Design of a Thin and Stretchable Metamaterial Cap to Enhance MRI Image Quality

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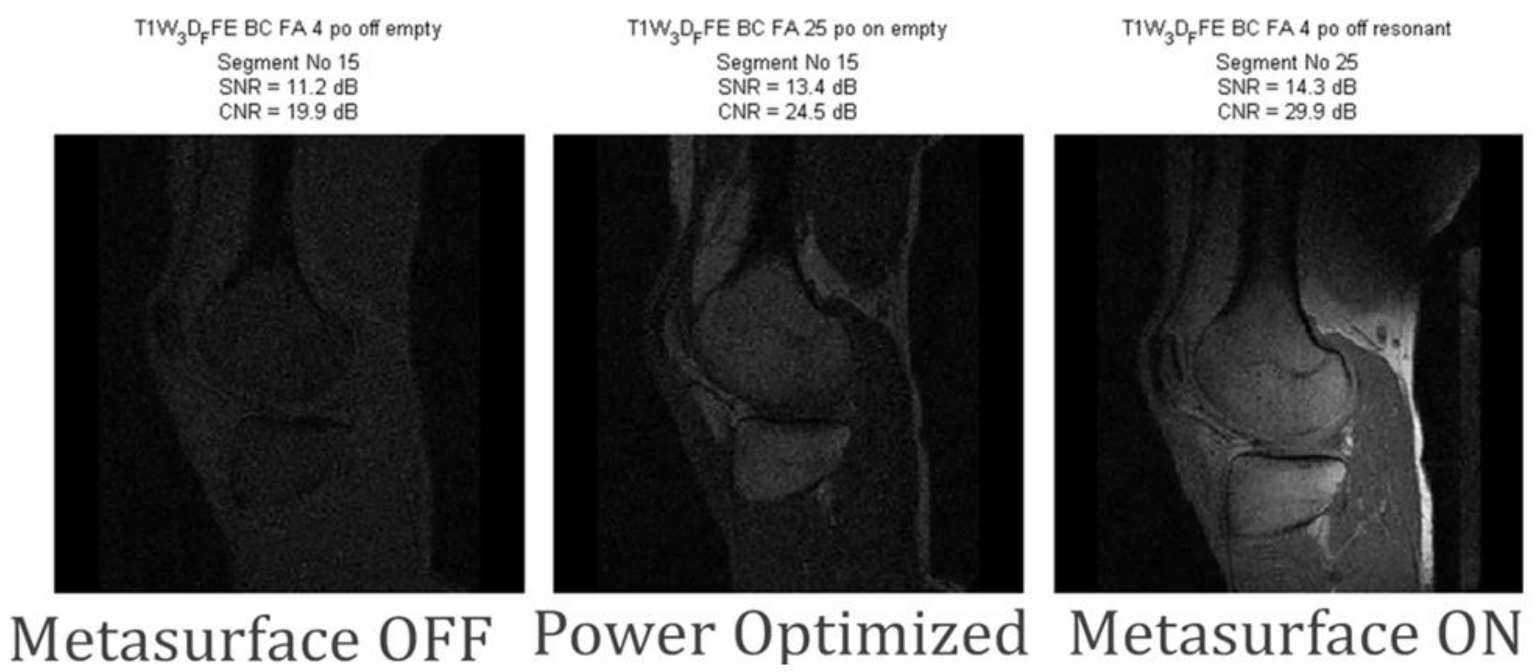
Background & Objective

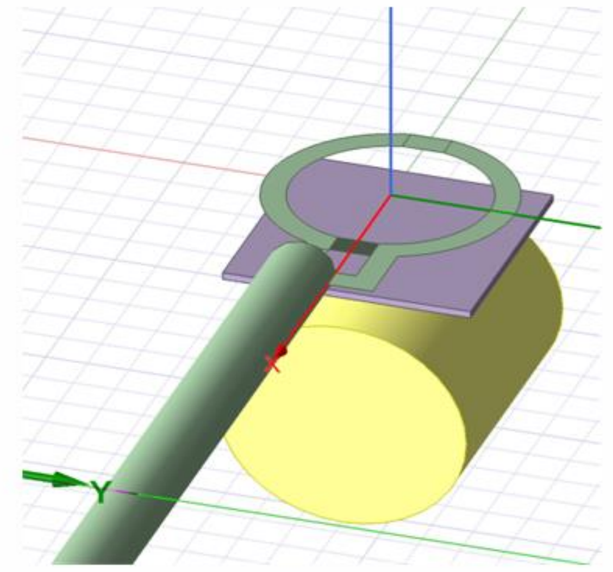
- Magnetic Resonance Imaging (MRI) is a medical imaging technique that utilizes a magnetic field and radiofrequency currents as a noninvasive diagnostic tool [1].
- Metamaterials are synthetic structures designed to exhibit special electromagnetic properties [2-5].
- A thin and flexible metamaterial designed in preliminary research was found to increase magnetic field uniformity significantly when wrapped around a phantom head [6,7].
- **Problem:** There lacks design specifications for a wearable soft cap using a stretchable metamaterial that can enhance the magnetic field and compensate for changes in resonant frequency caused by stretch distance, represented by the RLC formula $f = \frac{1}{2\pi\sqrt{LC}}$.



