Belgian Institute for Postal Services and Telecommunications

Study of 12 September 2018 on the impact of the radiation standards in Brussels on the deployment of mobile networks

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1. Context

In a letter received on 18 July 2018, Vice-Premier and minister in charge of telecommunications Alexander De Croo asked BIPT to issue recommendations concerning the changes to be made to the radiation standards in Brussels in order to meet the future needs of the telecoms sector.

In his letter, he more precisely asked this:

> *"In Belgium, radiation standards are set at the regional level. In Brussels particularly, the imposed standard (6 Volts per metre on a cumulative basis for all operators) makes it impossible to invest in 5G and an increasing number of congestion problems will arise for 4G.*
>
> *I think it is appropriate that BIPT should realise a study and draw up a recommendation on the radiation standards that are necessary to meet the minimum needs of the sector in the near future.*
>
> *And this, in order to be able to objectify the debate."* (free translation)

In a letter received on 17 August 2018, Céline Fremault, minister for the Environment, asked BIPT to give her an opinion on the existing radiation standards in Brussels, as well as on the possibility to abandon certain technologies that are used today.

In her letter, she more precisely asked this:

> "*Could you then give us your opinion on the state of saturation of the current network in Brussels (2G, 3G, 4G) within the framework of the current 6 V/m standard? Concretely, does the current 6 V/m standard allow to ensure a quality and efficient network with the technologies that are currently used (2G, 3G, 4G)?*
>
> *Could you also mention in that opinion if it is possible to integrate the new 5G technology in the context of the current 6 V/m standard while taking account of the current networks and technologies?*
>
> *Besides these questions, could you also mention if it is conceivable, in the short or medium term, to abandon certain technologies that are currently in use and replace them by the 5G technology? If so, could the withdrawal of a technology happen quickly enough to free some space for 5G while maintaining efficient networks for all types of users?*" (free translation)

This impact study answers to both requests.

2. Radiation standards

The purpose of radiation standards is to protect the public against the effects that may arise as a consequence of exposure to electromagnetic fields.

The radiation limits are generally specified by a limit of the electric field expressed in V/m, or by a limit of the power flux density expressed in W/m².

There is a relationship between the power flux density (P_s) and the electric field (E):

$$P_S = \frac{E^2}{376{,}73}$$

When we double the power of an antenna, the power flux density produced by that antenna is doubled, while the produced electric field is multiplied by $\sqrt{2}$ (about 1,4).

The radiation limits generally vary with the used frequency. For reasons of simplicity, we often only specify the radiation limit corresponding to the 900 MHz frequency.

Exposure standards already exist for decades and are intended to protect people against excessive levels of RF radiation, and this in different environments. Depending on the environment, different standards are applied internationally. Typical examples are military standards, workers standards and standards for the general public. Stricter standards are systematically applied in each of these domains.

The ICNIRP[1] standard for workers and the general public is the best known worldwide. This standard is based on the scientific observation that tissue can heat up when it is exposed to RF energy (for instance coming from a microwave). ICNIRP standards ensure that this heating will not happen.

The EU issued a recommendation with standards for the general public that comply with this ICNIRP standard. The different regions of Belgium have decided to implement additional stricter standards.

There is a consensus in the scientific community about the proven character of these standards to offer guarantees in order to avoid the above-mentioned heating. For years, studies have been carried out on the physical and medical mechanisms underlying other potential effects. BIPT is not competent and does not have the necessary competencies in terms of environment and public health. Moreover, BIPT does not have any proof suggesting that other effects are possible.

That is the reason why, in this document, we study the radiation level based on the technical characteristics of the radio communications networks and in order to ensure their optimal functioning, and this without taking into account other potential effects. This document only presents the values based on what is possible at a radio engineering level and what is necessary for the deployment of networks. It should be noted that it is technically possible to set the transmitting power of a mast within certain limits. This has an impact on coverage and on the quality of the service delivered via the mast. The two extremes – maximum power with a maximum quality (see section 7.3) and the current power per MHz with the current quality (see section 7.4) – will be discussed later in this document.

3. Radiation standards in Belgium

3.1. General

The Constitutional Court found[2] that the general competence of the Regions to address environmental protection implied the taking of measures to prevent and limit the risks associated with non-ionising radiation, including the limitation of exposure of people to the risk of this type of radiation which spreads in the environment.

Radiation standards vary then from one Region to the other. The three Regions have set radiation standards that are stricter than what is recommended by the ICNIRP[3] and the European Union[4].

3.2. Brussels-Capital Region

The ordinance of 1 March 2007 on the protection of the environment against any harmful effects and nuisance caused by non-ionising radiation sets a cumulative limit of 0,096 W/m² (i.e. about 6 V/m) at a frequency of 900 MHz, in the zones accessible to the public. This limit varies depending on the frequency :

---

[1] International Commission on Non-Ionizing Radiation Protection, https://www.icnirp.org/

[2] Arrest nr 2/2009 of 15 January 2009.

[3] International Commission for Non-ionising Radiation Protection, "*Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)*", *Health Physics* 74(4): 494-522 (1998).

[4] Council Recommendation 1999/519/CE of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz).

- 0.043 W/m² for frequencies between 0.1 and 400 MHz;
- f/9375 in W/m² between 400 MHz and 2 GHz, where f represents the frequency in MHz;
- 0.22 W/m² for frequencies between 2 GHz and 300 GHz.

According to the Decree of the Government of the Brussels-Capital Region of 30 October 2009 on certain antennas emitting electromagnetic waves, all the antennas of an operator shall not exceed 33% of the cumulative limit.

The Decree of the Government of the Brussels-Capital Region of 8 October 2009 laying down the methodology and terms for measuring the electromagnetic field emitted by some antennas as well as the Ministerial Order of 30 June 2010 concerning the validation of a simulation tool calculating the electric field emitted by an antenna emitting electromagnetic waves also apply.

3.3. Flemish Region

The Decree of the Flemish Government of 1 June 1995 laying down the general and sector-bound provisions regarding environmental hygiene (VLAREM II) sets a cumulative limit of 20.58 V/m at 900 MHz, for all the zones that are accessible to the public. This limit varies depending on the frequency:

- 13.7 V/m for frequencies between 10 and 400 MHz;
- 0,686 √ f expressed in V/m between 400 MHz and 2 GHz, where f represents the frequency in MHz;
- 30.7 V/m for frequencies between 2 GHz and 10 GHz.

Pursuant to the Decree of the Flemish Government of 1 June 1995, each antenna[5] of an operator cannot exceed 3 V/m at 900 MHz, which corresponds to 2.125%[6] of the cumulative limit.

In practice[7], the limit per antenna is always the most restrictive.

3.4. Walloon Region

The Decree of 3 April 2009 on the protection against any harmful effects and nuisance caused by non-ionising radiation generated by stationary transmitting antennas lays down a limit of 3 V/m for each antenna[8] of an operator, regardless of the frequency.

4. Standards in Brussels in 2018

4.1. Comparison with the other standards

The radiation standards in Brussels are almost 50 times stricter than what is recommended by the ICNIRP and the European Union.

