6GEM

UNIVERSITÄT DUISBURG ESSEN

WP4.8: 6G.Bioelectromagnetics Interactions

Towards a Virtual Microdosimetry of Biological Tissue at 6G Frequencies

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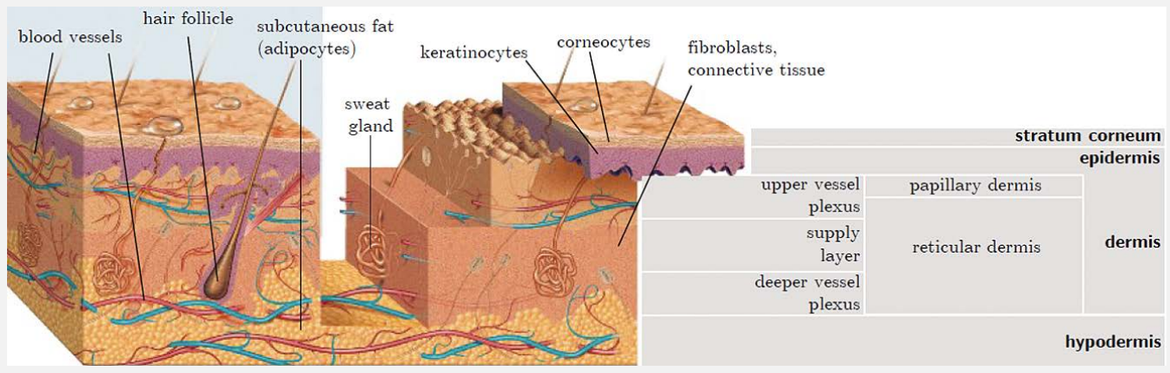
At 6G frequencies electromagnetic (EM) waves are absorbed within the top (sub-) mm domain of the skin tissue. The bioelectromagnetic analysis of EM interactions within the microstructure of biological tissue in the framework of an exposure scenario is therefore essential to our research.

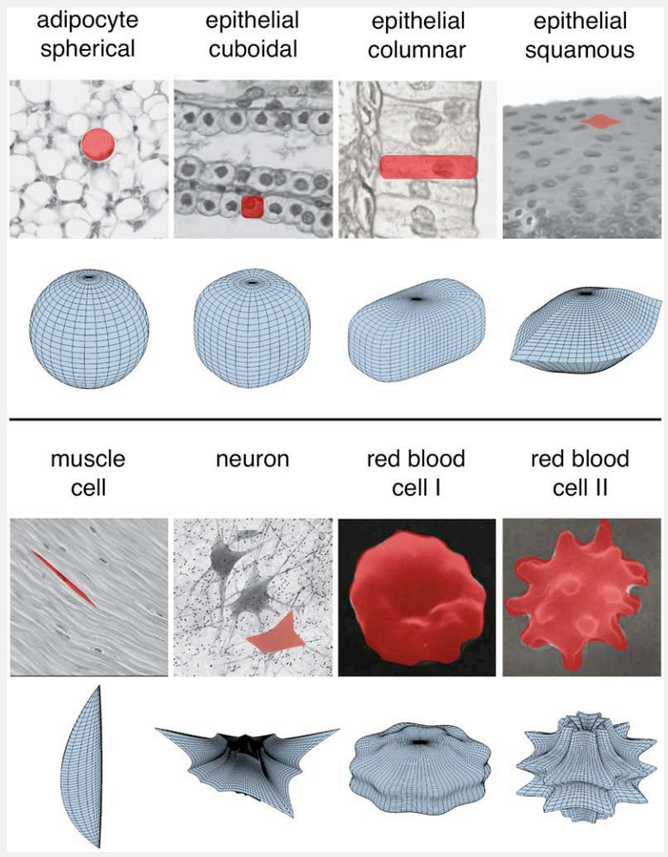
Here we rely on a model-based framework consisting of a virtual microdosimetry that can be linked to experimental irradiation scenarios. We also envisage an extension to less anthropocentric exposure scenarios such as the irradiation of invertebrates like polluting insects (bees).

