Nieuwe ontwikkelingen rond 5G, de maatschappelijke impact van de uitrol van 5G netwerken op de stralingsblootstelling

In-situ 5G NR-metingen in Haasrode

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IN-SITU 5G NR-METINGEN IN HAASRODE

Dit rapport kadert in de studie "Nieuwe ontwikkelingen rond 5G, de maatschappelijke impact van de uitrol van 5G netwerken op de stralingsblootstelling" (bestek nr. OMG-VPO/2018/59).

In dit rapport worden de in-situmetingen besproken van radiofrequente elektromagnetische velden in de nabijheid van een 5G NR-basisstation in Haasrode.

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INHOUDSTAFEL

1 INTRODUCTION

This report describes the measurements of radiofrequency (RF) electromagnetic fields (EMF) in the vicinity of a 5G New Radio (NR) base station in Haasrode, Belgium, on 16–17 September 2020.

The main objective of the study was to obtain data on the average and maximum exposure levels around a 5G NR base station using the measurement procedure designed by IMEC-WAVES [Aerts 2019]. In addition, the following issues were addressed: (a) the influence of the position of the UE with respect to the measurement probe, (b) the influence of multiple active UEs, and (c) the influence of vertical beamsteering on the measurement results.

2 MATERIALS AND METHODS

2.1 5G NR MEASUREMENT METHOD

To measure both the **time-averaged instantaneous** and the **maximum exposure** to radiofrequency (RF) electromagnetic fields (EMF) in the vicinity of a 5G New Radio (NR) base station, IMEC-WAVES designed the following five-step measurement procedure [Aerts 2019]:

Step 1 "Spectrum overview" – A spectrum overview measurement in the frequency range between 700 MHz and 6 GHz to identify at the measurement site the RF environment in general and the 5G NR signals in particular.

Step 2 "Identification of the SSB (or SS burst)" – For each present 5G NR signal, an in-band measurement to detect the bandwidth (and therefore the numerology or subcarrier spacing (SCS)) and frequency position (SS_{REF}) of the channel's Synchronization Signal Block (SSB) or SS burst, as well as the channel bandwidth.

Step 3 "Assessment of the electric-field level per RE of the SSB and PDSCH" – For each present 5G NR signal, a measurement of the electric-field strength per resource element (RE) E_{RE} of the SSB(s) as well as of the Physical Downlink Shared Channel (PDSCH), which carries the downlink traffic.

Step 4 "Assessment of the instantaneous, time-averaged electric-field level" – For each present 5G NR signal, a 3-min measurement of the instantaneous electric-field strength E_{avg} over the channel bandwidth.

Step 5 "Post-processing" – Post-processing of data and calculation of the maximum theoretical electric-field level, using

$$E_{max} = \sqrt{12\ N_{RB}}\ \sqrt{f_{TDD}}\ E_{RE,PDSCH}\ \left[\frac{V}{m}\right] \tag{1}$$

with

$E_{RE,PDSCH}$	the electric-field level per RE allocated to PDSCH in the direction of the evaluation point,

N_{RB}	the number of resource blocks (with 1 RB containing 12 REs) depending on the channel bandwidth and numerology or SCS, and
f_{TDD}	the Time-Division Duplexing (TDD) factor, which depends on the NR frame structure.

2.2 MEASUREMENT EQUIPMENT

Two measurement setups were used in this study (

Table 1): one consisting of a Rohde & Schwarz FSV spectrum & signal analyzer connected to a tri-axial Satimo electric-field probe and a laptop with Matlab software and the second a Narda SRM-3006 field strength analyzer.

Table 1: Measurement equipment used in this study.

Setup	Equipment	
FSV	***Spectrum analyser***	
	Type	Rohde & Schwarz (R&S) FSV-30 with option R&S FSV-K14 spectrogram
	Frequency range	10 Hz – 30 GHz
	Tri-axial antenna	
	Type	Clampco Sistemi AT6000
	Dynamic range	0.35 mV/m – 300 V/m
	Frequency range	400 MHz – 6 GHz
	Measurement uncertainty	±3 dB
SRM	***Spectrum analyser***	
	Type	Narda SRM-3006
	Frequency range	9 kHz – 6 GHz
	Tri-axial antenna	
	Type	Narda three-axis antenna 3502/01
	Dynamic range	0.14 mV/m – 160 V/m
	Frequency range	420 MHz – 6 GHz
	Measurement uncertainty	±3 dB

The FSV setup was used for Steps 1 to 4. The optimal settings can be found in [Aerts 2019] but are also listed in Appendix (Table 5).

The SRM setup was also used for Step 4, to validate its use to capture the time-averaged electric-field strength E_{avg} ('in-band measurement'), as well as to measure the actual field levels due to other telecommunications frequency bands (only downlink) ('overview measurement'). Its settings can also be found in Appendix (Table 6).

2.3 USER EQUIPMENT

Four 5G NR-capable user devices (user equipment or UE) were put at our disposal by Proximus. When used (further denoted as 'active UE'), an HTTP download of a 100 GB file was set up via http://speedtest.tele2.net/ to generate the maximum amount of downlink traffic. The standard placement of the UE was on a plastic cart at 2 m in front of the measurement probe (i.e. towards the base station), in order to "attract" the PDSCH beam towards the measurement probe and to minimize the influence of the measurement setup and experimenter(s) on the field distribution.

2.4 DESCRIPTION OF THE ENVIRONMENT

The measurements were conducted in Haasrode, Belgium, on 16 and 17 September 2020, at 16 positions in the vicinity of the 5G NR base station with ID '16HIZ' (Figure 1). The base station configuration parameters are listed in Table 2.

