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STUDENT PAPER

Comparison of Human EM-exposure in Fifth Generation Wireless Technologies: ATTO vs. massive MIMO

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In this paper, we compare two potential 5G wireless technologies, ATTO-cell and massive MIMO, from a human EM-exposure point of view. A scenario, which allows one to make such comparison, was proposed. A set of finite-difference time-domain simulations was performed in order to estimate an average worst-case specific absorption rate in both cases. It was shown that starting at a certain distance from a massive MIMO base station, its exposure becomes lower than exposure by ATTO-cells.

Introduction

It is expected that in future 5G networks, the required bandwidth and data throughput will increase. One potential approach to deal with this increase in network demands, is to deploy an ultra-high density access network consisting of large number of very small cells, so called attocells. These are integrated in a floor and cover very small areas of only a few dm^2. Yet, they provide a very high data rate in these small areas [1, 2]. Since attocells will be smaller and widely distributed in indoor environments, the antennas used in attocells will be closer to the user than those employed in previous generations of cellular networks. This close distance might be a risk in terms of personal exposure to the Radio Frequency (RF) Electro-Magnetic Fields (EMFs) emitted by the antennas.

Another prospective technology is a network consisting of massive multiple-input multiple-output (MIMO) antenna arrays [3]. Massive MIMO makes use of a large excess of service antennas over active terminals. Extra antennas focus energy into very small regions of space to bring huge improvements in throughput and radiated energy efficiency. These antennas will cause RF-EMF exposure as well.

The goal of this paper is to compare human EM-exposure caused by ATTO-cell and massive MIMO technologies in a generalized industrial environment in terms of specific absorption rate (SAR).

Methods and materials

The studied model consists of one male human standing on a dielectric floor in an empty room. The male is either exposed by ATTO-cells in the floor or, alternatively, by MIMO antennas in the far-field. Both potential exposure scenarios are analyzed using numerical simulations. All simulations use the finite-difference time-domain (FDTD) method, implemented in Sim4Life (Zürich Med Tech, Zürich, Switzerland). The Virtual Population (ViP3.1) [4] heterogeneous Duke model (adult male) was used as a human phantom.

The studied attocell was the one described in [2]. A layer of acrylic glass (thickness = 6mm) was placed at the distance of (60 mm) above the attocells array to represent a surface of the floor. Each cell contained an antenna that operated between 3.25 GHz and 3.75GHz. We used a CAD-model of the linearly polarized planar, substrate-integrated-waveguide (SIW) cavity-backed slot antenna. Nine antennas, arranged into a 3x3 array, were supported by a layer of plastic (thickness 5mm), oriented along the same axis and equidistantly separated, which resulted in square cells of 15 x 15cm^2. The communication protocol applied a maximum input power of 1 mW at the feed point of the antennas. These emitted a harmonic signal at a frequency of 3.5GHz.

To model a worst-case realistic exposure, it was assumed that all antennas are constantly supplied with maximum power, with, however, uncorrelated relative phases. The phantom was placed 10mm above the floor surface, centered with respect to the center tile of the array. Then nine simulations were executed with each antenna radiating separately with zero phase. After this 10^4 post-processing runs were made, in which the induced EM-fields of the nine simulations were combined with uniformly distributed random phases. Spatial peak SAR averaged over 10 g cubes (SAR_{10g}) [5] was evaluated for each of the 10^4combinations.

Massive MIMO interaction occurs in the far-field region of a base station (BS). Only line-of-sight (LOS) exposure was taken into account. A set of 24 single plane wave (3.7GHz) FDTD-simulations for 12 uniformly distributed angles of incidence in horizontal plane (with vertical and horizontal polarizations) was performed. The power flux density of a plane wave was set to a reference value of 1 W/m^2 in each simulation. We assume that in realistic conditions all angles of incidence in horizontal plane have equal probability. Thus, to estimate mean exposure it is reasonable to use an average of all samples and variance as a measure of uncertainty [6].

A free space loss model (LOS) was used to represent SAR_{10g} as a function of distance between phantom and the BS. The total power supplied to the BS and its maximum gain were set to 46 dBm and 15 dBi respectively [7].

Results and discussion

The resulting distribution of SAR_{10g} induced by the ATTO-cell floor is depicted in Figure 1. It can be approximated by a normal distribution with mean value of 5.692 mW/kg and relative standard deviation of 22.8%. Its mean value may be interpreted as an average SAR_{10g} in worst-case conditions for the ATTO-floor. Peak-SAR cubes were primarily located inside the toes, which were the lowest part of the phantom. A slight skew in initial distribution was possibly caused by phantom's natural asymmetries or misalignment with respect to the central tile.

For massive MIMO the average SAR_{10g} was found to be 101.4 mW/kg ± 25.3% at power density of 1 W/m^2. In our model it is observed at a distance of around 20 m from the BS. Depending on the plane-wave angle of incidence, peak-SAR cubes were located inside the nose, ears or fingers. A plot of the peak SAR_{10g} as a function of distance from the massive MIMO BS is shown at Figure 2. A red vertical line indicates a distance d_{equiv} at which exposure level drops below that of attocell floor. We found d_{equiv} to be approximately equal 42 m.

Conclusion

Comparison of human EM-exposure in terms of SAR_{10g} was made for ATTO and massive MIMO technologies in a reference scenario. It was shown that only from distances to BS larger than 42 m, SAR_{10g} of massive MIMO becomes lower than that of the ATTO-cell floor. However, in this study we did not consider non-line-of-sight exposure of massive MIMO BS, changes of throughput with distance from BS and uplink exposure of both technologies. These are the main topics of the ongoing research.

