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Exposure of the South Korean population to the 5th generation (5G) of mobile phone networks (3.4 to 3.8 GHz) and its respective contribution among other radio frequencies in the country.

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Abstract

The race to install and deploy 5G has taken an important turn in industrialized countries. Certain countries have taken the lead, and 5G is already operational in these locations. South Korea is among those countries that have already deployed 5G. In this study, we conducted experimental measurements of exposure to electromagnetic fields in this country to see the contribution of 5G compared to other frequencies such as 2G, 3G and 4G. The results of the study showed that the emission of 5G is about 15% of the global level. The highest level was observed in the vicinity of the antenna and remains below the limits set by ICNIRP.

Keywords: 5G, 3.4-3.8 GHz, radiofrequencies, electromagnetic field

1. Introduction

5G is the next generation of mobile networks introduced by the electronic and wireless communications industry and standards organizations. It corresponds to the requirements of the International Telecommunication Union (ITU) called "IMT-2020", which defines the main categories of performance that these new technologies will achieve. This new mobile technology is expected to provide high quality services such as high-speed, low-latency, efficient and reliable mobile networks.
If the implementation of this new technology on new frequencies brings more capacity to mobile networks, 5G will make several important technological breakthroughs in the field of wireless electronic communications, such as.

1) ultra-mobile broadband (eMBB: enhanced Mobile Broad Band); combined with higher frequencies, theoretical speeds will be at least 10 times higher than those of existing technologies;
2) massive internet of things (IoT) (mMTC: massive Machine Type Communication). 5G should allow a high density of connected objects per surface as well as the simultaneous connection of a very large number of objects. Additionally, it is expected to have greatly reduced energy consumption, which will substantially increase the duration of the battery life of the objects thus connected;
3) ultra-reliable and very low latency network (uRLLC: ultra-Reliable Low Latency Communication); this segment brings together the use cases requiring guaranteed network access and very high reactivity, and therefore very low latency, for the communications carried by the 5G connection;
4) the "tailor-made network"; this last notion concerns the technology known as "network slicing", which allows both the end-to-end management of a quality of service and the organization of networks so that services which require different performances can coexist on the same network.

Based on this improved performance, the development of new innovative services is expected; these services could not have been provided with existing technologies, or in any case, not with the same ease or flexibility.

In 2016, the European Commission launched an action plan aimed at defining a common European calendar for the launch of the first 5G networks. The aim is to free up and allocate so-called “pioneer” frequencies for 5G (700 MHz, 3.5 GHz and 26 GHz) in order to be able to launch 5G commercial services in each country of the European Union before the end of 2020.
The present study is meant to characterize the exposure of people to non-ionizing radiation from these new networks in an area where its commercial exploitation is already fully effective. As of April 2019, South Korea has entered the commercial exploitation phase of these networks. Therefore, we decided to characterize the exposure of people to 5G in South Korea, since it had the greatest maturity in terms of users, coverage and implementation. The frequency rolled out for 5G in South Korea is the same as the frequency chosen in France for network start-up, i.e., 3.5 GHz (3.4 to 3.8 GHz).

The measurements were carried out at the end of November 2019 in collaboration with the Korean institute in charge of telecommunications regulation, the National Radio Research Agency (NRRA), 6 months after the opening of the network to Korean public customers. This collaboration provided an initial vision of the organization of the 5G service, distinction between the antennas of the various Korean operators and information on the distribution of antennas in the country. The measurements carried out were exposimeter measurements, global exposure measurements and spectral measurements. We made these measurements in several different areas of activity and in two South Korean cities representing two different types of urban environment: South Korea's largest city, Seoul, and a smaller city, Naju.

In addition, measurements were made during transportation and at a fixed-point for different durations.

2. Materials and Methods

General data on the 5G network in South Korea
The three main operators that activated their 5G services in South Korea were KT, SKT (SK Telecom) and LGU+ (LG Uplus). LGU was allotted the frequencies 3.4 to 3.5 GHz, KT was given 3.5 to 3.6 GHz and SKT was given 3.6 to 3.7 GHz. However, these different operators have made different choices for the manufacturers of the base stations that constitute their 5G network. Available information on the number of base stations of the operator KT on November 24, 2019 is listed in Table 1. This table shows the number of base stations spread over the largest Korean cities at that time. The city of Seoul and its metropolitan area have the largest number of base stations. As seen in Table 1, Samsung had 81% of the total antennas deployed for 5G in South Korea, while Ericsson and Nokia had 11% and 8%, respectively (data retrieved on Nov. 24, 2019).

