A Transmit-Only/Receive-Only (TORO) RF System for High Field MRI/MRS Applications

E.A. Barberi 1, J.S. Gati 2, B.K. Rutt 1,2, and R.S. Menon 1,2

1 Department of Diagnostic Radiology, University of Western Ontario
2 Imaging Research Laboratories, The John P. Robarts Research Institute, London, Ontario, CANADA

Introduction

MRI/MRS techniques requiring the use of receive-only surface and phased array coils are currently unavailable at very high field (>2T) due to a lack of high field transmit-only RF volume and body coils. Adiabatic pulses offer a solution in some cases, but these are limited in applicability and pose certain SAR restrictions. Here, we present a high field transmit-only/receive-only RF system, based upon the proven sensitivity of the hybrid birdcage resonator, which permits the use of all pulse sequences with no modifications.

Methods

We designed and built a prototype high field (4T) transmit-only/receive-only (TORO) RF system, comprised of a 28 cm diameter, 21 cm long transmit-only hybrid birdcage head coil, a single turn 8 cm diameter receive-only surface coil, and a custom fiber optic gated T/R driver. The dimensions of the transmit-only coil were chosen to match those of our existing transmit-receive hybrid birdcage head coil for purposes of comparison. Active decoupling of the transmit-only volume coil is achieved through the use of high voltage PIN diodes distributed across one set of end-ring capacitors, figure 1a. The T/R driver applies a -290V reverse bias (TX coil on) and a +10V forward bias (TX coil off) on the bias rails (20 μs rise time, <2 μs fall time), which are connected to the anode and cathode of the PIN diodes, through RF choke inductors. The two-stage active decoupling of the single loop receive-only coil is shown in figure 1b. It should be stressed that excellent decoupling between the transmit-only coil and the receive-only coil is critical since the surface coil rests on the inner bore of the transmit-only coil, with a coil-to-coil separation of just 3.5 cm.

Results and Discussion

Isolation of greater than 30 dB between the transmit-only and receive-only coils was measured on the bench. Isolation was also assessed on our 4T Varian/Siemens Unity Inova whole-body MRI/MRS system (Palo Alto, CA/Erlangen, Germany). Phantom images acquired with the transmit-only coil biased as a transmit-receive coil showed no changes in SNR and homogeneity with and without the decoupled receive-only coil placed directly on the surface of an 18 cm diameter spherical phantom. Additionally, a comparison of the transmit-only coil, biased as a transmit-receive coil, with an identically dimensioned conventional transmit-receive hybrid birdcage revealed identical homogeneity, SNR, and power requirements for identical 90° square pulses (960 watts for a 160 μs square pulse). SNR profiles of the TORO system are compared with those obtained from an 8 cm single turn transmit-receive surface coil in figure 2a. Profiles demonstrate consistent SNR benefits of the TORO system over the transmit-receive surface coil over the entire range of coil-to-voxel distances. In figure 2b, we show proton STEAM spectra with identical acquisitions and no line broadening. The SNR advantage of this 11 cc voxel in the occipital pole was 4.0 compared to the head coil. The spectra were acquired with 256 averages and a TR of 2s (8.5 min). This means a spectrum of the quality shown in the top trace could be acquired in under a minute with the TORO system.

Conclusions

This rapidly switching, high duty cycle configuration allows all pulse sequences, particularly those requiring homogeneous refocusing or inversion pulses to be performed with the higher sensitivity of a surface coil. No pulse sequence modifications are necessary and the full patient and RF safety system operation is preserved. Future work will involve developing a body-size TORO RF system.

References