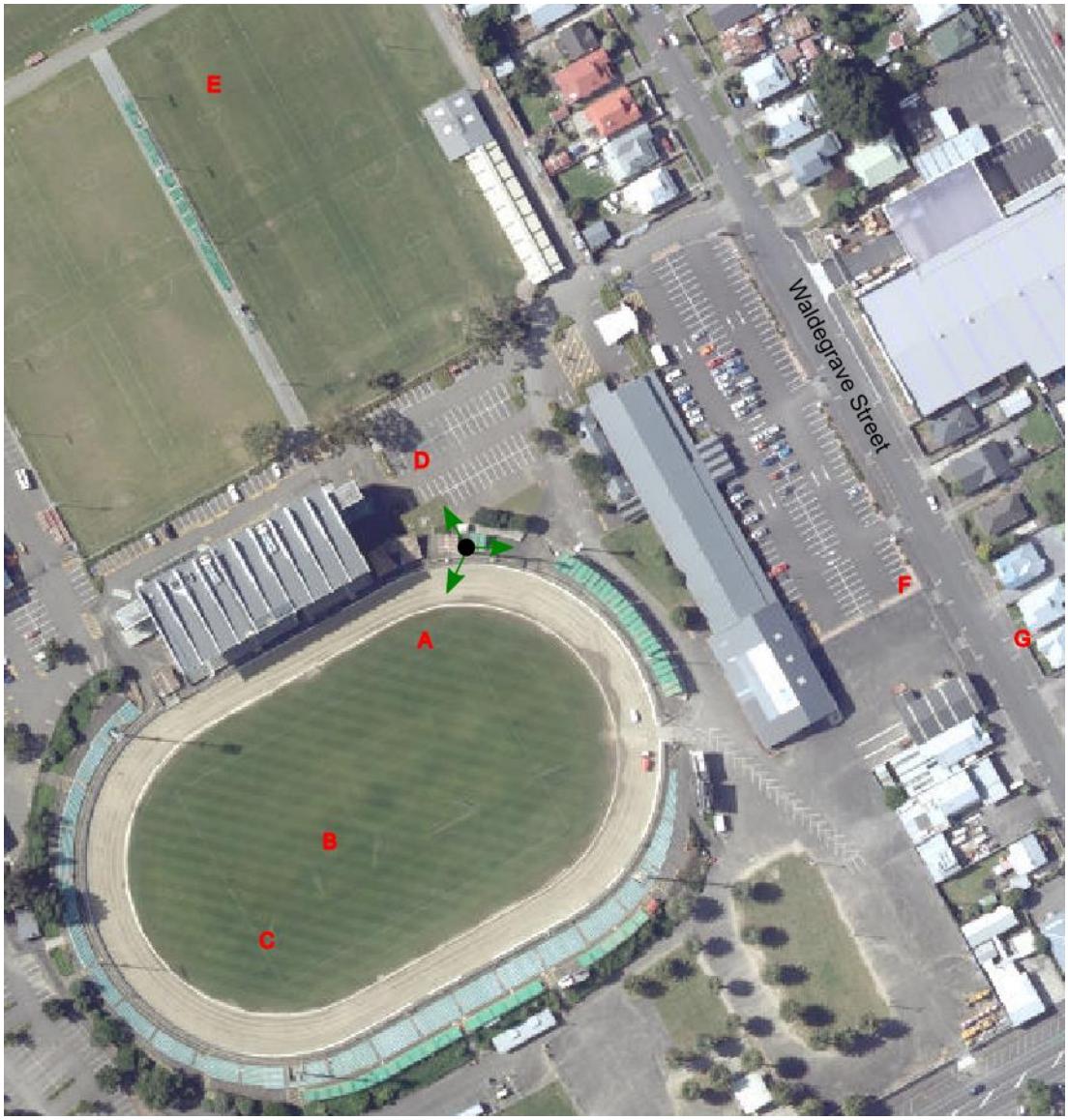

Fig 21. Measurement locations near the Takaro site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

Measurement results are shown in the graphs below.

