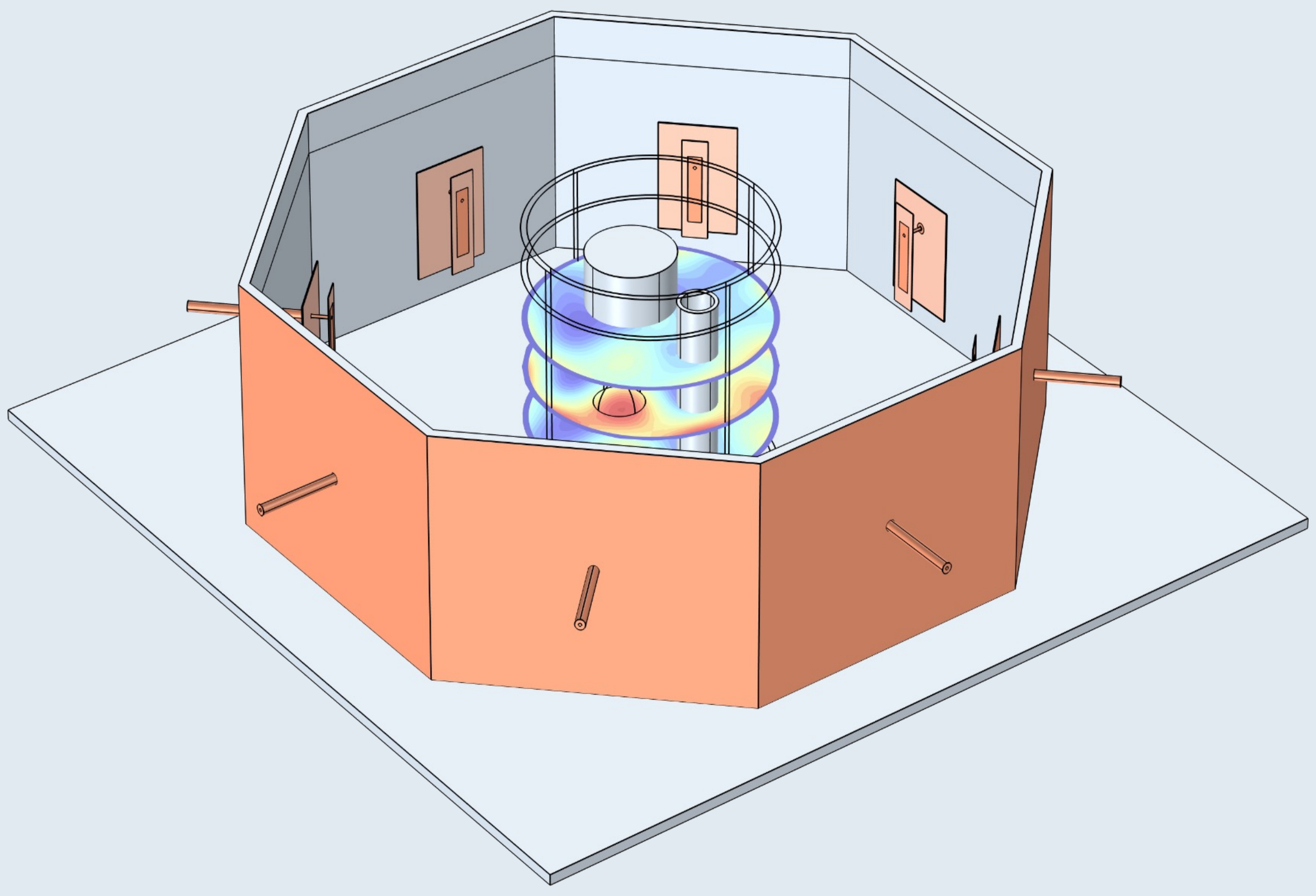

# Digital Twin of a H&N Microwave Cancer Hyperthermia Setup

This work explores the development of an experimental mock-up reproducing a hyperthermia treatment in the head and neck (H&N) region and its in-silico counterpart simulated in COMSOL Multiphysics®.


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## Abstract

Microwave hyperthermia (HT) improves cancer treatments by selectively heating tumors to 40-44°C, boosting radiotherapy and chemotherapy efficacy (Ref. 1).
This study focuses on the development of an experimental mock-up of an HT system for the head and neck (H&N) region, along with its digital twin in COMSOL Multiphysics®.
The setup consists of a PMMA container filled with a phantom mimicking the human neck tissue (Ref. 2), provided with one solid and one hollow PMMA cylinder to simulate the spine and the trachea, respectively. A circular array of eight patch antennas with water substrate (Ref. 3) was used to localize heating on a tumor target through array feeding optimization performed in COMSOL Multiphysics.
The results showed a good agreement between experimental and simulated temperatures confirming the functionality of the digital twin created in COMSOL Multiphysics.