Figure 1 compares the radiation limits (at 900 MHz) in the different European Union countries.

[5] Concerning the Flemish Region, it must be borne in mind that there is an antenna per deployed technology and per frequency band.
[6] $(3/20{,}58)^2$.
[7] Up to 47 antennas.
[8] Concerning the Walloon Region, it must be borne in mind that there is an antenna per deployed technology.

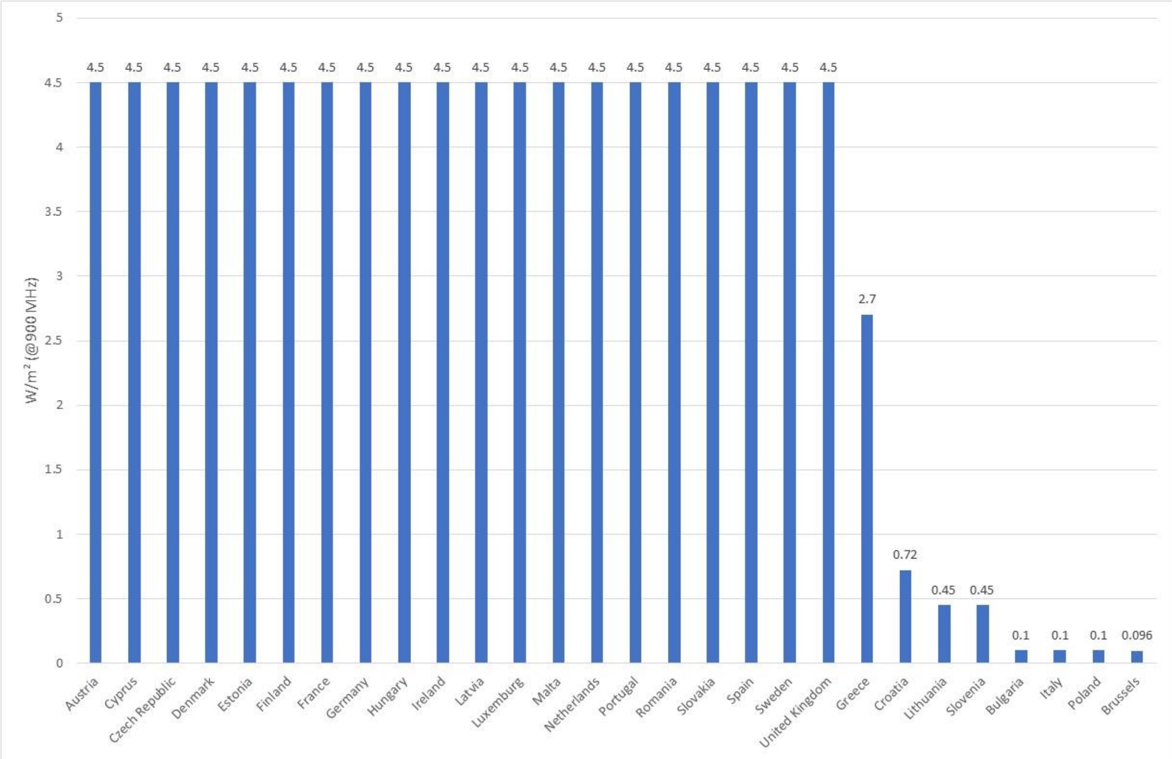


Figure 1 – Comparison of the radiation limits (at 900 MHz) in the European Union[9]

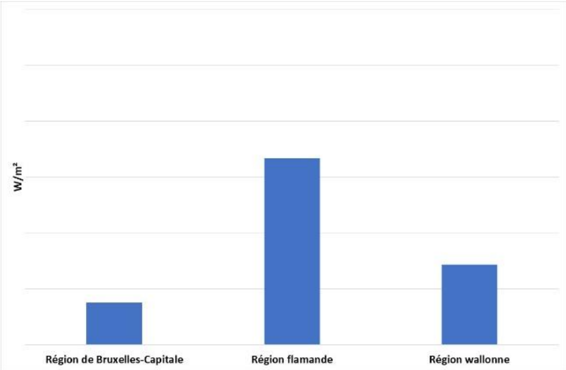
It is not an easy task to compare the standards of the Brussels-Capital Region (cumulative limit) with the standards of the other two Regions (limit per antenna). In the case of limits per antenna, the resulting total limit depends on the number of operators, the number of deployed technologies and the number of used frequency bands. With the advent of 5G, new frequency bands or even a fourth operator, the number of antennas will rise and the gap between the standards in the Brussels-Capital Region and the standards in the other two Regions will keep on increasing.

Figure 2 compares the standards in the three Regions, respectively for the deployments of the current mobile networks[10] (see section 6.1), and for the deployments of the mobile networks planned after 2020[11] (see section 6.3), in the case of three operators. The calculations are detailed in annex 1. In the case of four operators, the gap would be even greater.

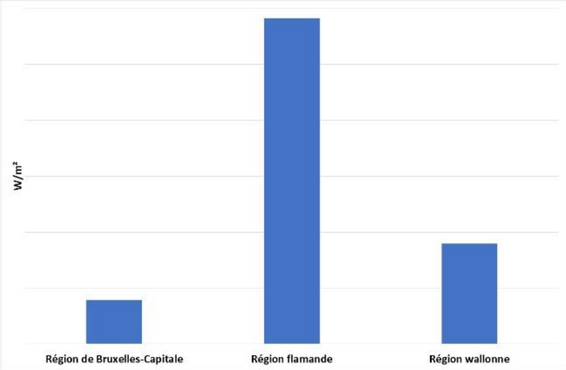
[9] Based on data in "*Comparison of international policies on electromagnetic fields*", National Institute for Public Health and the Environment, The Netherlands. For countries without limits, we use the limits in the recommendations of the ICNIRP and of the European Union.

[10] 6 antennas (LTE800, GSM900, UMTS900, DCS1800, LTE1800 and UMTS2000) per operator for the Flemish Region, and 4 antennas per operator for the Walloon Region (GSM, DCS, UMTS and LTE).

[11] 10 antennas (NR700, LTE800, GSM900, UMTS900, NR1400, DCS1800, LTE1800, UMTS2000, LTE2600 and NR3600) per operator for the Flemish Region, and 5 antennas per operator for the Walloon Region (GSM, DCS, UMTS, LTE and NR).



Current mobile networks



Mobile networks planned after 2020

Figure 2 – Comparison of standards in the three Regions

For the deployments of the current mobile networks, the radiation standards in Brussels are 4 times more stringent than the Flemish standards and 2 times more stringent than the Walloon standards. For the deployment of the mobile networks planned after 2020, the radiation standards in Brussels will be 7 times more stringent than the Flemish standards and more than 2 times more stringent than the Walloon standards.

4.2. Impact on the telecommunications development

The necessity to design mobile networks complying with radiation standards that are more stringent than the international recommendations results in less flexibility for the deployment of the network, particularly in terms of optimal site location. Moreover, operators must, in order to comply with the radiation standards, reduce the radiated power of their antennas. This reduction impacts coverage, which in turn impacts the quality of the service provided to users.

