# Multiscale Computational Electromagnetics Modeling and Validation of Current and Energy Flows in the Skin Tissue Microstructure at mm-Wave Frequencies (MicroBioEM)


## Abstract

Wireless mobile communication of the fifth generation (5G) technology standard began (as the successor of present LTE and 4G technology) deploying worldwide since 2019 offering new real-time services through significantly increased bandwidth and interconnectivity, where the latter tends no longer to distinguish between dense indoor environments and public telecommunications networks. With the 5GNR(new radio) frequency classification (cf. frequency range 2, 24.25-52.60GHz) the 5G standard is now at the brink to invade the very mm-wave range where new communication hardware such as radio-over-fiber (RoF) in conjunction with massive MIMO (multiple-input multiple-output) schemes using smart beam-forming antennas are currently under intense investigation. Together with the increase in the public awareness of potentially altered personal/environmental exposure scenarios the implementation of the 5G technology has re-fueled public and political discussions on the reliability of existing electromagnetic (EM) safety limits. The need to reconsider EM exposure levels more accurately in particular at mm-wave frequencies was already anticipated by ICNIRP in their latest report [10]. The report also addresses fields of future research supported by refined exposure models in order to assess potential risks regarding adverse effects of radiofrequency EM fields on health where the latter is summarized in appendix B - and this is where our study kicks in.

The study encompasses an accurate EM multiscale tissue model, that is rooted on the cellular level and evolves within a bottom-up approach through careful homogenization into a frequency dependent, anisotropic, multilayer skin representation that provides quantities such as e.g. (mean)fields and power densities, and that can be linked either to numerically defined or experimentally preset 5G/mm-wave irradiation fields (respective power densities) at the skin surface. The punchline of the model lies on the other hand in a top-down approach by taking these mean fields as a boundary condition for the subordinate length scale yielding a scale back-projection of these surface exposure conditions down to the cellular level into the tissue's very microstructure. In conclusion we aim at a model-assisted, experimentally validated microdosimetry of the skin for 5G/mm-wave frequencies. Within the study several measurement setups will be engineered, validated and compared, starting with accurate, transmission experiments based on 3D-printed dielectric waveguides, which are complemented with high-resolution EM nearfield probing of the tissue surface. For the most realistic experimental studies we shall rely on few $cm^2$-sized human skin samples. THz imaging of the tissue morphology at sub-mm resolution and thermography are foreseen as well to keep track on local variations in the energy intake and the resulting temperature distribution. These results will contribute to ongoing discussions on potential health effects at high field strengths/power densities due to biological substructures within tissue layers, and in particular within the

skin which will be most exposed by future 5G systems operating above 6GHz and well into the mm-wave range.