▲ **Fig. 1 MRI scan comparison with metasurface.**

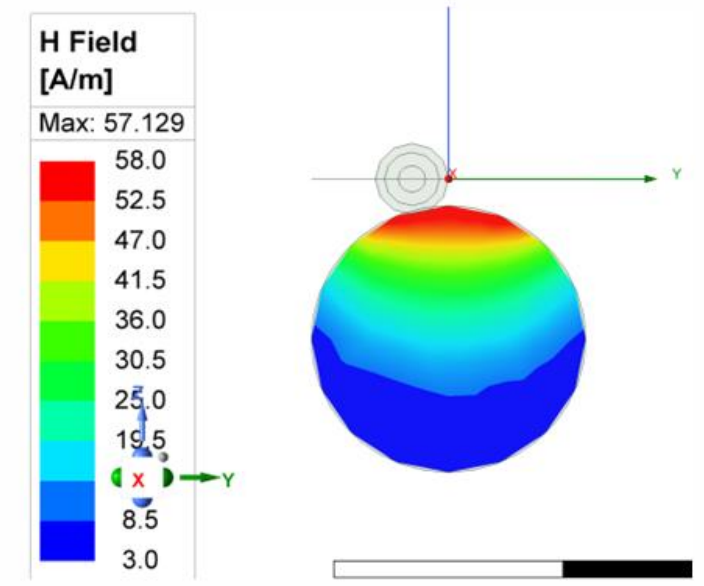
- **Solution:** A stretchable, conductive metamaterial pattern was designed to create safer and higher quality MR images, measured by its ability to increase RF magnetic field intensity and signal-to-noise ratio (SNR) of an MRI scan.
- **Objective:** To supply healthcare professionals with access to higher detailed anatomical information for better medical care.

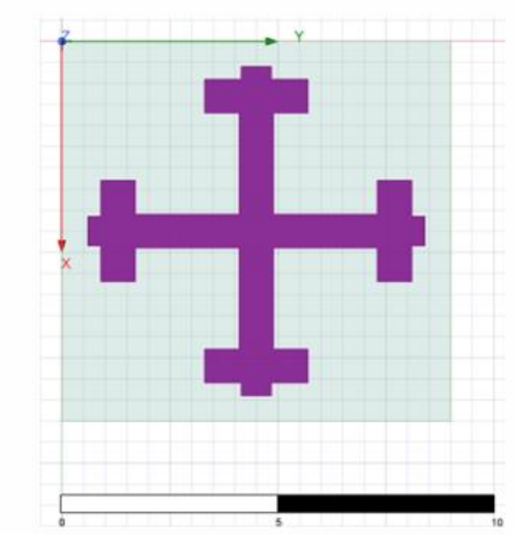
Results



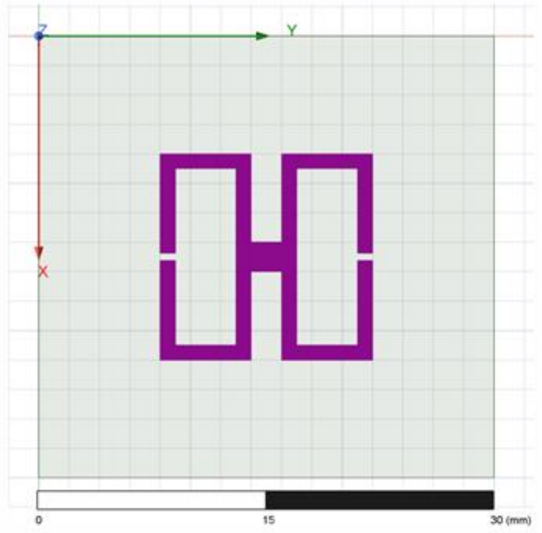
◄ **Fig. 3 Standard simulation schematic.**