Takaro – exposures at the time of measurement

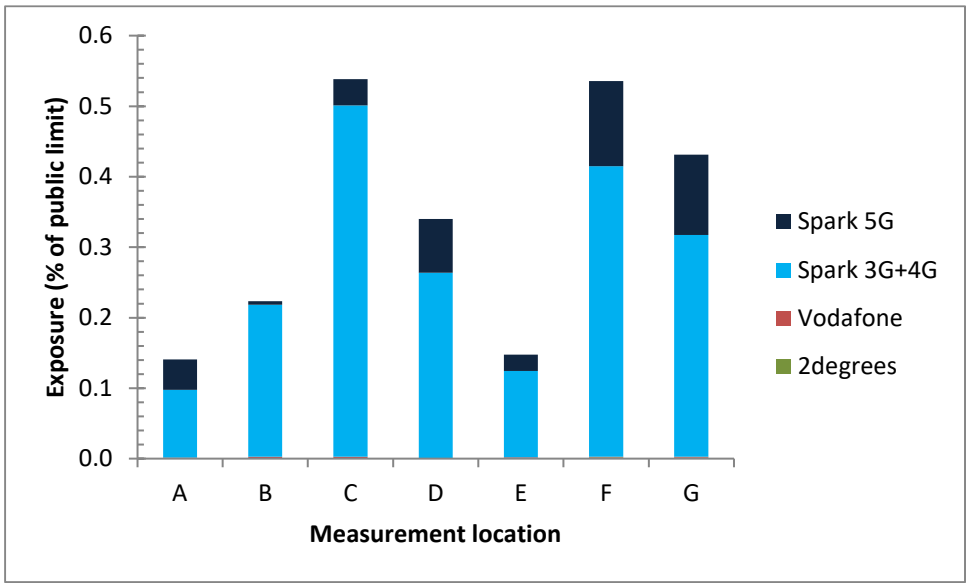

Fig 22. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 0.54% of the public reference level. Almost all of the exposures at all seven locations were attributable to the Spark site.

Takaro – theoretical maximum exposures

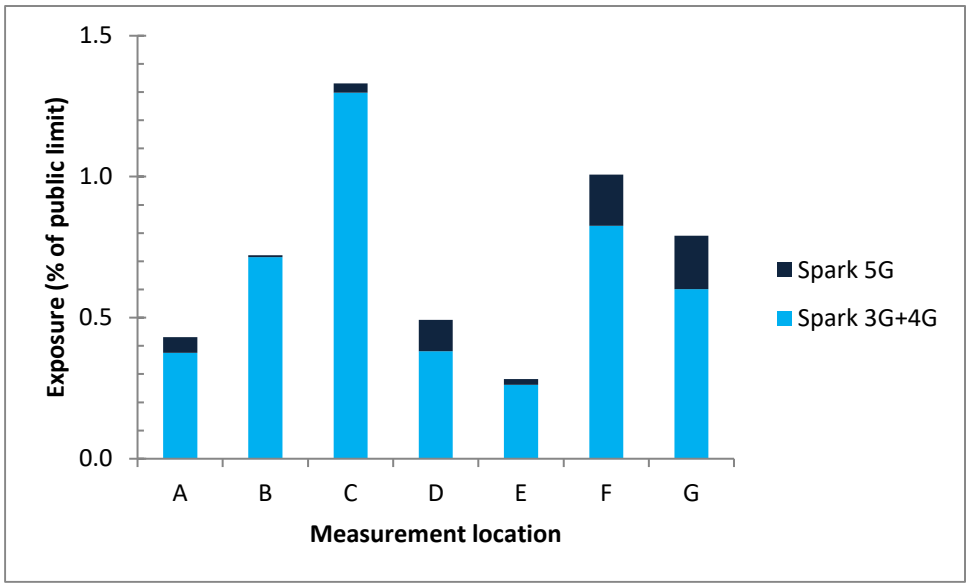

Fig 23. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Takaro site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark site operate at maximum power would be 1.3% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.19% of the reference level.

