# Simulations of the virtual roll out of 5G in Flanders with regard to electromagnetic exposure.

Dr Liesbeth Gommé, Mr Mart Verlaek, Mr Niels De Kempeneer, Mr Michel Goethals, Mrs Tine Van Hoof, Mrs Sophie De Mulder, Dr Karen Van Campenhout

Department of Environment & Spatial Development, Flemish Planning Bureau for the Environment and Spatial Development, Brussels, Belgium

## I. INTRODUCTION

In 1998, the International Commission on Non-Ionising Radiation Protection (ICNIRP) established guidelines for limiting exposure to non-ionising radiation. These guidelines were adopted by the European Commission and form the basis for the legislative framework in most European member states. In 2020, the ICNIRP published new guidelines on radiofrequency radiation [1]. In Belgium, regional governments are responsible for the electromagnetic policy of their territory. Flanders, the northern region of Belgium, drafted its first legislation in 2010 based on the ICNIRP guidelines to limit exposure to electromagnetic fields from transmitting antennas, with the precautionary principle and scientific research as corner stones.

Since mobile telecommunications technology evolved significantly over the past 10 years, an adaptation of the legislation seemed indispensable. Given the forthcoming roll out of a widely available 5G network, this called for an exposure assessment of the additional 5G NR base stations before the deployment [2,3].

Therefore, in 2019, the Flemish Department of Environment & Spatial Development investigated the roll out of 5G antennas, in addition to the existing telecom antennas, and the implications on exposure and the new legislation.

In the new Flemish legislation, that came into force in 2022 [4,5], the cumulative limit adhering to the ICNIRP guidelines was preserved. However, the previous legislation also implemented a limiting value per antenna which is no longer suitable for limiting exposure to electromagnetic radiation from transmitting antennas due to the technological evolutions. Therefore, the introduction of a technology-independent limit, a limit per operator, was investigated to underpin the new legislation before it came into effect.

This paper synthesises this feasibility study. Hereto simulations in multiple areas in Flanders were performed: 5G antennas were added to existing antenna sites of which the technical data is available from conformity certificates issued for fixed transmitting antennas. Operators who want to install or modify an antenna must apply for such a conformity certificate before the antenna starts transmitting. This certificate lists technical information concerning the antenna installation and is delivered when the antenna complies with the applicable legislation.

## II. METHODOLOGY

To determine the impact of the adapted legislation, the study investigates whether the per-operator limiting value would impose restrictions on networks with fixed transmitting antennas. To this end, an application was used that calculates the exposure to non-ionizing radiation at a given location in Flanders based on technical data from conformity certificates issued for fixed transmitting antennas.

This application was then adapted for adding 5G antennas to existing antenna sites to simulate the roll out of 5G and the change in exposure.

### *A. Selecting the locations*

To give a representative picture of several spatial environments in Flanders, three simulation areas with different characteristics were selected: one with urban characteristics (i.e., higher radiation exposure due to the shorter distance from the antennas), one with rural characteristics and one with both. Compared to other European urban environments, the population density in Flemish urban centres is on average fairly low (about 3.200 inhabitants per km²). Rural environments in Flanders have a fairly high population density (about 150 inhabitants per km²), compared to other European rural environments.

The first location is the city centre of Ghent, the second most populous city in Flanders (5,60km², 44.150 inhabitants, 8.400 inhabitants per km² in 2019). This location was chosen because it lies in an urban environment with a lot of antennas and allows to map exposure to a context with higher buildings. A second simulation was carried out for Leopoldsburg with a mainly rural character (22km², 15.800 inhabitants, 700 inhabitants per km² in 2019). In rural areas, the antennas have a higher transmit power as they are spaced further apart. The last location is Sint-Niklaas, a city that combines both rural and urban characteristics (84 km², 77.800 inhabitants, 923 inhabitants per km² in 2019).

### *B. Simulating a worst-case scenario*

A worst-case simulation is set up, using the maximum possible power for the existing antennas as well as for the added 5G antennas. Moreover, each site will have 5G antennas added at 700, 1400 and 3500 MHz, the additional 5G spectral bands, whereas it is probable that not all frequencies will be used at each site. Also, for the indoor calculation of the electromagnetic field strength, the lowest attenuation possible for a building (5dB) was considered.