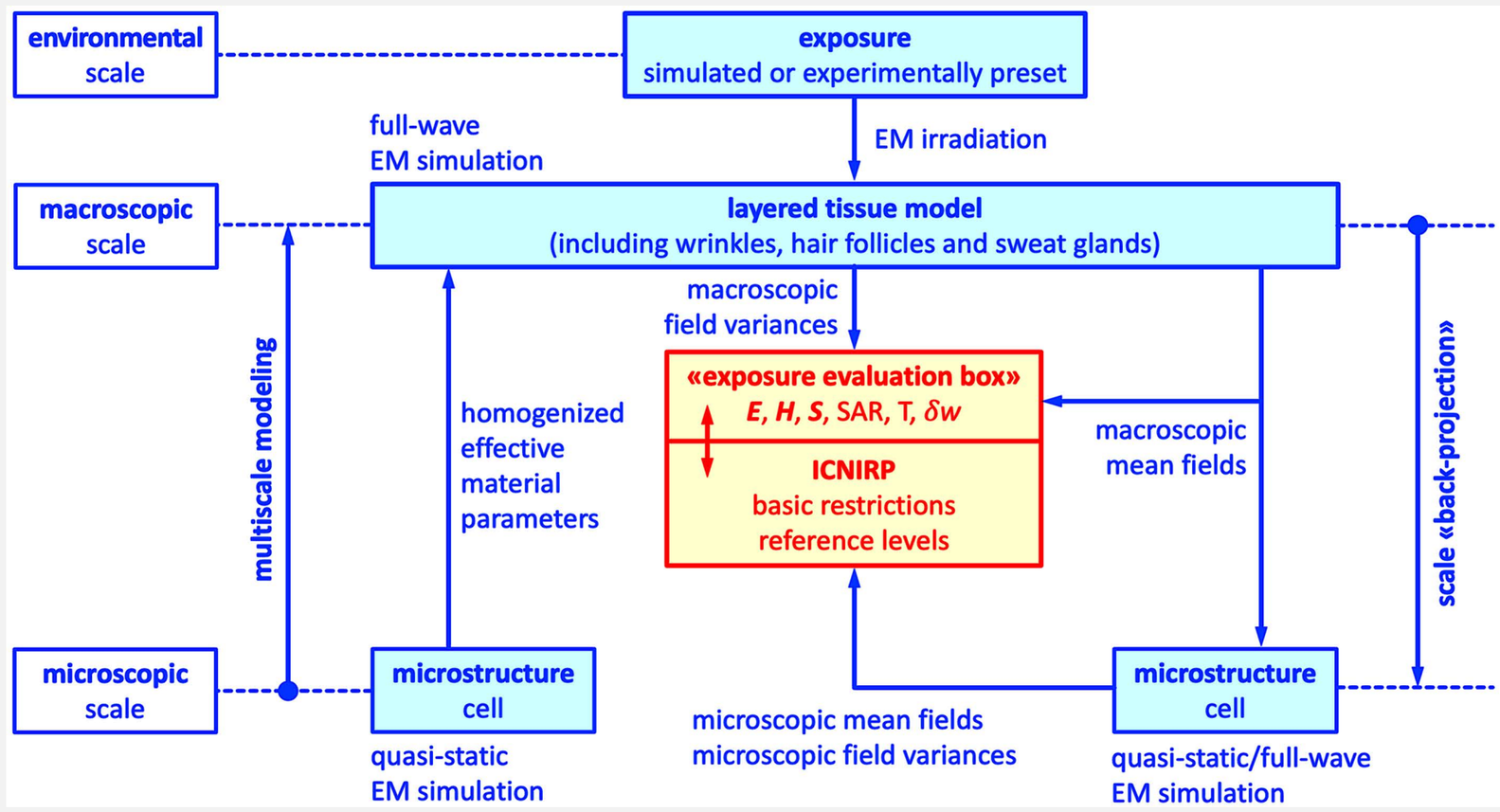
Problem and Methodology



1. Multi-scale skin models [5]

- Cell scale: cell shapes via superquadrics, idealized cell interior
- Tissue scale: effective material model (dispersive ε^*-tensor)
- Skin scale: layered skin model (SC, E, D, HYP), hairs, vessels,
- Scale-back projection: irradiation ⟹ energy intake at cell level
- Virtual microdosimetry: where is the irradiation exactly absorbed?

