Circularly polarized coil for traveling wave MRI

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Introduction

Since its realization, most traveling wave (TW) imaging has been done in 7T preclinical MR scanners [1,2]. The typical excitation method for such a system is a patch antenna that is a practical choice for the ultra high field with sufficient bore size ($D \sim \lambda_{cr}$). However, for systems with a small bore diameter-to-critical-wavelength ratio, the patch antenna approach, if possible at all, is not the best choice. Previously we have shown that TW excitation can be done with the loop-coil probes and a dielectric insert both at low [3] and ultra high [4] MRI systems. The main problem with such probes is the relatively low SNR due to linear polarization of the B_1 field.

Here we present a novel loop-coil probe concept allowing propagation of a circular polarized B_1 field. Unlike patch antennas, such probes can be used in systems with low bore diameter-to-critical-wavelength ratio, and can directly couple the TW mode to a dielectric waveguide or other load. We analyze the performance of this coil using an unmodified GE (Waukesha, WI, USA) Discovery 750 3T clinical system.

Methods and Materials

In our previous experiments [3], we utilized an orthogonal loop-coil probe [5], where its B_1 field was orthogonal to the B_0 field. Alternatively, we used a parallel loop-coil with B_1 parallel to B_0. Neither of these probes allow for a circular polarized B_1 field. Our new probe consists of two loop-coils (D=15cm) placed orthogonal to each other (Fig 1), and each B_1 field is also orthogonal to B_0. The loop-coils are mounted on an acrylic frame to ensure that they remain orthogonal, hence ensuring that they are completely decoupled with isolation between the loops to be -18dB. The loops are driven in quadrature using a quadrature hybrid splitter, which divides the transmit signal and recombines the MR signal, connected to the inputs of the coils. A balun is present at each coil input to minimize currents flowing on the cable shields. The connection between the quadrature hybrid and scanner is accomplished using an interface board with a low-impedance preamplifier and coil-ID functionality.

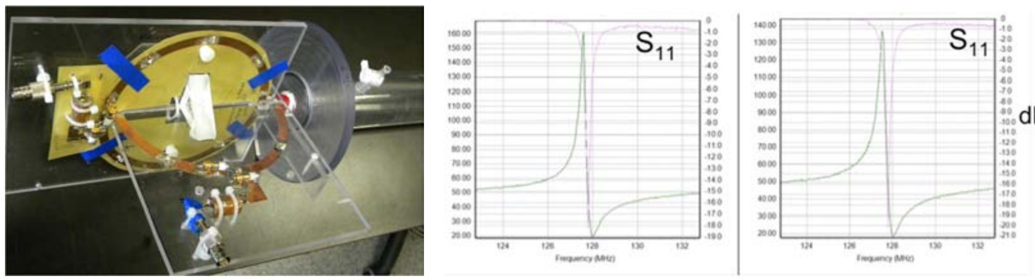

Figure 1: *(left) Picture of orthogonal 15cm diameter loop coils positioned at the end of dielectric rod. Typical return loss plots (pink curves on the right) for the two orthogonal coils with minimum S11 of -18dB and -20dB.*

Our waveguide consists of an RF shield (inside a 60 cm diameter bore) incorporated into the bore, a single high dielectric rod (length=1 m, diameter=5 cm, filled with 0.9% saline solution) and a quadrature T/R coil system as a probe for mode coupling into/from the guide. Such a dielectric loaded cylindrical waveguide allows propagating complex waveguide modes [6].

The coils are loaded with the dielectric rod inside the magnet bore and were carefully tuned to 127.8 MHz, 50Ω impedance matched, with a typical return loss of less than -20dB for each loop-coil (Fig. 1b). In-bore tuning was accomplished using an MRI-compatible vector impedance analyzer (VIA Echo MRI, AEA technologies, Carlsbad, CA, USA).

Results

We obtained images of the dielectric rod and compared it with a single loop-coil placed orthogonally to the guide edge. Data were acquired using a standard GRE pulse sequence: TR=100ms, TE=18.5ms, flip angle=45^0, (128x128) matrix, FoV=240mm, slice=10mm, rbw=2.1kHz, 8NEX, 1:46 min scan time. The SNR was measured in a bottle of 0.9% saline imaged with both the quadrature (Fig. 3 a) and linear coils using an axial image on a slice 295mm from the edge of the coils. The SNR was 26.6 for the quadrature coils and 16.8 for the linear coil. Image uniformity was also improved with the use of the quadrature coil.

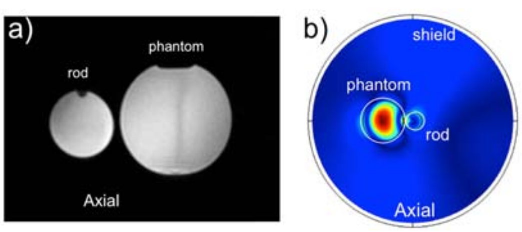

Figure 3: *MRI axial image with quadrature coils a) and simulations of B_1 field map b) of a dielectric rod and a bottle phantom placed next to it and 20 cm away from the coils.*

Conclusion

We designed novel quadrature coil for TW excitation allowing circular polarized B_1 field excitation. This coil can be a good choice for TW excitation for systems with a small diameter-to-critical-wavelength ratio. We demonstrated a much higher SNR with the new coil than with the previously available linear polarized coils. With a dielectric rod insert, TW concept can be applied to clinical field strength (3T) with the potential application of accessing hard to reach areas, as well as for dealing with B_1 field inhomogeneity issues at 3T. The efficiency improvement with new coils also offers the opportunity to adapt far-field imaging concepts [7] to applications at low and ultra-high fields [4].

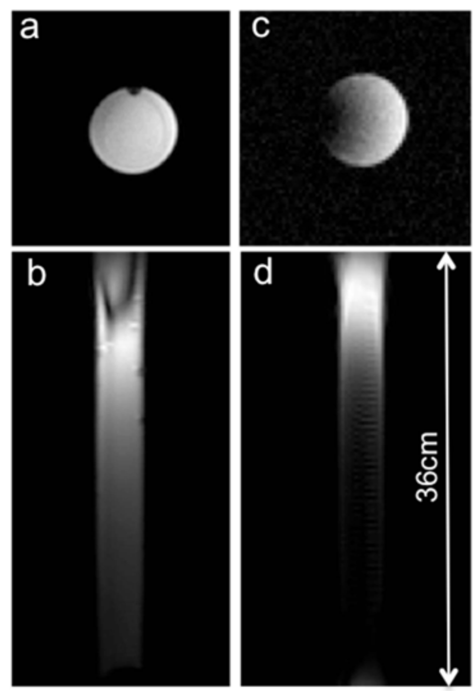

Figure 2: *MRI images of the tube filled with saline: (a) axial and (b) sagittal slices taken with circular polarized coils; (c) axial and (d) sagittal slices taken with linear polarized coil. Axial images were acquired at a distance of 295mm from the T/R coils.*

References: [1] Brunner D.O. et al., Nature 2009, 457: 994-999; [2] Brunner D.O. et al., MRM 66:290–300, 2011; [3] Tonyushkin A., Konyer N., Noseworthy M., and Kiruluta A., Proc. ISMRM 20, 2012; [4] A. Tonyushkin, J. Muniz, S. Grant, and A. Kiruluta, Proc. ISMRM 20, 2012; [5] Webb A. G., et al., MRM 63:297–302, 2010; [6] Tonyushkin A. and Kiruluta AJM, Proc. ISMRM 19, 2011; [7] Kiruluta AJM, JMR 2006, 182: 308-314.