Flexible Fractal-Inspired Metamaterial for Head Imaging at 3 Tesla MRI

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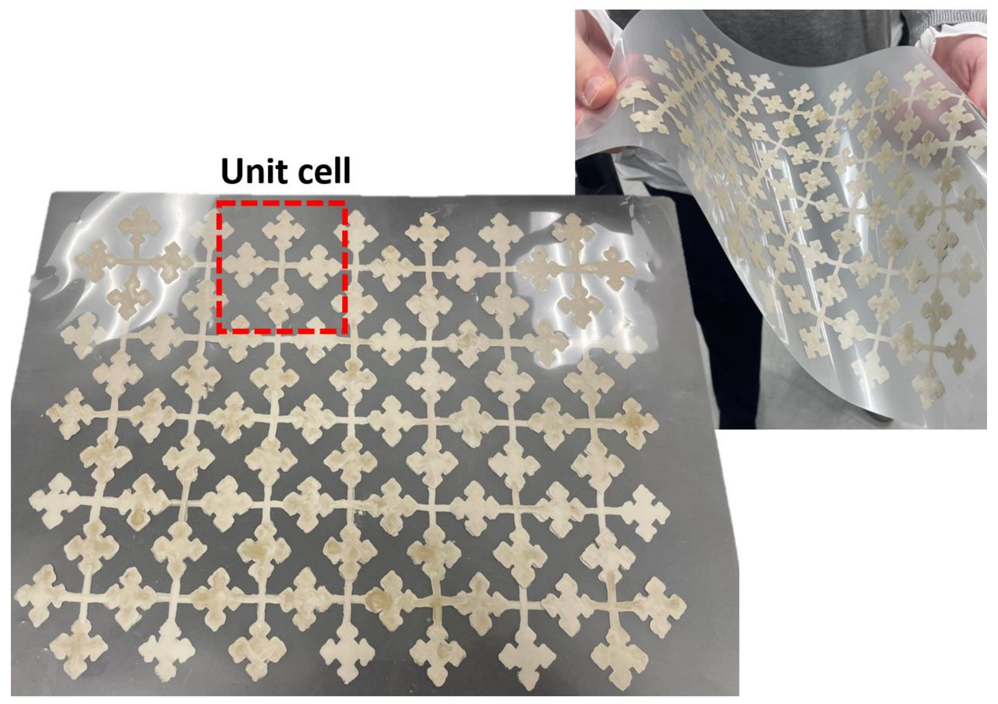
Introduction

- Magnetic resonance imaging **(MRI) is a non-invasive clinical imaging technique** [1].
- A **strong static magnetic field (B_0)** aligns hydrogenic nuclear spins in the body in the field's direction. A transmitted radiofrequency (RF) pulse from transmit coils in the MR hardware contains the **B_1 magnetic field** and knocks the spins out of alignment with $\mathbf{B_0}$. The spins now **precess** about the $\mathbf{B_0}$ field until the pulse stops [1,2,3].
- **PROBLEM:** MR imaging at 3 T (128 MHz) corresponds to short wavelengths that lead to the **standing wave effect** inside the MR bore, producing **bright and dark spots** in the resulting MR image [4,5].
- A **metamaterial** is an artificial periodic structure designed to exhibit specific electromagnetic properties [6].
- The phenomenon of **fractalization** may be used to increase the intrinsic capacitance in a metamaterial [7,8].
- **SOLUTION:** A **flexible fractal-inspired metamaterial** was designed to mitigate the standing wave effects observed at 3 T (128 MHz) by **homogenizing the B_1 field** inside the brain (ROI).

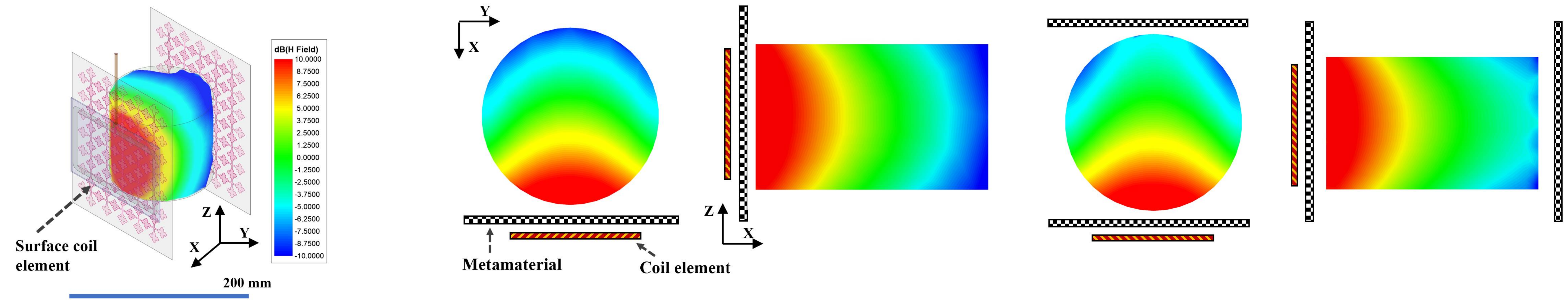
Methodology

A fractal-inspired unit cell was painted onto a flexible plastic substrate with MG Chemicals 842WB Super Shield silver nanoparticle-based paint.