The modifications of the radiation standards in Brussels in 2014 allowed to roll out 4G in reasonably acceptable conditions. However, the modified standards, which remain 50 times more stringent than the international recommendations, are not a long-term solution for the deployment of 4.5G and 5G. The Communication by the BIPT Council of 15 February 2013 on the radiation standards in the Brussels-Capital Region, and particularly its section 3, is still relevant.

The standards in Brussels forced operators to reduce the power of most of their base stations, impacting the coverage of networks (particularly indoors) and their ability to simultaneously cover the needs of a large number of users.

As fields produced by active networks already reach the limit in Brussels (6 V/m), it is impossible to bring more frequency bands into service. Furthermore, the standards in Brussels already have blocked the use of frequencies assigned to operators. The current networks (2G, 3G, 4G) are clearly saturated within the context of the current 6 V/m standard.

The standards in Brussels already have a negative impact on the provision of existing services, but they could especially very seriously hinder the advent of new services, such as 4.5G or 5G.

5. Evolution of the mobile telecommunications sector

5.1. Technological evolution

A new generation of mobile telecommunications standards appears each decade.

The use of mobile phones started in the 1980s. These mobile phones only allowed analogue voice calls. Several telecommunications standards of the first generation (1G) were coexisting and the frequency bands that were used were not really harmonised.

The second generation (2G) came in the 1990s. The 2G standards were initially intended for digital mobile telephony, even if the evolutions that followed allowed data transfer. In Europe, the 2G standard that is in use is the GSM standard and its evolutions (GPRS and EDGE).

The third generation (3G) came in the years 2000. The 3G standards essentially allowed mobile data transfer, in addition to mobile telephony. In Europe, the 3G standard that is in use is the UMTS standard and its evolutions (HSDPA, HSUPA and HSPA+).

With the arrival of the fourth generation (4G), we went from mobile data to broadband mobile data. In Europe, the 4G standard that is in use is the LTE standard and its evolution LTE-Advanced (4G+).

The deployment of 4.5G has already started. The 4.5G (LTE-Advanced Pro) standard is an evolution of the LTE standard, where several frequency bands are simultaneously used to increase the offered speed.

The fifth generation (5G) is intended to take over from the fourth generation in the years 2020. 5G is introduced as a breakaway generation, which is not a simple increase in speeds, as it was the case for the previous generations. In Europe, the 5G standard which will be used should be the NR standard[12]. It is no longer just about providing high-performing broadband voice and data connections to the general public, but also to digitise and interconnect a wide variety of economic and social sectors. In the context of 5G, these sectors are called “verticals”. This concerns among others the automotive industry, the security services sector, the energy sector, the health sector, the media, etc. Each sector will be characterised by specific communications needs. 5G will be a technology developed with this aim, from the design phase, and usable in all these various domains.

The specific technical features of 5G can be compared with those of 4G at three levels:

1. High-speed mobile connexions with a maximum speed (up to 20 Gbit/s as peak capacity and 100 Mbit/s for each user);

2. A highly improved latency or a faster response time (1 ms);

3. The number of connected objects (up to 1,000,000 objects per square kilometre).

This will lead to a strong improvement of mobile communications, extremely reliable networks for the Internet of Things and applications for which a very low latency is crucial, e.g. for autonomous vehicles.

5.2. Increase in traffic

The mobile data traffic has literally exploded in Belgium, from 3.86 billion megabytes in 2012 to 127.84 billion megabytes in 2017 (see figure 3)[13]. The average monthly data consumption in Belgium stays however far under the OECD average.

[12] *New Radio*.

[13] See “Situation of the electronic communications and television market in 2017”, section 5.

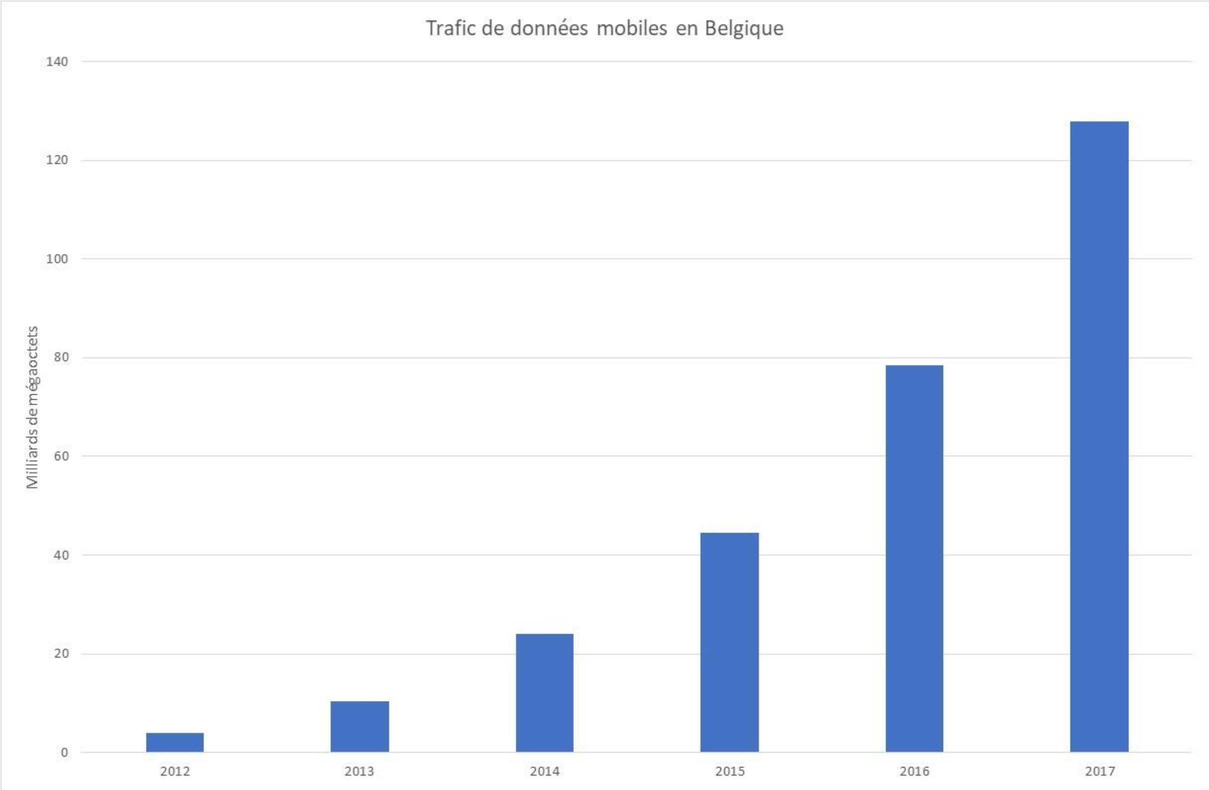


Figure 3 – Evolution of the mobile data traffic in Belgium between 2012 and 2017

This trend is likely to continue in the years to come. According to Ericsson's estimates, mobile data traffic in the whole of Western Europe should be multiplied by a factor of 7 between 2017 and 2023, going from 1,800 to 12,000 billion megabytes per month (see figure 4).

