Avoiding Resonant Lengths of Wire with RF Chokes at 4 Tesla

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Introduction

Applications that introduce electrically conductive lengths into the MR environment are becoming more prevalent. Most common are the MRI tracking of guidewires and catheters for interventional vascular procedures, and acquiring physiological measurements (ie. EEG, EKG) concurrent with MR data. However, RF electric fields can drive high frequency currents in conductive wires within the RF volume, resulting in B_1-related image artifacts and heating. Low-pass or band-pass circuit elements such as MR compatible RF chokes can be employed to segment the length of the wire that is conductive to RF signals[1], which may help to avoid resonance conditions and thus minimize the unwanted energy coupling effects. This approach may be particularly useful for high magnetic field MR scanners ($\geq$ 3 T), where the resonant lengths may be similar to the lengths of wires used for MR-guided intervention and physiological monitoring. *The purpose of this study was to investigate the efficacy of using RF chokes to avoid resonant energy coupling between RF electric fields and conductive wires at 4 Tesla as evidenced by the induction of image artifacts.*

Methods

Non-ferrous molded RF chokes (1.0 μH, phenolic core; 9230-20, J. W. Miller Magnetics) commonly used in our RF coil laboratory were selected for this study based on their ability to filter out RF currents at 4 T (~ 170 MHz). The impedance of the chokes at lower physiological frequencies was determined using an impedance analyzer. Imaging experiments were performed on a 4 T Varian *UNITY*INOVA whole body scanner equipped with a quadrature hybrid birdcage RF head coil and Siemens Sonata actively shielded gradients. A long, cylindrical 15% agarose gel phantom (diameter = 7.5 cm, length = 60 cm) with [NaCl] = 150 mM (salinity matched to human skin tissue) was centered with respect to the z-axis within the volume of the RF coil, and was positioned with a y-offset near the top coil wall to maximize electric field coupling. Previous work had identified the resonance pattern of image artifacts vs. conductive wire length in the same experimental set up. Specifically, a resonant length of 35 cm was shown to generate severe image artifacts, while shorter wires ($\leq$ 20 cm) and a 70 cm length generated no artifact (**Fig. 1**). Based on these findings, 35 cm and 70 cm lengths of wire were sequentially tested for image artifacts in two forms: (a) unmodified and (b) bisected with a single RF choke. Each length of insulated copper wire (with or without choke) was placed directly on the leveled surface of the agarose with its proximal tip aligned with the front of the RF coil rungs and its distal tip extending parallel to the static field. Images of the phantom were generated with a 3D gradient echo (GE) FLASH sequence (12 contiguous 2 cm thick slices, TR = 10.1 ms, TE = 5.5 ms) and were inspected for artifacts.

Results

The RF chokes provided strong filtering of RF currents (~ 3 kΩ at 170 MHz) while minimizing the impedance at physiological signal frequencies (< 1 Ω for f $\leq$ 1 kHz, **Fig. 2**). Furthermore, the non-ferrous chokes minimized MR signal loss due to dephasing. Image artifacts induced by each RF choke-bisected wire closely matched artifacts induced by the non-bisected wire of half the length (**Fig. 3**).

Discussion

The RF chokes were effective in segmenting the lengths of the wires that were conductive to RF currents. The choked 70 cm wire behaved as two resonating 35 cm wires, generating the same severe image artifact pattern as the unmodified 35 cm wire. More applicably, the choked 35 cm wire acted as two 17.5 cm wires, thus avoiding the resonant length while maintaining the wire dimension. Future work is required to confirm that heating effects occurring at the same resonant wire lengths can be similarly avoided with the use of RF chokes. *Consequently, RF chokes may prove essential for safely and effectively performing interventional MRI, physiological monitoring, etc on high field scanners.*

References

(1) Ferhanoglu O, Eryaman Y, Atalar E. MRI Compatible Pacemaker Leads. Proceedings of the 13th Annual Meeting of ISMRM, Miami, Florida, USA 2005:963.

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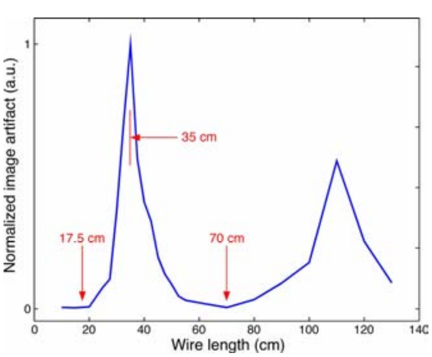

Fig. 1. Normalized pattern of image artifact vs. length of wire for free-floating insulated copper wire. A resonant length is seen at 35 cm, while 17.5 cm and 70 cm lengths exhibit minimal artifact.

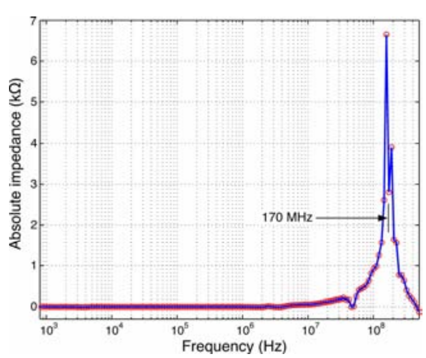

Fig. 2. Impedance sweep of RF choke. The choke delivers high impedance (~3 kΩ) for RF signals (~170 MHz at 4 T) and low impedance (< 1 Ω) at physiological frequencies (< 1 kHz).

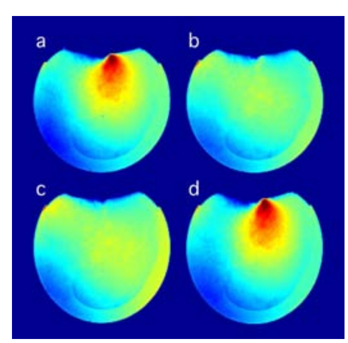

Fig. 3. Conductive bisection of wire lengths with an RF choke as evidenced by current induced image artifacts. Shown are gradient echo images of an agarose phantom underneath: (a) 35 cm wire, (b) 70 cm wire, (c) 35 cm wire bisected with RF choke, and (d) 70 cm wire bisected with RF choke.