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Evaluation of exposure induced by a 5G antenna in the 3,4 - 3,8 GHz band.

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Abstract
This paper presents the exploratory measurements performed by ANFR during the first 5G trials in the band 3400-3800 MHz in order to better understand 5G signals, to anticipate the need to update the in situ measurement protocol and to work on the definition of a new indicator of the exposure. The paper focuses on a case: the trial of Bouygues Telecom at Bordeaux-Mérignac with a Huawei antenna.

Résumé
Cet article présente les mesures exploratoires réalisées par l'ANFR lors des premiers essais 5G dans la bande 3400-3800 MHz afin de mieux comprendre les signaux 5G, d'anticiper la nécessité de mettre à jour le protocole de mesure in situ et travailler sur la définition d'un nouvel indicateur de l'exposition. L'article porte sur un cas: le pilote de Bouygues Telecom à Bordeaux-Mérignac avec une antenne Huawei.

1 Introduction

The key elements of 5G, for exposure, in the new frequency bands are steerable beam antennas to users, wider frequency bands, finer beams and alternating exposure (Time Division Duplex, TDD mode). And the expected consequences are a lower level of exposure outside the beams, a higher exposure level in the beam, a shorter exposure time.

The French National Agency of Frequencies (ANFR) carried out exploratory exposure measurements during the first trials in collaboration with the operator and the antenna manufacturer in order to better understand 5G signals, to anticipate the need to update the in situ measurement protocol and to work on the definition of a new indicator.

In this paper, we are focused on the trial of Bouygues Telecom at Bordeaux-Mérignac with a Huawei antenna.

2 5G trial of Mérignac

On this site (cf. Figure 1), a 64T64R (64 transmission and 64 reception antennas) station is installed at 12 meters of height in a false tree and the traffic is generated using a CPE "customer premise equipment" as a receiver.

Figure 1 : on the left, satellite view of the 5G site at Bordeaux-Mérignac, position of the CPE receiving the data and axis of measurements; and on the right, CPE custom premise equipment used to receive the 5G data.

The main characteristics of the 5G signals used on that site are in the Table 1:

Parameter	Values	Parameter	Values
Central frequency	3650 MHz	**Centrale frequency of SSB***	3650 MHz
Bandwidth	100 MHz	**SSB periodicity**	20 ms
Space subcarriers	30 kHz	**Number of SSB**	7
Frame format	DDDSU	**Rated power**	200 W
TDD factor	75% downlink		

Table 1 : main 5G characteristics of the site of interest in this paper located in Mérignac

*SSB : synchronisation signal block

The measurements are performed with a Narda SRM 3006 and a tri-axial probe. Channel power are performed over 100 MHz at a height of 1,5 meter above the ground and 6 minutes time-averaged values are recorded.

2.1 Results with no traffic

In the absence of traffic, only signaling signals are transmitted. Figure 2 illustrates the spectrum observed in the absence of traffic. The colors indicate the occurrence of the power levels, indicated on a logarithmic scale on the ordinate, as a function of the frequency on the abscissa (120 MHz around the central frequency of the antenna emission band). The most frequently measured level is shown in yellow and corresponds to the noise level in the band: in fact, most of the time, in the absence of traffic, there is no emission. More rarely, the signaling signals are emitted (blue color in the figure). These signaling signals consist of SSB which occupy a bandwidth of 20 block resources (BR), that is to say 7.2 MHz and are located in the center of the band. The other signals are other reference signals RS (reference signal).

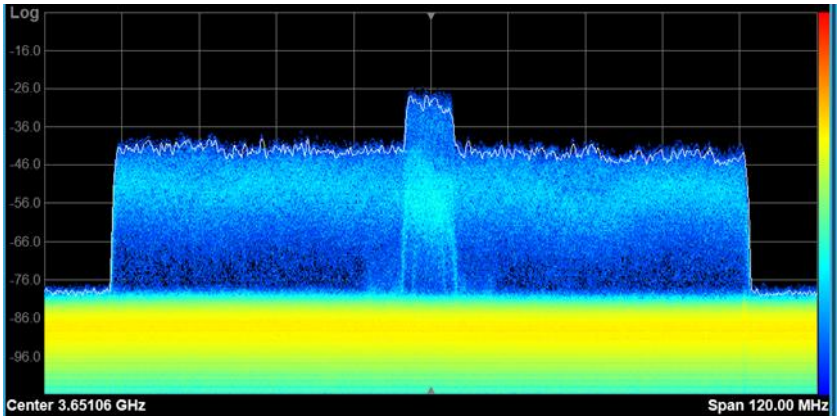

Figure 2: Spectrum (Huawei – Bouygues Telecom – Mérignac)

The average electric field level measured at distances from 35 m to 200 m from the 5G antennas, in the absence of traffic, on the 100 MHz frequency band of the transmitters, is between 0.01 V/m and 0.6 V/m.

2.2 Results in continuous transmission in one direction

In that test configuration, the antenna is fully loaded and is transmitting continuously towards a unique receiver. It is worth pointing out that this configuration is not realistic but has the advantage to be well defined, stable in time and reproducible.