### *C. Adding 5G antennas to existing antenna sites*

Simulations were performed in which 5G antennas were added to existing antenna sites of which the most recent technical data was retrieved from conformity certificates issued for transmitting antennas in Flanders. As 5G antenna type we used a type already installed by the operators.

### *D. Calculating exceedance of the limits*

#### i. Approach

Using the application that the Flemish Department of Environment & Spatial Development developed together with the WAVES research group of the Department of Information Technology of Ghent University-IMEC, the 5G roll out was then simulated. Per location (section A) we selected all antennas per operator, and we simulated for worst-case exposure (section B) using the computational model in section ii. The calculated exposure is checked against the newly proposed limit per operator and the cumulative limit (section iii).

The exposure to antennas of other operators, which are not required to meet the limit per operator, is also calculated, in order to examine whether this makes a significant contribution at the positions where telecom antennas result in the highest exposure.

#### ii. Computational model

The computational model behind the simulations uses the antenna's technical characteristics, near-field and far-field equations and antenna site specifications. When the exposure is calculated, attenuation values for buildings where people stay (e.g., houses, schools, offices…) are applied.

For 5G antennas using Time Division Duplex (TDD) and beamforming, correction factors are introduced: these are equal to 1.2 and 6 dB respectively because the maximum radiation beam is only observed for a limited part of the time at a given location. The attenuation factors were substantiated by the WAVES research group through own research and literature study ([6-11]). The computational model was compared to other solvers such as FEKO and showed good agreement.

#### iii. Evaluation against the limiting values

In a 5 x 5 metre grid defining the simulation points, field strengths are calculated for different heights. The ground level is chosen at 2.2 m height because this is considered a worst-case approach to exposure at ground level considering human body height. The other heights that were calculated are 4, 7, 10, 13 and 16 metres, each corresponding to an additional floor. Taking into account the height of nearby buildings, 16 m height was sufficient.

The result of the electric field strength calculations is evaluated against the cumulative limiting value as maintained in the new legislation [4]. This limit applies to places where people can come and to the sum of field strengths of all transmitting antennas together.

The result of the electric field strength calculations is also evaluated against the limiting value per operator as newly introduced in the legislation [5]. This limit applies to buildings where people stay and to the sum of field strength of all transmitting antennas of a single operator.

For the calculation of exposure per operator, an attenuation of 5dB, corresponding to a wall including windows, is applied because the limit applies only to buildings where people stay.

## III. RESULTS AND DISCUSSION

### *A. Ghent city centre*

Figure 1 shows the several sites (blue dots) of the telecom operators in Ghent city centre, leading to 838 simulated antennas.

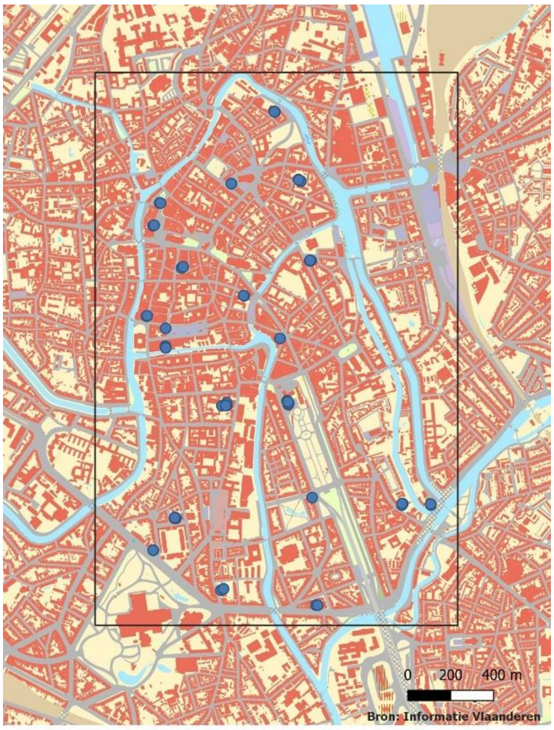


Figure 1: Selection of the area with antenna sites in Gent

Regarding the limit per operator, it is found that over the different heights and operators, in simulated points 12 to 122% of the limiting value can be reached when the 5G sites are not added. The exceedances were situated where there are no buildings where people stay and therefore it does not qualify as an exceedance.

