High-frequency incident power density assessment on non-planar tissue models

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Introduction

- International guidelines for human protection against electromagnetic fields have undergone revision due to the active deployment of 5G worldwide [1]
- As 5G enters *mm*Wave frequency spectrum, a dosimetric quantity above **transition frequency** of 6 GHz is defined as the **incident power density** (**IPD**), since known biological effects concerned with tissue heating pertain to skin surface and are negligible elsewhere [2]
- Currently, the irradiated area of skin surface is represented as a planar multi-layer model in most of the research [3]
- This work extends the current state-of-the-art and utilizes spherical representation of the irradiated skin

Description of the research problem

- At frequencies higher than 6 GHz, the IPD on the skin surface has taken as the dosimetric measure because of the short power penetration depth in tissue
- Mathematically, the IPD is defined as the **surface integral** of the real part of the magnitude of the Poynting vector:

$$S_{ab} = \frac{1}{2A} \oiint_A \Re[\vec{S}]\vec{ds}$$

- Considering realistic surfaces of interest, the Jacobian *ds* is unfeasible to be derived analytically:
  Approach I.
  realistic 3-D head model → **spherical head model**
  surface, *A*, is parametrizied by defining a system of curvilinear coordinates, i.e., azimuth and polar angle
  Approach II.
  neural network parametrization
  e.g., of *y*-axis: *y ≈ f(x, y)*. *f* is any feedforward architecture that complies to the principles of universal approximation theorem [4]

Research methodology

- This research deals with the **Gaussian quadrature** on the surface of the spherical head model (approach I) in order to obtained the IPD:
  1. Computing the current distribution over the realistic radiating antenna (half-wave dipole shown as a red line in Figure 1) by solving Pocklington integro-differential equations
  2. Computing the electric and magnetic vector field (and, subsequently, power distribution) over the observed surface by utilizing field equations that yield from the boundary element formalism (right subfigure in Figure 1)
  3. Computing the IPD by solving the surface integral numerically

Results

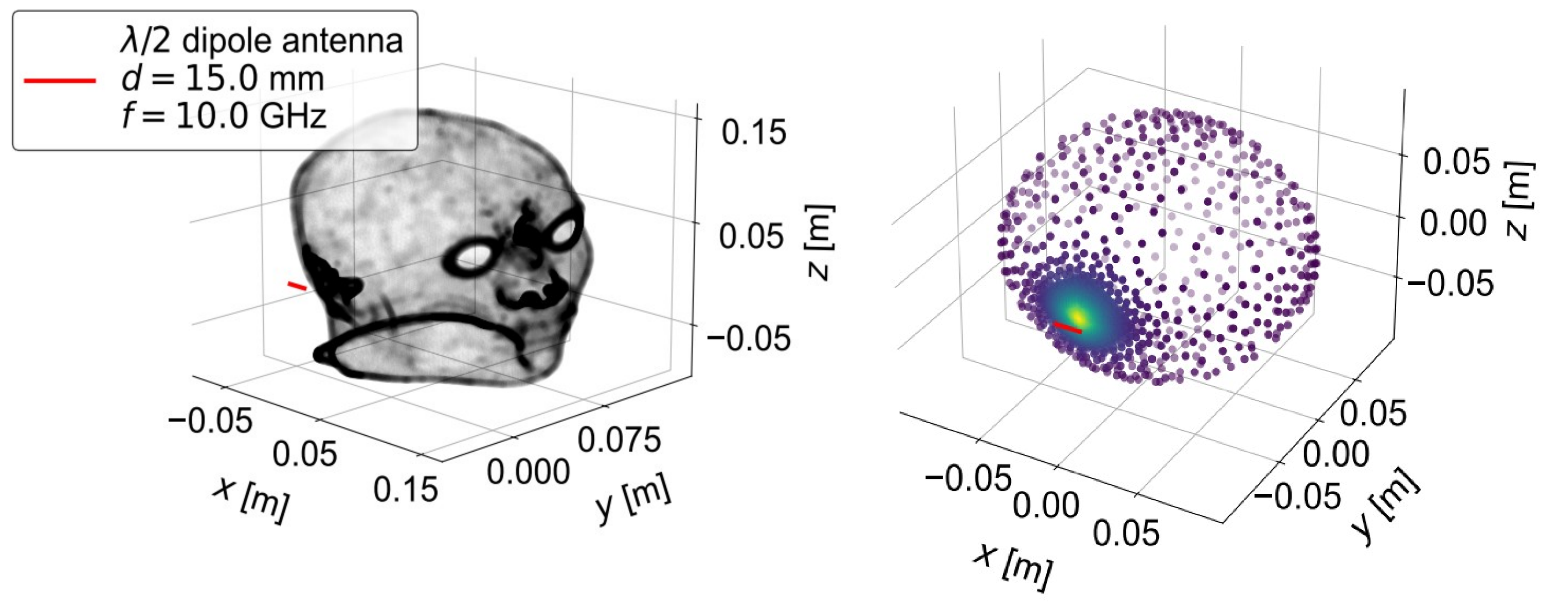

Figure 1. Spherical representation of the realistic model of human head. The radiating body is placed at a distance of 15 mm from the ear, simulating the use of personal mobile device.

