# Tic Tac Toe: Highly-Coupled, Load Insensitive Tx/Rx Array and a Quadrature Coil Without Lumped Capacitors

**T. S. Ibrahim[1], Y-K. Hue[2], F. E. Boada[1], and R. Gilbert[2]**

[1]Radiology and Bioengineering, University of Pittsburgh, Pittsburgh, PA, United States, [2]Radiology, University of Pittsburgh, Pittsburgh, PA, United States

## Introduction:

To RF coil designers, the transition from low to high and ultrahigh field imaging has resulted in a similar transition from using circuit and transmission line theories (very specific cases of Maxwell's equations) to using the more general, fully Maxwellian, electromagnetic theory. The presence of the non-transverse electric/magnetic/electromagnetic (TEM/TE/TM) hybrid modes and the differences between the transmit and receive fields [1, 2] during high and ultrahigh field experiments warranted new RF approaches to overcome these issues. To this aspect, this work presents a new coil design, ***Tic-Tac-Toe***, that is highly load insensitive (negate high-field/frequency electromagnetic effects), yet is highly coupled (utilizes inherent SNR properties associated with coupled coils.) The ***Tic-Tac-Toe*** was successfully tested as a transmit/receive array and as a standard 4-port quadrature coil at 7T

## Methods:

The ***Tic-Tac-Toe*** coil is based on cross-pole antennas. As shown in Figure 1, it is described as a Tic-Tac-Toe of coaxial TEM elements [3]. As demonstrated in the photo, the plane that encapsulates these elements is in *xy* (perpendicular to the magnet, z, axis). The coil is excited from the four alternate ends of the Tic-Tac-Toe. A copper sheet is positioned at the back of the coaxial elements. The shield however was only placed to increase SNR (can be easily removed or slotted for EPI imaging) As can be seen from the Figure 1, the subject lies at right angle (padded) of coil structure. There is 1-2in of space in-front of the head which give relatively significant comfort and reduce the subject's claustrophobia.

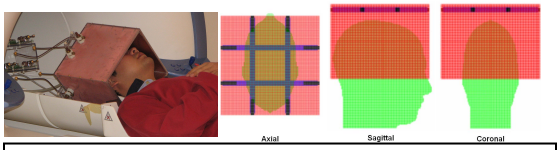


Fig. 1: Photo and Schematics of the ***Tic-Tac-Toe*** coil

The ***Tic-Tac-Toe*** coil does not posses lumped capacitors and can be easily tuned to 50 Ohms. As the coil is highly-load insensitive, the Q is relatively lower (measured at 100 for the human head loaded-coil.) Figure 2 shows the S11 (-30.8dB), S12 (-4.8dB), S13 (-7.9dB), of the coil when loaded with human head. These scattering matrix values change very insignificantly between different heads. We found that one-tune can fit all.

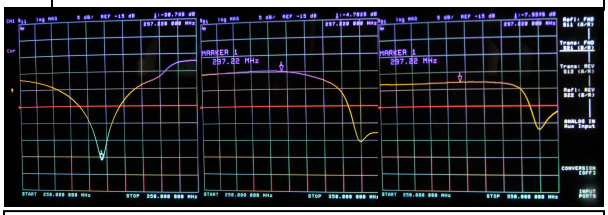

Fig. 2: S matrix of the ***Tic-Tac-Toe*** loaded with human head.

## Results and Discussion:

To demonstrate the load insensitivity, using the same tune, the ***Tic-Tac-Toe*** coil was tested with human head, watermelon, and a saline phantom with different sets of excitation voltages including distinct sets of amplitudes and phases (done with coaxial cables and attenuators.) We noticed relatively a very similar pattern for all the loads. Sample of these studies are presented in Figure 3 where 4-port quadrature and anti-quadrature excitation/Sum of Square reception was used to image human head, saline phantom, and watermelon. The images from each port and combined demonstrate very similar pattern for all the loads. To demonstrate homogeneity in the quadrature mode, Figure 4 shows 576*576 unprocessed axial brain images at 7T.