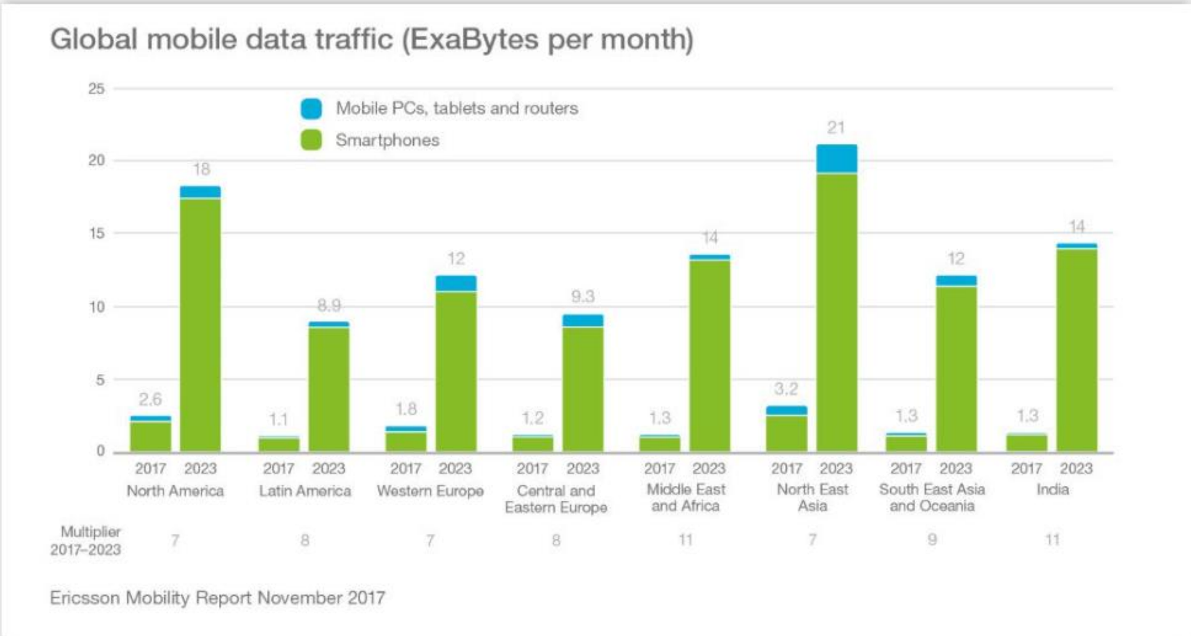


Figure 4 - Forecasting of the evolution of monthly mobile data traffic in Western Europe

5.3. Massive MIMO

The 5G technology introduces a new concept in mobile telephony: Massive MIMO. This is a technology that has been applied for several decades in other domains (e.g. military domains).

A mobile telephone network is traditionally composed of transmitting antennas built across the country. Per active operator, 3 antennas (per 2G, 3G or 4G technology) are generally on the mast, each of them ensuring the coverage of an area in a different direction around the mast.

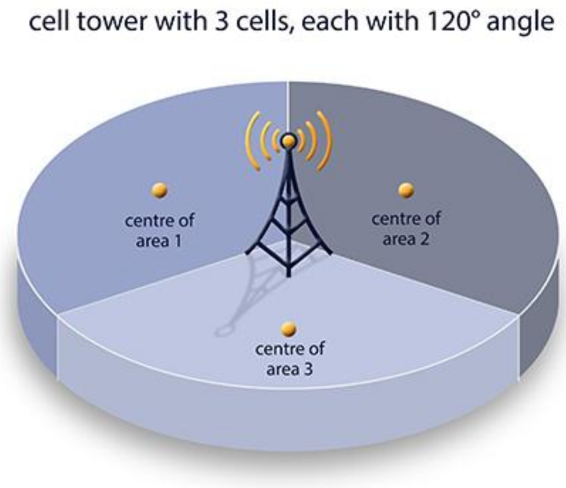


Figure 5 – Division in three cells of the area around a mast with three sectorial antennas (sources: http://wiki.opencellid.org/wiki/FAQ)

The MIMO (Multiple In Multiple Out) concept will use different antennas to cover a same antenna sector. This technique offers several advantages: increasing the speed per user (spatial multiplexing) or optimising the signal quality in locations that are difficult to cover (spatial diversity). Traditional MIMO techniques are already in use today in the mobile telephony sector: a 2x2 MIMO configuration is used in most 4G masts (allowing to double the speed). Even in 3G, the diversity of antennas was already used.

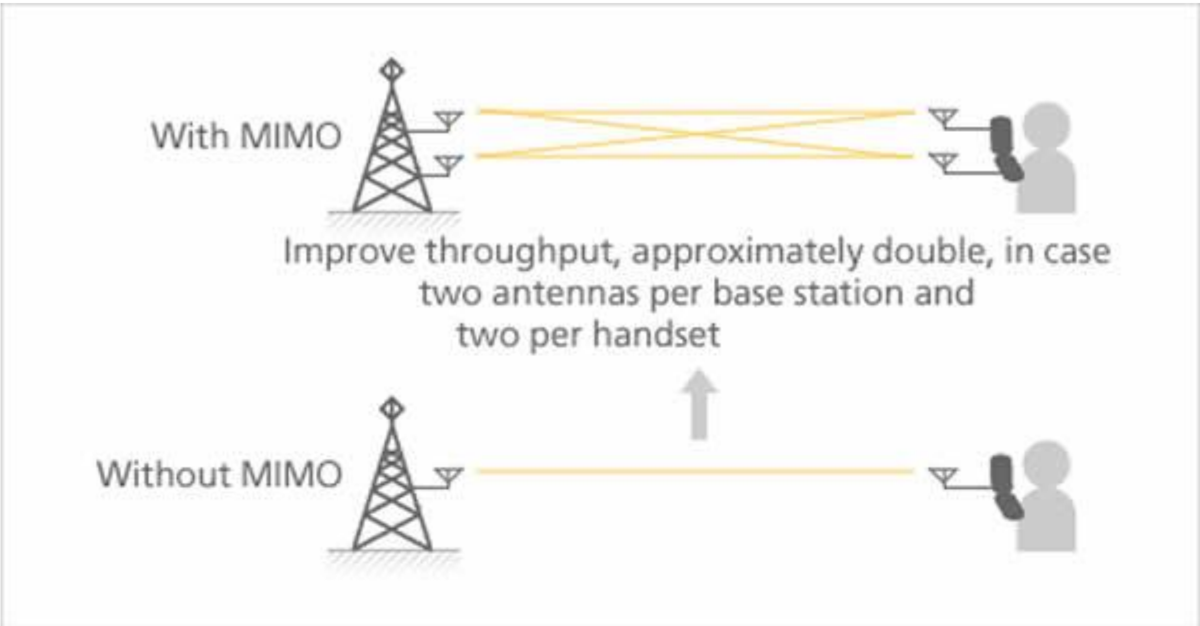


Figure 6 – Schematic illustration of the different connections without MIMO and for 2x2 MIMO (source: https://www.4g.co.uk/4g-lte-advanced/)

The major innovation brought by 5G is that several MIMO streams will be used to simultaneously send a different traffic to several users (multi-user MIMO). A large number of antennas is necessary to achieve this. Hence the name "massive" MIMO. Concerning classic MIMO, a number of antennas (2 or 4 for instance) are used to emit or receive, but in the case of massive MIMO, the base station will deploy numerous antennas (dozens, even up to 100) based on an array formation.