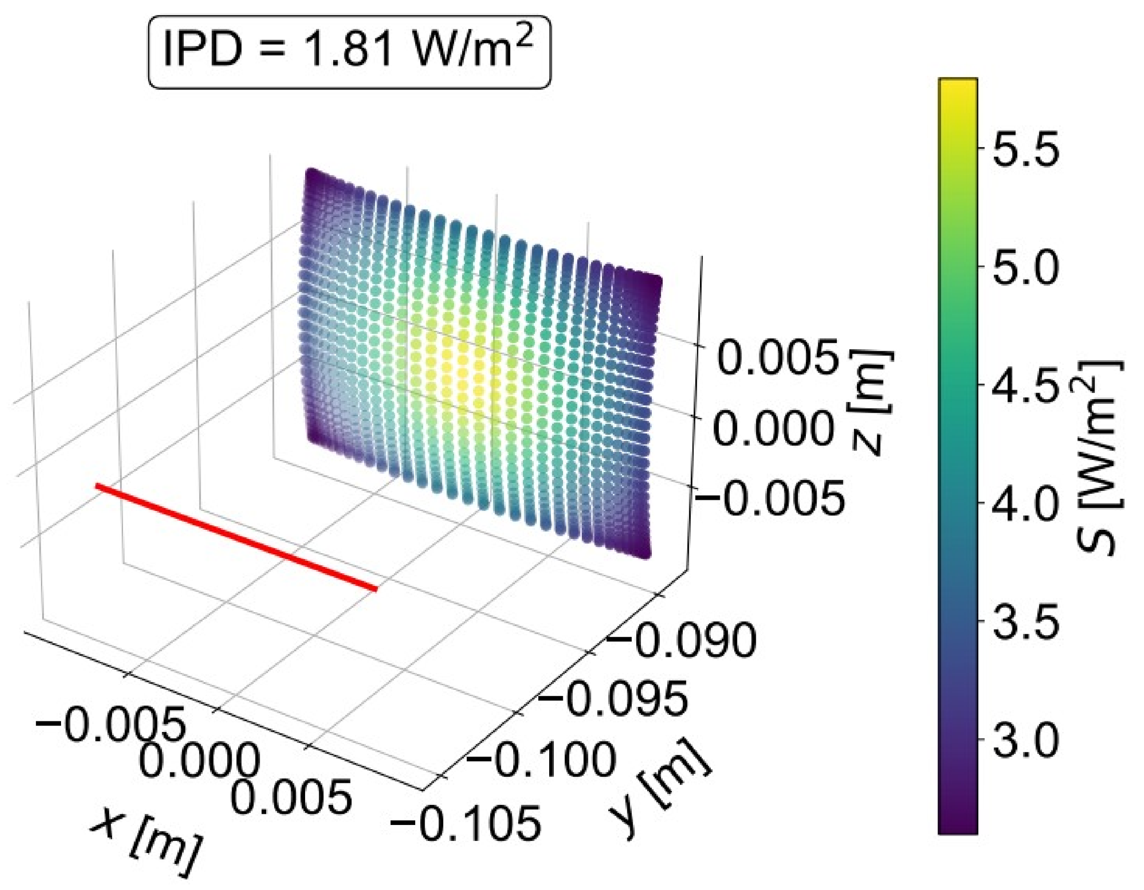

Figure 2. Power density distribution on the skin. Incident power density is averaged over effective skin surface of 1cm².

Conclusion

- **Research contributions:**
  1. Automatic differentiation-based solver for computing the electric and magnetic vector field distribution
  2. Realistic exposure scenarios where non-planar tissue model is considered instead of standard planar geometry
  3. Gaussian quadrature-based surface integral solver capable of handling arbitrary functions over the (part of the) surface of a sphere
- **Future work:**
  Extending the Gaussian quadrature surface integral solver for any irregular surfaces (approach II)

References

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[3] Hirata, A. et al. "Human exposure to radiofrequency energy above 6 GHz: Review of computational dosimetry studies", Physics in Medicine & Biology (2021) 66(8):-.-
[4] Hornik, K. et al. "Multilayer feedforward networks are universal approximators", Neural Networks (1989) 2:359-366

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