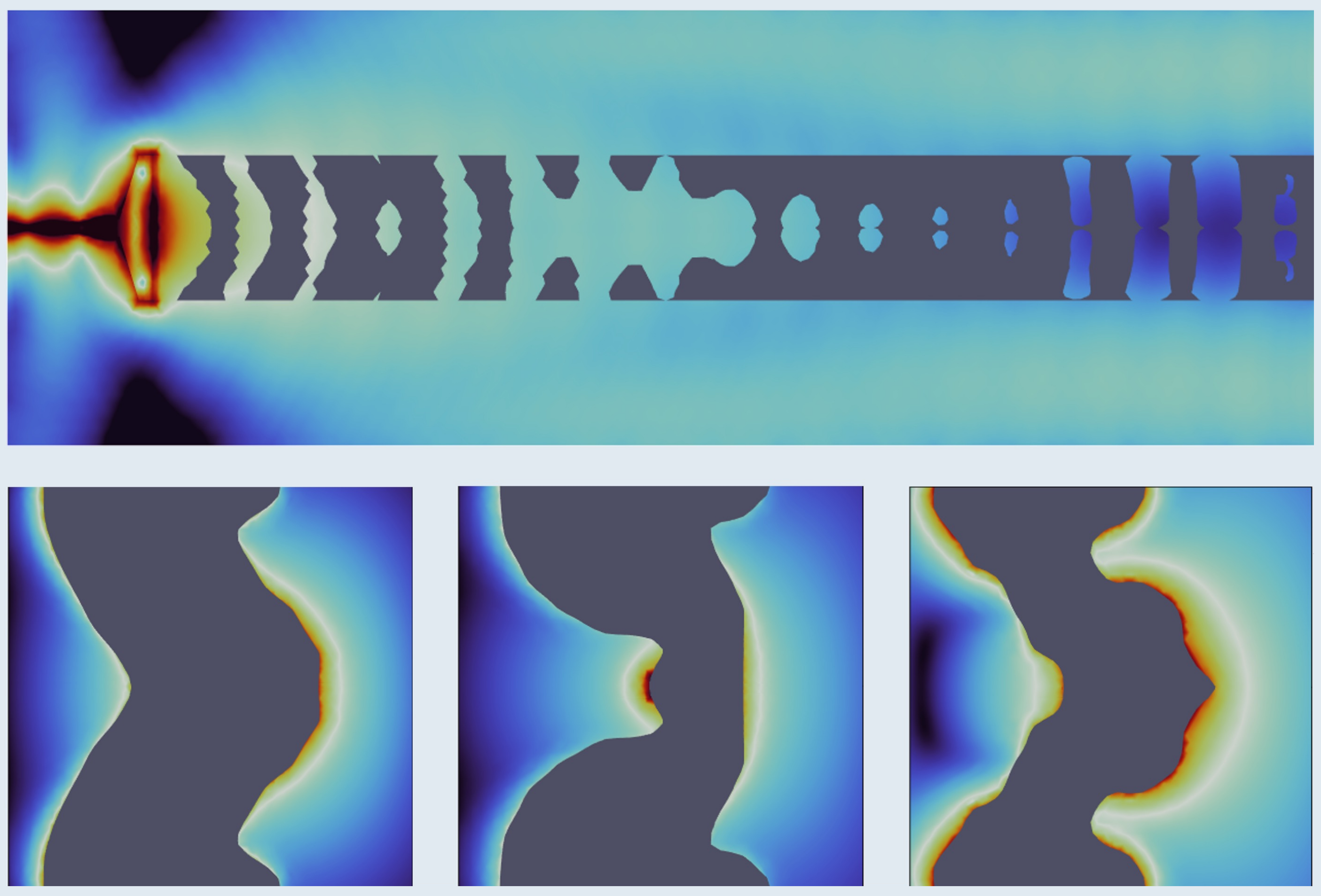

Topology Optimization of Antennas in COMSOL Multiphysics: Considerations and Preliminary Results

Preliminary results concerning the application of topology optimization for the design of two types of metallic antennas that are very different from each other: a leaky-wave antenna radiating at broadside, and an epidermal patch antenna, optimized to favor radiation coupling into the human body.

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Abstract

Topology optimization is a mathematical method that allows to find the material distribution within a defined domain which optimizes a predefined objective function, fulfilling given constraints. This technique has a wide range of applications in different research fields, such as aerospace, mechanical, bio-chemical and civil engineering.

The idea to apply this method in antenna design is not new (Ref. 1); in this context, the method is usually employed to change the metal distribution on the antenna surface, accepting the appearance and disappearance of holes.

In this work, we will present a 2D preliminary example showing the possibility to use the topology optimizer implemented in COMSOL Multiphysics® to optimize the metallic surface of a leaky-wave antenna (LWA) (Ref. 2), and the 3D topology optimization of the metal surface of an on-body patch antenna designed for biomedical applications (Ref. 3, 4).