Region	Number of KT 5G base stations
All over the country	38999
Seoul	9878
Seoul metropolitan area (Incheon)	11716
Gangwon-do	1107
Chungcheong-do	3529
Jeolla *(Naju is a city in South Jeolla Province)*	3124
Gyeongsang-do	9241
Ile de Juju	404

Table 1. Geographic repartition of base stations

Areas covered by measurements

To ensure the representation of the diversity of environments encountered throughout South Korea, different environment types where exposure measurements should be carried out have been identified. These different areas were the following:
- Rural residential area—Old town of Naju,
- Rural administrative area—Old town of Naju,
- Rural commercial area—Old town of Naju,
- Urban residential area—New city of Naju,
- Urban business area—New city of Naju,
- Urban commercial area—New city of Naju,
- Dense urban residential area—Seoul,
- Dense urban business zone—Seoul,
- Dense urban commercial area—Seoul.

In parallel to these zones representing different environments, we decided to carry out measurements during car/bus and train journeys, as 5G-NR technology can offer a high availability of its network on these transport routes.

Measurements at fixed points over 12 h or 24 h were carried out to consider the variability of the traffic according to the time of day.

The measurement equipment
To perform the dosimetry recordings, two devices were used: ExpoM-RF Dosimeter (from Fields at Work, Switzerland; 88-5875 MHz = ExpoM) and EME Spy 200 Dosimeter (from MVG/EME SPY 200, France; 88-6000 MHz = EME Spy). These dosimeters are programmed to acquire the electric field of several services, including 5G-NR (New Radio), 5G TDD (Low Band) B42TDD 3400-3600 MHz and 5G TDD (High Band) B43TDD 3600-3800 MHz.

The sensitivities of these dosimeters are
EME Spy: 0.05 V/m (80 MHz – 0.7 GHz, 3 GHz – 6 GHz); 0.02 V/m (0.7 GHz – 3 GHz)
ExpoM: 0.005 V/m (470 MHz – 1900 MHz); 0.003 V/m (1920 MHz – 3600 MHz)

3. Results

Table 2 presents data for 5G TDD low band (LB) measurements in different geographical areas in South Korea, with two dosimeters (ExpoM and EME Spy). The average levels of 5G TDD (LB) varied according to the type of environment and area. These values varied from 20 to 560 mV/m with the ExpoM and between 20 and 70 mV/m with the EME Spy. However, the 5G TDD high band (HB) measurements, which are presented in Table 3, were only performed with the EME Spy, since the ExpoM dosimeter can't measure EMF in this band. EMF average levels measured in different locations were quite equal (20 to 30 mV/m), except when they were measured close to a 5G-NR base station (170 mV/m).
The variability of the traffic has been estimated by the 24-hour measurement at a fixed point (Table 4). We can see that the maximum recorded EMF level for 5G was 130 mV/m. Figure 1 represents the temporal variation over 24 h of the 5G TDD low band level measured with the ExpoM-RF.
Tables 5 and 6 represent the 5G maximum level and the 5G power channel measurement, either on the building roof at 15 m from the antenna or in the street at 150 m (in the main lobe of the 5G antenna beam) from where the 5G antenna was set. They present the evolution of the electric field levels as a function of the measurement parameters (bandwidth, type of antenna, etc.) and of the settings of the 5G antenna, considered at nominal power or at maximum power.

Evaluation type	Global level for all the services [mV/m]	5G TDD (LB) Average level [mV/m]	5G TDD (LB) Maximum level [mV/m]	5G TDD (LB) SD [mV/m]
Dense Urban zone	1850	140	2140	160
	1740	70	2060	130
Rural zone	340	20	800	50
	120	20	90	2
Urban zone	470	20	260	30
	120	20	100	7
Close to 5G-NR base station	1040	560	2580	670
	300	50	2550	170
Railway line (Seoul – Naju)	370	20	730	30
	500	20	90	3
Urban trip	810	50	1550	60
	190	20	300	10
Extra urban trip	280	20	500	40
	120	20	90	4

SD: Standard deviation, LB: Low Band

Table 2. 5G TDD low band measurements in different geographical areas. First line measurements were performed with the ExpoM (blue backwall) and second line measurements with the EME Spy (white backwall).