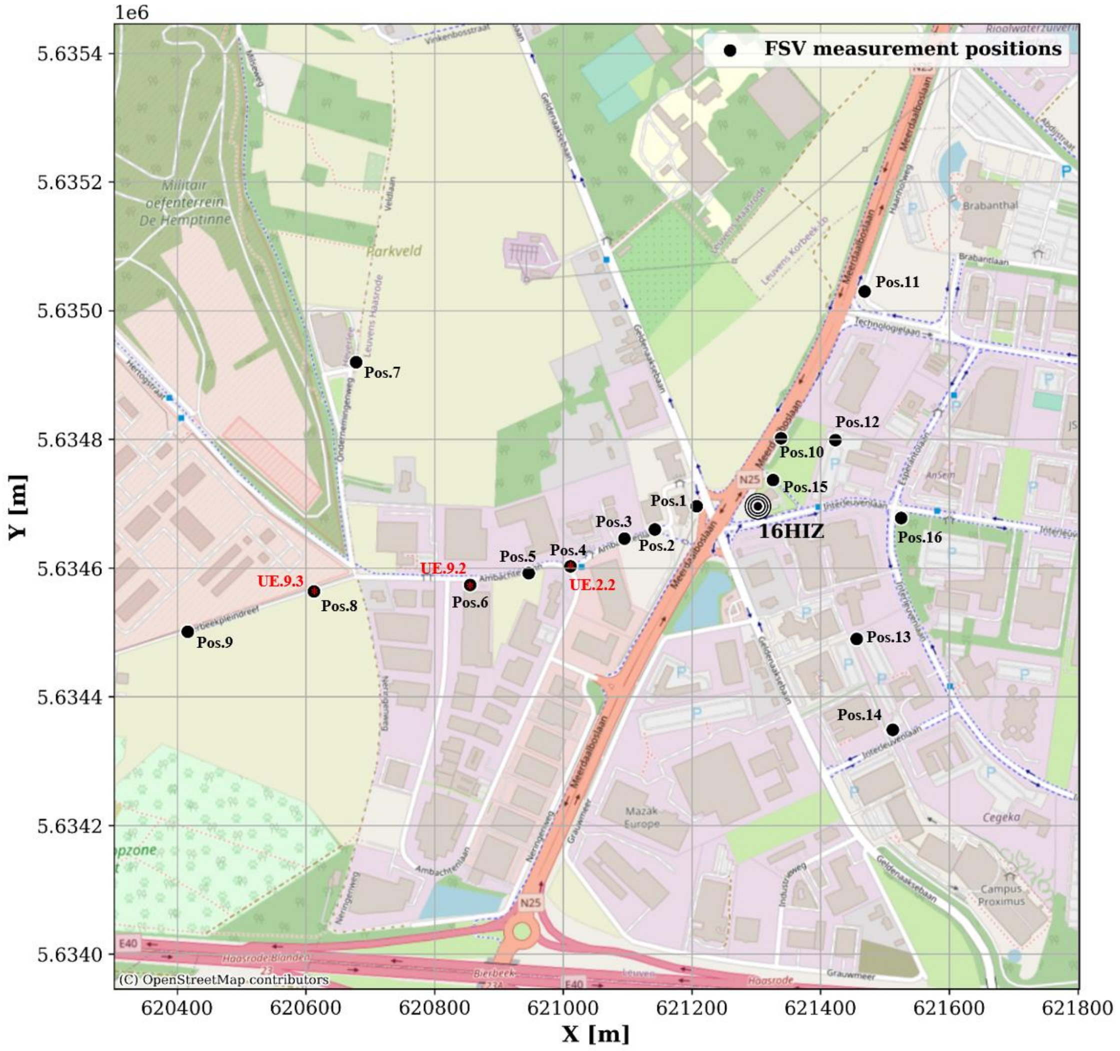

Figure 1: Overview of the area surrounding 5G New Radio base station '16HIZ', with indication of the measurement positions, denoted as "Pos.x", as well as divergent positions of the UE (i.e. not at 2 m behind the measurement probe), denoted as "UE.x.y".

Table 2: Configuration of the 5G New Radio (NR) base station with ID ‘16HIZ’ at the time of the measurements. It should be noted that the maximum allowed antenna power, according to the certificate of compliance, is actually 46 W (46.60 dBm).

Configuration parameter	Value
Sector azimuths	30°, 150°, 270°
Electrical down tilt	-6°, -6°, -6°
Mechanical down tilt	0°, 0°, 0°
Configured power of the antenna	20 W (43.01 dBm)
Number of antenna elements	192
Frequency band	3760–3800 MHz
Channel bandwidth	40 MHz
Frame structure	DDDSU
Number of broadcast beams	7
SS_{REF}	3780.48 MHz
SSB period	20 ms

The 16 measurement locations – at which both FSV and SRM measurements were conducted – are indicated on Figure 1 as ‘Pos.x’ (with $x = 1…16$). They were divided over the three antenna sectors of 5G NR base station ‘16HIZ’ (1st sector: Pos.10 – Pos.12 and Pos.15; 2nd sector: Pos.13, Pos.14, and Pos.16; 3rd sector: Pos.1 – Pos.9), and the distance to the base station ranged from 48 m (Pos.15) to 907 m (Pos.9).

At two measurement locations, Pos.2 and Pos.9, the UE was additionally placed at positions away from the probe: at Pos.4 (denoted as ‘UE.2.2’) and at Pos.6 (‘UE.9.2’) and Pos.8 (‘UE.9.3’), respectively. The additional UE positions were in line with the probe and the base station, and the objective was to assess the impact of vertical beamsteering on the exposure at the measurement location.

Only Pos.13 was in non-line-of-sight (NLOS) of the base station. At Pos.16, no connection could be set up between UE and base station.

2.5 OBJECTIVES

The main objective of this study was to gather data on the average and maximum exposure levels at various positions in the vicinity of a 5G NR base station.

In addition, the following issues were addressed:

1. **The influence of the position the UE with respect to the measurement probe.** Do the field levels change at the (fixed) measurement location when placing the active UE at other positions around the measurement probe (e.g. behind, or to the left or right) or at another distance (e.g. 3 m instead of 2 m).

2. **The influence of the number of active UEs.** Do the field levels change at the (fixed) measurement location when using more than one active UE …
    a) … at the same position, in the near vicinity of the probe?
    b) … at different positions, generating spatially separated PDSCH beams?
3. **The influence of vertical PDSCH beamsteering.** Do the field levels change at the (fixed) measurement location when placing the active UE closer to or further away from the base station (but on the same line between probe and base station), changing the vertical angle to the base station?

3 RESULTS AND DISCUSSION

3.1 IDENTIFICATION OF THE NR CHANNEL

The spectrum overview measurement of Step 1 (Figure 2) was performed without active 5G NR UE. Nonetheless, because of the presence of broadcast (in a narrow bandwidth) and control signals (situated over the entire channel), the NR channel was easily identified at approximately 3800 MHz (Figure 2).