Fig. 4 H-field of phantom before metamaterial insertion. ►

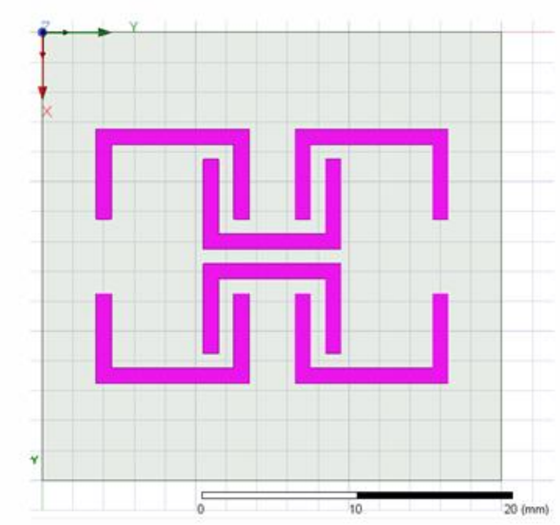




▲ **Fig. 5 Unit cell design based on previous experiment.**



▲ **Fig. 6 "Infinity" unit cell design.**

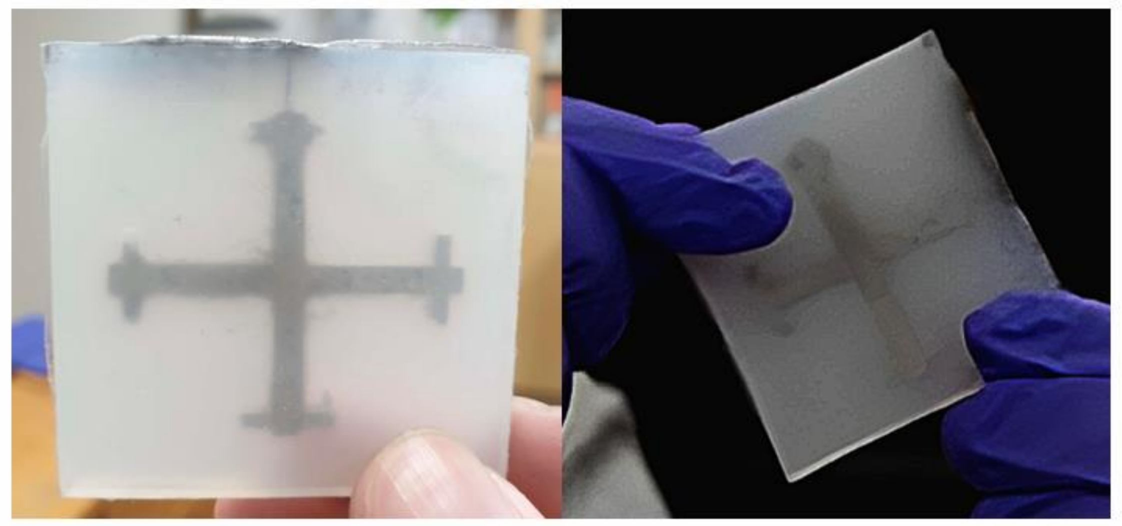


▲ **Fig. 7 "Staples" unit cell design.**

Methodology

- Electromagnetic simulation for metamaterial circuit design was performed using Ansys High Frequency Structure Simulator (HFSS Student Version).
- Simulations were conducted using a single unit cell as representation for the full periodic structure of the metamaterial.
- Upon fabrication, imaging results will be compared to traditional MR images.
- A 400 MHz RF coil and phantom were placed around metamaterial in HFSS.

Fig. 2 Proof-of-concept model using Ecoflex polymer and liquid metal to show stretchability. ►



Future Work

- Further simulations with stretching conditions in both the x and y directions will be conducted.
- Following subsequent modifications, the metamaterial will be fabricated using silicon and a 3D printed mold.
- Properties will be physically analyzed by vector network analyzer, oscilloscope, and RF probes.
- For bench testing, 3T whole-body MRI scanner at Barrow Neurological Institution for MRI examination.

References

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