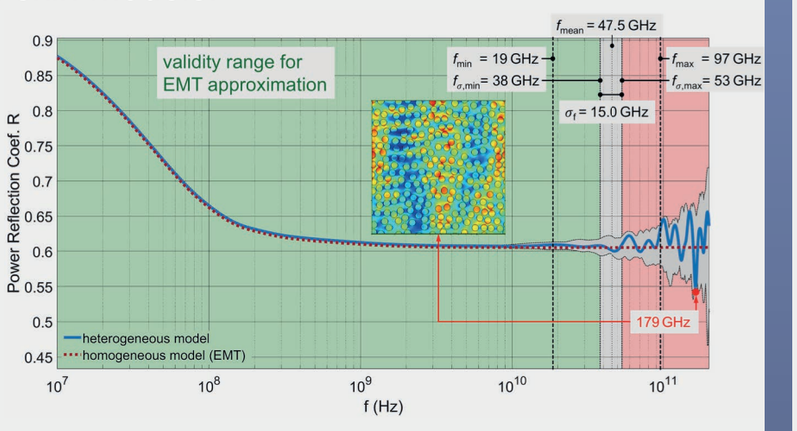




Results

2. Limits of effective material-based tissue models [2], [4]

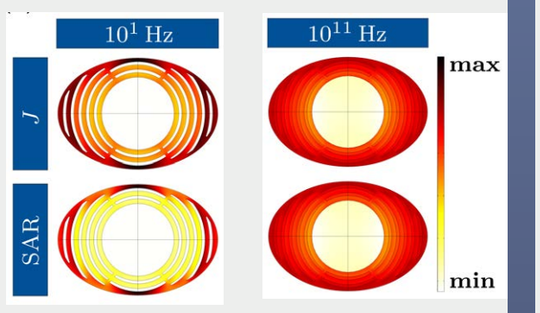
- MC analysis for estimating the validity range of effective material theory (EMT)-based skin models.
- HYP with adipose cells as example.
- Astonishingly low: from 38-53 GHz.
- Forbidden range: apt for sensing purposes via, e.g., spectral fingerprints.



3. Impact of sub-cellular structures [1], [3]

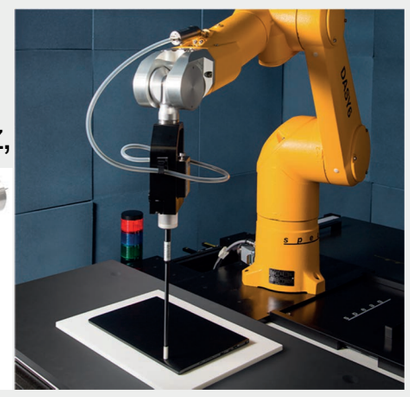
- Cell membrane, organelles, and ER.
- Energy intake (SAR) into compartments.
- SAR increases with *f*
- Organelles have decreasing impact

EM cell model with nucleus and ER



4. Experimental setups

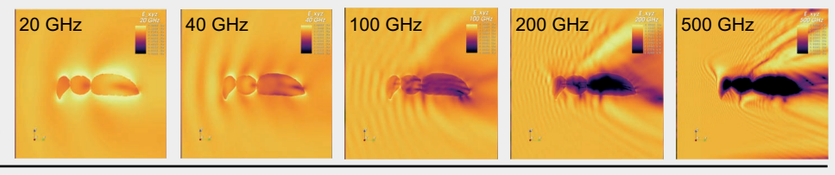
- Material characterization with SWISSto12 transmission measurement setups 26-40GHz, and 110-170 GHz.
- SPEAG vectorial mm-wave nearfield scanner DASY6 (750 MHz-110 GHz).



5. EM exposure in the framework of insect monitoring

- Simplified bee model, first 3D COMSOL & EMPIRE XPU simulations
- How does the bee energy intake (SAR) compares to ICNIRP limits?

Bee model and |E| field



[1] K. Jerbic, J. T. Svejda, B. Sievert, A. Rennings, J. Fröhlich, and D. Erni, "The importance of subcellular structures to the modeling of biological cells in the context of computational bioelectromagnetics simulations," *Bioelectromagnetics*, 2022, (submitted).

[2] K. Jerbic, J. T. Svejda, B. Sievert, X. Liu, K. Kolpatzeck, M. Degen, A. Rennings, J. Balzer and D. Erni, "The identification of spectral signatures in randomized (sub-) surface material systems," *5th Int. Workshop on Mobile THz Systems (IWMTS 2022)*, July 4-6, University of Duisburg-Essen, Duisburg, Germany, 2022.

[3] K. Jerbic, J. T. Svejda, B. Sievert, A. Rennings, J. Froehlich, and D. Erni, "The role of organelles in electromagnetic microdosimetry based on broadband multiscale skin models of eukaryotic cells," *BioEM 2022*, June 19-24, Aichi Industry and Labor Center (WINC AICHI), Nagoya, Japan, Session 14: 'S14: Computational Dosimetry', 2022.

[4] K. Jerbic, K. Neumann, J. T. Svejda, B. Sievert, A. Rennings, and D. Erni, "Limits of effective material properties in the context of an electromagnetic tissue model," *IEEE Access*, vol. 8, pp. 223806-223826, Dec. 28, 2020.

