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=λc). 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 B1 field. Here we present a novel loop-coil probe concept allowing propagation of a circularly polarized B1 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 B1 field was orthogonal to the B0 field. Alternatively, we used a parallel loop-coil with B1 parallel to B0. Neither of these probes allow for a circular polarized B1 field. Our new probe consists of two loop-coils (D=15cm) placed orthogonal to each other (Fig 1), and each B1 field is also orthogonal to B0. 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.

Our waveguide consists of a 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°, (128x128) matrix, FOV=240mm, slice=10mm, r=2/1kHz, 16NEX, 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.

Conclusion

We designed novel quadrature coil for TW excitation allowing circular polarized B1 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 B1 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].