Design of a new dual-helix loop coil for intravascular MR imaging

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Introduction

To discriminate between the vessel wall layers and plaque constituents in atherosclerosis, the image pixel size must be decreased to less than half a millimeter as the artery wall and fibrous cap thicknesses are very small (e.g. a fraction of a millimeter). For this purpose, researchers have introduced different types of intravascular loop and loopless coils, of which the single-helix loop coil is one. These coils are simply receiver antennas which have to be transported to the region of interest through a catheter and produce artery images with the highest pixel SNR in MRI. So far, some types of helix loop coils are presented as single-helix coils, single and array opposed-solenoid coils. In this study, a new dual- helix loop is introduced. Its SNR maps in radial and longitudinal planes have been analyzed and compared with a conventional single-helix loop coil. The results show that for the coil design introduced here, the amount of pixel SNR is increased by 33% compared to a conventional single-helix loop coil.

Theory and Methods

Antenna theory proves that by adding another helix coil to a single-helix loop with windings in the opposite direction, it is possible to increase the SNR around the coil. Based on this idea we presented a new dual-helix loop design with the length of 13 mm and a diameter of 3 mm. The metal wire for the proposed coil is assumed copper which is coated by a biocompatible insulator with $\mu_r=1$, $\varepsilon_r=3.9$.

The pixel SNR around the coil can be expressed using the coil related parameters as $SNR=H1_{xy}/\sqrt{R}$ (1), where $H1_{xy}$ is the magnitude of right-handed circular polarized of transverse component of H1 vector, and R is the real part of the coil input impedance [1]. H1 is the magnetic field intensity vector which is produced by an RF coil with 1A RMS current. Computing SNR distribution is done in both radial and longitudinal plane using High Frequency Structures Simulation (HFSS) and MATLAB inside a saline phantom with $\mu_r=1$, $\varepsilon_r=80$, $\sigma=0.8$ S/m (Fig.1) The radial plane is assumed to be a ring with inner and outer diameters 1.9 and 3.5 mm respectively and placed at z = 5 mm. Thus the longitudinal planes are 1.6 by 11 mm and positioned in x = 0 plane. The radial plane has more importance than the longitudinal plane, because in MR images the vessel wall and plaque cross sections are placed in this plane. However, the coil should have sufficient length or longitudinal field-of-view (FOV) to cover the entire length of plaque. Furthermore, to highlight the results of the new coil design we compared its SNR maps with a conventional single-helix loop coil in both planes.

Results

We studied the pixel SNR distribution according to equation (1) in two radial and longitudinal planes. Figure 3 shows the 2D SNR map in the radial and longitudinal planes for both the introduced and the conventional coils. The color bars show that the SNR is enhanced by 30% in radial plane and 33% in longitudinal planes for the proposed coil.

Discussion

As antenna theory predicted, the results of this study show that by adding an extra helix with proper geometry to a single-helix loop coil, we can increase the magnitude of $H1_{xy}$ and therefore pixel SNR around a single-helix loop coil. In turn, this improves the contrast to noise ratio (CNR) and spatial resolution in arterial MR imaging.

References:

[1] Hoult DI, Richards RE, The signal to noise ratio of the nuclear magnetic resonance. J. Magn. Reson. 1976; 24:71-85.

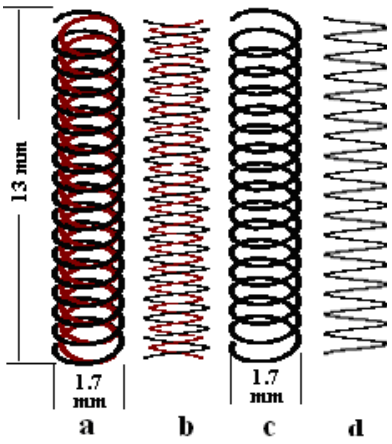

Fig. 1: (a) 3D view of the dual-helix loop coil, (b) 2D view of the dual-helix loop coil, (c) 3D view of a single-helix loop coil, (d) 2D view of a single-helix loop coil. Coil wire is copper which is coated by 10µm of a biocompatible insulator.

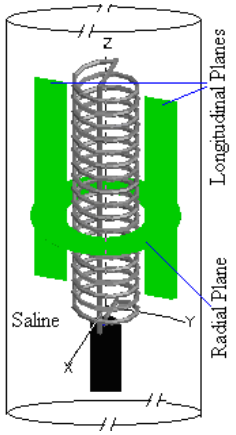

Fig. 2: Saline phantom, radial plane, and longitudinal planes. Coil is connected to a coaxial cable at (0,0,0) Inside saline phantom. To magnify the simulation planes, Saline phantom is shown smaller than its real geometry. longitudinal planes are positioned in yz plane and started from z=1 mm.

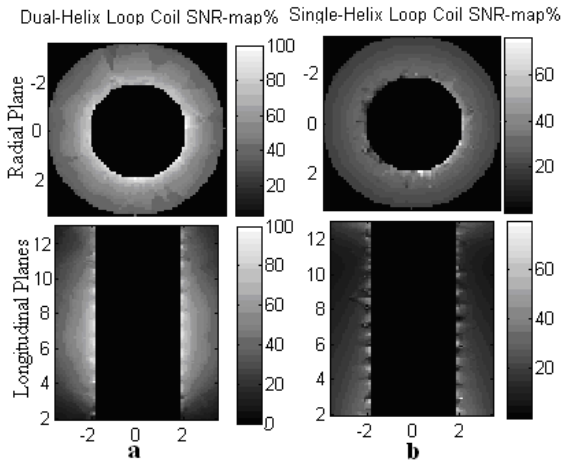

Fig. 3: 2D SNR maps of dual-helix loop (a) and (b) single-helix loop coil in radial and longitudinal planes inside saline phantom. Color bars show the SNR enhancement in proposed coil's images.