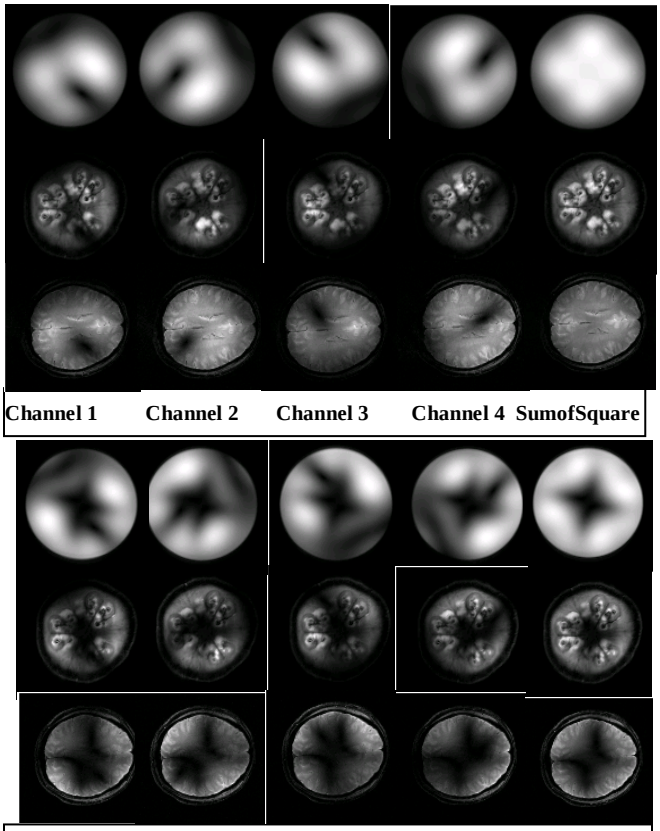


Fig. 3: GE images obtained with the 4-channel Tx/Rx ***Tic-Tac-Toe*** coil loaded with human head, watermelon, and saline spherical phantom. The same tune was utilized for all the loads. The top set represents quadrature excitation and bottom represents anti-quadrature excitation.

## References:

1. Wang, J., et al., *Polarization of the RF field in a human head at high field: a study with a quadrature surface coil at 7.0 T.* Magn Reson Med, 2002. **48**(2): p. 362-9.
2. Ibrahim, T.S., et al., *Electromagnetic perspective on the operation of RF coils at 1.5-11.7 Tesla.* Magn Reson Med, 2005. **54**(3): p. 683-90.
3. Roschmann, P.K., *High-frequency coil system for magnetic resonance imaging apparatus.* 1988, U.S. Patent.

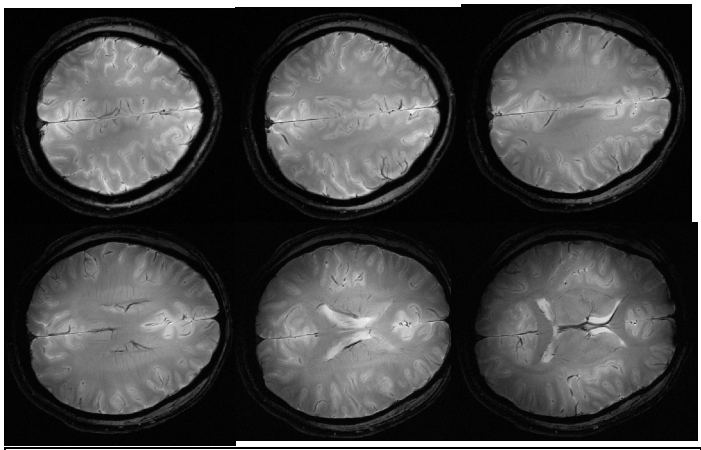

Fig. 4: Axial brain images using the ***Tic-Tac-Toe*** coil operating in quadrature at 7T.