This allows to considerably expand the capacity of the base station without requiring more spectrum. The purpose is to serve several users at the same time based on separated antenna beams per user.

Massive MIMO is considered as one of the keys and basis components of a new modern 5G network.

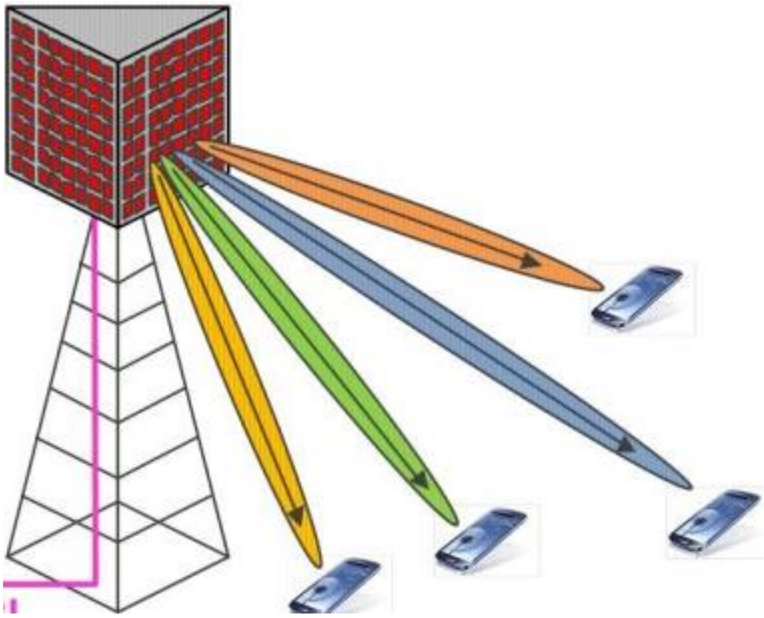


Figure 7 - [source: www.semanticscholar.org]

Contrary to traditional mobile telephony antennas, systematically transmitting all the signals uniformly to all users over their full cellular surface, the massive MIMO system will direct the signal to the mobile terminal for which it is intended. As a consequence, less energy is wasted as radiation is not emitted in directions where it is not necessary (as it is the case today). In other words, massive MIMO in 5G will temporarily raise the level of radiation on the user side, but there will be less constant radiation for all those who are in the coverage area of the mast.

6. Evolution of mobile telecommunications in Belgium

6.1. Current situation

Each of the three Belgian mobile operators has a 2G, a 3G and a 4G network. Each of these networks simultaneously uses a low band (under 1000 MHz) and a high band (over 1000 MHz).

The low bands are used to cover the whole territory and to ensure an indoor coverage as well. The high bands are generally used only where additional capacity is necessary.

Table 1 shows which technologies are deployed in which bands.

Technology	Bands used for coverage	Bands used for capacity
2G	900 MHz[14]	1800 MHz[15]
3G	900 MHz	2000 MHz[16]
4G	800 MHz[17]	1800 MHz

Table 1 – Bands used by mobile networks in 2018

For 4.5G, the 2000 MHz and/or 2600 MHz[18] bands will be used, in addition to the 800 MHz and 1800 MHz bands.

6.2. Multi-band auction

2G and 3G licences are valid until 15 March 2021. The 900 MHz, 1800 MHz and 2000 MHz bands will no longer be assigned from that date. These frequency bands are intensively used by mobile operators.

At the European level, three new bands are planned for the public mobile networks: 700 MHz[19], 1400 MHz[20] and 3600 MHz[21]. The 700 MHz and 3600 MHz bands are crucial for the deployment of 5G from 2020. The 1400 MHz band allows to offer additional downstream capacity.

BIPT will organise, most likely in 2019, one or several auctions for the six bands mentioned above.

It should be noted that these auctions represent an opportunity for a fourth mobile operator. In addition to the provision of new frequency bands, a considerable amount of spectrum will be reallocated.

6.3. Situation after 2020

Mobile operators will deploy 4.5G and 5G networks.

Table 2 shows which technologies are deployed in which bands.

Technology	Bands used for coverage	Bands used for capacity
2G	900 MHz	1800 MHz
3G	900 MHz	2000 MHz
4G	800 MHz	1800 MHz
4.5G	800 MHz	1800 MHz, 2000 MHz and 2600 MHz
5G	700 MHz	1400 MHz and 3600 MHz

Table 2 – Bands used for mobile networks after 2020

Once 2G and 3G technologies have disappeared, the 900 MHz and 2000 MHz bands can be used for 4.5G and 5G.

6.4. End of 2G and/or 3G

2G and 3G technologies are to disappear in the course of the years 2020.

[14] Paired frequency bands 880-915 MHz and 925-960 MHz.
[15] Paired frequency bands 1710-1785 MHz and 1805-1880 MHz.
[16] Paired frequency bands 1920-1980 MHz and 2110-2170 MHz.
[17] Paired frequency bands 852-862 MHz and 791-821 MHz.
[18] Paired frequency bands 2500-2570 MHz and 2620-2690 MHz.
[19] Paired frequency bands 703-733 MHz and 758-788 MHz.
[20] Frequency bands 1427-1517 MHz.
[21] Frequency bands 3400-3800 MHz.

3G will only be ended once the number of non-compatible 4G smartphones has become negligible[22].

In Belgium, the number of 2G mobile phones is still high. Furthermore, numerous M2M[23] clients still use 2G modems. The end of 2G will certainly raise more problems than the end of 3G. It is thus very likely that 3G will disappear before 2G.

Finally, the end of 2G would prevent a large number of foreign visitors to connect via roaming to Belgian mobile networks.

Today, 2G, 3G or VoLTE[24] can be used for voice calls. The complete end of 2G and 3G technologies requires that all terminals support VoLTE.

It should be noted that if we turn off a 2G or a 3G network, the traffic supported by that network will not disappear and will have to be taken up by another network. As a consequence, the radiation produced by the 2G and 3G networks will be replaced by radiation produced by another network.

It is thus hardly imaginable to abandon 2G or 3G in the short term. In all cases, abandoning 2G and 3G before deploying 5G is not realistic.

7. Evolutions of the standards in Brussels

7.1. General

The increase in mobile data traffic has inevitably an impact on the radiated powers of operators' antennas. Indeed, according to fundamental physics, a certain level of minimum power is necessary to transmit one bit of information (voice or data). Taking into account the same level of efficiency and with the same transmission sites, the radiation level of antennas is thus proportional to the data rate.