[5] D. Erni, K. Jerbic, A. Rennings, S. Huclova, and J. Froehlich, "Mehrskalige elektromagnetische Gewebemodelle für den mm-Wellen-Bereich," *FSM-Workshop: Millimeterwellen – Stand der Forschung, Forschungsstiftung Strom und Mobilkommunikation*, June 18-19, ETH Zürich, Zürich, Switzerland, Session 'Technologie, Modellierung', 2019, (invited presentation).

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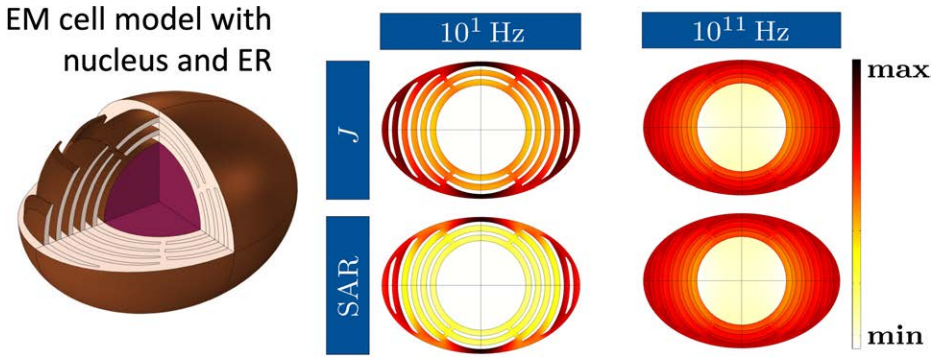
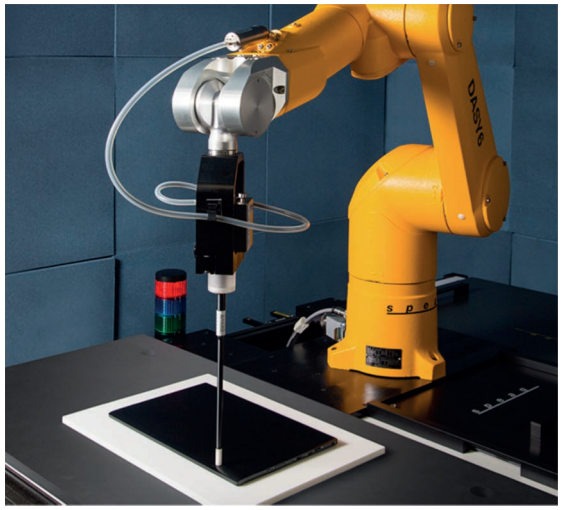
Multi-scale skin models

- Multi-scale EM tissue model.
- Model-based virtual micro-dosimetry of the skin.
- Projecting irradiation at the skin surface into the tissue's micro-structure (cell level).
- Where does the EM energy intake exactly takes place?



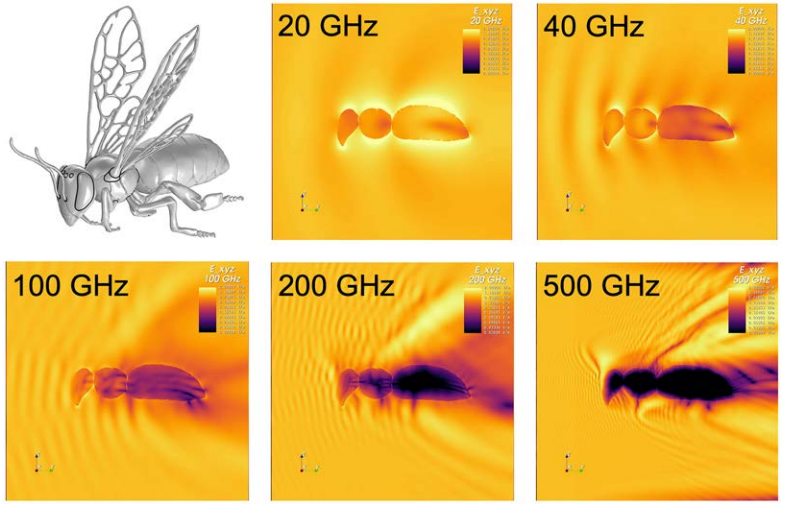
Experimental setups

- Material characterization SWISSto12 for 26-40 GHz, and 110-170 GHz.
- Setting up SPEAG vectorial mm-wave nearfield scanner DASY6 (750 MHz-110 GHz).