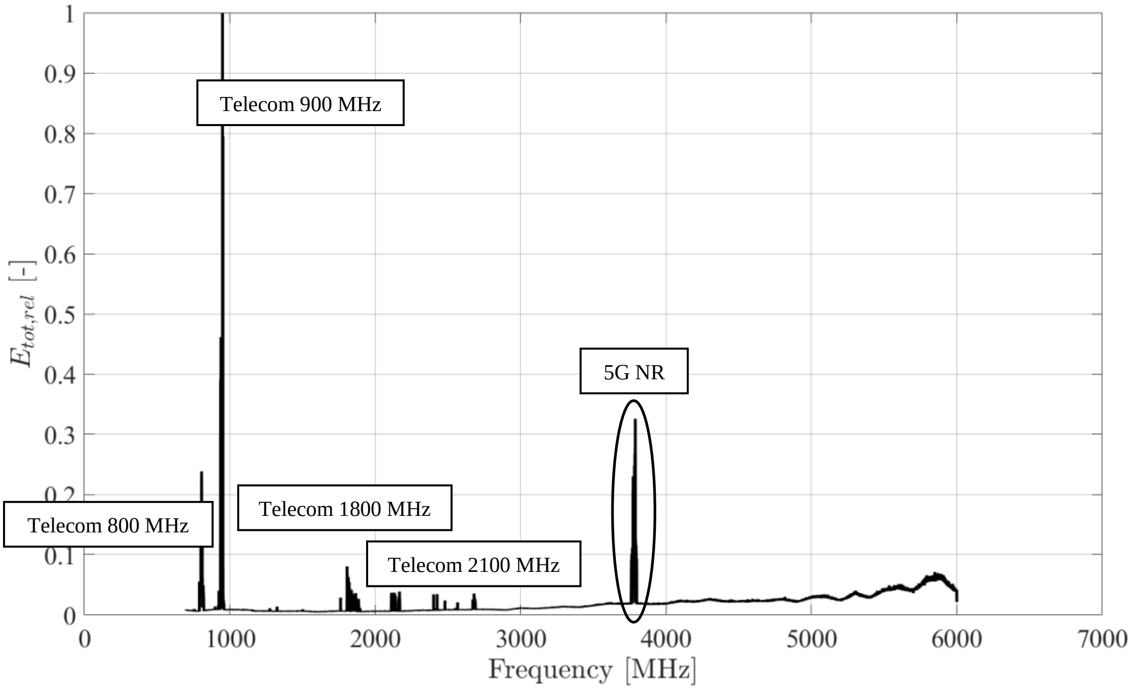

Figure 2: Spectrum overview between 700 MHz and 6 GHz. Because the measurement settings were not optimal for exposure assessment, the electric-field strength was normalized to the maximum.

Then, the location and bandwidth of the SSB were identified using the measurement of Step 2. Figure 3 shows this identification. By retaining only those signals (i.e. sequences of samples above the noise floor) with a duration of four symbols, a broad peak was observed with a bandwidth of approximately 7 MHz (the resolution of this measurement was only 1 MHz) and a centre frequency of approximately 3780 MHz (Figure 3). The closest SS_{REF} – which is situated on the Global Synchronization Raster – is 3780.48 MHz (Figure 3), and the roughly 7 MHz bandwidth corresponds to an SCS of 30 kHz.

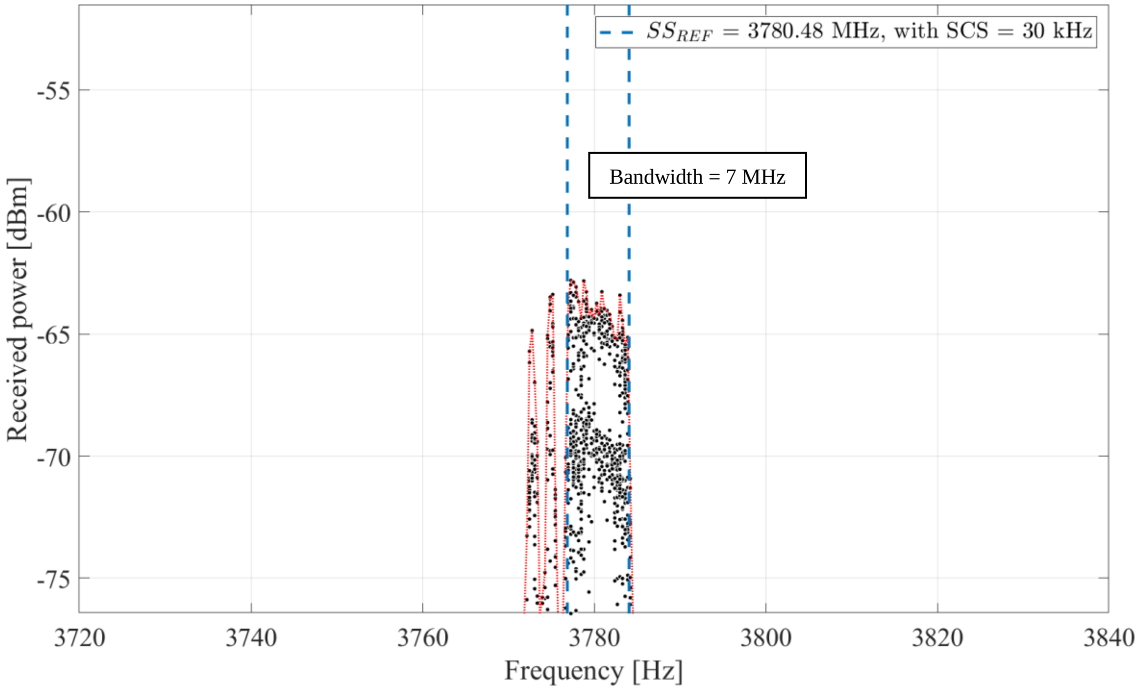

Figure 3: Identification of the frequency band used by the Synchronization Signal Block. The SSB centre frequency SS_{REF} (here, 3780.48 MHz) is defined by the Global Synchronization Raster Channel (GSCN). The bandwidth (here, ~7 MHz) is linked with the subcarrier spacing (SCS; in this case, 30 kHz).

3.2 EXPOSURE ASSESSMENT

3.2.1 Average electric-field strength

In Figure 4, E_{avg}, measured with an active UE (i.e. with maximum downlink traffic) using both FSV and SRM setups, is shown as a function of the (horizontal) distance of the measurement location to the base station (BS). The maximum field level measured with the SRM was 2.26 V/m at Pos.1 (at 95 m) and with the FSV setup 1.94 V/m at Pos.3 (at 213 m). At further distances, the exposure levels quickly decreased: < 0.9 V/m at 300 m and < 0.5 V/m at 650 m.

The correlation between the two types of measurements was 0.94, with a median relative difference of 0.3 dB.

