Nitinol-Enhanced Wireless Radiofrequency Coils: Advancing MRI Diagnostic Technology with Shape-Memory Alloys

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Research Question: Is it possible to implement nitinol into wireless RF coils to improve imaging and features?

Background

- Traditional MRI RF coils use copper as the standard conductor due to its high conductivity
- Nitinol is a shape-memory alloy, meaning it has superior biocompatibility and flexibility
- Nitinol is non-ferromagnetic, demonstrating MRI compatibility and artifact-reducing
- Implementation of nitinol may lead to greater adaptability for coil designs
- Potential for a new generation of wireless RF coils

Methods

Based on data found via VNA measurements or calculations based on the chosen geometry of the nitinol coaxial cable…

- Inner core diameter = 1.0mm, Outer core diameter = 3.99mm, length = 0.3302m
  - Characteristic Impedance (Z0) = 55.07 Ω
  - Capacitance Per Unit Length (C') = 91.26 pF/m
  - Inductance per Unit Length (L') = 276.76 nH/m
  - DC Resistance (Nitinol) = 0.332 Ω
  - DC Resistance (Copper) = 0.00733 Ω
  - AC Resistance (Nitinol) = 11.24 Ω/m
  - AC Resistance (Copper) = 1.64 Ω/m
  - Skin depth (Nitinol) = 22.37 µm
  - Skin depth (Copper) = 3.26 µm
  - Resonant Frequency (Nitinol) = 301.51 MHz
  - Resonant Frequency (Copper) = 290.34 MHz

$$Z_0 = \frac{1}{2\pi}\sqrt{\frac{\mu}{\varepsilon}}\ln\frac{b}{a} \qquad R = \rho\frac{L}{A} \qquad \delta = \sqrt{\frac{2\rho}{\omega\mu}}$$

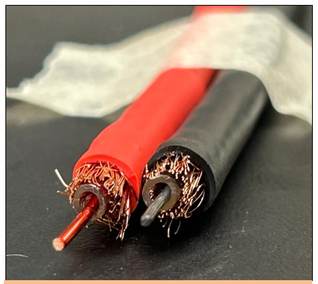

Fig 1: Nitinol and copper coaxial cables side by side

Fig 2: Nitinol and copper coaxial resonators side by side

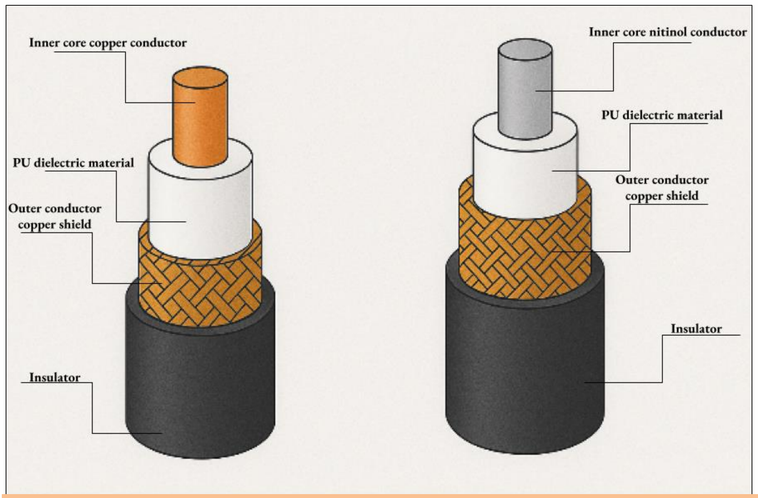

Fig 3: Dissection of nitinol and copper coaxial cables

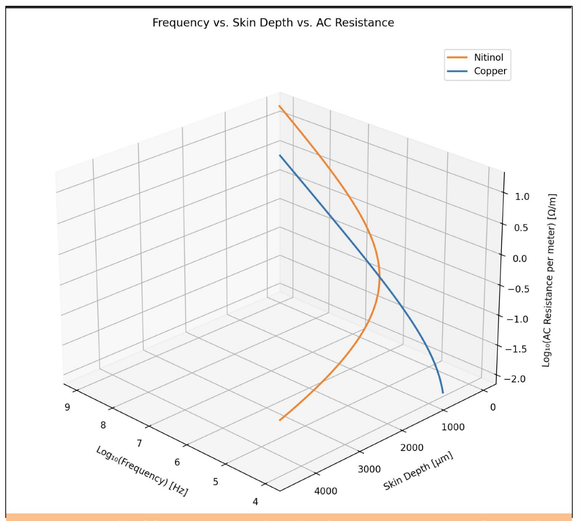

Fig 4: 3D graph of frequency vs. skin depth vs. AC resistance of nitinol and copper coaxial cables

Conclusion/Discussion

- Nitinol coaxial cables have similar impedance, capacitance, and inductance to copper coaxial cables
- The DC resistance of nitinol is roughly 45x higher than copper, and its AC resistance at 400MHz is roughly 7x greater – resulting in higher susceptibility to signal loss and power dissipation
- Skin depth analysis shows that nitinol allows deeper current penetration, which may lead to increased heating at high frequencies
- General rosin-core solder is incompatible with nitinol, presenting a difficult challenge when attempting to make electrical connections

Given its advantage with shape-memory behavior, flexibility, and MRI safety, nitinol most certainly has a place in the future of MRI technology, despite having a higher resistance than copper. While nitinol's greater signal loss is an obstacle, the resonant frequency and impedance demonstrate that it still has RF potential. Optimization through hybrid designs or integrated amplification circuits may prove to be the most promising.

Future Work

Advanced Prototype Development → MRI Imaging Test and Design Validation → Implementation Into Other Coil Designs

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