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

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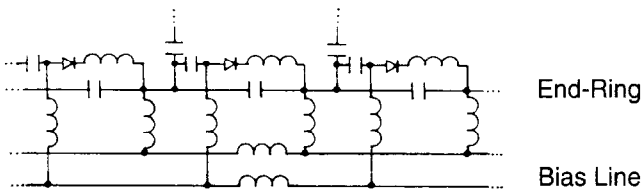
Introduction

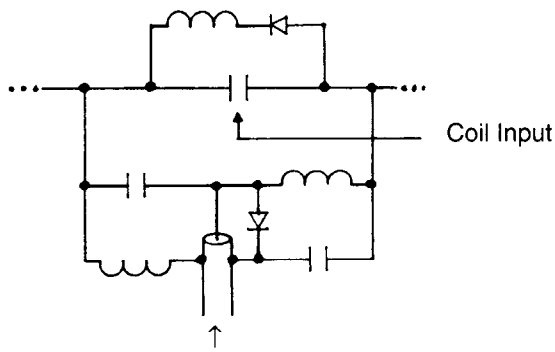
MRI/MRS techniques requiring the use of receive-only surface and phased array coils are currently unavailable at very high field (>2T) due to a lack of high field transmit-only RF volume and body coils. Adiabatic pulses offer a solution is some cases, but these are limited in applicability and pose certain SAR restrictions. Here, we present a high field transmit-only/receive-only RF system, based upon the proven sensitivity of the hybrid birdcage resonator[1], 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.



(a) Transmit-Only Coil Decoupling Circuit

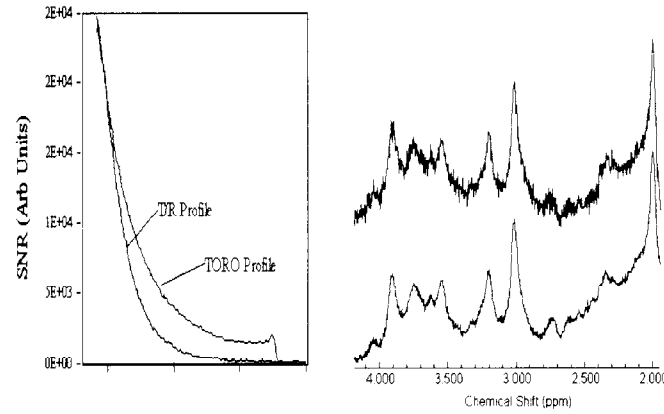


(b) Receive-Only Coil Decoupling Circuit

Figure 1

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.



(a) SNR Profile (b) STEAM Spectra

Figure 2

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

1. Barberi, E.A., Rutt, B.K., R.S. Menon, Proc. 4th Meeting ISMRM, pg 1417, N.Y., 1996.