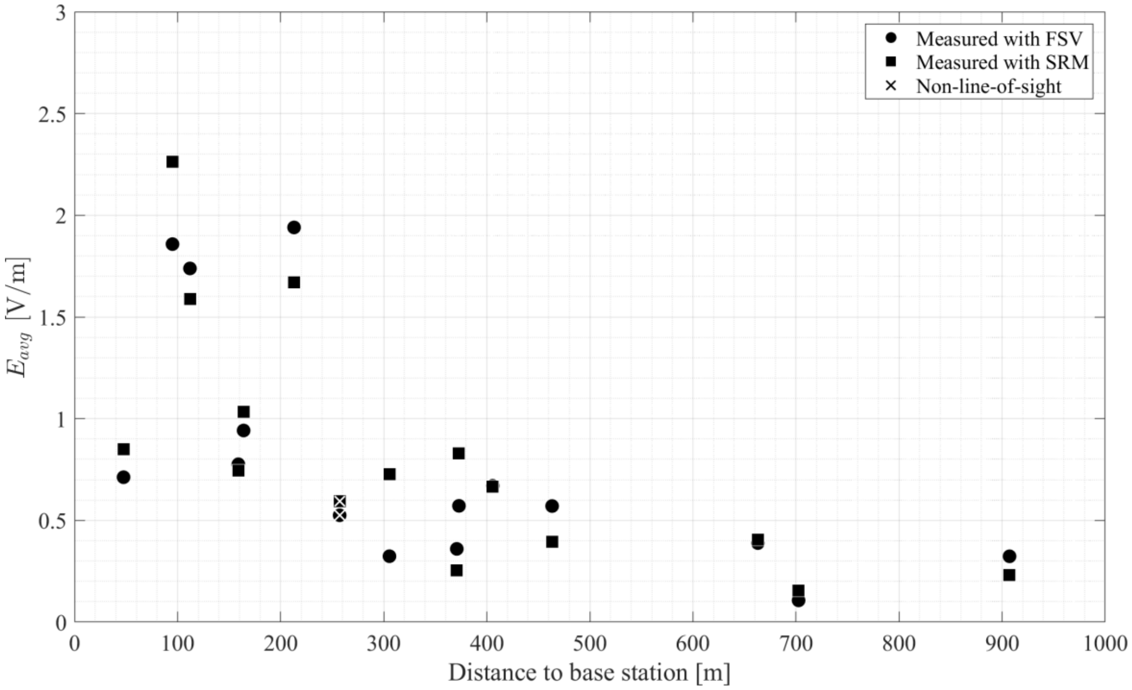

Figure 4: Average electric-field strength E_{avg} (V/m) measured with one active 5G NR UE, as a function of distance to the base station. Measurements were performed with FSV (circles) and SRM setups (squares), with the UE placed at in front of the measurement probe at 2 m distance. Positions in NLOS are indicated by a white cross.

3.2.2 Maximum electric-field strength

The maximum electric-field strength E_{max} was calculated by extrapolating the electric-field strength measured per individual resource element (RE) allocated to the Physical Downlink Shared Channel (PDSCH), which carries the downlink traffic from the BS to the user device.

To assess $E_{RE,PDSCH}$, the Step 3-measurements were post-processed such that the measurement samples (i.e. the received power measured over a bandwidth of 1 MHz around the SSB centre frequency) were aligned (in time) with the NR frame structure. Examples of this process can be found in Figure 5. The SSB period was 20 ms, hence successive pairs of NR frames of 10 ms were stacked on top of each other to identify the samples taking during an SSB signal or a PDSCH signal. *(Other (control) signals remain unspecified, as they are of no further interest.)*

Furthermore, from Figure 5, the TDD factor f_{TDD} could be obtained. In this case, it depended on the antenna sector: 0.74 for the 1st sector and 0.60 for the 2nd and 3rd sectors.

$E_{RE,PDSCH}$ was then obtained from the distribution of the PDSCH samples, taking into account a reduction factor to scale the 1 MHz bandwidth to the SCS (here, 30 kHz), and extrapolated to E_{max} using Eq. (1). More details about this approach can be found in [Aerts 2019].

