Implementation of a Novel 8-Ch Phase-Array Transmit/Receive Head Coil with RF Interface for Parallel Transmission on 3T

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INTRODUCTION High and/or ultra-high field (UHF) whole-body MR spectrometer emerges as a cutting-edge new millennium technology [1-2]. With significantly higher signal to noise ratio (SNR) and higher resolution, it obtains increased abilities in detecting human microscopic structures comparable with conventional histology, which were previously unseen in lower field. It also enables the observation and analysis of metabolic pathways and functions in living tissues with dramatically abundant details. However, UHF technology also prompts problems related with high frequency RF signals. At ultra high field, due to the sample's "dielectric resonance effect", the transmit RF signal generates inhomogenous B_1 distribution [3]. High resonance frequency also renders high energy deposition (high SAR values) in human subjects. One feasible solution for these issues is to implement multi-channel transmit/receive (Tx/Rx) RF coils in ultra high field, incorporated with parallel imaging techniques [1-4]. In this project, we have developed a novel 8-channel phase-array Tx/Rx head coil on a Siemens 3T Tim Trio system for parallel transmission, and examined the property of this Tx/Rx coil to expect higher SNR for visual stimulation fMRI experiments.

METHODS A novel 8-channel phase-array Tx/Rx head coil with related RF interface was constructed as shown in Fig.1 (a) and (b). The coil was made of polycarbonate and took a cylindrical mechanical structure with a slight bump in the nasal region. The coil inner diameter was 21cm with 26.5 cm in length and 5mm in thickness. The diameter of the coil was slightly less than the standard 12-channel head coil in order to achieve better SNR. A rectangular window of size 116mmx74mm was opened in the upper part of the coil to ensure an unblocked visual field for cognitive science studies. Eight relatively even-spaced rectangular surface loops were divided into 2 clusters, each consisting of 4 loops. The adjacent phase-array loops were decoupled via properly overlapped regions and/or shared common capacitors [5]. For the opposite surface loops, the coupling effect was neglected due to the geometric distance and low-impedance preamplifier decoupling [6]. All the elements were tuned to 123.2MHz and matched to 45-57 ohms with a 7300ml water phantom loading. Network analyzer output was as follows: S11 less than -16db for each channel, S21 decoupling less than -12db between adjacent and opposite loops. Parallel transmission pathway was implemented via a 1-to-8 power splitter and 8 T/R switches, as shown in Fig.1(b) and (c). Phase shifting was achieved using Belden RF coaxial cables with distinct length, and signal losses along the cables between the coil and preamplifiers were less than 0.3 dB. In this setup, RF shimming was achieved by applying linear phase shifters to upper and lower clusters of loops and there was a 180° phase shift of adjacent loops in two clusters. Using special mode-scanning excitation patterns via cable phase shifters and/or RF attenuators, we expect to get region-specific B_1 distribution, which may yield higher image SNR in regions of interest [7,8]. In the case of homogenous RF shimming, the global and local SAR distribution of this Tx/Rx coil seemed to function similarly as a TEM birdcage coil. We had set the global SAR control to a conservative value in conformity with the existing FDA standard. The local SAR distribution was monitored via the temperature measurment taken by a Fluke T125 thermal imager through long-time, high power-level, parallel transmission experiments on both a water phantom and a piece of 5kg pork meat. The standard GRE, T_1-MPRAGE, T_2-TSE and BOLD-EPI sequences were employed to examine properties of the Tx/Rx coil, in compliance with the SAR limitation.