Ratio of exposures with 5G transmitters operating continuously and normally

Some additional measurements were made near location F to determine the difference in exposure from the 5G transmitters when they were set to operate continuously at full power, and when operating normally. The measurement probe was placed on a stand about 1.5 metres above the ground and the maximum average exposure over 32 sweeps of the spectrum measured with the 5G transmitters operating normally. The 5G transmitters were then set to operate continuously at full power, and the theoretical maximum exposure recorded. The exposure with the site operating normally was about 150 times lower than the theoretical maximum.

Because there was almost certainly very little 5G traffic passing through the site in normal operation, this ratio is probably higher than would be found once the 5G service is operating commercially. However, it does give an idea of the magnitude of the differences that might be observed between the actual average exposure and the theoretical maximum.

CTER Terrace End

Address	23 Mihaere Drive, Palmerston North
Technology installed	2 x UMTS in 850 MHz band LTE in 700, 1800, 2100, 2300 and 2600 MHz bands NR in 3600 MHz band
Date and time of measurements	17 July 2020, 13:20
Weather	Cloudy, 10 °C
Maximum exposure at time of measurements	1.7% ±2.4 dB
Theoretical maximum exposure – all transmitters	6.0% ±2.1 dB of the NZS 2772.1 public limit
Theoretical maximum exposure – 5G	0.65% ±2.0 dB of the NZS 2772.1 public limit

Measurement locations are shown on the aerial photo below.

Fig 24. Measurement locations near the Terrace End site. Letters in red show where measurements were made. Green arrows show the orientations of the antennas at the Spark site.

Measurement results are shown in the graphs below.

Terrace End – exposures at the time of measurement

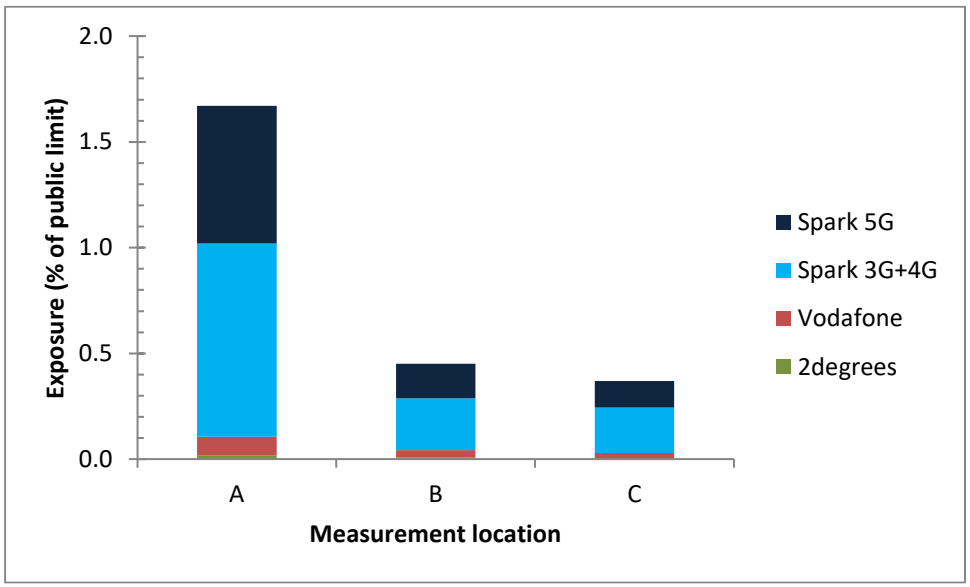

Fig 25. Breakdown of contributions to exposure at the time of measurement, as a percentage of the public limit in NZS 2772.1:1999.

The highest exposure at the time of measurement was 1.7% of the public reference level. Exposures from a nearby Vodafone site were taken into account at locations A and B when making the measurements to determine the theoretical maximum exposures.