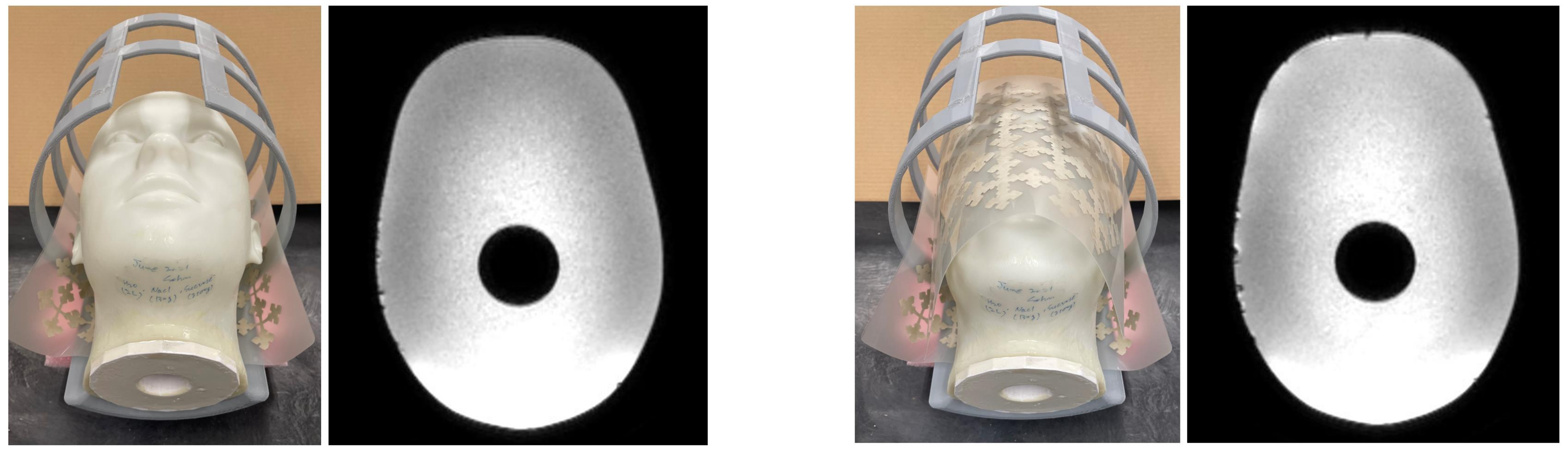
- Two metamaterial configurations were utilized to test the advantage of flexibility in the metamaterial substrate: **single-sided** and **double-sided**.
- Electromagnetic simulation was performed using Ansys High Frequency Structure Simulator (HFSS), and MR images were obtained from a 3 T Philips Ingenia scanner.
- Methodological approach was similar to that taken in [9].
- The degree of **B_1 field uniformity** and **signal-to-noise ratio (SNR)** will be used to compare single-sided and double-sided metamaterial configurations.

Results

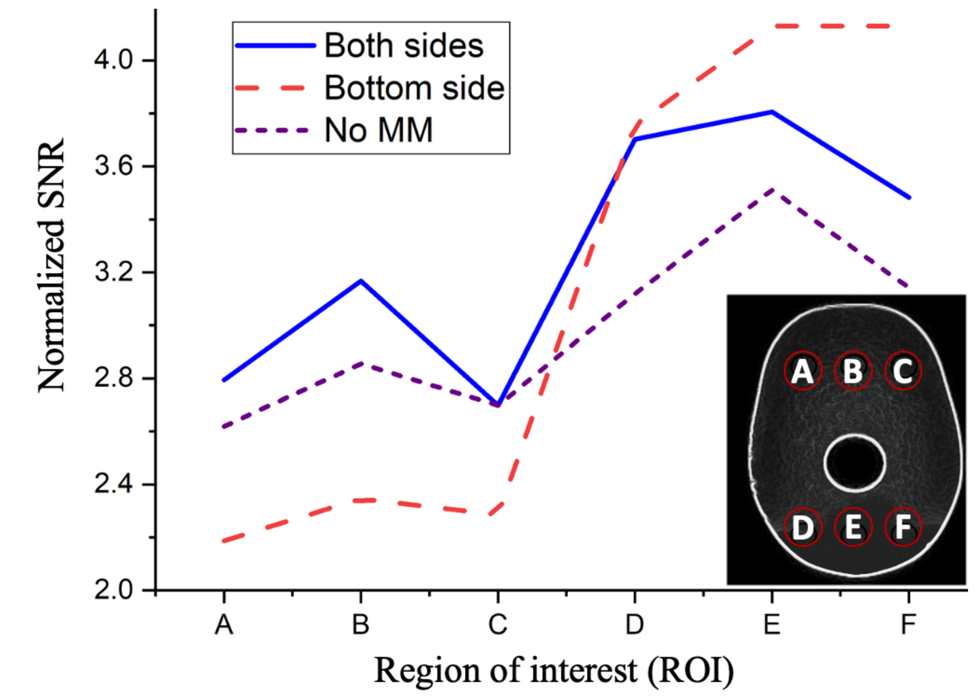


Electromagnetic simulation results using Ansys HFSS comparing single-sided (middle) and double-sided (far right) metamaterial configurations. The complex magnitude of **H** is plotted with a normalized scale from -10 dB to 10 dB.

The double-sided metamaterial configuration increases B1 field uniformity and shows an over 5% increase in normalized image SNR in five of six chosen ROIs in the double-sided configuration compared to no metamaterial use.



Imaging results using 3 T MR scanner for single-sided (left) and double-sided (right) metamaterial configurations



Normalized signal-to-noise (SNR) comparison of no metamaterial, single-sided, and double-sided configurations

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