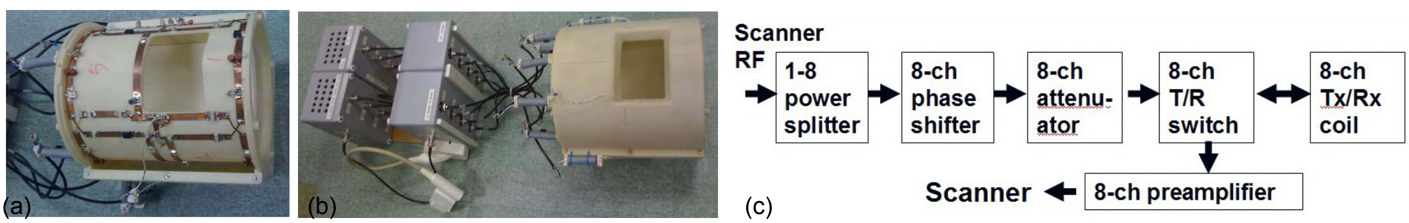

Fig.1 A novel 3T 8-ch phase-array Tx/Rx head coil (a) with RF interface including power splitters and T/R switches (b); (c) Schematic diagram of the 8-ch RF interface for the Tx/Rx pathway.

RESULTS Fig. 2 demonstrates the axial view of a water phantom image acquired by the GRE sequence (a), human brain images of a normal subject with GRE (b), TSE (c), and BOLD-EPI (d) sequences on our 8-ch Tx/Rx head coil. Images were homogenous in all four experiments, with high SNR in high-resolution GRE and TSE images compared with those acquired by the standard 12-ch head coil. The transmission power level of the 8-ch Tx/Rx coil was about half of the body coil. When performing the stability test for BOLD fMRI studies, images acquired by the Tx/Rx coil consistently yielded less signal magnitude drifting and therefore ensured more reliable measurements of BOLD signal change in the temporal course of fMRI experiments.

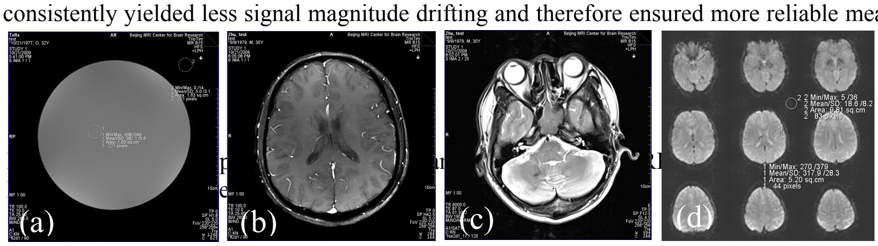

Fig.2 (a) GRE water phantom image; human brain images of GRE (b), TSE (c), and BOLD-EPI (d) sequences.

CONCLUSIONS This phase-array Tx/Rx head coil was constructed in a unique and exclusive mechanical and electronical design with a special decoupling pattern. It yields higher SNR and stability, combined with parallel transmission techniques. It is suited specifically for visual cognitive science experiments. B_1 shimming was achieved on water phantoms and human brain. We further did global and local SAR distribution measurements for safety concerns and would run selective regional B_1 excitation to achieve high SNR with reduced susceptibility artifacts in specific brain regions, such as anterior temporal lobes, which played an important role in emotional cognitive science studies.

REFERENCES [1] Adriany G, Uğurbil K, et al. MRM 53, 2005. [2] Setsompop K, Wald LL, et al. MRM 56, 2006. [3] Merkle H, Duyn JH, et al. Proc. ISMRM, 2008. [4] Smith MJ, King SB, et al. Proc. ISMRM, 2008. [5] Wang J. Proc. ISMRM, 1996. [6] Roemer PB, Edelstein WA, et al. MRM 16, 1990. [7] Lee RF, Xue R. MRI 25, 2007. [8] King SB, Smith MJ, Fontius U, Schmitt F, et al. Proc. ISMRM, 2008.

ACKNOWLEDGEMENTS The authors thank Dr. Jianming Wang from SMMR, Shen Zhen, China for his fundamental contributions in this project, and Mr. Helmut Stark from Erlangen, Germany for providing the key RF interface components and technical support in implementation of parallel transmission pathways.