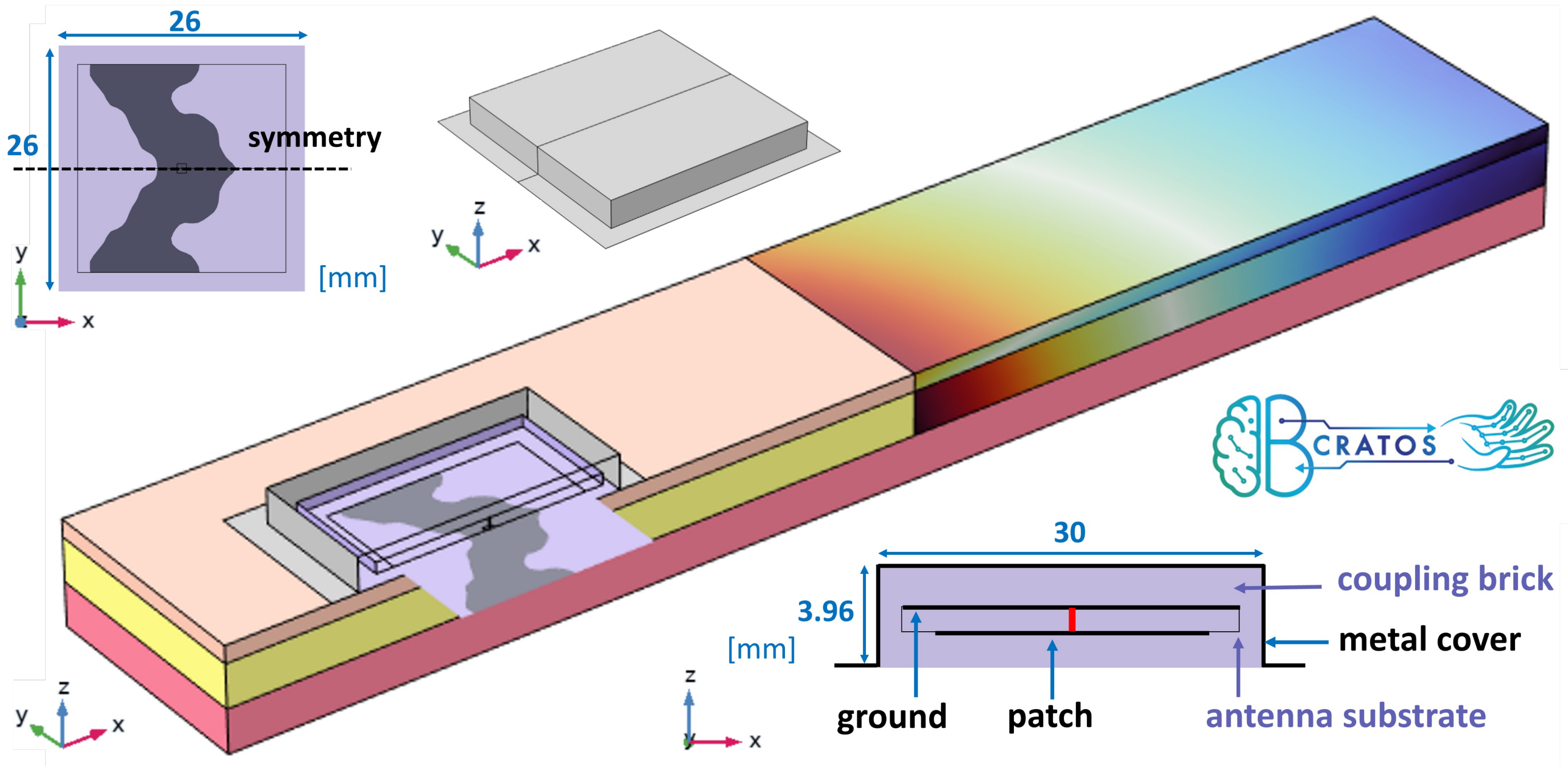

FIGURE 1. Layout of the patch antenna topologically optimized in COMSOL® to maximize the radiation coupling in the subcutaneous fat layer, allowing low-loss communication for implantable and wearable body networks (Ref. 3).

Methodology

In all the considered examples, a Density Model is applied to the design domain (antenna surface) to introduce a control variable field, which is bounded between 0 and 1. Then, a Transition Boundary Condition (TBC) is introduced on the antenna surface, and the filtered design variable is mapped to the electrical conductivity by (Ref. 1):

$$\sigma = 10^{(9\theta_p - 4)}, \text{ being } \theta_p \text{ the penalized material volume factor.}$$

In the case of the patch antenna, to obtain a more binary topology solution, a Helmholtz filter is introduced, gradually increasing the SIMP exponent and the projection slope with a Parametric Sweep (Ref. 5). Geometric symmetry has been enforced on the surface, with Perfect Magnetic Boundary Condition (PMC) on the $y = 0$ plane.

