Cylindrical Meanderline Intravascular MR Coils

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Introduction: The majority of intravascular RF coils that have been reported exhibit their maximum sensitivity at or near the central axis of the vessel, and not at the location of the pathology to be detected (the arterial wall). The cylindrical meanderline coil exhibits a sensitive volume that is restricted to a cylindrical shell, thereby maximizing the filling factor for plaques while reducing the blood signal. In this study the performance of the cylindrical meanderline coil is evaluated and compared to other common intravascular coil designs. The antiparallel alignment of adjacent conductors of a meanderline creates a rapid B_1 fall off with distance from the coil "plane." In the case of the cylindrical meanderline (Figure 1) B_1 decreases approximately as the (n+1)-th power of the distance from coil circumference, where n is the number of conductor pairs [1]. This sensitivity profile reduces interference from the blood signal and enhances the desired signal from the arterial wall.

Materials and Methods: A 3 mm fixed diameter cylindrical meanderline coil was compared with single loop and loopless designs. The meanderlines were etched into copper-clad flexible substrates and rolled into cylinders; other coils were built with discrete wires. Coils were immersed in 1.0 mM $MnSO_4$-doped water and imaged on a 4.7 T 30 cm Bruker Avance scanner. Finite difference time domain (FDTD) numerical simulations of the electric and magnetic fields at 200 MHz were performed using BioPro XFDTD 5.2 (Remcom, Inc., State College, PA). A prototype (larger than intracatheter) preamplifier circuit incorporating a pair of varactor diodes for remote electronic tuning, a PIN diode, and a low noise pseudomorphic high electron mobility transistor (PHEMT) amplifier stage was designed, built, and tested.

Results and Discussion: The cylindrical meanderline provides optimal performance for imaging at a fixed distance from the vessel centerline because its sensitivity peaks at the coil circumference (Figure 2), leading to local signal-to-noise ratio improvements of at least an order of magnitude over small diameter volume coils. FDTD simulations suggest that the arc-shaped region of sensitivity of simple cylindrical meanderlines is due to the effects of the high dielectric constant of water, correctable by the use of distributed or local tuning capacitance. A single capacitor across the coil leads resulted in a marked improvement in the circular symmetry of the sensitive region (Figure 3). Preliminary results of the use of local preamplification and electronic tuning suggest that a significant further improvement in signal-to-noise ratio is possible. Balloon-expandable cylindrical meanderline coils enable matching of the coil to the lumen diameter.

Conclusion: The annular sensitive volume of the cylindrical meanderline coil design suggests that it may be optimally suited for imaging artery walls. Highly compact SMD (surface mount device) versions of the preamplifier and electronic tuning circuitry should enable electronics modules that will fit within a 6F catheter.

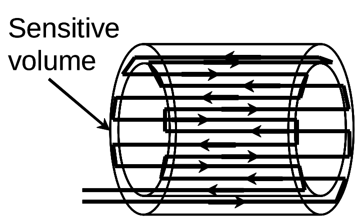

Figure 1. Cylindrical meanderline intravascular RF coil showing annular sensitive volume.

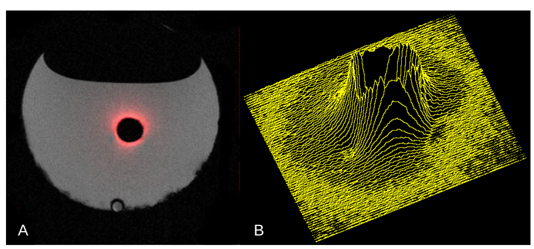

Figure 2. A: Overlaid images of 3 mm diameter cylindrical meanderline coil immersed in water; full volume image of water in tube (gray), image using cylindrical meanderline coil for reception (red). B: Sensitivity profile of cylindrical meanderline coil.

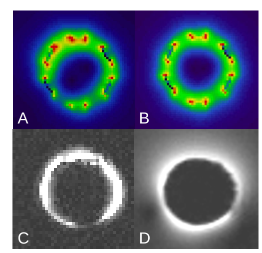

Figure 3. A,B: FTDT simulations of coil immersed in water without and with distributed tuning capacitance respectively. C,D: Images using coils with and without a single local chip capacitor, respectively.

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