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EXPERIMENTAL MEASUREMENTS OF A 5G OUTDOOR MASSIVE MIMO ANTENNA LOCATED INTO A SHOPPING CENTER

Ts. Shalamanova[1*], Hr. Petkova[1], M. Israel[2], V. Zaryabova[1]

[1]National Centre of Public Health and Analyses, Sofia, Bulgaria
[2]Medical University - Pleven, Bulgaria

Abstract. *The fifth generation mobile network (5G) is characterized not only by the expansion of the existing (4G) network, but represents an evolution of the current mobile technologies. Thanks to the use of millimeter waves and massive MIMO (Multi-Input Multiple-Output) technology, it will meet the ever increasing demands of users in terms of connectivity and capacity. The introduction of the new 5G technology is accompanied by problems related to the measurement and evaluation of electromagnetic fields (EMF). The first stage of implementation of 5G requires upgrading existing mobile 2G / 3G / 4G networks, which raises many concerns about the possibility EMF exposure limits to be exceeded. This is especially true for countries with more restrictive legislation than ICNIRP guidelines. The existing methodologies dedicated to EMF measurements of 2G, 3G and 4G networks are not suitable for 5G and can lead to significant overestimation of the exposure. The reason for that is mostly due to the specificity of the massive MIMO and the beamforming. This necessitated the use of a new approach in the assessment of the EMF exposure. This report considers experimental case of evaluating procedure of EMF exposure of the general public from an outdoor 5G massive MIMO antenna. The antenna was located into a shopping center for a demonstration the capabilities of the new 5G technology in front of the public. The power of the massive MIMO antenna was limited to 5 W because it was mounted indoor. For the purpose of the experiment 5G router was placed in different locations in order to steer the beam of the antenna. Test measurements were taken on the path of beam to evaluate the exposure in the premises. Changing the location and the height of the router, we managed to accomplish the safety limits of the EMF exposure (according to the Bulgarian legislation) for the visitors of the demonstration. We performed measurements during Ookla speed test to simulate the maximum traffic. As a result, the study can be used for the further assessment of similar cases and demonstrations for indoor premises.*

Keywords: *5G, mobile telecommunications, new radio, radiofrequency electromagnetic fields (RF-EMF), exposure assessment, measurement, massive MIMO*

1. Introduction

There is no doubt about the need of introduction of faster and more reliable wireless communication systems. Although the benefits of 5G are well discussed, there are still concern that exposure to electromagnetic fields emitted by 5G systems might have negative health impact. As the deployment of fifth generation (5G) mobile networks is under way, standardized methods for estimating human exposure to radio frequency electromagnetic fields from 5G equipment are needed. The development of accurate techniques and protocols for measuring EMF is very urgent and important task, especially for countries like Bulgaria which have more restrictive legislation [1] with respect to the Council Recommendation and ICNIRP guidelines [2, 3].

This report considers an experimental case concerning exposure assessment of outdoor 5G massive MIMO antenna. The challenge for us was that antenna was mounted into premise (a shopping center) for a special performance of one of the mobile operators aimed to demonstrate the capabilities of the new 5G technology in front of the public.

The report is organized in four sections. The first one introduces the case of the study. The next describes measurement procedure we have used. There we discuss the aspects and issues related with EMF measurements. The following section contains the exposure scenarios and results of our study where we present simulations of EMF exposure situations and measurements of emitted EMF performed on base of calculated data. The final section comprises discussions and conclusions.

2. Measurement procedure

The existing methodologies dedicated to EMF measurements of 2G, 3G and 4G networks are not suitable for 5G and can lead to significant

* ts.shalamanova@gmail.com

overestimation of the exposure. The reason for that is mostly due to the specificity of the massive MIMO and the beamforming. This necessitated the use of a new approach in the evaluation of the EMF exposure.

Measurement procedures used to assess the compliance with electromagnetic field exposure limits are described in the following standards, IEC 66232 "Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure" published by the International Electrotechnical Commission (IEC) [4] and IEC Technical Report (TR) 62669 "Case studies supporting IEC 66232" [5].

The maximal permissible level specified in Bulgarian legislation [1] for general public EMF exposure for frequency range 300 MHz – 30 GHz is 10 μW/m². All the results are compared to this level. We performed non- frequency selective measurement method of the RF field strength.

Before the start of the measurement procedure we got the technical characteristics of the source of the radio-frequency (RF) fields in order to estimate its likely propagation characteristics in the premise. On the base of the received information two simulations were developed.

We made visual inspection and background field measurements of the RF field in the premise before the start of the test, to be sure there is no influence of other sources of EMF. A picture of the mounted antenna could be seen in Figure 1.