Results

For both the antennas, the electric field norm was introduced in the definition of the objective function.

1. **LWA:** the example is 2D. The z-component of the electric field was integrated at the boundary of the computational domain and used as the objective function to maximize the radiation at broadside.
2. **On-body patch:** the electric field norm was integrated in a portion of the domain where the RX antenna is supposed to be placed. By adding a constraint on the reflection parameter ($|S_{11}| < -10$ dB at $f_c = 434$ MHz), the final value reached is -13 dB. Introducing the Helmholtz filter was essential to obtain a clearer distinction between metal and dielectric on the antenna patch.

- Work is in progress to extend the LWA optimization to the 3D case.

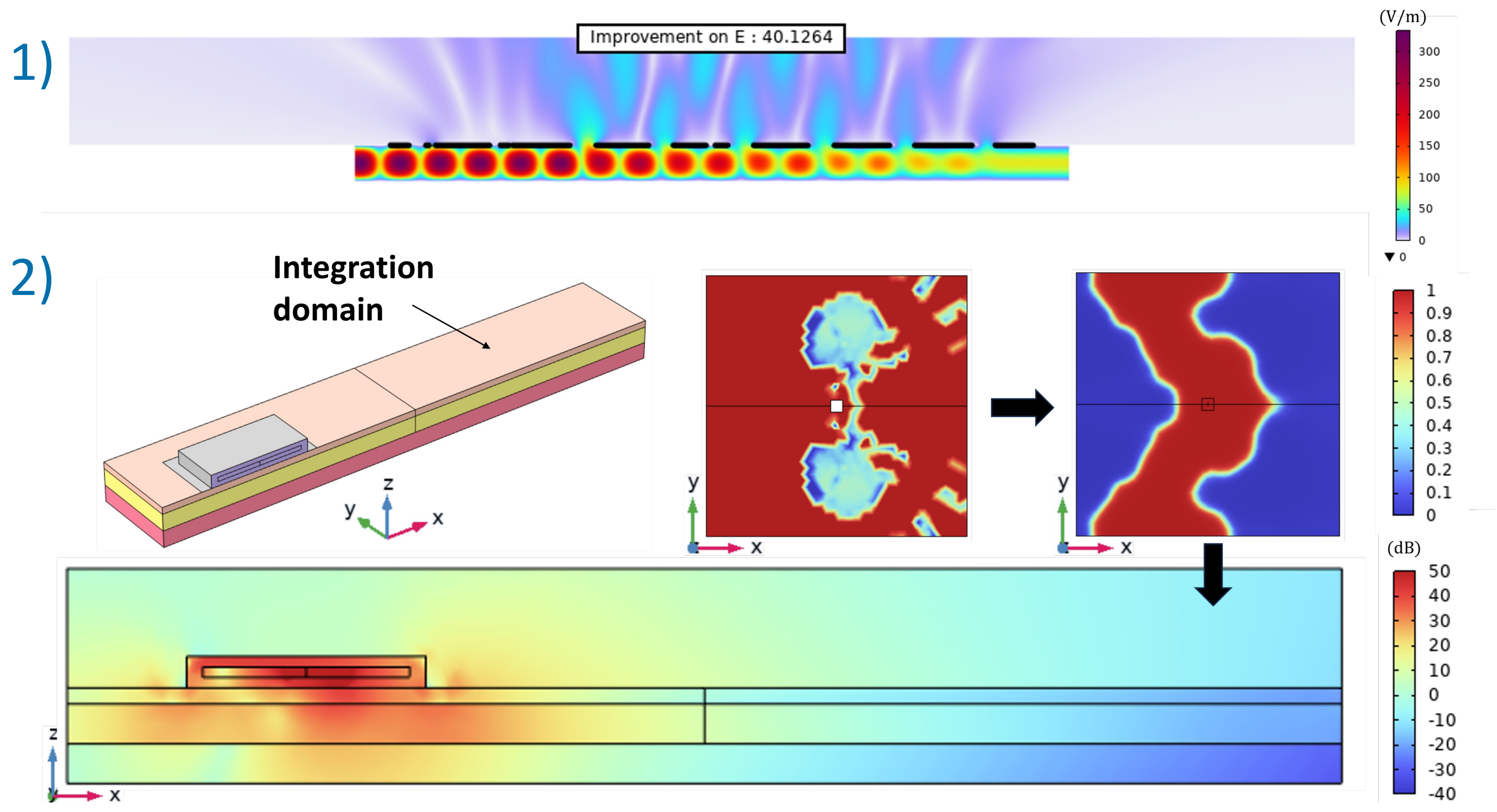

FIGURE 2. 1) Electric field norm of the optimized 2D LWA. 2) Optimized patch antenna before and after the application of the Helmholtz filter (*upper row*); electric field norm of the final optimized configuration (*lower row*).

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