However, if there is no lowering of the standards in Brussels, mobile data traffic will not be able to keep on growing, regardless of the technology/technologies deployed. The current radiation standards in Brussels do not allow to ensure a future high-performing quality network, even with only today's technologies.

Adding new transmission sites will allow to somewhat ease the problems. However, in addition to the extra charge for the operator, and thus for the consumer, the construction of new antennas is problematic for operators. Indeed, the extremely stringent standard in Brussels did not reassure the population, on the contrary. It has thus become extremely difficult for operators to find new transmission sites. Furthermore, the administrative procedures are very complex.

The disappearance of the 2G and 3G technologies will surely allow to increase the spectral efficiency for the use of the 900 MHz and 2000 MHz bands. However, this increase alone will not allow to cope with a 7-fold increase of the mobile data traffic. On the one hand, this increase is limited to two frequency bands. On the other hand, 2G and 3G technologies have undergone constant change and their spectral efficiency has already evolved considerably compared to the initial deployments. The disappearance of the 2G and 3G technologies would therefore not allow to make more room for 5G, in terms of radiation quotas.

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[22] In 2017, in Belgium, slightly over 79% of active SIM cards of mobile network operators used mobile data. 70.4% of these SIM cards generate 4G traffic ("Situation of the electronic communications and television market in 2017", section 5). This suggests that 23% of SIM cards are used with smartphones (or tablets/PC) that are not 4G compatible.

[23] By the end of 2017, the number of M2M SIM cards in Belgium amounted to 2,384,188 ("Situation of the electronic communications and television market in 2017", section 5).

[24] VoLTE (Voice over LTE) is the main technique for 4G voice calls. All 4G terminals do not support VoLTE.

7.2. Massive MIMO

As shown in figure 7, a massive MIMO antenna will concentrate its energy far more than a classic antenna for 2, 3 or 4G. Exposure to power will then be 5 times[25] higher, with a theoretical calculated field strength which is more than doubled, and this only because of the new antenna.

As mentioned above, massive MIMO uses a large number of antennas to direct the signal of the mast to the mobile terminal for which it is intended. This represents a major difference compared to the current situation, also in terms of exposure. Today, a person inside a mobile network cell will be subjected to a certain field strength from the mast, whether this person uses or not the mobile network. Things will be different with a massive MIMO antenna operating in 5G. A person who does not use the network (at a given time) will be subjected to a significantly lower field strength.

The permanent exposure generated by a traditional network cell at a given place disappears and is "replaced" by a stochastic exposure (sequence of random states). The beam goes from one place to another according to the person to serve at that moment. The exposure at a given place has thus become an ostensibly random event. As a consequence, traditional calculations allowing to determine the exposure based on the cell power and the type of antenna, and allowing to determine a permanent exposure in only one calculation, become obsolete.

Exposure becomes random (stochastic), which means that statistical analysis methods will have to be used to characterise the exposure. Such an analysis has already been carried out and suggests with a high probability (95%) that a random exposure (at a random place) will be 4 times lower (6dB) compared to the exposure calculated based on the traditional method[26].

This 6dB value is adopted in the IEC 62232[27] standard.

Taking this correction factor of 6dB into account is defensible as a higher field strength is only experienced in exceptional cases. Furthermore, the monitoring of radiation standards is generally based on a measurement of the average during a certain period, so that the inclusion of these 6dB gives a value which better matches with the measurements.

7.3. Optimal limits (rated power, maximum quality)

In this section, we examine what the field strength would be if a mast was equipped with all the current technologies (including 4.5G) and 5G, so that all technologies can operate with maximum quality (i.e. at the rated power).

A typical site will not necessarily use all these technologies in all the bands at full power. The operator will decide on a case-by-case basis which bands and powers should be used. In most cases, these exposure values will not be reached. This simulation shows the situation when the operator wishes to have all the maximum possibilities.

To that end, we use the following hypotheses (per operator) – the 6 dB correction for massive MIMO coming from the IEC62232 standard, as explained in section 7.2:

[25] A typical 4G antenna has a gain of about 17dBi, whereas a massive MIMO antenna in 5G will have a gain of about 24dBi. This means a difference of 7dB (which is equivalent to an increase by a factor of 5).

[26] Given the fact that mobile services are not constantly used at their maximum speed, that people move and that users are distributed more or less proportionally in the cell, scientific studies show, with a probability of 95%, that the radiation level experienced by the people in the cell is at least times 4 times (6dB) lower (it is even significantly weaker in many cases) than the maximum level inside the cell (which thus moves in a stochastic manner).

[27] IEC 62232:2017 "Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure".

Technology Band	NR 700	LTE 800	GSM 900	UMTS 900	NR 1400	LTE 1800	LTE 2000	LTE 2600	NR 3600
Power (W)	CONFIDENTIAL – CONFIDENTIAL – CONFIDENTIAL								
Tx ratio	1	1	1	1	1	1	1	1	0.7
Correction factor (dB)[28]	3	3	8	3	3	3	3	3	6
Antenna gain (dBi)[29]	16.5	17	17	17	16	17	17.5	17.5	24

Table 3 - Hypotheses

To calculate the field strength, we use a street with a width of 22 metres. The antenna is located on the roof of a building on one side of the street and the nearest point that is accessible to the public is the roof of the building across the street. The antenna is located 1 metre back from the frontage of the building where it is installed. We then obtain a distance of at least 23 metres between the antenna and the site that is accessible to the public.

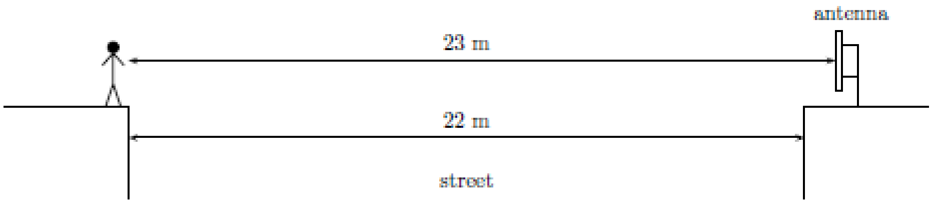

Figure 8 - Typical scenario in urban environment

Based on the configuration above, we obtain the following field strengths (recalculated at 900 MHz, according to the method described in annex 1), depending on the case:

	Per operator	Total for 3 operators
Without 5G/NR	17.7 V/m	30.7 V/m
With 5G/NR	24.0 V/m	41.5 V/m
5G/NR only	16.1 V/m	27.9 V/m

Table 4 - Generated fields

It should be noted that even with a correction factor of 6dB for massive MIMO, the contribution of the 3600 MHz band is the most important by far and vastly exceeds the limits imposed in the Flemish and Walloon regions.

The radiation generated by 5G only is equivalent to the radiation generated by all the other technologies (2G, 3G, 4G and 4.5G).

It is considered that a base station is impacted by the radiation standard if it cannot transmit at its rated power. As a reminder, decreasing the power of a base station affects coverage (particularly indoors) and the ability to simultaneously cover the needs of a large number of users.