When 5G sites are then added in simulated points 15 to 130% of the limiting value can be reached. However, the exceedances between 100 and 130% of the limit were found in only 0.01% of the simulated points. It should be considered that there are several possible solutions for this exceedance e.g., by reducing the power of the antennas causing the exceedance, giving 5G antennas a bit more power and older technology such as 3G a little less. The limit per operator allows this kind of adjustment. So, according to the simulations, the 5G roll out could take place in this area of Ghent after limited adjustments.

Regarding the cumulative limit, it is found that over the different heights, 18 to 78% of the limiting value can be reached when the 5G sites are not added and 23 to 103% when 5G sites are added. However, the exceedance was found in a building where people stay and hence requires a correction of 5dB attenuation which cancels the exceedance. It could be concluded that the cumulative limit is not exceeded.

### *B. Leopoldsburg*

For the rural location Leopoldsburg, figure 2 shows the several sites (blue dots) of the telecom operators leading to 207 simulated antennas.

Concerning the limit per operator, it is found that over the different heights and operators, in simulated points 8 to 35% of the limiting value can be reached when the 5G sites are not added. When 5G sites are added, 16 to 48% of the limit can be reached in simulated points. Hence, the limit per operator is not exceeded.

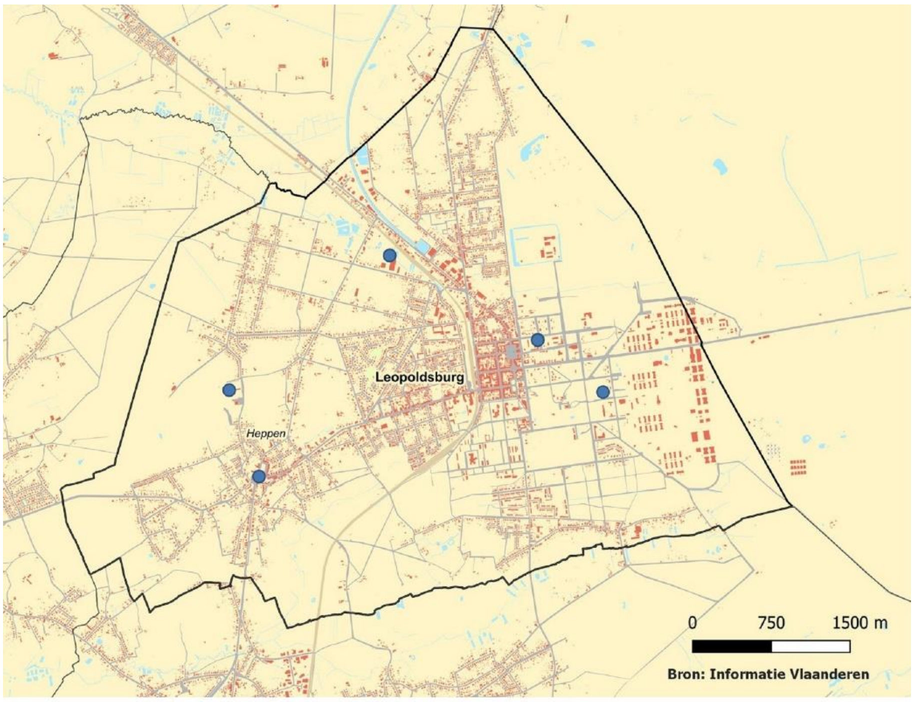


Figure 2: Selection of the area with antenna sites in Leopoldsburg

Regarding the cumulative limit, it is found that over the different heights, in simulated points 21 to 42% of the limiting value can be reached when the 5G sites are not added and 33 to 67% when 5G sites are added. Hence, the cumulative limit is not exceeded.

### *C. Sint-Niklaas*

Figure 3 shows the several sites (blue dots) of the operators, leading to 1.051 antennas.