In such configuration, the maximum electric field level was measured on this site at almost 9 V/m near the CPE served by the antenna. As a reminder, the regulatory limit in the considered frequency band is 61 V/m. Figure shows, on the left, the electric field level measured at different distances from the 5G antenna, in the axis of the CPE. Reflections on the ground lead to constructive and destructive combinations of the field which explain the field level of only 4 V/m at 120 m from the antenna and the field level of 8.5 V/ m at 90 m from the antenna.

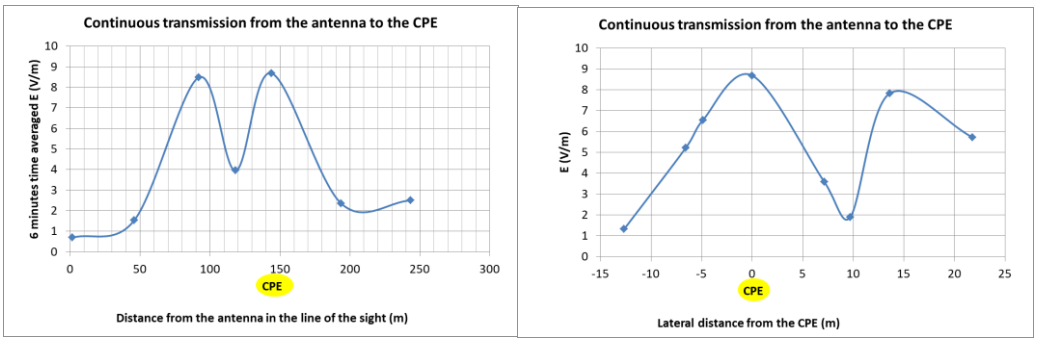

Figure 3: levels of time-averaged E-field measured over 100 MHz at 1.5 meters above the ground when antenna is transmitted continuously toward a CPE placed at 145 meters from the antenna.

On the right of the Figure 3, the beam width is illustrated at 1.5 m from the ground and at a distance of 150 m from the antenna. As you move away from the CPE which is served by the antenna, the average field level decreases rapidly (by a factor of 2 to 7.5 m on each side of the CPE). We observe on one side of the CPE the reflection of the field on the large building, this reflection induces a field level of 8 V / m at about 15 m from the CPE against a little more than 1 V/m at the same distance from the CPE, but on the other hand, in the absence of reflection.

2.3 Results with download of files

As a more realistic configuration, the 6 minutes time averaged E fields has been measured during the download of files with different sizes. In that case, the CPE was not able to receive more than 140 RB compared to the 273 RB available at the antenna. During the transmissions, the antenna was loaded at about 50% of its maximum Results are in the Table 2. As expected, the level of the time averaged E field is strongly dependant of the configuration.

Duration of download	File size	6 minutes time averaged E-field
No download	0 MB	0,2 V/m
2 s	150 MB	0,5 V/m
7 s	500 MB	0,8 V/m
15 s	1 GB	1,1 V/m
150 s	10 GB	3,9 V/m
Infinite	Infinite	6,5 V/m

Table 2 : results of 6 minutes time averaged E field corresponding to the download of files of different sizes.

These measurements made it possible to observe the frequency spectrum and the temporal occupation of the first 5G signals. They also highlighted the variation in the level of exposure as a function of usage and led to the proposal of a new indicator making it possible to better reflect the real exposure created by 5G networks with orientable beams. This indicator is based on a predictable usage pattern for 5G, which results in the sending, in a given direction, of one gigabyte of data every 6 minutes. With an assumption of an average speed of 500 Mbps, the antenna then transmits in the given direction about 15 seconds every 6 minutes (about 4% of the time). The hypotheses to define this indicator will be compared with the measurements of exposure carried out in the field, for 5G commercial networks. They will be revised if necessary.

This indicator results in a reduction factor which makes it possible to calculate the exposure under real conditions from the theoretical maximum power of the antennas. Field levels at 100 meters from a 5G antenna resulting from the application of the indicator appear comparable to those found at the same distance from a 4G antenna.

4G	Current	Future
Power	60 W	160 W
Gain	18 dBi	18 dBi
Attenuation over 6 minutes	- 4 dB	- 4 dB
Glazing	- 2 dB	- 2 dB
Estimated E field at 100 m	**1,7 V/m**	**2,8 V/m**

Table 3: estimation of the electric field level at 100 meters from a 4G antenna inside a building with an assumption of typical current transmitting power and an assumption of future transmitting power.

5G	Low assumption	High assumption
Power	80 W	200 W
Gain	24 dBi	24 dBi
Attenuation over 6 minutes	- 13,5 dB	- 13,5 dB
Glazing	- 2 dB	- 2 dB
TDD	- 1,25 dB	- 1,25 dB
Estimated E field at 100 m	**1,1 V/m**	**1,8 V/m**

Table 4: estimation of the electric field level at 100 meters from a 5G antenna inside a building with a low power and a high transmitting power assumption.

However, in 4G, the reduction factor applies to the maximum value of the antenna gain which is only observed in the main direction of the antenna: outside this main direction, the field level will be lower. However, with the 5G steerable beam antennas, the exposure calculated from the indicator will be valid in a larger number of directions.

3 Conclusion

This process of exposure evaluation has been set up on different 5G trials to cover different configurations (operator, manufacturer and 5G characteristics). The results have also been used to work on a new indicator of exposure as in situ measurement aims also at providing information on daily exposure.