Terrace End – theoretical maximum exposures

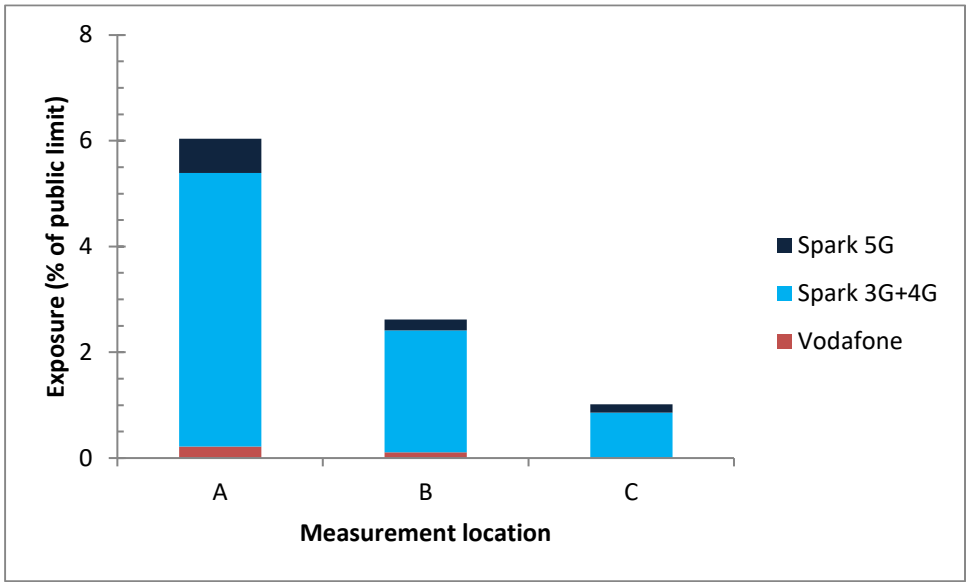

Fig 26. Theoretical maximum exposures, as a percentage of the public limit in NZS 2772.1:1999, if all equipment currently installed at the Terrace End site operates at maximum power.

The theoretical maximum exposure when all transmitters currently installed at the Spark site operate at maximum power would be 6.0% of the public reference level in NZS 2772.1:1999. The theoretical maximum exposure from 5G would be 0.65% of the reference level.

Appendix 1 Site description

As well as the 5G services operating in Spark's 3600 MHz band, each of the sites had 3G transmitters operating in Spark's 850 MHz bands and 4G transmitters in Spark's 700 and 2100 MHz bands. Some also had 4G services operating in Spark's 1800, 2300 and 2600 MHz bands.

Characteristics of the three technologies are summarised below.

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 Spark 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 1998[2], and reaffirmed in 2009[3] following a review of more recent research in this area[4], and again in 2017[5]. Research published since 2009 has been reviewed by a number of other health and scientific bodies[6], 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/m^2) depends on the frequency of the RF field as shown in the table below.

[2]http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf.

[3] http://www.icnirp.org/cms/upload/publications/ICNIRPStatementEMF.pdf

[4] 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.

[5] http://www.icnirp.org/en/activities/news/news-article/revision-of-hf-guidelines-2017.html

[6] 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*.

3.1 Measuring equipment

Two instruments were used in these surveys, a broadband meter and probe that records the total RF field exposure, and a narrowband meter and probe that can perform frequency selective measurements. Specifications of both meters are presented in Annexe A.

3.1.1 Broadband meter

Broadband measurements were made with a Narda NBM-550 Broadband Field Meter and EF-0691 isotropic electric field probe. This records the total electric field strength in the frequency range 100 kHz – 6 GHz, but cannot distinguish the contributions at different frequencies. This was used as described in 3.2.3 (below) to find the location of maximum exposure.

3.1.2 Narrowband meter

Frequency selective (narrowband) measurements were made with a Narda SRM-3006 Selective Radiation Meter and three-axis electric field probe connected by a 1.5 m cable. This records electric field strength in the frequency range 420 MHz – 6 GHz. 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. Settings used are presented in Annexe B.