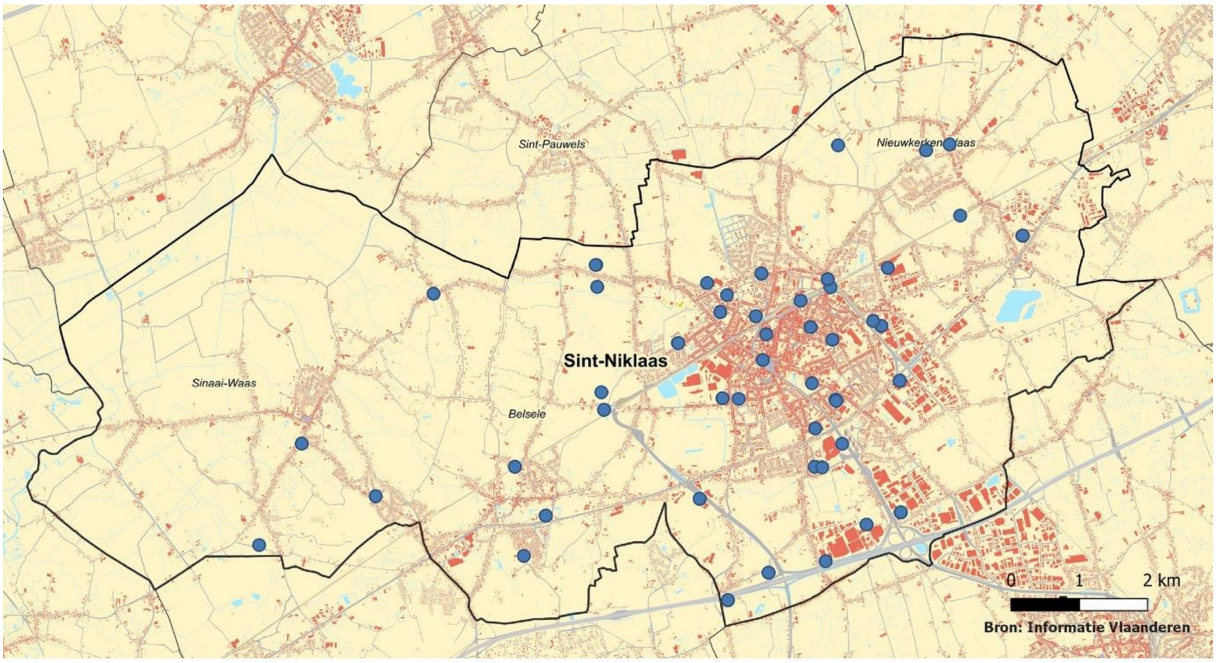


Figure 3: Selection of the area with antenna sites in Sint-Niklaas

Concerning the limit per operator, it is found that over the different heights and operators, in simulated points 18 to 104% of the limiting value can be reached when the 5G sites are not added. The exceedance of 104% was verified and it did not correspond to a place where people stay. Therefore, it does not qualify as an exceedance of the limit per operator.

When 5G sites are then added, in simulated points 23 to 133% of the limiting value can be reached. However, the exceedances between 100 and 133% of the limit were found not to be a place where people stay and therefore do not qualify as an exceedance.

Concerning the cumulative limit, it is found that over the different heights, in simulated points 23 to 66% of the limiting value can be reached when the 5G sites are not added and 32 to 90% when 5G sites are added. Hence, the cumulative limit is not exceeded.

## IV. CONCLUSIONS

This paper investigated the roll out of 5G antennas, in addition to the existing telecom antennas, and the implications on exposure and the new legislation.

Using the application that the Flemish Department of Environment & Spatial Development developed together with the WAVES research group of Ghent University-IMEC, the 5G roll out was simulated. Hereto simulations were performed in which 5G antennas supporting frequency bands of 700 MHz, 1400 MHz and 3500 MHz were added to existing antenna sites. For these sites, technical data is available from conformity certificates, issued for fixed transmitting antennas. A worst-case simulation is set up, using the maximum possible power for the existing antennas, as stated in the conformity certificates, as well as for each of the added 5G antennas.

This work presents the results of the simulations for three locations that are representative of Flanders: these sites are urban or rural or a combination of both. For each location, the simulation results indicate exceedances against the limit per operator and the cumulative limit. The padding of the limit per operator is only tested for buildings where people stay whereas the padding of the cumulative limit is tested for places where people can come.

Summarising the results, an exceedance was observed in less than 0.01% of the calculated points at a height in buildings where people stay. The exceedances were limited in size ranging from 1 to 1.3 with larger than 1 being an exceedance. The exceedances can be mitigated by limited adjustments to comply with the legislation (e.g., by reducing the power of the antennas causing the exceedance or distributing the power between the antennas of the site).

In conclusion, the new legislation, adopting the precautionary principle, manages to limit exposure to electromagnetic fields from transmitting antennas as well as allowing the roll out of 5G in Flanders.

## V. ACKNOWLEDGEMENT

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