An 8 Element Inductively Decoupled Transceiver Array for 1H MR of the Brain at 7T: Performance Characteristics Across 82 Subjects

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Introduction: Transceiver arrays using multiple RF coils and RF shimming have demonstrated both improved homogeneity and increased transmit efficiency in comparison to conventional volume coils at 7T in the human brain. However, the performance of these arrays is dependent upon the loading conditions which will reflect both head placement and head size, raising questions as to the consistency of their performance across a large group of subjects. Further, for arrays where the individual coils are strongly coupled, the entire network of coils must be tuned and matched leading to potential additional variability in performance. To address these issues we have developed and evaluated an 8 element transceiver using inductive decoupling between elements and a split geometry. The split geometry allows the coils length in the anterior-posterior direction to be altered (using different coil tops) to accommodate individual heads while maintaining decoupling and efficiency. To enhance reproducibility and coil efficiency we have used an RF shimming method which maximizes the transmit efficiency in the center of the head and minimizes overall power requirements. We have evaluated these methods in a variety of brain locations in 82 studies in patients and control subjects.

Methods: All studies were performed at 7T using a Varian Direct Drive System with an 8 channel CPC RF amplifier. The transceiver array consisted of 8 (9cm) evenly spaced rectangular surface coils. The array was split in two parts with the bottom part having five surface coils and the top portion three coils. To accommodate different head sizes and maintain optimal loading and decoupling, three different array tops were used, allowing the coil's height to be varied from 21- 25cm with a fixed width of 19.5 cm. Fixed inductive decoupling was used between adjacent elements, achieving at least -18 dB. To minimize the power required to excite central brain regions, B_1^+ maps were acquired (amplitude and phase) from each of the eight coils and phase coherence in the center of the brain (60mm diameter circle, red ROI Fig. 2) was maximized by setting the mean value of the phase over this region to be equivalent for all coils. The homogeneity of the B_1^+ field over the entire brain (green ROI Fig. 2) within the slice was then optimized using a least squares algorithm varying the amplitude of the individual RF channels. After optimization, a second B_1^+ map was acquired with all channels transmitting simultaneously to verify the homogeneity and peak power required to achieve a mean value of 1 kHz across the slice. As part of ongoing clinical studies at 7T, 82 studies were performed in adult controls and patients with neurological disorders.

Results: Unlike coils where the individual elements are strongly coupled to each other, the inductive decoupling allows each coil to be tuned and matched separately, without the need for a more complex network analysis. The average reflected power at each coil was -14.0dB (limited by tuning/matching display) in comparison to the forward power when transmitting individually, and -13.2dB when transmitting in combined mode, indicating the lack of coupling between the individual channels. Table 1 summarizes the performance data and includes: 1) the power (kW) required for a mean value of 1 kHz of B_1 over ROI_{amp} and 2) the SD of the B_1 over ROI_{amp} for 82 subjects. The data is grouped according to coil size used (small, medium and large) and brain location (cranial to caudal Fig. 2). The grouped brain locations include: 1) a superior location about the motor cortex and SMA, 2) an intermediate position, about the centrum semiovale and thalami and 3) an inferior location which was steeply angulated along the temporal lobe including the hippocampi (MTL).

Fig. 1 Transceiver Array

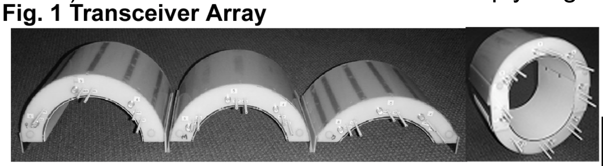

Fig 2. ROIs for B_1 Shimming

Red : ROI_{phase}
Green : ROI_{amp}

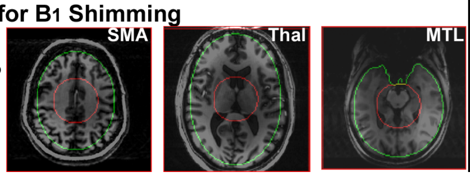

Table 1: Combined RF power required for 1 kHz in kW and % SD in the B_1 value over the ROI. n indicates the number of subjects.

		Location							
		Motor&SMA			CSO&Thal			Temporal	
Coil Size	n	Power (kW)	%SD(B1)	n	Power (kW)	%SD(B1)	n	Power (kW)	%SD(B1)
Small	8	1.8±0.2	8.0±1.6	8	2.0±0.4	10.0±1.4	2	2.6±0.1	18.9±1.78
Medium	9	2.2±0.4	9.2±2.3	31	2.7±0.4	11.5±2.5	11	3.0±0.5	19.0±2.1
Large	0			5	3.7±0.8	11.7±1.1	8	4.1±0.7	18.2±1.4

Conclusions: The use of inductive decoupling between adjacent coil elements and selectable geometries allows for simplified tuning and matching and consistent performance for a given coil size and brain location. Increasing the size of the coil increases the power required to achieve 1 kHz of B_1 across all locations. Spatially, increased power and decreased homogeneity was observed for all coils as the target slice was moved in the caudal direction. Although the homogeneity varies by brain location, within a given location, independent of which coil top is used, the achieved homogeneity is similar. This suggests that the overall homogeneity is largely determined by the brain location and angulation used (i.e. relationship of the selected ROI to the coil geometry), while the size of the coil determines the required power.