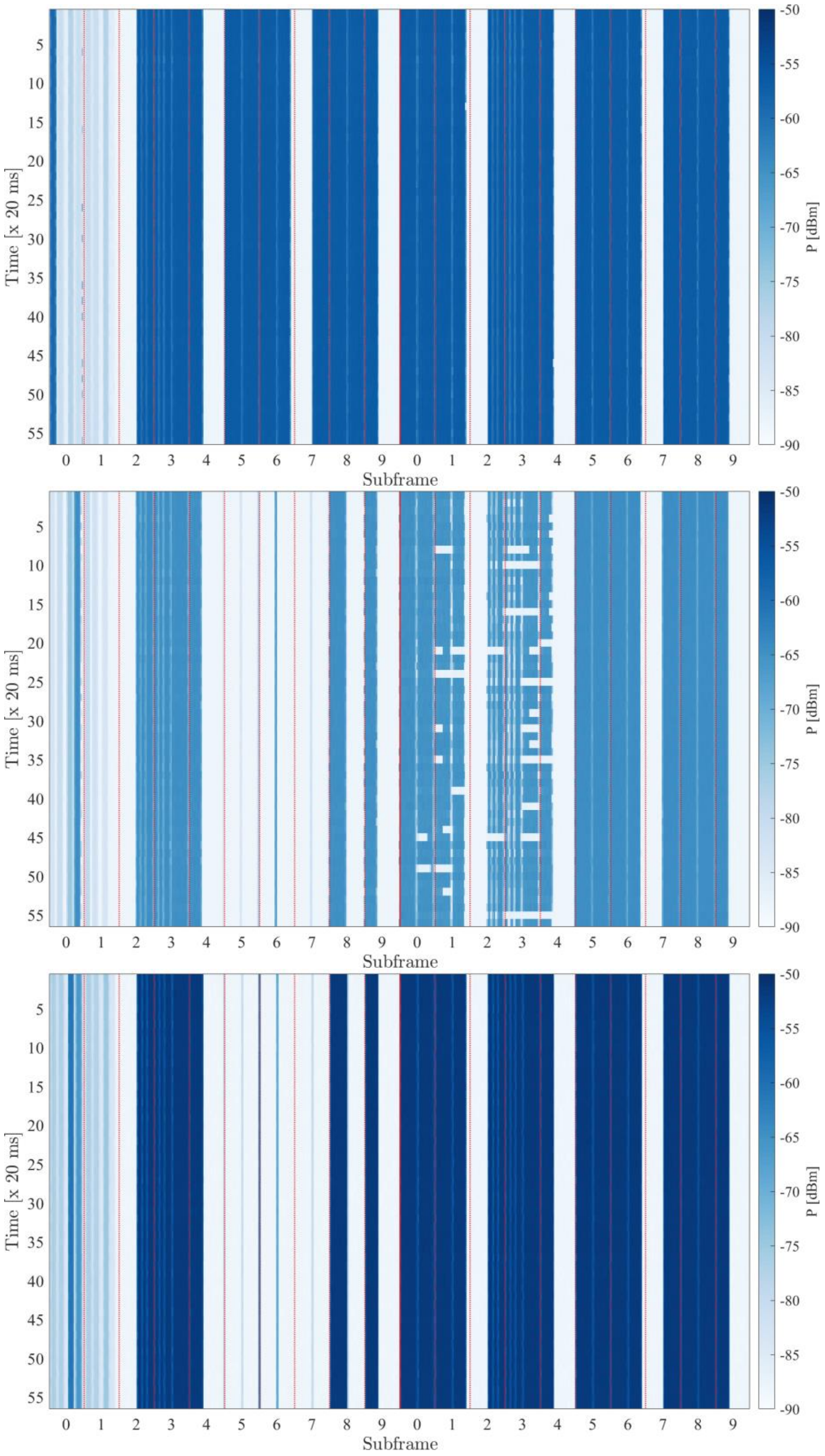

Figure 5: Waterfall diagrams made from post-processed Step 3-measurements of one of the components of the electric field at (top) Pos.10 in the 1st sector, (middle) Pos.14 in the 2nd sector, and (bottom) Pos.1 in the 3rd sector. Sequential measurement samples are plotted per two NR frames of 10 ms (i.e. 20 subframes), with the shade of blue proportional to the received power within the resolution bandwidth of 1 MHz. At the left of these diagrams, seven SSBs are observed (the SSB period was 20 ms). The other observed bands indicate PDSCH-allocated slots as well as some unspecified control signals. More details about this approach can be found in [Aerts 2019].

Figure 6 compares E_{max} to the E_{avg} values measured at the same location with an active UE. From this, it is clear that E_{max} is a conservative value: on average, it was 80% (2.6 dB) higher than E_{avg} obtained with a UE forcing a maximum downlink stream. This discrepancy is probably due to an incomplete filling of PDSCH resources (see Figure 5): not all PDSCH-allocated resources are constantly in use, not even when forcing a maximum download rate. Finally, the maximum E_{max} found [ICNIRP 2020].

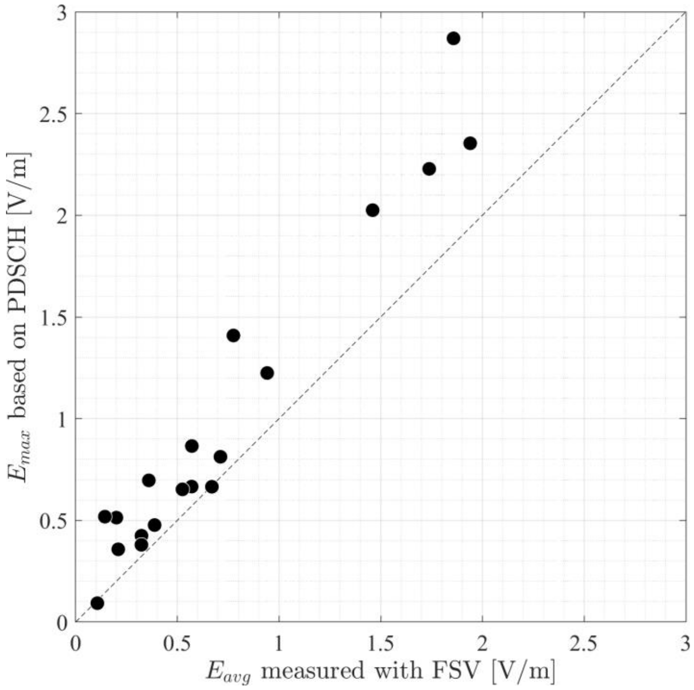

Figure 6: Maximum electric-field strength E_{max} (V/m), based on measurement of the PDSCH resources, versus the average electric-field strength E_{avg} (V/m) measured with the FSV setup (with one active 5G NR user equipment).

3.3 IMPACT ON ENVIRONMENTAL RF-EMF EXPOSURE

At each position, except Pos.16 (Figure 1), additional SRM measurements were conducted to assess the contributions of the different frequency bands used by other wireless telecommunications networks to the environmental RF-EMF exposure, and compare them to the exposure induced by the NR BS with an active UE (generating maximum downlink traffic) at the measurement position. The results are shown in Figure 7 and the maximum contributions per frequency band are listed in Table 3.