Evaluation type	Global level for all the services [mV/m]	5G TDD (HB) Average level [mV/m]	5G TDD (HB) Maximum level [mV/m]	5G TDD (HB) SD [mV/m]
Rural zone	120	30	150	20
Urban zone	120	30	520	20
Close to 5G-NR base station	300	170	4090	550
Railway line (Seoul – Naju)	500	20	160	8
Urban trip	190	30	3440	60
Extra urban trip	120	30	350	20

HB: High band;

Table 3. Electric field measurement for 5G TDD high band within different geographical areas (performed only with the EME Spy).

Evaluation type	Equipment	Global level for all the services [mV/m]	5G TDD (LB) Average level [mV/m]	5G TDD (LB) Maximum level [mV/m]	5G TDD (LB) SD [mV/m]
At fixed point	ExpoM-RF	590	5	130	4
	EME Spy 200	340	≤20	≤20	0.0

Table 4. Temporal variability at a fixed-point exposure over 24 h for 5G TDD low band (EME Spy and ExpoM).

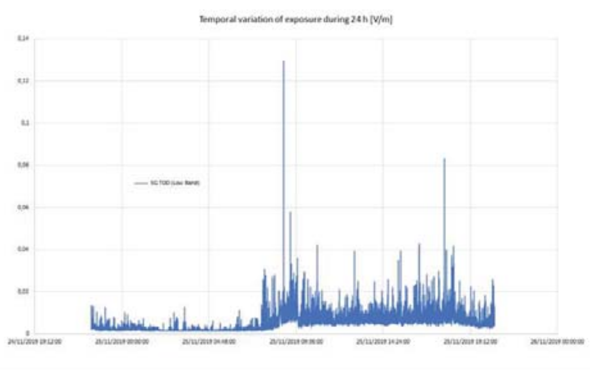

Figure 1. Temporal variation of exposure during 24h.

Measurements	Power Channel [mV/m] BW around 3.55 GHz	
	BW 20	BW 100
RMS measurement around KT central frequency with a horn antenna	300	680
RMS measurement around KT central frequency with a horn antenna (max. hold mode)	590	1310
Power channel measurement around KT central frequency at 5G base station max. power	290	
Power channel measurement around KT central frequency at 5G base station initial power	170	

BW: Bandwidth

Table 5. 5G maximum level and 5G power channel measurements on the building roof at 15 m distance from where the 5G antenna was set.

Measurement	Power Channel BW around 3.55 GHz [mV/m]	
	BW 20	BW 100
RMS measurement around KT central frequency with a horn antenna	14	37
RMS measurement around KT central frequency with a horn antenna (max. hold mode)	17	73
Power channel measurement around KT central frequency at 5G base station max. power	15	

Table 6. 5G maximum level and 5G power channel measurements carried out in the main lobe of the 5G antenna beam, in the street at 150 m from the antenna.

Measurement point	Level in the bandwidth 100 kHz – 6 GHz [V/m]	Comments
1 (15 m from the antenna)	12.1	KT base station initial power
1	21.0	KT base station max. power
2	8.8	KT base station max. power
3	3.8	KT base station max. power
4	4.7	KT base station max. power

Table 7. Wide band electric field with a 100 kHz–6 GHz field meter on the roof, close to the antenna (15 m). GPS coordinates: 35° 01’17.45’’N/126° 47’37.50’’E; At the corner of Hanbit Road and Bitgaram Road; Level R + 6; NAJU - SOUTH KOREA (See Figure 2).

