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Exposure Assessment of a 5G indoor planar array antenna using Computational Dosimetry

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Abstract

The following work is focused on the assessment of exposure levels in indoor environment, taking account the innovations of the upcoming 5G network technology. More in details, it was analyzed the exposure caused by a 5G access point in a room, modelled with an indoor 8x8 planar array antenna. The working frequency of the planar array antenna was selected according to the frequency range that will be used firstly in Italian 5G networks and will be 3.7 GHz. The exposure levels were assessed using the Ella model from the Virtual family. The quantity analyzed will be the specific absorption rate in the head tissues.

1 Introduction

Thanks to new technology innovations, the upcoming new generation of 5G network will be characterized by data rate increase, low latency and higher number of connected devices. Among these innovations, the most innovative aspect will be the use of the mm-wave spectrum for wireless communication (ranging from 3 to 300 GHz frequencies) [1, 2]. In Italy, the first new licensed frequency ranges will be 3.6 – 3.8 GHz and 26.5 – 27.5 GHz [3]. The use of these frequencies will imply the possibility to use smaller cells at the base station but will cause also high path loss. For these reasons, the use of mm-wave spectrum will be coupled with the MIMO (Multiple Input Multiple Output) antenna and beamforming techniques, to obtain directional and high focalized beams [4, 5]. All these aspects will converge on the possibility to develop the IoT world and smart societies. However, it is important to underline that the network changes will also drastically modify the population exposure levels to RF-EMF [3]. These changes will not regard only the outdoor scenario, where the massive MIMO Base Stations (BS) will be installed but also the indoor scenario. In fact, the mm-wave frequency range is suitable for dense small cells deployments, serving short range areas and providing indoor applications [6-9]. For this reason, the present work is focused on a particular indoor exposure scenario, where it is simulated the presence of a 5G access point in a room. In details, the levels of exposure of a human head model to an 8x8 indoor planar array antenna working at mm-wave frequencies are in fact evaluated based on specific absorption rate (SAR) assessment, following the ICNIRP guidelines [10]. The working frequency was chosen at 3.7 GHz, following the indication of the first 5G launch in Italy. Details of the exposure scenario are described in the following paragraph.

2 Materials and Methods

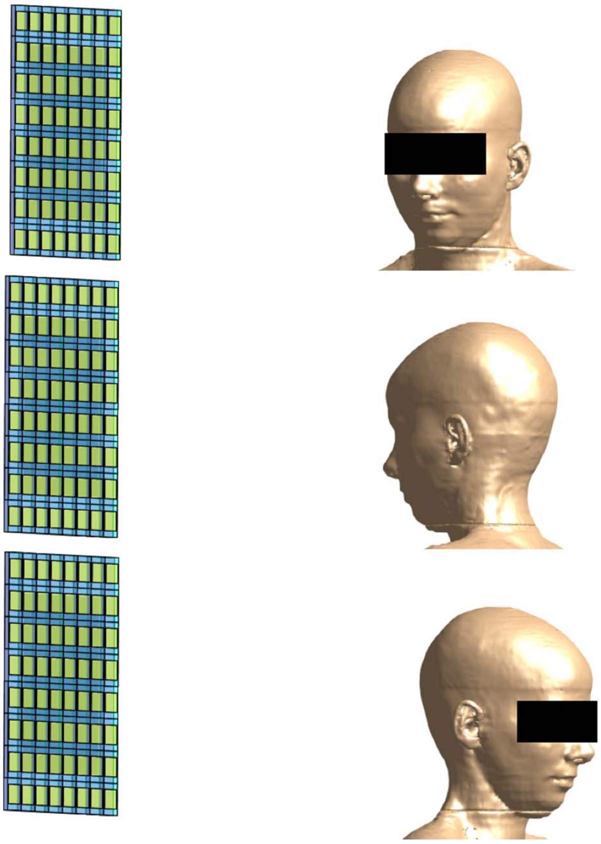
[redacted]
[redacted]

Figure 1. The three different configurations analysed for the indoor 5G exposure scenario with an 8x8 planar antenna array at 3.7 GHz for the Ella head model.

In Fig.1 it can be seen the resulting 8x8 indoor array antenna and the three different exposure configurations that were analysed for this work. More in details, each element of the antenna is composed by a single patch antenna with three layers. Both the ground and the patch layers are modelled as PEC materials. The substrate layer is identified with a dielectric material, whose properties are $\varepsilon_r = 2.25$ and $\sigma = 0.0005\ S/m$, according to literature data [11]. In total the dimensions of the array are around 29x29 cm, for a thickness of 0.5 cm. Furthermore, as it is shown in Fig.1, the model used to assess the human exposure levels is Ella, from the Virtual Family.

The model represents an average adult female human (age = 26 years old, height = 1.63 m, mass = 57.3 kg , BMI = 21.6 kg/m^2). In the present exposure scenario, the antenna is placed at a distance of 50 cm to the central point of the model head for all the three configurations, i.e. the lateral position, the frontal one and the posterior one. The three simulations were conducted using the finite-difference time-domain (FDTD) method implemented in the platform Sim4Life. For all the three case, it was considered the worst exposure scenario, where antenna elements phase shift is set to zero and each single element is excited at the same time by a gaussian signal at 3.7 GHz, with a total input power of 100 mW. The domain of interest was limited on the head area and the boundaries of the simulations were modelled with absorbing condition with perfectly matched layer (PML). The tissues properties of the model at 3.7 GHz were chosen according to literature [12, 13] and the mesh step was set to 0.9 mm, in order to correctly discretize the head tissues. The exposure levels were evaluated based on the specific absorption rate (SAR). In particular, the total average SAR for the head, each average whole-tissue SAR (SAR_{wt}) and SAR averaged on 10 g of tissue (SAR_{10g}) were evaluated for the head tissues.

3 Results

The preliminary analysis about the exposure assessment at 3.7 GHz showed that the scenario that caused the highest exposure levels is the lateral one. In fact, the total average SAR for the head was equal to 5.9 mW/kg in the lateral configuration, 5.1 mW/kg for the frontal one and around 3.8 mW/kg for the posterior one. These considerations are reinforced by the evaluation of the SAR_{10g} distribution in the skin tissue. In Fig.2, that shows SAR_{10g} distributions for the three configurations, it can be seen that for the posterior configuration the highest value of SAR_{10g} is equal to 51 mW/kg, for the frontal configuration the peak value is a equal to 104 mW/kg, whereas for lateral one, the highest values are obtained principally in the ear skin area, with a peak of SAR_{10g} equal to 196 mW/kg. For all the three configurations the values obtained are well below the ICNIRP limit of 2 W/kg for the average head and torso exposure. Moreover, the highest values obtained for the posterior configuration are only equal to a quarter of the peak value for the frontal configuration. Future analysis will involve the evaluation of SAR also for other superficial tissues of the head model, to better characterize the level of exposure for 5G indoor scenarios.

Figure 2. Distribution of SAR_{10g} induced by the 8x8 planar array antenna at 3.7 GHz for 100 mW input power on the head skin model. In the upper part for the lateral configuration, in the middle part for the posterior one and in the lower part for the frontal one.

4 Conclusion

This work represents a first preliminary result for evaluating the human exposure assessment in indoor scenario, considering the incoming 5G network technology. Future works will involve the examination of different frequency ranges (e.g. 26.5 – 27.5 GHz) for the same configurations setting between the antenna and the model. Furthermore, the additional use of non-deterministic dosimetry approaches, based e.g., on Machine Learning or stochastic methods [14-15], will also permit to evaluate the variability of exposure that will occur in future 5G exposure scenarios.

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6 References

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