3.2 Measurement technique

3.2.1 Exposures at the time of measurement

Exposures at the time of measurement were obtained using the meter in safety evaluation mode. In this mode, the meter measures the power flux density in each of a number of preset frequency bands (called "services" in the instrument terminology), plus the total power flux 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 probe was hand-held in the area of interest. At each measurement location, the probe was moved around slowly over the area of interest to find the point with the highest exposure. These measurements were made after the readings to determine the theoretical maximum exposure, and these measurements indicated where the highest levels would be found.

The meter was set to average the readings from four successive sweeps through the frequencies of interest. As noted in Appendix 1, the power of the Spark transmitters (and other operators' cellular phone base station 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 which is representative of the transmitters operating at the upper end of their power, the exposure was monitored for 45 – 60 seconds in each location and the maximum 4-sweep average obtained over that period stored is presented in this report.

3.2.2 Theoretical maximum possible exposures

For all measurements made to determine the theoretical maximum possible exposure the probe was hand held and swept slowly from about 2 m above the ground to about 0.75 m above the ground, and the maximum reading stored.

2G transmitters

If a nearby Vodafone site made significant contributions to the total exposure, theoretical maximum exposures from the Vodafone 2G (GSM) transmitters were determined by measuring the exposure from the BCCH control channel in level recorder mode. This channel transmits at constant power, and the total exposures from all the 2G transmitters can be determined by multiplying the exposure from the control channel 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 of 4G transmitters in all bands except the 2300 MHz band 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.

In the 2300 MHz band, measurements are made in Level Recorder mode, using measurement parameters recommended by Narda[7]. Effectively the technique measures the exposure from the PBCH, PSS and SSS signals, which can then be extrapolated to give the maximum exposure from the whole carrier when it is operating at full power.

5G transmitters

Measurements were made in safety evaluation mode using a single service table to cover Spark's 5G spectrum, and the maximum reading stored.

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[8,9].

[7] A different approach is used in this frequency band as time division duplexing is used, rather than frequency division duplexing.

[8] 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.

[9] Mahfouz Z et al. Influence of Traffic Variations on Exposure to Wireless Signals in Realistic Environments. Bioelectromagnetics 33:288–297, 2012.

3.2.3 Choice of measurement locations

The main interest in this survey was to determine the maximum total exposure and the maximum exposure attributable to the 5G transmitters. An initial estimate of the location of the maxima on each sector was obtained by using the site's technical characteristics to calculate the theoretical maximum exposure 2 m above the ground as a function of distance from the site. An example for sector 3 of the Takaro site is shown in figure 27. In this example, the maximum exposure occurs close to the site and is attributable to sidelobes in the antenna radiation pattern. The maxima due to exposures from the main beams of the antenna occur at distances of about 160 m for both the maximum exposure from all transmitters, and the maximum from the 5G transmitter.