Exposure of bees

- Looking at non-anthropo-centric exposure measures for invertebrates.
- Energy intake (and RCS) of e.g. bees (size ≥ λ/2).
- Compare ICNIRP to bee SAR



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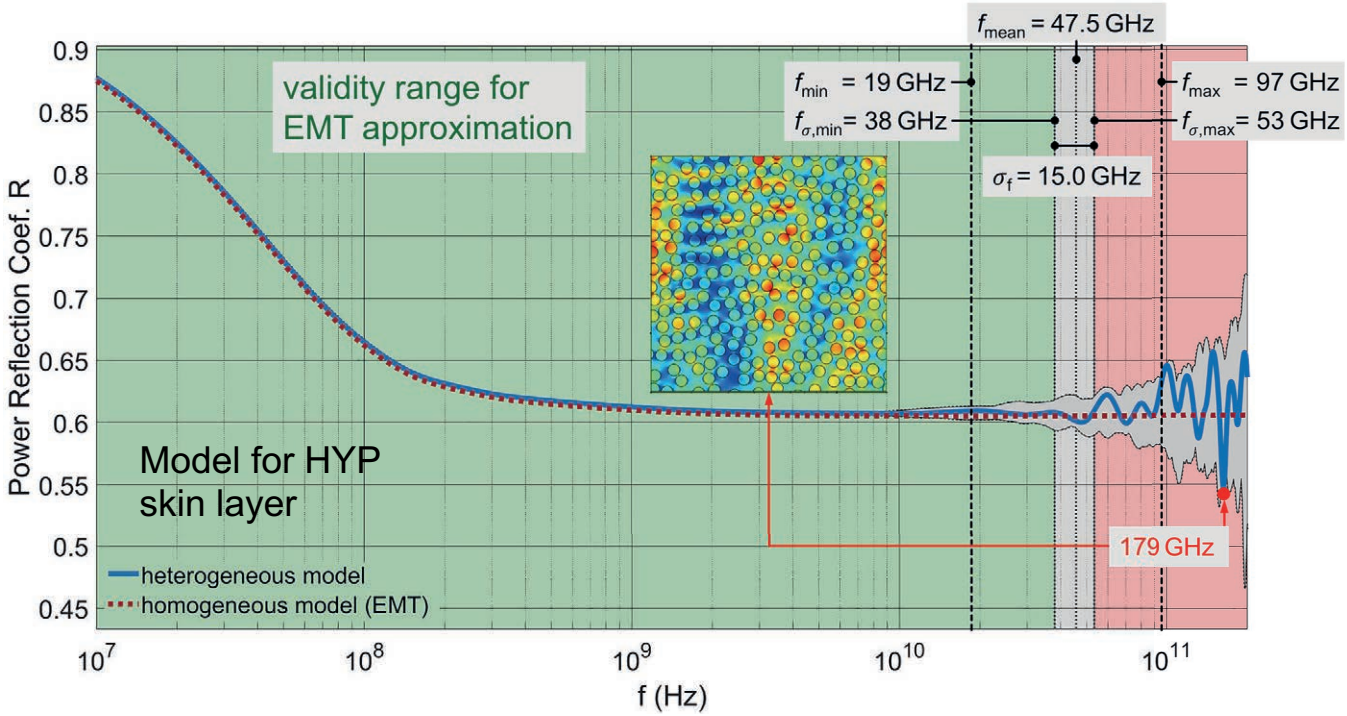
Current status of the project

- T4.8.1 – 6G.Microdosimetry:
  – EM multi-scale models are on the way
  – establishing an overall simulation process for virtual microdosimetry.
- T4.8.2 – 6G.Immission:
  – first transmission measurements
  – setting up of mm-wave near-field scanner.
- T4.8.3 – 6G.BioEMCenter:
  – preliminary work in setting up a center by pooling all our existing activities under this label. Steps towards insect monitoring.
- Staff situation:
  – selection process still ongoing (2. round)



Publications

[1] K. Jerbic, J. T. Svejda, B. Sievert, A. Rennings, J. Fröhlich, and D. Erni, "The importance of subcellular structures to the modeling of biological cells in the context of computational bioelectromagnetics simulations," *Bioelectromagnetics*, 2022, (submitted), arXiv: https://arxiv.org/abs/2206.09757

[2] K. Jerbic, J. T. Svejda, B. Sievert, A. Rennings, J. Froehlich, and D. Erni, "The role of organelles in electromagnetic microdosimetry based on broadband multiscale skin models of eukaryotic cells," *BioEM 2022*, June 19-24, Aichi Industry and Labor Center (WINC AICHI), Nagoya, Japan, Session 14: 'S14: Computational Dosimetry', 2022.

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