EM-Art: Electromagnetic artificial human - paradigm shift in dosimetry for 5G and beyond

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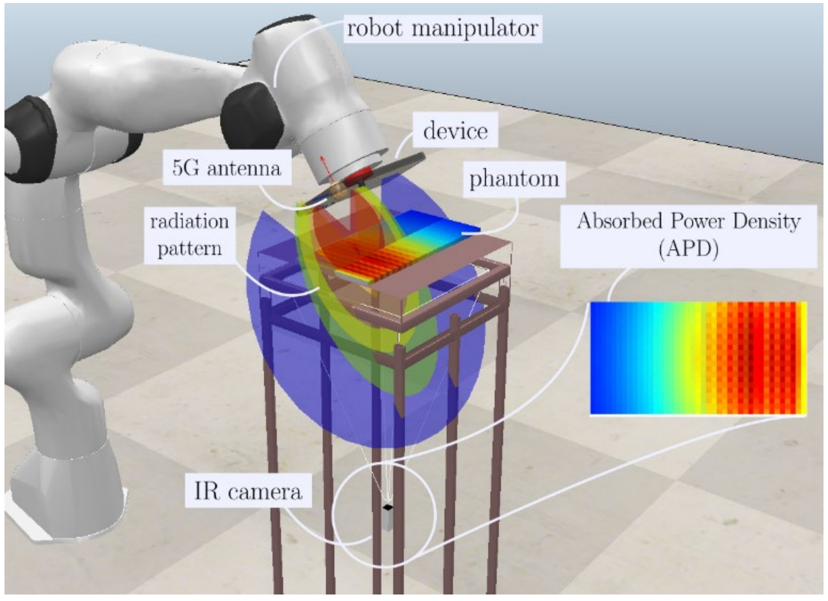
Robot-assisted worst-case exposure scenario identification

Objective

To elaborate a strategy towards the fast and reliable identification of the worst-case exposure scenario for a robot-manipulated 5G wireless device. The device operates in proximity to human body, represented by a novel reflectivity-based phantom, to maximize Absorbed Power Density (APD) in the phantom, measured by an IR camera.



Problems to address

Calibration of the 5G mmWave antenna configuration

Estimate the **configuration** (i.e., 3D position, orientation, radiation pattern) of the antenna by **minimizing the difference between actual APD measures and model-based predictions**.

$$\boldsymbol{\eta}^* = \min_{\boldsymbol{\eta}} \sum_{i=1}^{N_x} \sum_{i=1}^{N_y} \| h_{i,j}(\boldsymbol{\eta}) - z_{i,j} \|^2$$

Identification of the maximal APD antenna configuration

Predict and command the robot manipulator to drive the device towards the configuration that **maximizes the APD over the target surface,** in the proximal space around the surface, leveraging the identified antenna configuration.

Calibration of the 5G mmWave antenna configuration: formalization and results

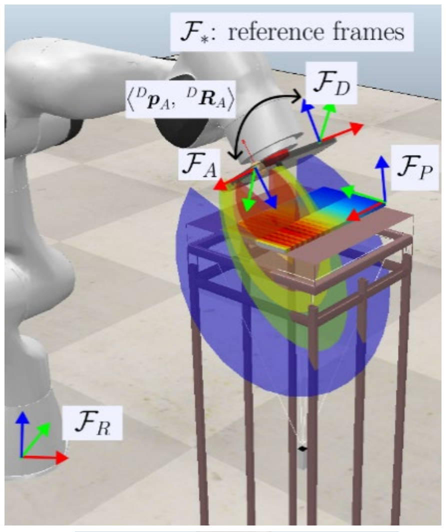
Estimation problem

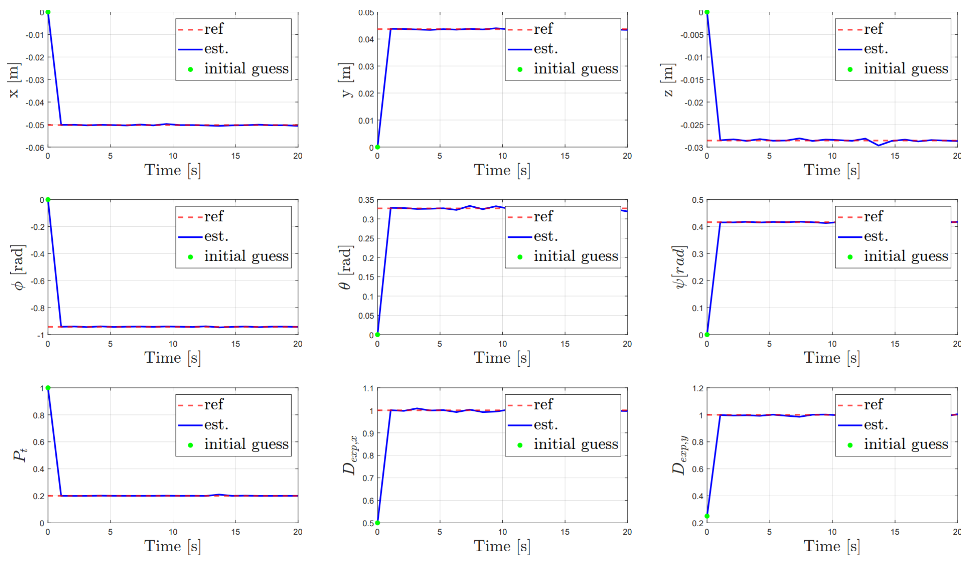
$$\boldsymbol{\eta}^* = \min_{\boldsymbol{\eta}} \sum_{i=1}^{N_x} \sum_{i=1}^{N_y} \| h_{i,j}(\boldsymbol{\eta}) - z_{i,j} \|^2$$