Figure 1. Picture of the fixed antenna
on the inner wall of the premise

With the start of the measurement procedure a scan of the area under investigation using the handheld sweep method was performed to determine the locations of significant RF field strength levels in the premise and to figure the investigated volume. Efforts are made to avoid the coupling between isotropic probe and physical objects in the premise.

The power of the massive MIMO antenna was limited to 5 W by the mobile operator for the aim of the event. 5G router was used to steer the beam of the antenna. The measurements were performed during Ookla speed tests to simulate the maximum traffic. Specific time characteristics of the test required measurements to be made over a thirty seconds period. For the evaluation the average maximum values of RF field are used.

In order to assess the RF field strength levels regarding the exposure scenarios that might occur due to the position of antenna in the premise we conducted two sets of measurements. Test measurements were taken on the path of beam to evaluate the exposure in the premise.

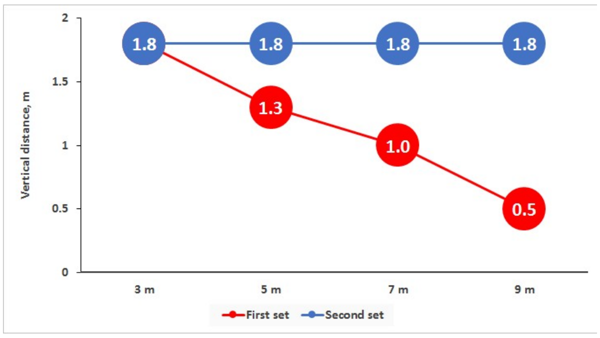

Figure 2. Scheme of points of the two sets of measurements

Measurements were performed at horizontal and vertical plane. In this case the isotropic probe was set to a wooden tripod to avoid the influence of the operator body on the measurement. First set of point measurements were taken at heights from 1.8 m to 0.5 m above the floor. Second set of point measurements were taken at heights of 1.8 m. In horizontal plane both sets of measurements were taken at a distance from 3 m to 9 m. That is presented in Figure 2.

2.1. Measurement equipment

We used a NARDA broadband field meter, model NBM-550, with an E-Field isotrope probe, EF1891: 3 MHz - 18 GHz. This equipment measures the integral EMF levels received at a given point of interest. The measurement equipment is calibrated in accredited calibration laboratory.

Figure 3. Narda NBM-550, NARDA Safety Test Solutions

3. Exposure scenarios and results

3.1. Exposure scenarios

To estimate the expected RF field strength we asked the mobile operator to give us the initial data concerning the antenna and router they will use for the purpose of the event. The transmitter is Massive MIMO ZXRAN A9611 S35 5G antenna which to be mounted on an internal wall in a commercial site shop at a height of 2 metres. The antenna has the following technical characteristics: frequency: 3400 - 3600 MHz; gain: 25 dBi; number of antenna elements: 192; nominal power: 200 W; maximum actual power during the test measurements: 5 W.

The client receiver which communicates with the antenna is 5G router ZHRAN TUE600 S3500.

We made preliminary simulations of the emitted EMF using the software NARDA EFC-400 EP for computing and simulating electromagnetic fields. Simulations represented the ideal case in free space.

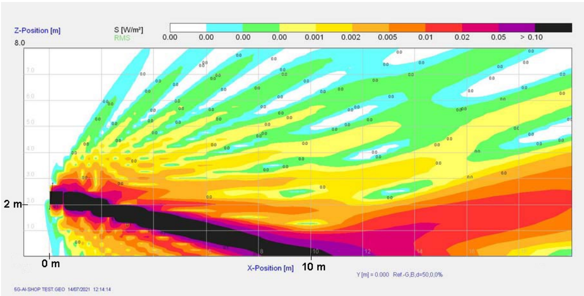

Figure 4. Simulations of the EMF beam pointed to the ground position of the receiver.

The first simulation shows the situation in which the client receiver (router) is on the ground as it was required by the mobile operator. The beam was pointed to the presumed horizontal distance between the client and receiver of 10 metres. We set a model of a transmitter with a length of 0.8 m, positioned 2 m above the ground. The simulation predicts the possibility the RF fields to be above the exposure limit (Figure 4) at a distance up to the estimated location of 10 meters from the RF source.

We changed the possible vertical position of the receiver so the beam to be steered above the average human height.

The second simulation shows that exposure values are expected to be in compliance with maximal permissible level according Bulgarian legislation [1]. On the following Figure 5 it can be seen the simulation of the EMF beam pointed to the position of the receiver, where the client is 2 meters above the ground and horizontal distance between the client and receiver is 10 metres. We used the same model of a transmitter with a length of 0.8 m, positioned 2 m above the ground.