Figure 2. Wide band electric field test site

4. Discussion

As far as we know, this measurement campaign in South Korea is the first one carried out to determine the contribution of the newly deployed 5G-NR to human EMF exposure. These measurements were carried out by a field meter and exposimeters to determine the global exposure measurements and spectral measurements in several different areas of activity in two South Korean cities: Seoul and Naju.
When assessing EMF exposure, it is of interest not only to address the radiation emitted by cellular network antennas, but to compare it to the cumulative radiation emitted by various RF signal sources. Moreover, the human body is affected by the cumulative EMF: therefore, all signals belonging to different radio technologies that were present during our measurements have been included in the cumulative EMF exposure level.
As a result, our EMF measurement methodology has considered all RF signal sources, including those operating in different radiocommunication systems that coexist in a given area.
It appears that the contribution of 5G-NR to the EMF global exposure is small in comparison to other frequencies. Indeed, the measurements carried out in Seoul and in different geographical areas of Naju showed that this contribution is less than 15% of the global exposure in rural and urban zones, and it was the same during the trip outside of the city. However, 5G exposure in the urban trip (the trip inside of the city) was also about 15% of the global exposure.
Our results show that 5G exposure levels were under the exposure limit set by ICNIRP. Indeed, for 5G, the threshold is 39 V/m at 700 MHz and 61 V/m at 3.5 GHz and 26 GHz. Our data show that the maximum exposure measured in the vicinity of the base station on the roof was still below the threshold exposure limit set by ICNIRP, and at moving positions in the nearby street, it was far below this level (below 0.08 V/m).
In the different areas where the measurements were performed, it appears that the largest contribution to the measured exposure levels comes from the frequencies of the previous generations of mobile technology (2G, 3G and 4G). The highest level we observed in the band used for 5G was 25% of the global level.

Measurements over 24 h at a fixed point showed that the EMF emission from the base station is usually stable over time, at around 5 mV/m, except during rush hours, which are concentrated in the morning (around 8-9 am), where exposure increases up to 130 mV/m, and in the evening (around 6-8 pm), which shows only a two-fold increase compared to the median day and night time level. It can also be seen in this location that 5G is a very tiny part of the global exposure. The variability is in part due to the adaptability of the antenna power to the traffic during the entire 24 hours of measurements.

Measurements with a field meter in the vicinity of the 5G-NR base station were found to be 12 V/m (at 15 m from the antenna) with its initial power. This value increased to 21 V/m when the antenna was at its maximum power at the same distance. The exposure level remained under the ICNIRP limit.
This is in line with some experimental studies based on measurements recorded from operational mobile networks that have highlighted that for 2G, 3G and 4G systems, a base station's output power rarely reaches values close to the theoretical maximum [Joshi et al., 2015; Colombi et al., 2013].

The results with the two different dosimeters, ExpoM-RF and EME Spy 200, present some variability. This is mainly attributed to the different sensitivity thresholds of each device when the ambient exposure is close to this threshold. However, at significant exposure levels, the measured values converge.

This study is a preliminary study because electromagnetic field measurements were carried out only 6 months after the opening of the network to the Korean public. It is therefore likely that the 5G network was not being used to its maximum, the number of subscribers being still relatively low and given the tendency of young people to use Wi-Fi spots for free services. It will be necessary to repeat EMF measurements to monitor the overall trends in the long term. Nevertheless, it appears from this study that the exposure levels from 5G were in a low range. Moreover, the fact that the radio signal beam will be mainly focused on the terminal users will contribute to reduce exposure in unnecessary areas.
This work is part of a work realized during a measurement campaign in South Korea (final report: Rapport expertise, 10 Mai 2019).

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5. References

Joshi P, Agrawal M, Thors B, Colombi D, Kumar A, and Törnevik C. 2015. Power level distributions of radio base station equipment and user devices in a 3G mobile communication network in India and the impact on assessments of realistic RF EMF exposure. IEEE 3:1051-1059.

Colombi D, Thors B, Persson T, Wirén N, Larsson L-E, Jonsson M, and Törnevik C. 2013. Downlink power distributions for 2G and 3G mobile communication networks. Radiation Protection Dosimetry 157 (4): 477–487.

Rapport d'expertise. 2019. Mesure de l'exposition au rayonnement radiofréquence de la téléphonie 5G-NR en Corée du sud. https://www.ineris.fr/fr/mesure-exposition-rayonnement-radiofrequence-telephonie-5g-nr-coree-sud