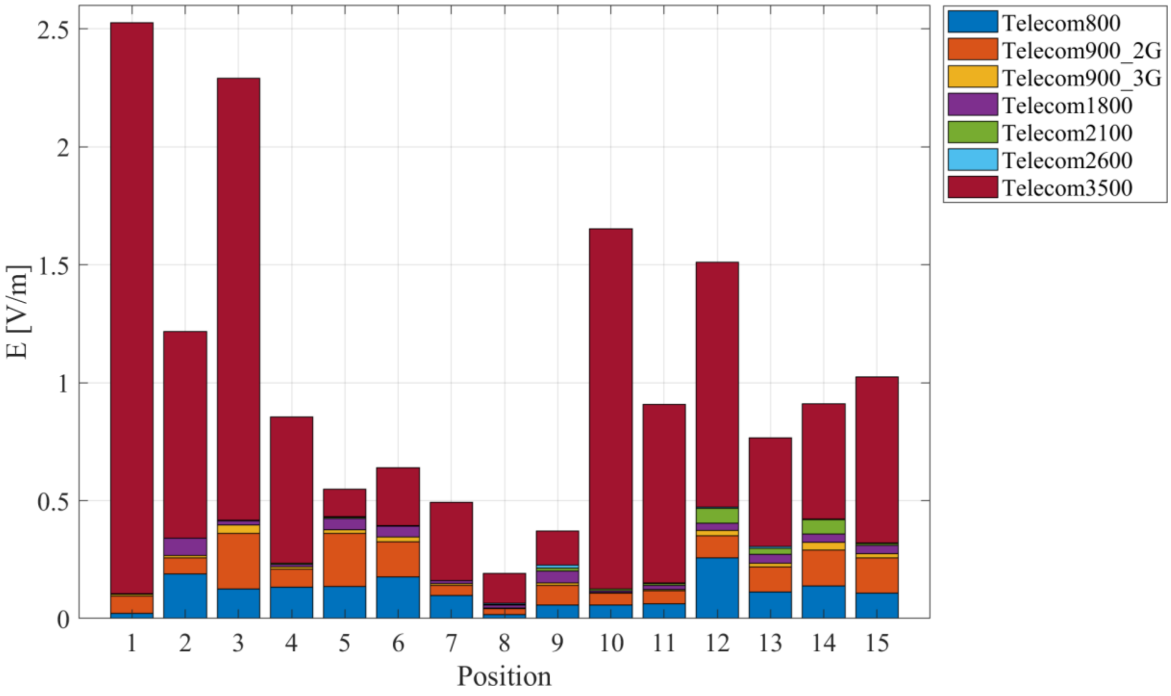

Figure 7: Relative contribution of different wireless telecommunications bands ("Telecom"), including the 3.5 GHz band ("Telecom3500") used by 5G NR, to the total environmental RF-EMF exposure $E_{tot,telecom,avg}$ (in V/m), measured at different positions in line-of-sight of the NR base station (Figure 1), during maximum NR downlink traffic induced at the measurement position. (Measurements conducted with SRM-3006.)

Table 3: Maxima of the average electric-field levels (in V/m) measured per telecom frequency band, as well as total, of Figure 7.

Telecom frequency band	**Maximum E_{avg} [V/m]**
800 MHz	0.62
900 MHz	0.79
1800 MHz	0.30
2100 MHz	0.31
2600 MHz	0.07
3500 MHz	2.47
Total	***2.53***

With maximum downlink traffic at the evaluation point, which is the extreme case, the additional exposure due to the NR BS was significant: the largest contribution of the 3.5 GHz band was 95% of the total field value (at Pos.1 [Figure 1], Figure 7), with a maximum field level of 2.47 V/m (Table 3) – which is in agreement with the results of the previous sections, and the average contribution was 65%.

3.4 OTHER ISSUES

3.4.1 Influence of the position of the UE with respect to the measurement probe

With the measurement probe fixed at Pos.1, the UE was placed at eight different positions around it: in front of it (i.e. towards the BS), on the left and on the right of it, and behind it, and at a separation distance of either 2 m or 3 m. The average electric-field strengths E_{avg} measured in these scenarios are visualized in Figure 8. Although E_{avg} with the UE on the side were slightly lower, all measurements were well within 3 dB of $\overline{E_{avg}}$, so the eight positions of the UE could not be distinguished.

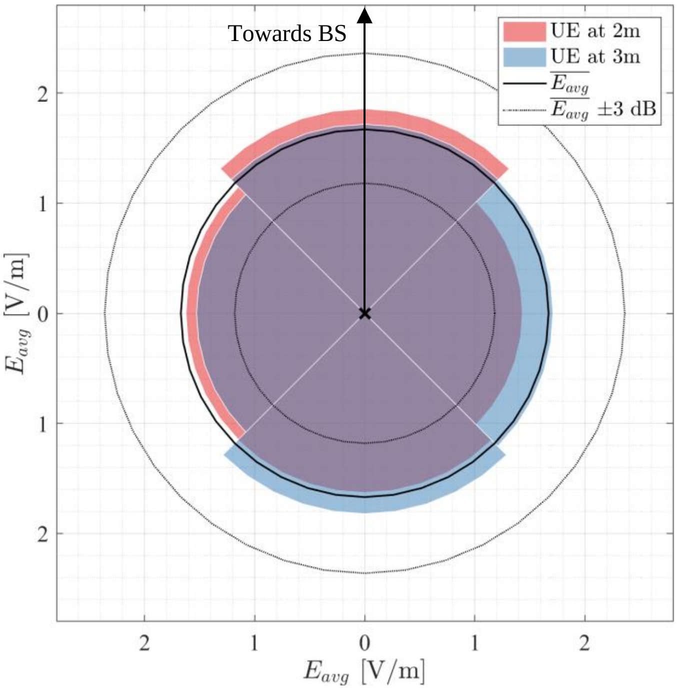

Figure 8: Difference in average electric-field strength E_{avg} (V/m) at a fixed location (X) when the UE was positioned at either 2 m (red) or 3 m (blue) from the measurement probe (at X) in four directions: in front of (i.e. towards the BS), left of, right of, or behind the measurement probe. (The purple area [i.e. the overlap] indicates the smaller of the two values.) The average of the eight measurements is indicated with a black line, and the ±3 dB deviations (i.e. the measurement uncertainty) from this average with dotted lines.

3.4.2 Influence of the number of UEs

3.4.2.1 At the same position; same beam

One to four simultaneously active UEs were placed at 3 m behind the measurement probe at Pos.1. With E_{avg} ranging from 1.80 V/m to 1.87 V/m, there was no apparent influence of the number of simultaneously active UEs on the exposure (see also Figure 8 for the case with one UE).

3.4.2.2 Spatially separated; other beams

With the measurement probe fixed at Pos.1, zero to four simultaneously active UEs were placed at different positions in the antenna sector such that they were assumed to be served by different PDSCH beams (i.e. they were spatially separated). The average electric-field strength E_{avg} measured (at Pos.1) in these scenarios is visualized in Figure 9.