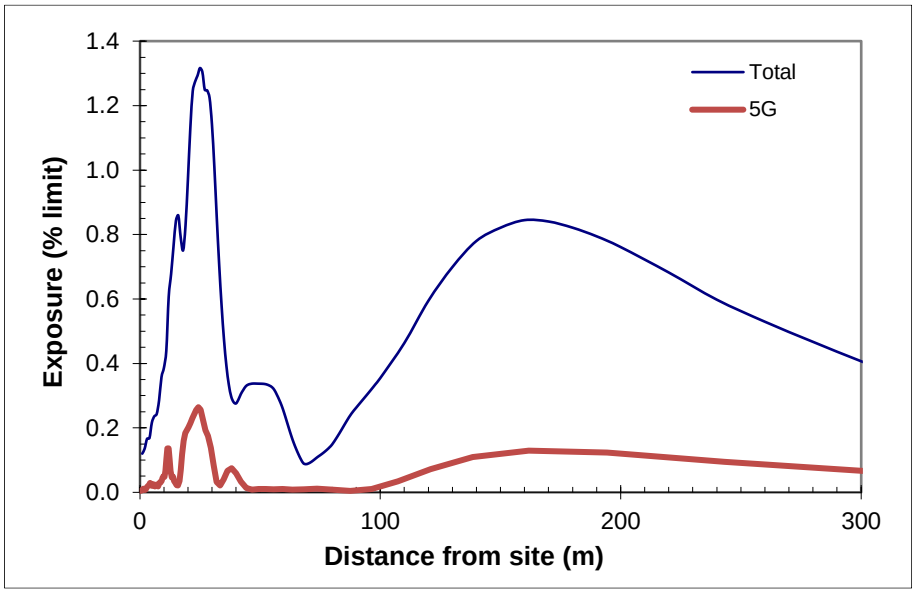

Fig 27. Calculated exposures 2 m above the ground as a function of distance from the site for sector 3 of the Takaro site. Blue curve shows the theoretical maximum exposure if all transmitters were to operate at maximum power, red curve shows the theoretical maximum exposure from the 5G transmitters if they were to operate at maximum power.

The locations and values of the maxima vary from sector to sector, but generally the maxima due to exposures in the main beams occur around 150-200 m from the site, and the exposure varies little over several tens of metres. Maxima due to sidelobes may or may not be greater than the maxima in the main beams, but are always of very limited extent.

On each sector, the procedure generally adopted was to find an accessible location close to where the maximum exposure was calculated to be, and make preliminary measurements using a broadband meter to determine where the highest exposures were found. These may be supplemented with preliminary measurements using the narrowband meter set to look only at the 5G exposures to check where the maximum 5G exposure occurred. More detailed measurements were then made at these locations.

For many of the sectors, there was no access to the areas where the highest exposures were expected, especially if these were attributable to sidelobes and very close to the site. Thus the number of measurements made at a site was dependent on accessibility to the areas of interest. The calculations assumed flat ground around the site, and while this was mostly true there were exceptions, in which case broadband measurements were used to determine where the highest total exposures would be found. All measurements were made in locations with a clear line of sight back to the antennas.

Annexe A Measuring equipment specifications and uncertainty

A1 Meter specifications

A1.1 Broadband meter

Manufacturer	Narda Safety Test Solutions GmbH, Pfullingen, Germany
Meter	NBM-550 s/n E-0322, firmware v 2.2.2
Probe	EF-0691 electric field probe s/n D-0099
Measurement range	0.04 V/m – 650 V/m (0.0004 – 1,120 W/cm^2)
Frequency range	100 kHz – 6 GHz
Calibration	By the manufacturer, December 2018
Recommended calibration interval	2 years

Full specifications are available at:
www.narda-sts.com/en/safety/products/high-frequency/nbm-550/e-field-6-ghz/

A1.2 Narrowband meter

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 ±a dB. No uncertainty assessment is shown for the broadband meter as this was only used for qualitative measurements.

A.2.1 Overall uncertainty assessment – exposures at the time of measurement

Parameter	Uncertainty data source	Standard uncertainty *u* *(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 – theoretical maximum exposures (no 2300 MHz carriers)

Parameter	Uncertainty data source	Standard uncertainty *u* *(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.

A.2.3 Overall uncertainty assessment – theoretical maximum exposures (2300 MHz carriers present)

Parameter	Uncertainty data source	Standard uncertainty *u* *(dB)*
Meter and probe	Data sheet*	±1.15
Transmitter power	Manufacturer data	±0.41
Extrapolating LTE measurements at 2300 MHz	Manufacturer data	±0.42
	Combined standard uncertainty	±1.29
	Coverage factor	1.64
	Expanded uncertainty	**2.1**

* 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 theoretical maximum 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 4-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	Key result is the maximum exposure value, which is stored by the meter, so uncertainty source mitigated.
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. Recording maximum values gives worst case exposures.

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
Sp 5G	Spark 5G	3630	3690	0.00053

*On 10 mW/m^2 measurement range.

Settings – Safety evaluation mode – exposures at the time of measurement

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Maximum 4-sweep average
Service table	As shown above
RBW	50 kHz

Settings – Safety evaluation mode – Spark 5G

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Max
Service table	Single service, 3630-3690 MHz
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 – 4G TDD transmitters

Measurement range:	As required to avoid overloading input stages of meter
Result type:	Peak
Centre frequency:	Set for each 4G TDD transmitter
RBW	800 kHz
VBW	1.6 kHz