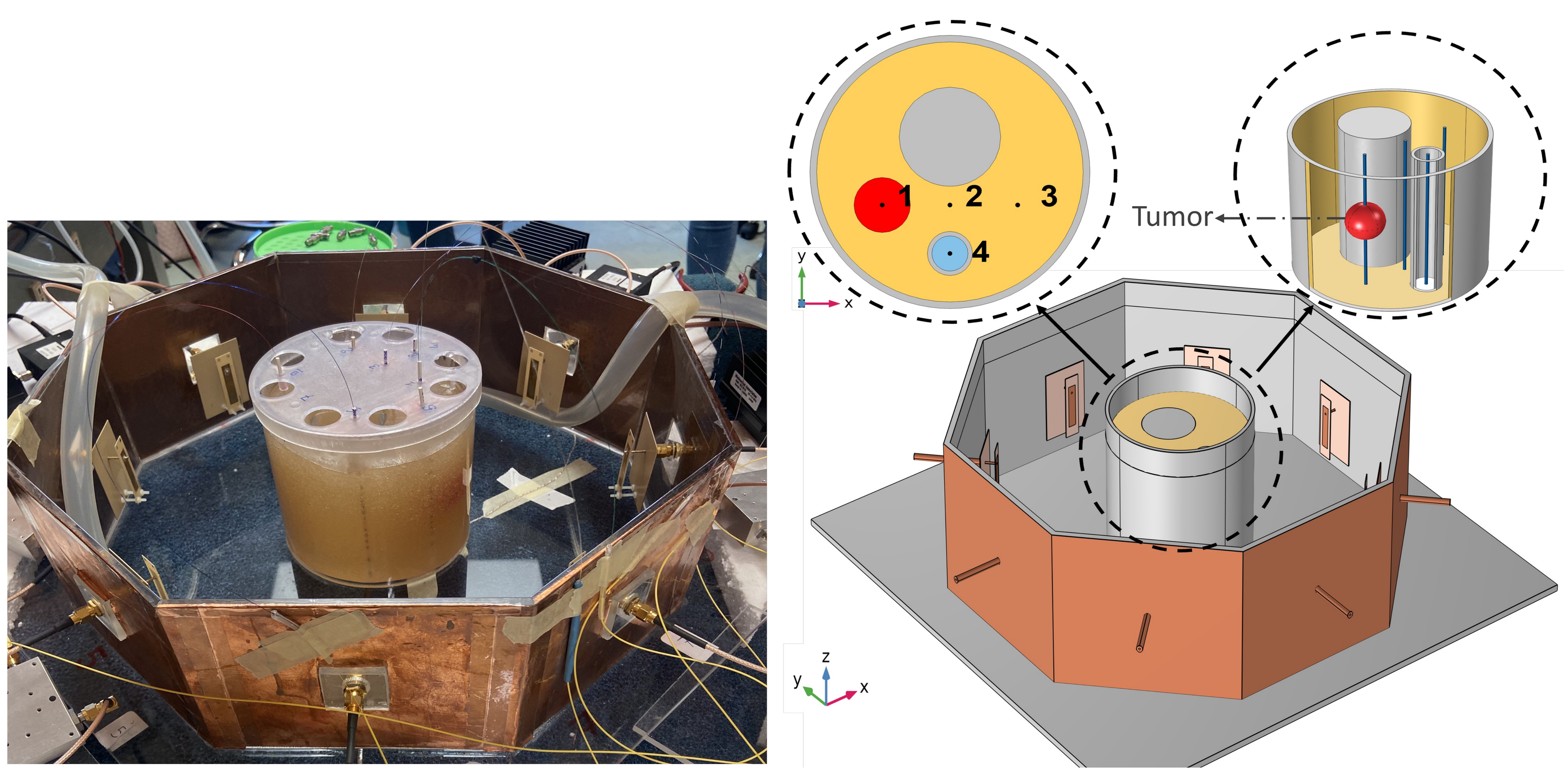


FIGURE 1. 3D view of the realized H&N HT system and its COMSOL digital twin with the used system of FBG sensors.

## Methodology

- The experimentally measured dielectric and thermal properties of the phantom (Ref. 4) were integrated into the simulation to create the digital twin.
- LiveLink for MATLAB® was utilized to optimize the antenna array coefficients, focusing the specific absorption rate (SAR) on the tumor target while minimizing hotspots in the surrounding tissue.
- To verify the localized heating, temperature data were collected experimentally using arrays of Fiber Bragg Grating (FBG) sensors.
- The experimental heating session lasted for 130 minutes with a total input power of 60W, while cold water was circulated in the internal space between the antenna and the neck phantom, simulating the presence of the water bolus.

