An adaptable 8-channel Transmit array head coil for parallel Transmit and B0 mitigation at 3T

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Introduction: Parallel excitation with multiple transmit channels provides the potential to mitigate B_1^+ inhomogeneity (1) and thru plan B_0 inhomogeneity(2). Spatially tailored excitations (such as in B_1^+ mitigation) requires spatially distinct, and preferably spatially orthogonal spatial profiles from the array elements, whereas for the thru plan B_0 inhomogeneity correction, a distinct spatial profile limited to the region of the susceptibility gradient is desired. In this work we have designed and constructed an 8-channel stripline based transmit array coil whose spatial profile is easily adaptable to the imaging needs. The 8-channel array coil is driven with four transmit channels by splitting the transmit RF power with different Wilkinson splitter configuration. For example the array allows the most spatially localized channels to be concentrated in the vicinity of the orbital-frontal cortex. In this region, fine control of the excitation's phase ramp in z (gained by time shifting the excitation) allows mitigation of the orbitral frontal dephasing seen in EPI. The remaining elements can be phased to produce birdcage-like excitation modes in the posterior head.

Methods: Imaging experiments were performed on a TIM Trio 3T whole body scanner (Siemens Medical Systems, Erlangen, Germany.) Parallel transmission was achieved using a custom RF transmission system separate from the 3T scanner. The system consisted of a four transmitter Tecmag Apollo NMR console (Tecmag Inc., Houston, TX) with four 300 W amplifiers. An 8 channel stripline coil (Figure 1) was constructed on a acrylic tube of outer diameter 28 cm. The stripline elements had a strip width of 1.25 cm and the shield width was 5cm, separated by Teflon dielectric of thickness 1.25 cm. The length of the entire coil was 18cm. The adjacent stripline elements were capacitively decoupled. Since the value of the decoupling capacitor was very low (~1pF), we used the capacitance between the top and bottom plates of a thin strip of 62 mil thick, double sided, copper clad FR4 circuit board. The value of this capacitance can be precisely trimmed by changing the area of the copper plates with the help of a rotary grinding tool. This decoupling capacitance was found to be relatively invariant to patient loading or any other external factors. A T/R switch and preamplifier followed each stripline element allowing reception with the 8 stripline elements as a conventional 8 channel array.

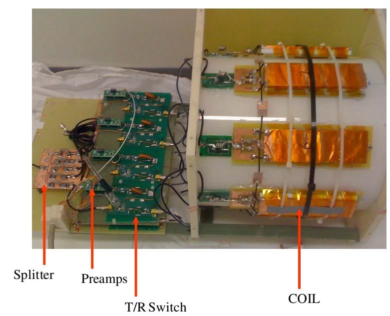

Fig. 1 The 8-channel stripline mode configurable array.

In addition to using the 8 stripline elements as a conventional 8 channel Tx array, we also configured a reduced set of modes of the array to provide spatial patterns tailored to the susceptibility mitigation application. Since most of the susceptibility artifact is found in the prefrontal cortex, the three stripline elements closest to the prefrontal cortex were driven independently with separate transmit channels. When the 3D "spokes" or echo volume excitation trajectory is used, those waveforms could be time shifted to create a spatially localized through-plane phase ramp to cancel the phase induced by the susceptibility gradient. The other five coils which cover the back and the sides of the head where vectorally combined in a circularly polarized birdcage mode and driven by a single transmit channel using a 5-way Wilkinson splitter with 45º phase increments at the output. The phase shifts were achieved by varying the length of the output coaxial cable in the splitter.

The second mode of operation was designed to provide 4 spatially distinct modes of equal energy for use with RF shimming or parallel transmit acceleration algorithms. In this case, pairs of adjacent coils were driven from a single channel using a 2-way Wilkinson splitter whose outputs have a 45º phase difference between them.

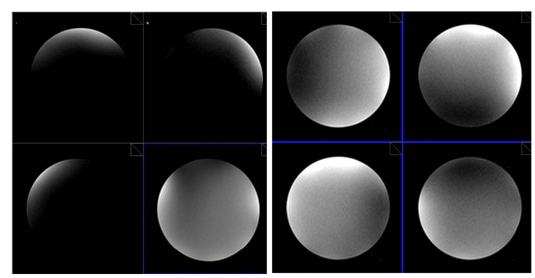

Fig. 2 Spatial patterns of the mode choices. Left) Profiles optimized to correct for the B_0 inhomogeneity with time-shifted slice-select pulses. Right) more conventional modes with equally distributed spatial patterns for pTx applications.

Results: The average S_{12} coupling between the neighbors was better than -20 dB for the 8 stripline elements. Additionally, the S_{11} match at each element was better than -20 dB. Figure 2 shows the model profiles for the two, 4-channel configurations. To the left is the B_0 mitigation mode, with the 3 anterior elements driven independently and the posterior section driven as a uniform birdcage mode. Figure 2 right shows the mode designed for 4 channel parallel transmit with equal distribution in the 4 spatial modes. Figure 3 shows an axial EPI image acquired with a regular slice-selective RF pulse (left) and a spatially tailored RF pulse (right) designed to correct both the thru plane B_0 imhomogeneity and B_1^+ inhomogeneity. The signal void in the prefrontal cortex improves dramatically with the time-shifted RF pulses applied to the frontal elements.

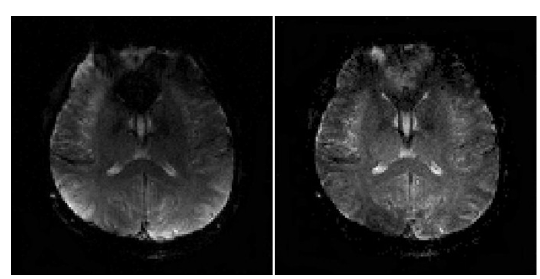

Fig. 3 Axial EPI slice with and without simultaneous B_0 inhomogeneity and B_1^+ imhomogeneity correction.

Conclusion: A configurable transmit array is demonstrated which allows spatial modes to be tailored to a specific transmit application. In this case either a conventional 4 channel pTx of accelerated spatially tailored excitations such as would be used in B_1^+ mitigation, or as a 4 mode set with maximal spatial variation over the orbital frontal cortex for susceptibility dephasing mitigation using parallel Tx. The constructed transmit array coil was successfully tested *in vivo* and demonstrated with simultaneous thru plane B_0 inhomogeneity correction and B_1^+ inhomogeneity correction.

References: 1. Stenger et al. In: Proceedings of the 2nd international workshop on parallel MRI, Zurich, Switzerland, 2004 p 94.
2. Deng et al. ISMRM, 2008, Toronto, Pg 622.

Acknowledgement: Funding support from R01DA019912.