# A Shielded 8 Channel TxRx Head Array with Triangular Elements and Second Order Decoupling

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**Introduction:** As more advanced Parallel Transmit (PTx) technology at high field continues to emerge, the development of compatible Transmit-Receive(TxRx) arrays with good transmit and receive sensitivity as well as decoupling has become a greater priority. A triangular array design has been described which allows for capacitive decoupling of neighbors, and inductive decoupling of next nearest neighbors, resulting in a highly decoupled array which retains the transmit efficiency of a surface coil loop element [1]. An additional benefit is diverse B1 profiles for the individual elements, including variation along Z. A first prototype head coil based on this design was described with 8 triangular elements, but the B1+ field of the coil was found to drop off too quickly along the z-direction, and again inductance limits prevent the design from being lengthened. We describe here a shielded version of the 8 channel triangular array with greater length in z for head imaging at 7T MRI designed to address these limitations.

**Method:** The shielded 8 channel Triangular array was built on an oval former 24.2 cm in long axis, 20.4 cm in short axis. The conductive structures were machined from FR4 circuit board, with all conductors of 1 cm width (Fig. 1). The length of the each coil in the Z direction was 16 cm, increased from 14 cm in the first prototype. The shield which was built on an oval former 2.4 cm away from the coil, was carved with triangle shape gaps in accordance with the arrangement of the coil inside and connected with 330 pf capacitors for prevention of eddy currents (Fig. 2a). The head array was securely mounted inside the shield (Fig. 2b) and matched to 50 Ω coax by using a series L and shunt C matching circuit.

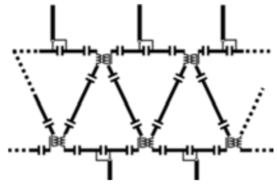

Figure 1: Circuit diagram of triangular array

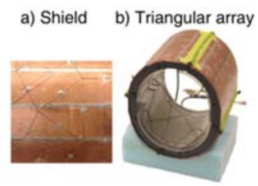


Figure 2: Shield and triangular array

The triangular array was connected to the 8 channel parallel transmit capable scanner (Siemens, Erlangen Germany) with an in-house built 8 channel Tx/Rx interface system. For performance comparison, a Nova Medical Head Coil 1TX / 24RX was used on the normal single channel system. Signals from all ports were recorded and combined in Root Sum of Squares (RSS) combination. Appropriate SAR limits were determined for the PTx experiment by measuring heating in a tissue equivalent gel phantom using a novel sequential heating approach [3] To determine the RF voltage needed to achieve a 90 degree flip angle in the center of the head, a turbo-FLASH sequence with various preparation pulses was used [4]. The B1+ distribution was mapped with a similar method using a manufacturer works-in-progress sequence (Siemens Healthcare, Erlangen, Germany) [5] for Nova Head Coil and with a DREAM sequence [6] for our new triangular array. SNR was measured using gradient echo acquisitions both with and without RF excitation and calculated according to the "Kellman" method [7]. 3D head images were acquired using 3D VIBE sequence (TR/TE/Flip/BW = 20/2.1/25/491, FOV=220mm, Matrix=192, Slice = 1.1 mm, R =2).

**Results:** Because of the increasing inductance, tuning and matching is usually relatively difficult for a large surface coil. With the shield, our triangular head array can be easily tuned using relatively high capacitor values, two 6.8 pf capacitors on shared leg respectively and 3 capacitors of values 3.9 pf on the end ring of each element as well as one capacitor trimmer for tuning, which was about the same as the shorter triangular array we described before. The shield functioned as we expected, preventing the capacitors value from decreasing while we increase the length of coils and therefore the coil inductance, and allowed us to use larger decoupling inductors for the next nearest neighbor elements. The triangular array was very straightforward to decouple and the decoupling between elements was -15dB or less for next nearest neighbors (Fig.3), which was slightly worse than the unshielded version we described before. We also observed that shield changed the distribution of the coupling, with more coupling between elements at opposite sides of former, which can also be seen from Fig. 4. $Q_{UL}/Q_L$ is about 6 for the triangular array.

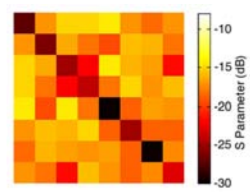


Figure 3: Coupling matrices (S21) for 8 elements triangular array. Values on the diagonal are S11 reflection for each element

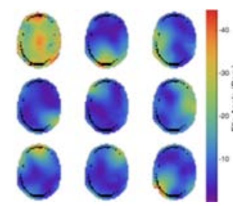

Figure 4: $B1^+$ maps for overall and each element of Triangular array

With the triangular Head array driven with equal power to each channel and appropriate phases to create circular polarization in the center of the head, a 90 degree flip angle could be achieved with a 277 volt 500 µs hard pulse (or a 98 volt pulse per channel). For comparison, with the same volunteer in the Nova Medical coil a 265 volt 500 µs hard pulse was required. The $B1^+$ maps were shown in Fig. 5, similar excitation patterns can be seen for each coil. Looking at the SNR maps of each coil (Fig. 6), the overall SNR of triangular array is lower than the Nova coil, which may be attributed to the smaller number of larger elements and shielding effects. Head images acquired with a 3 spokes KT-points excitation [8] in a 3D VIBE sequence using the triangular head array are shown in Fig. 7.

**Discussion:** The triangle array design which allows for explicit decoupling of 1st and 2nd order neighbors, creating a highly decoupled array which is suitable for PTx applications. By shielding the coil, it was possible to increase the length in Z compared to the original prototype. However, the shield reduced the transmit efficiency and sensitivity of the coil, and increased the coupling between opposite elements. Further investigation will be pursued to optimize the triangular array design.

[1] Wiggins G, ISMRM 2012[2] http://cds.ismrm.org/protected/12MPresentations/0309/ [3] Cloos M, ISMRM 2013 (submitted) [4] Breton E, NMR Biomed. 2010 23(4):368-74 [5] Klose U, Med. Phys. 19 (4), 1992 [6] Nehrke K, ISMRM 2012:605[7] Kellman P. MRM 54:1439– 1447(2005) [8] Cloos M, MRM 67:72-80(2012)

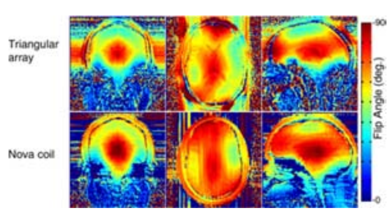


Figure 5: $B_1^+$ maps for the 2 coils

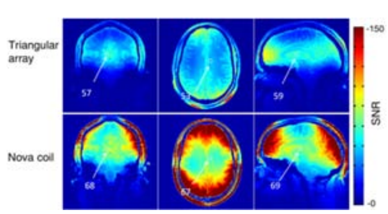


Figure 6: SNR plots for root sum of squares reconstruction for the 2 coils

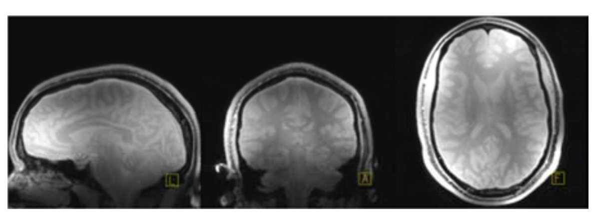

Figure 7: 3 axis reformats of 3D VIBE images obtained with kT-spokes excitation