[28] These values were taken over from the Decree of the Government of the Brussels Capital Region of 30 October 2009 on certain antennas emitting electromagnetic waves, except for the 6 dB value for the massive MIMO, taken over from the IEC62232 standard.
[29] Concerning the antenna gain, the values have been taken over for the base station antenna type EOOOO17X65V12D10 of the company Gamma Nu.

To ensure that a base station as represented in figure 8 is not affected and can continue to transmit at its rated power, a cumulative limit of at least 30.7 V/m, without the introduction of 5G, or of 41.5 V/m, with the introduction of 5G, would be necessary. The 41.5 V/m limit almost corresponds to the international recommendations (41,25 V/m).

Figure 9 shows, according to the cumulative limit in force, the distance at which a transmission site should be standing from the areas accessible to the public, in order to avoid any impact (with three operators active on the site).

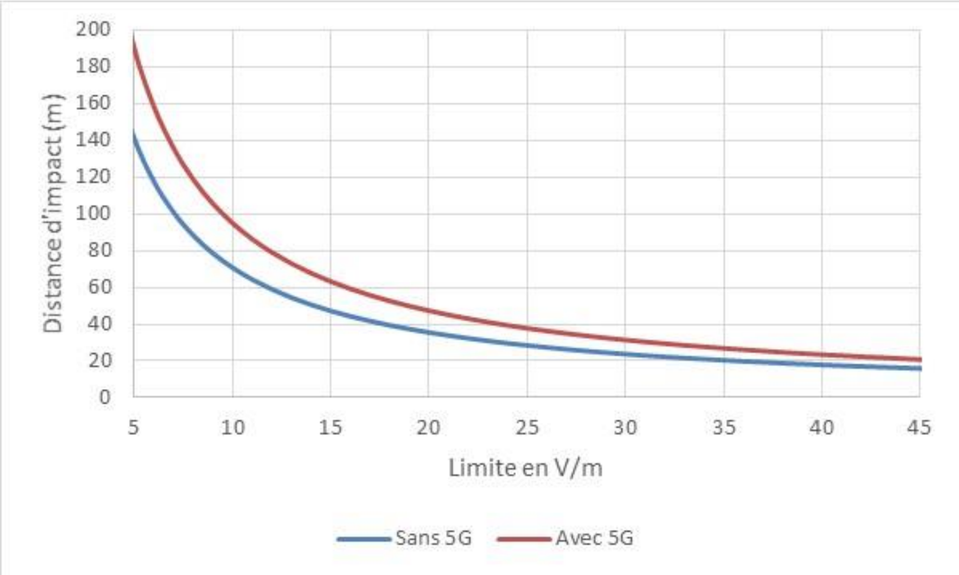

Figure 9 – Impact distance depending on the radiation limit

Figure 10 shows, depending on the cumulative limit in force, the reduction in power, compared to the rated power (for a base station as shown in figure 6), that is necessary to comply with the radiation standard in force.

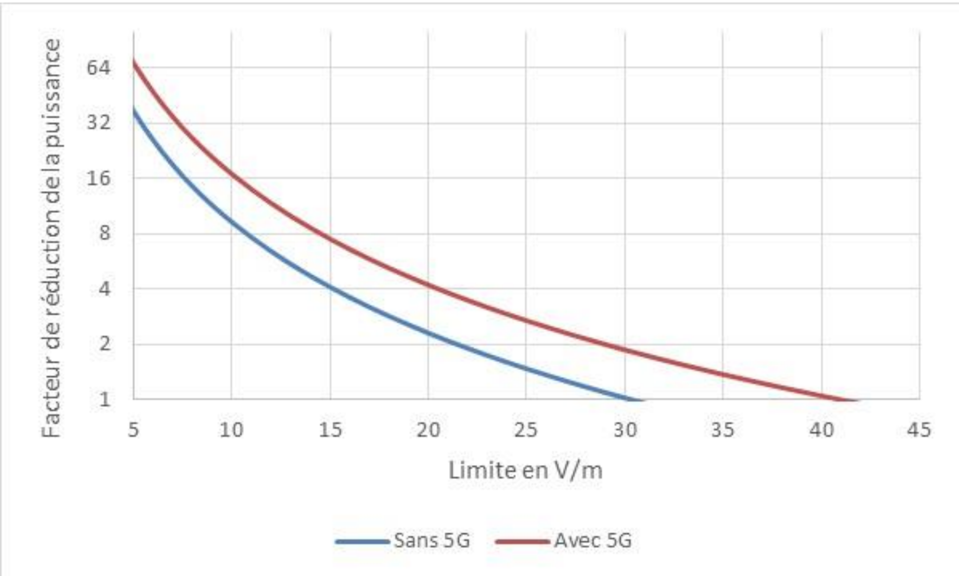

Figure 10 – Necessary reduction in power depending on the radiation limit

7.4. Conservative limits (current power per MHz, current quality)

Currently, the operators use together 185 MHz duplex[30] in FDD[31] for their 2G, 3G and 4G networks. The base stations of all mobile networks are thus transmitting in a total of 185 MHz.

In the medium term, operators will use additional spectrum: 100 MHz duplex[32] in FDD, 380 MHz[33] in TDD[34] and 90 MHz[35] in SDL[36]. The base stations of all mobile networks are transmitting in a total of 375 MHz plus 380 MHz during 75% of the time (by assuming a 3:1 asymmetry), namely in the equivalent of 660 MHz[37].

The quality of a radio link depends, among other things, on the power spectral density, that is to say the power transmitted per Hz. It is essential not to force operators to reduce the power spectral density delivered to antennas.

For the 3600 MHz band, operators will use massive MIMO antennas. The maximum gains of these antennas should reach about 24dBi, namely around 7dB higher than the maximum gain of traditional antennas (see section 7.2). In practical terms, the maximum field produced is $\sqrt{5}$ times higher than with a traditional antenna. It is imperative that the calculation method, set in the implementation orders, be adapted in order to take the massive MIMO antennas into account.

If the calculation method does not take the massive MIMO antennas into account, the power-flux density limit (expressed in W/m^2) must be multiplied by the ratio between (375 + 285 x 5) and 185[38], which corresponds to a cumulative limit of 0.934 W/m^2 (or 18.7 V/m) at 900 MHz.

If the calculation method allows to take the massive MIMO antennas into account by applying a corrective factor of 6dB (see section 7.2), the power-flux density limit (expressed in W/m^2) must be multiplied by the ratio between (375 + 285 x 2.5) and 185[39], which corresponds to a cumulative limit of 0.564 W/m^2 (or 14.5 V/m) at 900 MHz.

The above-mentioned limits should only allow not to increase the number of base stations which are impacted due to the radiation standard, i.e. the number of base stations which cannot transmit at their rated power. However, we know that the number of base stations that are impacted is very high. These limits should indeed allow a certain deployment of 5G in Brussels under conditions which could be similar to the conditions of deployment of 4G in recent years. However, we know that the conditions for the deployment of 4G, in order to comply with the imposed standards, led to an underutilisation of the potential of installations and, as a consequence, to an inefficient use of the scarce resources for the provision of a quality service to users. These limits represent then a threshold below which it is hardly conceivable to go without spoiling a minimum quality, but they would certainly not allow an optimal development of the telecommunications sector and should therefore be revised upwards in the short term, otherwise network congestions may quickly appear.