## Results

The **RF module** (central frequency: $f_c = 434$ MHz) and LiveLink for MATLAB were used to optimize the array feeding coefficients and extract the optimized SAR, which was then used as input source for the **heat equation** (Heat Transfer Module), completed with the definition of the **heat flux boundary conditions** (B.C.):

$$\rho C_p \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \rho \text{SAR}, \qquad \hat{\boldsymbol{n}} \cdot (k \nabla T) = \boldsymbol{h}(T_{ext} - T)$$

The heat transfer coefficient $\boldsymbol{h}$ was determined for the following interfaces by fitting the model to the available experimental data: phantom's upper boundary with air ($h = 5\text{W}/(\text{m}^2\text{K})$), lower boundary with air ($h = 3\text{W}/(\text{m}^2\text{K})$), lateral walls with the water bolus ($h = 82\ \text{W}/(\text{m}^2\text{K})$).

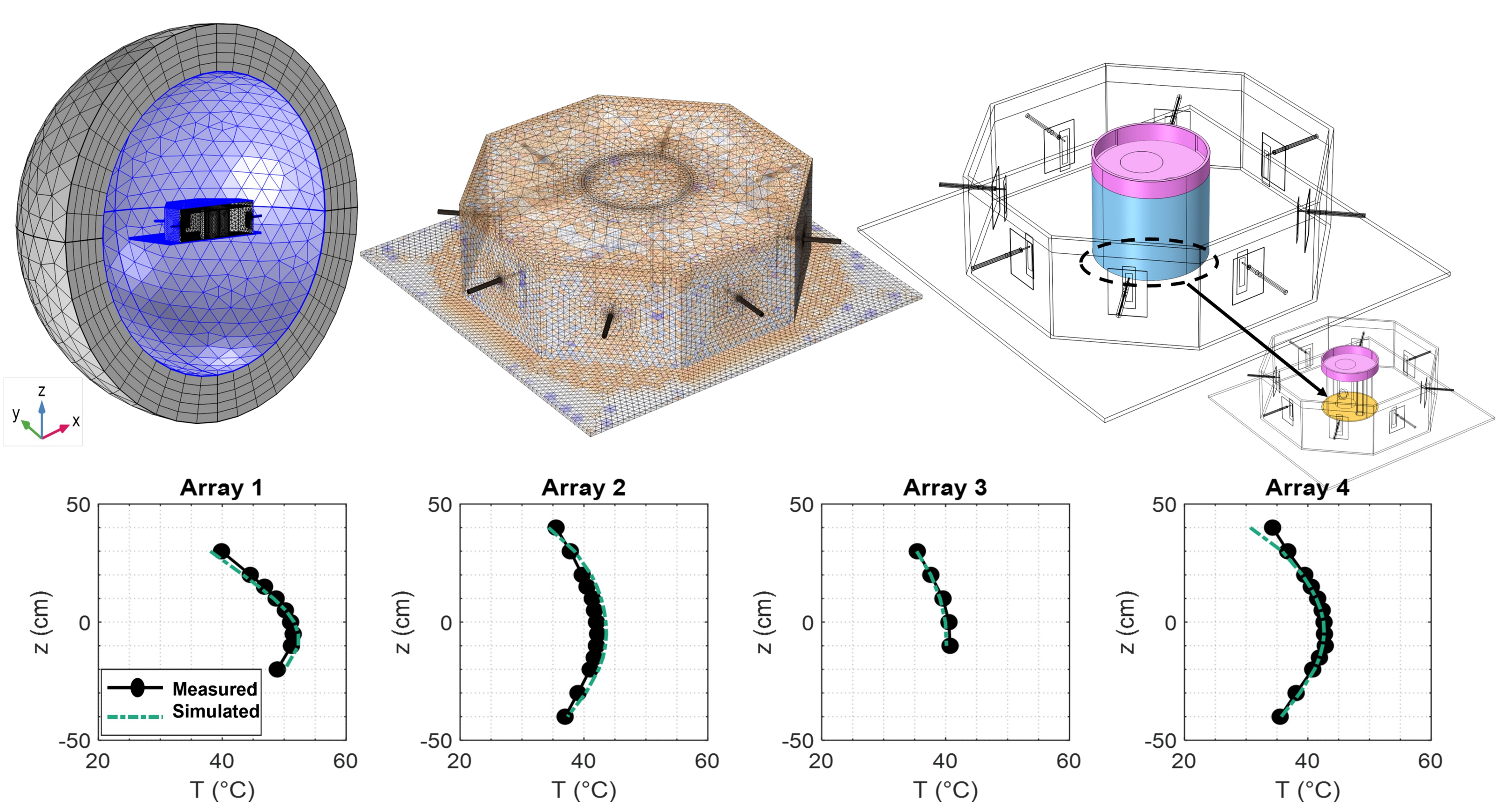


FIGURE 2. PML in grey, mesh detail and thermal B.C. of the realized HT digital twin (top). Measured and simulated temperatures from FBG system along $z$-axis at the end of the heating session (bottom).


## REFERENCES

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