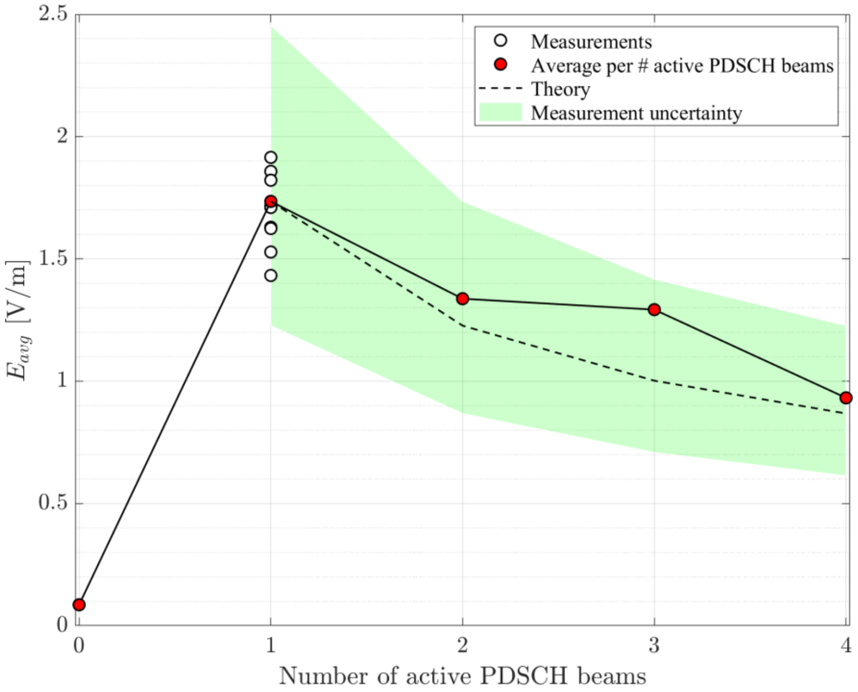

Figure 9: Difference in average electric-field strength E_{avg} (V/m) at a fixed location (X) when zero to four simultaneously active UEs were placed at different positions in the antenna sector, generating spatially separated PDSCH beams. The red markers depict the average E_{avg} measured for that number of active PDSCH beams. The dashed line indicates the theoretical decrease in E_{avg}, starting from the average E_{avg} measured with one PDSCH beam directed towards the measurement probe (the eight measurements of Figure 8 are depicted [white markers] and the average of those was retained [red marker]). In green, the measurement uncertainty of ±3 dB is shown.

When comparing the measurements with the theory, E_{avg} decreases as expected (within the ±3 dB measurement uncertainty – green area in Figure 9), starting from the average exposure level measured with one active UE near the measurement probe (1.74 V/m; the average of the eight measurements of Figure 8), which is the case of one PDSCH beam, directed towards the probe. For two active spatially separated UEs – which means the antenna power was split over two PDSCH beams – E_{avg} was 2.3 dB lower (close to 3 dB, which was expected, which corresponds to a factor 2 in power density, or √2 in electric-field strength); for three UEs, E_{avg} was 2.6 dB lower (less than the 4.8 dB which was expected, but within the measurement uncertainty); and finally, for four UEs, E_{avg} was 5.4 dB lower (very close to 6 dB, i.e. a factor 2 in electric-field strength, which was indeed expected) (Figure 9).

The (slight) overestimation observed in Figure 9 is probably due to a small but measurable contribution of the beams to the electric field at the measurement position (due to the side lobes of the antenna pattern). However, no additional measurements, without PDSCH beam directed toward the probe, were conducted to confirm this.

3.4.3 Influence of vertical beamsteering

Table 4 lists the exposure levels measured at Pos.2 and Pos.9 with the UE placed at different positions in line with the probe and the BS.

Table 4: Exposure levels at measurement locations Pos.2 and Pos.9 with the UE at different positions (Figure 1).

Position of probe	Position of UE	*d* [m]	ϑ [°]	E_{avg} [V/m]	E_{max} [V/m]
Pos.2	Pos.2	164	15.7	0.94	1.22
Pos.2	Pos.4	305	11.2	0.20	0.51
Pos.9	Pos.9	907	7.8	0.32	0.59
Pos.9	Pos.8	703	8.3	0.14	0.54
Pos.9	Pos.6	463	9.5	0.21	0.37

d = the horizontal distance between user equipment (UE) and base station (BS); θ = the vertical angle between UE and BS; E_{avg} = the average electric-field strength (in V/m) measured at the position of the probe; and E_{max} = the maximum electric-field strength (V/m) measured at the position of the probe.

At Pos.2, there was a clear difference: E_{avg} and E_{max} were significantly lower (13.4 dB and 7.6 dB, respectively) when the UE was placed at Pos.4 (UE.2.2 in Figure 1). The latter position was almost twice as far from the BS, altering the vertical angle ϑ between UE and BS by 4.4°, which clearly resulted in a readjustment of the PDSCH beamsteering angle.

At Pos.9, on the other hand, the conclusions are less clear. First, though there was a decrease of 7.2 dB in E_{avg} when placing the UE at Pos.8 (UE.9.3 in Figure 1), E_{max} remained very similar. The 200 m difference in distance of the UE to the measurement probe only resulted in a change of 0.5° in ϑ, which was probably not enough to alter the PDSCH beamsteering angle. However, we don't know what caused then the discrepancy in $E_{avg.}$ Second, when placing the UE at Pos.6 (UE.9.2 in Figure 1) – 344 m closer and a difference of 1.7° in ϑ – E_{max} decreased by 4.1 dB (and E_{avg} by 3.7 dB), clearly hinting at a readjustment in beamsteering angle.

Table 4 shows that there is a limit on the separation distance between UE and measurement probe if the objective is to "attract" the beam towards the probe. For this antenna configuration, a difference of more than 1° in vertical angle between the UE and the BS can result in a different PDSCH beamsteering angle.

4 CONCLUSIONS

This report described the measurements of radiofrequency (RF) electromagnetic fields (EMF) in the vicinity of a 5G New Radio (NR) base station in Haasrode, Belgium, following the procedure designed by IMEC-WAVES [Aerts 2019].

The NR channel was located at 3760–3800 MHz (40 MHz bandwidth), the center frequency of the Synchronization Signal Block (SSB) was 3780.48 MHz, and the antenna input power was configured at 20 W (43.01 dBm) – although the maximum allowed power, according to the certificate of compliance, was 46 W.

The time-averaged electric-field strength E_{avg} was assessed using two types of measurement equipment: an FSV spectrum & signal analyser and an SRM-3006 field strength analyser. With an active user device, which forced a maximum downlink stream, near the measurement probe, E_{avg} measured with the FSV ranged from 0.11 V/m at 700 m from the base station to 1.94 V/m at 95 m.

The SRM measurements were very similar; the correlation between the two types was 0.94. Furthermore, the maximum electric-field strength E_{max} was extrapolated from measurements of the electric-field strength per resource element allocated to the downlink traffic, $E_{RE,PDSCH}$. On average, E_{max} was 80% higher than the corresponding E_{avg}, with a maximum of 2.87 V/m (at 95 m from the base station). This discrepancy was probably due to an incomplete filling of PDSCH resources: not all resources that *can* be allocated to PDSCH constantly *are*, not even when forcing a maximum download rate.

All field levels were well below the reference level of 61 V/m at 3.7 GHz as issued by ICNIRP [ICNIRP 2020]; the maximum ratio was just 0.22%. However, the potential impact of the NR base station on the total environmental RF-EMF exposure induced by all telecommunications networks is significant: with an active UE inducing maximum downlink traffic towards the measurement location, on average 65% of the total exposure could be attributed to NR.

Furthermore, a number of remaining issues in the procedure were addressed.

First, it was concluded that for a separation distance of 2 to 3 m, the position of the UE with respect to the measurement probe did not have a significant impact on the measurement results. However, to minimize influence from the measurement equipment and the experimenter on the field distribution, it is **advised to place the UE in front of the probe (i.e. towards the UE) at a distance of 2 m**.