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Figures

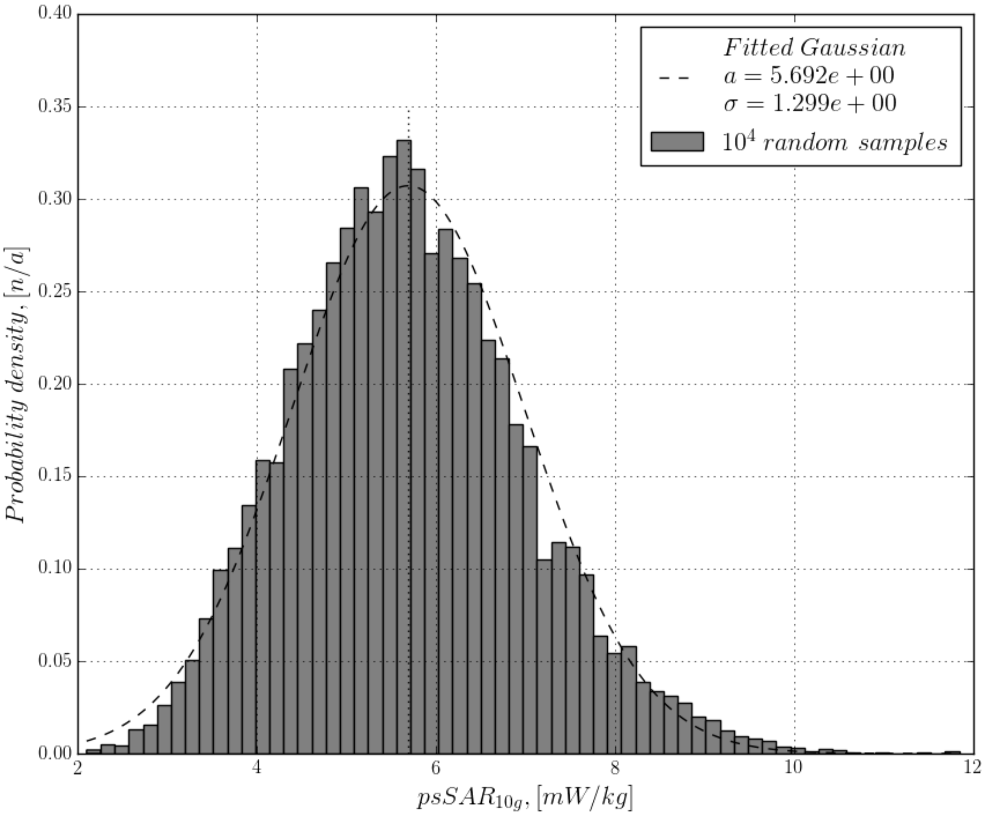

Figure 1. SAR_{10g} distribution for 10^4 random phase combinations of ATTO-cells. Grey bars indicate the normalized histogram of obtained samples. The dashed line shows a fitted normal distribution with the mean value of 5.692 mW/kg and standard deviation 1.299 mW/kg.

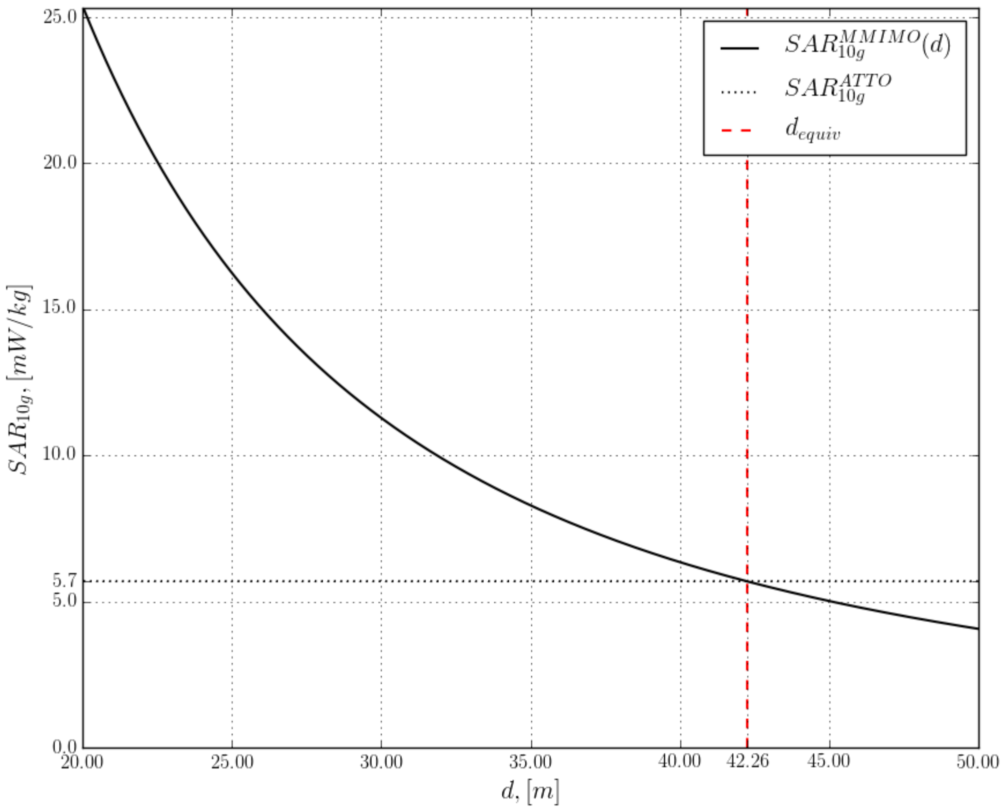

Figure 2. SAR_{10g} as a function of distance from the massive MIMO BS. Red dashed line indicates the distance after which massive MIMO exposure becomes less than that of the ATTO-cell floor.