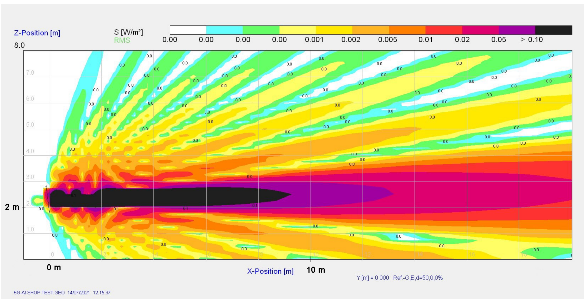

Figure 5. Simulations of the EMF beam pointed to the position of the receiver - 2 meters above the ground.

3.2. Results

The background field measurements before starting the test showed that there is no significant contribution from other sources in the RF frequency range in the investigated area. The measured values of power density were in the range 0.1 ÷0.6 μW/cm².

The first set of measurements corresponds to the preferred position of the router by the mobile operator. The preliminary simulation of RF field we made, shows that the EMF values will exceed the maximal permissible level according Bulgarian legislation at the area of the event.

The second set of measurements takes into account the exposure scenario with the changed position of the receiver. We made a visual scheme which illustrates the paths of the beam corresponding to the situations we observed (Figure 6).

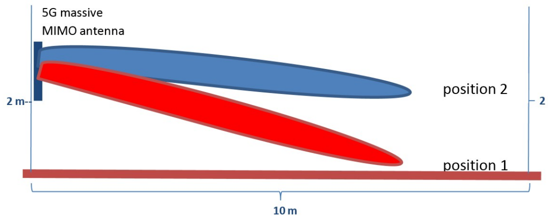

Figure 6. Scheme of the beamforming of the massive MIMO antenna according to the position of the router.

The results of point measurements performed at different distances between the transmitting antenna and the router are presented in Figure 7.

The router was portable which facilitates the right placement. During each measurement, the router was loaded via the Ookla speed test, in order to simulate maximum traffic.

The in-situ measurements confirmed the computed results. As it can be seen in Figure 7 the measured values of power density in red colour are well above the maximal permissible level 10 μW/m² when the router was located on the floor to the opposite wall. At some points, the measurement values exceeded 10 to 40 times the maximal permissible level specified in Bulgarian legislation [1]. Despite that fact these values are still in compliance with the Council Recommendation and ICNIRP Guidelines [2,3].

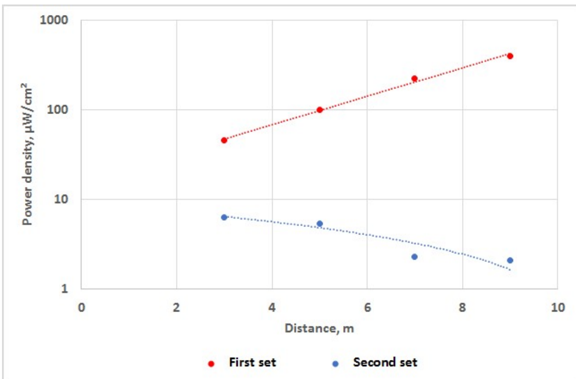

Figure 7. Measurement results of EMF values corresponding to the position of the router.

In order to reduce the exposure levels and on the base of the simulation, the router was positioned 2 meters above the floor on the same wall. The resulting EMF levels are shown on the same figure in blue colour. Considering this exposure scenario, the measured values of power density are in compliance with the national legislation.

The chart clearly shows that changing the location of the client and thanks to the technology of beamforming reducing of the EMF exposure on the place of interest can be provided.

4. Discussion and conclusion

The case presented in this paper is not a typical situation and it requires a specific approach to be applied. Preliminary study and simulations of the exposure scenarios that may arise played a key role during the on-site electromagnetic field assessment. Applied approaches and methods for exposure assessment had to take into account specific circumstances, such as the location of the antenna in the room, the beamforming, the limited space, the proximity of the audience to the demonstration and the requirements of the mobile operator for positioning of the client receiver. All these circumstances influence the EMF levels and hence the compliance with national legislation for protection the population from electromagnetic fields.

The EMF exposure limits of most of the European countries is according to Council Recommendation and ICNIRP [2,3]. In fact, some countries like Bulgaria have more restrictive limitations with respect to the ICNIRP guidelines [2]. This case raises questions about the influence of our national legislation on the implementation of 5G mobile networks.

Challenges following the introduction of 5G New Radio (NR) include the use of new radio bands and advantages such as massive MIMO technology.

Considering the relevant methods and practical approaches for exposure assessment of 5G massive MIMO antenna, we were able to demonstrate compliance with national legislation regarding EMF, which ensures the safety of the general population. This would not be possible to be realized in such way with fixed pattern conventional antenna.

More practical research is needed on 5G installations to improve existing methods and approaches for exposure assessment of new generations of mobile technologies.

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