Second, **the number of active UEs** placed **at the same position (same beam)** with respect to the probe did **not have a significant influence** on the measurement results. However, when **multiple active** UEs (i.e. each generating a maximum downlink stream) are placed at **different locations (different beams)** of the antenna sector, the average electric-field strength **decreases as more spatially separated PDSCH beams are generated**. For example, in the case of four simultaneously active, spatially separated UEs, E_{avg} decreases by 6 dB (i.e. a factor 4 in power density).

Third, if applicable, the **vertical beamsteering** of the PDSCH also **limits the maximum distance at which the UE can be placed with respect to the probe**. It was found that a difference of more than 1° in vertical angle between the UE and the base station can result in a different PDSCH beamsteering angle. This strengthens our advice to place **the UE at a distance of 2 m** from the measurement probe.

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APPENDIX A

In this appendix, the settings of the FSV (Table 5) and SRM (Table 6) measurement equipment are listed.

Table 5: Optimal spectrum analyser settings for the accurate measurement of 5G NR signals with frequencies below 6 GHz. (CF = centre frequency, RBW = resolution bandwidth, RBW_{SA} = *minimum RBW or the SA,* SWT = sweep time, SS_{REF} = centre frequency of SSB, rms = root mean square).

	SA mode	CF [MHz]	Span [MHz]	Detector	RBW [MHz]	SWT [s]	Number of display points	Sweep mode	Measurement time[a] [s]
Step 1	frequency	3350	5300	peak	0.3	177[b]	17667	maximum hold	177
Step 2	frequency	CF of the 5G NR signal	100	rms	1	$11.9\ 10^{-3}$	333	actual	200
Step 3	zero-span	SS_{REF}	0	rms	1	x[c]	32001	actual	60
Step 4	frequency	CF of the 5G NR signal	100	rms	1	y[d]	101	actual	360[e]

[a] Per vector component of the electric field, except for Step 2, for which only one component has to be measured.

[b] The measurement time per sample is the duration of one 5G NR frame (i.e., 10 ms). If the measurement time per sample would be too short, signals could be missed and it would take too much time to build up the spectrum.

[c] x = 32000 × SSB symbol time, such that the measurement time per sample is equal to the SSB symbol time.

[d] y = 101 × SS burst period, such that the measurement time per sample is equal to the SS burst period. If not known, take the maximum SS burst period of 160 ms.

[e] 30 minutes is the averaging time recommended by [ICNIRP 2020], but the actual measurement time can be shorter if the signal is deemed stable.

Table 6: Measurement settings of the SRM-3006 for a spectrum overview measurement and a 5G NR in-band measurement. Both measurements were performed in Spectrum mode. (RBW = resolution bandwidth, SWT = sweep time, Avg. time = averaging time.)

Measurement	Frequency range	RBW [MHz]	SWT* [ms]	Avg. time [min]
Overview	600 MHz – 4 GHz	0.3	1104	6
In-band	200 MHz around CF of 5G NR channel	1	94	6

* The SRM's sweep time (SWT) is not configurable.

APPENDIX B BROADBAND VERSUS FREQUENCY-SELECTIVE

The broadband measurement setup, NBM-550 in combination with the probe EF-0691 (frequency range 100 kHz - 6 GHz) can give a first indication of the total exposure with and without an active 5G UE. Moreover the broadband setup gives also a good idea of the contribution of the 5G DL-signal towards an active 5G UE by comparing the broadband measurements with and without the active 5G UE.

Figure 10 shows the results of the cumulative electric-field strength of the present telecommunication signals measured with the frequency-selective SRM setup and with the broadband NBM-setup as function of the distance to the 5G BS, with and without an active 5G UE. The results with both measurement setups are comparable and the contribution of the 5G signal towards the active UE is significant and detectable.

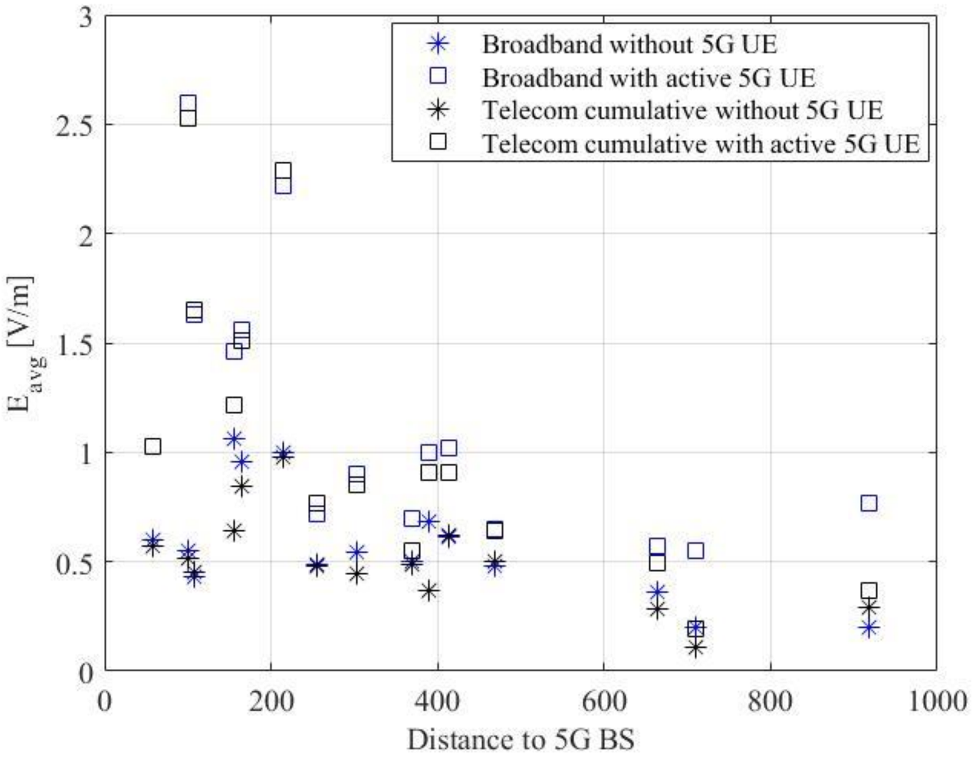

Figure 10: Cumulative electric-field strength E_{avg} (V/m) measured without and with one active 5G NR UE, as a function of distance to the 5G NR base station. Measurements were performed with the frequency-selective SRM-setup (black) and with the broadband NBM-setup (blue).