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[30] 30 MHz duplex in the 800 MHz band, 35 MHz duplex in the 900 MHz band, 75 MHz duplex in the 1800 MHz band and 45 MHz duplex in the 2000 MHz band.
[31] *Frequency Division Duplex*.
[32] 30 MHz duplex in the 700 MHz band and 70 MHz duplex in the 2600 MHz band.
[33] 380 MHz in the 3600 MHz band.
[34] *Time Division Duplex.*
[35] 90 MHz in the 1400 MHz band.
[36] *Supplemental Downlink*.
[37] 375 MHz + 0,75 x 380 MHz.
[38] 24 dBi - 17 dBi = 7 dB (or 5).
[39] 24 dBi - 17 dBi - 6 dB (corrective factor massive MIMO) + 3 dB (corrective factor LTE) = 4 dB (or 2,5).

8. Conclusions

For the deployment of 5G, it is imperative that the calculation method, set in the implementation orders, be adapted in order to take the massive MIMO antennas into account. This applies to the Flemish and Walloon regions, but also to the Brussels-Capital Region.

The 6 V/m standard does not allow to deal with the expected increase in mobile data traffic, regardless of the technology used to transport this data. It does not allow to ensure a future high-performing quality network with the technologies that are used today. Adding new transmission sites will certainly allow to somewhat ease the problems. However, besides the extra cost for the operator, and consequently, in the end, for the user, the construction of new antennas will remain difficult and will not provide an effective solution. Without any modification of the radiation standard in Brussels, network coverage and the ability of networks to simultaneously cover the needs of a large number of users will be significantly affected.

The 6 V/m standard does not allow to deploy 5G in Brussels. 5G alone should be able to generate at least as much radiation as what is generated by the technologies that are currently in use.

It is hardly imaginable to abandon 2G or 3G in the short term. In all cases, abandoning 2G and 3G before deploying 5G is not realistic. Anyway, the disappearance of the 2G and 3G technologies would not allow to make room for 5G.

BIPT strongly advises against a cumulative limit under 14.5 V/m at a frequency of 900 MHz. A conservative limit of 14.5 V/m should only allow the start of a minimum deployment of 5G in Brussels under conditions that are relatively similar to the deployment conditions of 4G in recent years, which have proven to be insufficient. Furthermore, the 14.5 V/m limit is a threshold that will have to be rapidly revised upwards as it will impose a limit to the current evolution in terms of data consumption, which will lead to a congestion at the level of the radio access to the network quicker than in other locations. Finally, the conservative limit of 14.5V/m implies that massive MIMO antennas are taken into account by applying a corrective factor of 6dB.

Therefore, BIPT proposes to adopt the standard above 14.5V/m and up to 41.5V/m. The closer we get to the European standard, the more it will guarantee the capacity and the quality of mobile networks, and it will thus also ensure the user experience for the final clients. This will allow us to be among the European leaders concerning the deployment of 5G.

Annex 1: Comparison of national standards

Brussels-Capital Region

For the Brussels-Capital Region (cumulative limit), we use an average of the limits for the different technologies/frequency bands.

Technology/band	Centre frequency (MHz)	Limit (W/m²)	
		Currently	After 2020
NR700	773.0		0.08245
L800	806.0	0.08597	0.08597
G900	942.5	0.10053	0.10053
U900	942.5	0.10053	0.10053
NR1400	1472.0		0.15701
G1800	1842.5	0.19653	0.19653
L1800	1842.5	0.19653	0.19653
U2000	2140.0	0.22000	0.22000
L2600	2655.0		0.22000
NR3600	3600.0		0.22000
Average		**0.15002**	**0.15796**

Flemish Region

For the Flemish Region (limit per antenna), we add up the limits of the different antennas[40].

Antenna	Centre frequency (MHz)	Limit (W/m²)	
		Currently	After 2020
NR700	773.0		0.02052
L800	806.0	0.02139	0.02139
G900	942.5	0.02502	0.02502
U900	942.5	0.02502	0.02502
NR1400	1472.0		0.03907
G1800	1842.5	0.04891	0.04891
L1800	1842.5	0.04891	0.04891
U2000	2140.0	0.05328	0.05328
L2600	2655.0		0.05328

[40] One antenna per technology and per frequency band.

Antenna	Centre frequency (MHz)	Limit (W/m²)	
		Currently	After 2020
NR3600	3600.0		0.05328
Total (3 operators)		**0.66756**	**1.16599**

Walloon Region

For the Walloon Region (limit per antenna), we add up the limits of the different antennas[41]. When a technology is used in multiple frequency bands, we then use for this technology (antenna) an average of the limits for the different frequency bands.

Technology/band	Antenna	Limit (W/m²)	
		Currently	After 2020
NR700	NR		0.02389/3
L800	LTE	0.02389/2	0.02389/3
G900	GSM	0.02389	0.02389
U900	UMTS	0.02389/2	0.02389/2
NR1400	NR		0.02389/3
G1800	DCS	0.02389	0.02389
L1800	LTE	0.02389/2	0.02389/3
U2000	UMTS	0.02389/2	0.02389/2
L2600	LTE		0.02389/3
NR3600	NR		0.02389/3
Total (3 operators)		**0.28668**	**0.35835**

[41] One antenna per technology.

Annex 2: Calculation method used to obtain the optimal limits

The field strength at a given R distance from a transmission antenna, with a G_{TX} gain transmitting with a given P_{TX} peak power is determined based on the free space formula:

$$E_{eff} = \frac{\sqrt{30 \, P_{Tx} \, G_{Tx}}}{R}$$

This field strength is then multiplied by the T_X (TDD) ratio and, if applicable, corrected based on the correction factors of the Decree of the Government of the Brussels Capital Region of 30 October 2009 on certain antennas emitting electromagnetic waves.

Then, to obtain an equivalent field strength at 900 MHz, the following conversion is applied, which is also in accordance with the ICNIRP approach:

$$if \ f < 400MHz\text{:} \ E_{eff,900} = \sqrt{\frac{900}{400}} \times E_{eff}$$

$$if \ 400MHz < f < 2GHz\text{:} \ E_{eff,900} = \sqrt{\frac{900}{f}} \times E_{eff}$$

$$if \ f > 2GHz\text{:} \ E_{eff,900} = \sqrt{\frac{900}{2000}} \times E_{eff}$$

All the field strengths referenced at 900 MHz can then be combined for the different technologies in the different frequency bands, and this based on the following formula:

$$E_{eff,900,total} = \sqrt{\sum_i E_{eff,900,i}^2}$$

Assuming that the three operators use a similar configuration, the total field strength distributed among all the operators will then be a factor$\sqrt{3}$ that is superior to the total field strength per operator.