model-based prediction | APD measurement

Estimating state

$$\boldsymbol{\eta} = (x, y, z, \theta, \phi, \psi, P_t, kx, ky)^T = ({}^A\boldsymbol{x}_D, P_t, kx, ky)^T$$





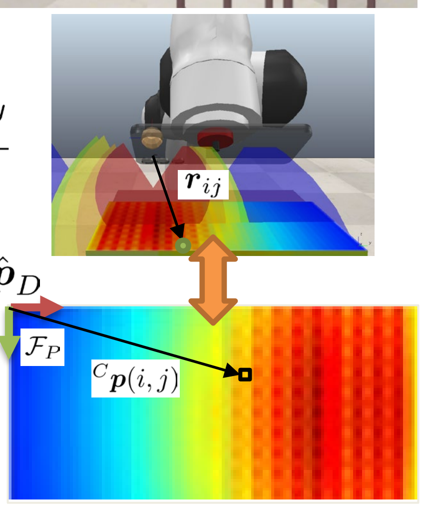
Measurement model

$$h_{i,j}(\hat{\boldsymbol{\eta}}) = \mathrm{APD}_{i,j} = \hat{P}_t \frac{cos(\hat{\alpha})^{\hat{kx}} cos(\hat{\beta})^{\hat{ky}}}{4\pi \|\hat{\boldsymbol{r}}_{ij}\|^2}$$

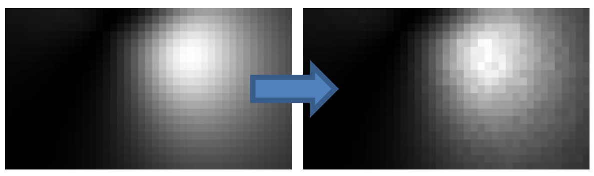
$$\hat{\boldsymbol{r}}_{ij} = {}^A\hat{\boldsymbol{R}}_D ({}^D\boldsymbol{R}_C \, {}^C\boldsymbol{p}(i,j) + {}^D\boldsymbol{p}_C) + {}^A\hat{\boldsymbol{p}}_D$$

$$\hat{\alpha} = -\mathrm{atan2}(\hat{r}_{ij}(1), \hat{r}_{ij}(3))$$

$$\hat{\beta} = -\mathrm{atan2}(\hat{r}_{ij}(2), \hat{r}_{ij}(3))$$



- Measurement noise simulated with SNR = 40dB

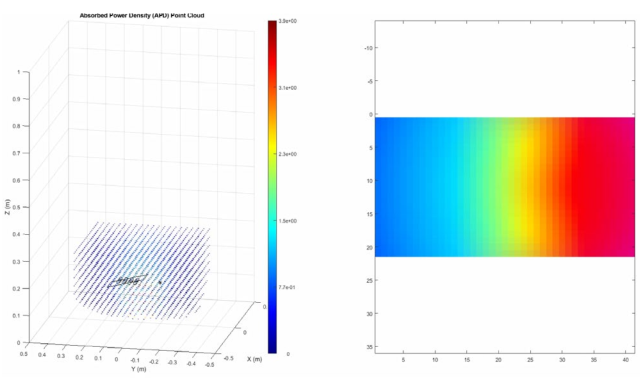


- For symmetric models (e.g., $k_x = k_y$), possible local minima issues may arise (i.e. multiple configurations may generate the same APD pattern at the phantom surface)
- Estimation accuracy (i.e., fitting error between true and model-based predicted antenna) also depending on the initial guess

Towards realistic numerical radiation patterns

Universal interface for reading the simulated or measured data for a wireless device under test.

Extract a 2D power density distribution from 3D near-field data, by selecting an appropriate slice from the volumetric data, aligned with the phantom surface.



Next actions

- Validation of the interface for the readout of the 3D near-field data
- Identification of the antenna position/orientation inside a wireless device under test, considered as a black box, for generic 5G antennas with multi-beam and scanning capabilities
- Development of the robot-based optimization strategy to identify the worst-case user exposure scenario
  - Enhanced prediction accuracy and convergence rate
  - Signal-to-Noise ratio as driving metric of the optimization
  - Intelligent optimization strategy to minimize the measurement time