

Catheter coil design using transmission line resonators for endovascular MR imaging

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Introduction

Catheter RF coil is desired in endovascular imaging due to its potentially high SNR compared with conventional body coil or surface coil (1-3). Due to its compact size and requirement for high sensitivity and low heating effect, it is technically challenging to design efficient catheter RF coils. In this work, we present and investigate a new catheter RF coil design technique using the $1/4$ wavelength ($\lambda/4$) transmission line resonator. This method is characterized by high B1 fields, low SAR, compact physical size and easy to construct. The prototype coil was designed and constructed based on this technology. MR imaging in phantoms was performed to validate the design on a clinical 1.5T MR scanner.

Methods and Materials

A $\lambda/4$ (or $n\lambda/4$, $n=1,3,5,\dots$) co-axial transmission line resonator was formed by shorting one end of 50 Ohm low loss co-axial line (G01130HT, Huber+Suhner, Switzerland). At the shorted end of the transmission line resonator, the current reaches maximum and the voltage goes down to zero. This feature is desired in MR imaging, providing high B1 sensitivity and low tissue heating effect. Figure 1 shows equivalent circuit of the $\lambda/4$ resonator and the prototype catheter coil operating at 64MHz for proton imaging at 1.5T. The short circuit was implemented by using a small copper loop with a diameter of ~ 4 mm. The impedance of small copper loop at 64 MHz is small enough and thus can be modeled as a short circuit. The other end (open) of the resonator connected to the feeding circuit including tuning and matching components and also passive detuning diodes. With the detuning function, the catheter coil is able to be used in a platform of body coil transmit and catheter coil receive. This catheter coil was also modeled and simulated by using FDTD numerical calculation algorithm. Its B1 field and SAR distributions were mapped in the loaded case. MR imaging experiments were performed using the prototype catheter coil with vascular phantom on a 1.5T Philips clinical MR scanner. A simple gradient echo sequence was used in all imaging acquisitions. As a comparison, imaging with body coil transmit and receive was conducted using the same phantom with the presence of the catheter coil.

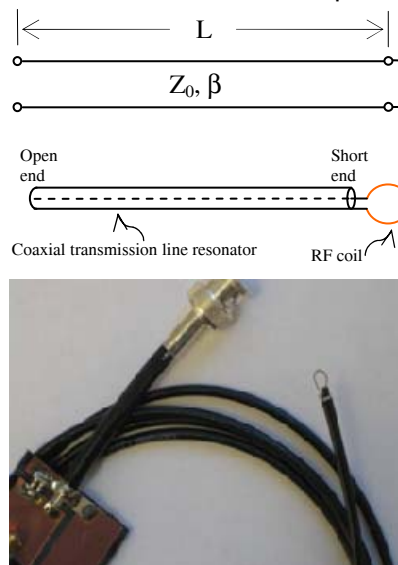


Fig. 1 Schematic (top) and photograph (bottom) of the prototype catheter RF coil using transmission line resonator (TLR) design for endovascular interventional MR imaging at 1.5T.

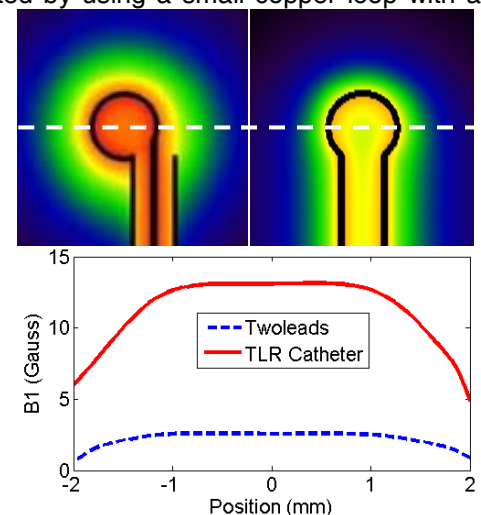


Fig. 2 1D plots of B1 fields calculated along the white dash line in the image for TLR catheter coil and the conventional catheter coil. The proposed TLR catheter coil achieved 6-fold B1 gain over the conventional lumped element catheter coil.

Results and Discussion

As shown in Figure 2, B1 fields of the proposed $\lambda/4$ catheter coil in the imaging area is much stronger than that of a conventional lumped element loop coil. This is essential for gain SNR in vascular imaging. The SAR calculation (not shown here) also demonstrates the advantage of using this transmission line catheter coil design over the lumped element loop coil. Measured SNR based on the MR images acquired at 1.5T demonstrates that catheter coil receive/body coil transmit has an approximately 200 to 300-fold SNR gain over imaging with body coil transmit and receive (Fig 3). Since there is no need to use lumped capacitors in the resonant circuit, it is convenient to build compact catheter coils using the transmission line resonator technology.

References

- (1) Rudin S, et al, Med Phys 2008; 35:301-309. (2) Martin AJ, et al, MRM 2009; 61:45-53; (3) Ladd ME, et al, JMRI 2000; 12:534-546

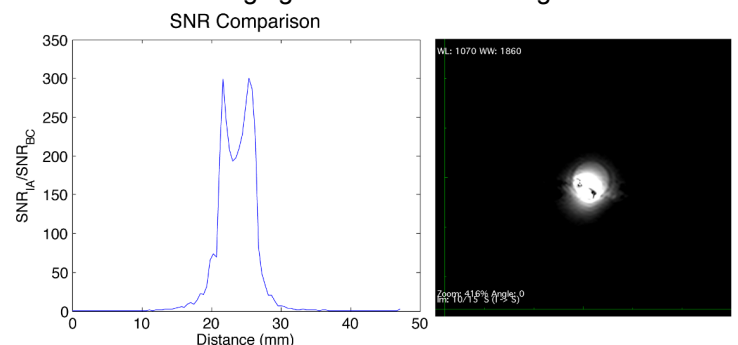


Fig 3. On the left is a plot of the SNR comparison between the transmission line resonator intra-arterial (IA) coil and the body coil (BC). The IA coil provides a significant SNR increase (a factor of 200 to 300) over its imaging volume relative to the body coil. On the right is a representative image created by the IA coil in a vascular phantom with nominal vessel diameter of 1 cm.