Efficient EPI Friendly 3x3 Array with Receive-Only Array Insert

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Introduction: Typical coupled coils/transmit arrays are 1) highly load dependant, 2) difficult to tune with more than 4-ports unless they are decoupled, and 3) not good receivers as coupling increases noise during reception. These operational and technical challenges have dampened their use in parallel/multi-transmit applications. The first prototype of the multi-transmit, coupled array, Tic-Tac-Toe, [1], was proposed based on cross-pole antenna theory [2]. In this work, we will examine the efficiency of Tic Tac Toe RF array designs including the original 2x2 and new 3x3 versions and extend their usefulness to become more application friendly. This will be achieved by yielding optimal SNR (through a combination with a separate 7-channel receive-only array) and by designing echo-planar imaging (EPI) compatible prototypes.

Methods: 1st Tic-Tac-Toe array (2x2) is described as a Tic-Tac-Toe of square coaxial elements. The plane that encapsulates the elements is perpendicular to the magnet axis. The array is excited from the 4 alternate ends of the Tic-Tac-Toe (Fig.1 (top left)). The **Tic-Tac-Toe** does not possess lumped capacitors and can be easily matched to 50 Ohms. The scattering matrix values change very negligibly between different heads. Additionally, one tune/match can fit all heads. In one part of this work, the design was extended to a 3x3 version (Fig.1 (bottom left.) A similar behavior in terms of tuning and coupling was obtained for 4-port excitation/reception. Compared to the 2x2 version, a better coverage over the head volume was obtained with the 3x3 version.

As methods that implement intensive use of gradients such as spiral trajectories and EPI require minimal eddy current distortion, we have systematically (in an overlapping approach) slotted a 3x3 prototype which contains more copper due to the addition of two more elements.

The strong coupling on the Tic-Tac-Toe RF array necessitates the development of decoupled receive-only array to reduce the noise and thus increase SNR. A picture of the receive-only decoupled array insert (to the Tic Tac Toe arrays) is shown in Fig 3. It is composed of 7 receive decoupled loop elements.

Results and Discussion: We experimentally investigated efficiency of the Tic Tac Toe designs on a head-sized spherical phantom with brain like properties. These studies were performed on 1) the coupled design, 4-port Tx/Rx TEM array (half-capped for maximum efficiency), 2) the decoupled (loop based) design, *Rapid Biomedical Inc* (commercial), 8-port Tx/Rx array, and 3) the 4-port Tx/Rx, 2x2 Tic-Tac-Toe array. The B_1^+ mapping was done using the head-sized brain phantom in order to achieve consistency for optimal placement with each coil. For consistency, the TEM and the 2x2 Tic-Tac-Toe arrays were tuned to the head but then loaded with the phantom. The TEM and Tic-Tac-Toe arrays were operating in 4-port quadrature excitation mode and the *Rapid Biomedical Inc* array was operating in 8-port quadrature excitation mode. The B_1^+ measured data are shown in Fig. 2. The data shows the flip angle map for the top 9.5 cm of the 17.5 cm in-diameter spherical phantom. For about the top half of the load, the results also show higher B_1^+ intensity for the Tic-Tac-Toe when compared to the coupled TEM array and for the TEM array when compared to the decoupled loop-based array.

The EPI results for 2x2 & 3x3/slotted arrays are shown in Fig. 1. The results qualitatively show the effectiveness of the slotted shield in achieving better quality EPI images. No signal loss was observed after slotting the shield.

Fig 4 displays sample images obtained with the 3x3 array using 4-port quadrature excitation W and WO the 7-channel Rx-only insert. In the 3x3 optimal excitation region (the top ½ of the head volume,) the results show an increase of 3 folds in SNR when compared to the Tx/Rx operation. No noticeable changes were observed in the Tx operation of the 3x3 array.

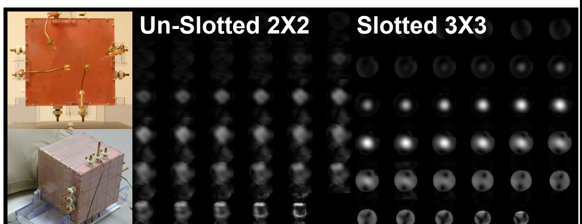

Fig. 1: EPI images and pictures of a slotted 3X3 and un-slotted 2x2 arrays.

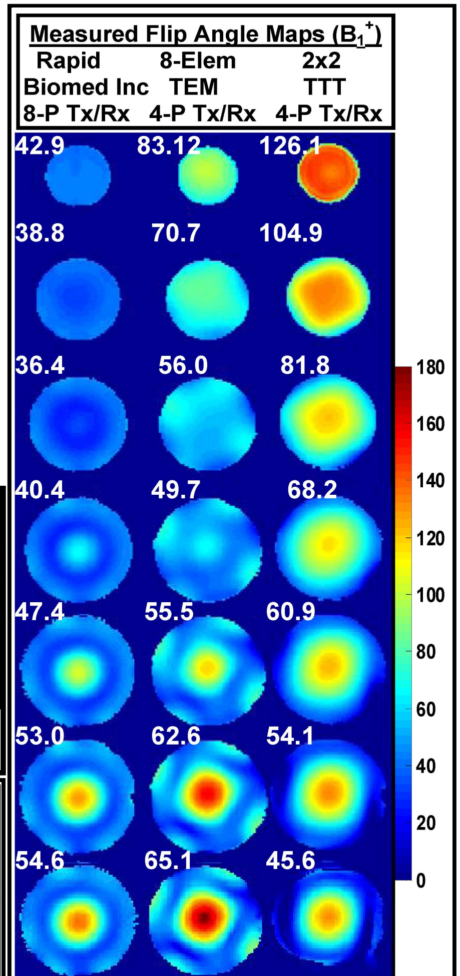

Fig 2. Measured B_1^+ field maps for the head-sized brain phantom. The values above each subfigure represent the average flip angle in the specified slice. The data for all 3 coils are obtained using quadrature excitation and a specified input power.

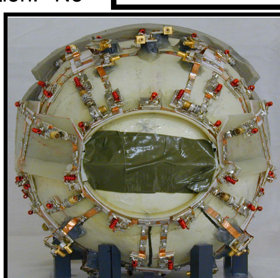

Fig. 3: 7-channel Rx-only insert combined W 3x3 or 2x2 arrays.

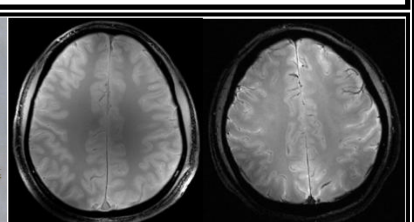

Fig 4: In vivo 512x512 7T images of the 3x3 array W(L) & WO(R) 7-channel Rx-only insert. SNR increases by approx. 3 folds in the top half of the brain W Rx-only insert.

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1. Ibrahim, T.S., et al. *Tic Tac Toe: Highly-Coupled, Load Insensitive Tx/Rx Array and a Quadrature Coil Without Lumped Capacitors*, *ISMRM*, 2008. **2.** Balanis, C., *Advanced Engineering Electromagnetics*. 2nd ed. 1989: John Wiley.