An Open Faced 4 ch. Loop Transmit / 16 ch. Receive Array Coil for HiRes fMRI at 7 Tesla

Gregor Adriany[1], Matt Waks[2], Brandon Tramm[2], Scott Schillak[2], Essa Yacoub[1], Federico de Martino[1,3], Pierre-Francois Van de Moortele[1], Thomas Naselaris[1], Cheryl Olman[1], Tommy Vaughan[1], and Kamil Ugurbil[1]

[1]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States, [2]Virtumed LLC, Minneapolis, MN, United States, [3]Maastricht University, Netherlands

Objective

Fast switching head gradient inserts can significantly improve spatial and temporal resolution in EPI, however their physical presence reduces task presentation capabilities and makes integration of efficient transmit coils near receive arrays challenging. The aim of this work was to develop an open 7 Tesla Tx/Rx surface array coil operational inside a head gradient coil (HGC), thereby permitting excellent task presentation capabilities and the ability to do high resolution fMRI of the visual, occipital and auditory cortices. An important second aim was to combine the advantages of transmit arrays at 7 Tesla with the benefits of tight fitting receive arrays to achieve both efficient and homogeneous RF excitation and high SNR in known problem areas at 7T (lower cerebellum, occipital cortex).

Methods

A tight fitting custom coil housing was built utilizing Fused Deposition Modeling (FDM**)** (Fig. 1a-c). The housing was designed to be modular to allow for a convenient swap between different sized transmit and receive coil combinations. The receive coils were built into the upper holder (Fig. 1b), while the base holder contained the transmitter array and related RF components (Fig. 1d). The receive insert had provisions for system interface hardware, including secure locations for preamplifier mounting and cable routing. The initial prototype transmit array consisted of four overlapped loop coils. Two transmit coils (Tx #'s 1 & #4) (Fig. 1d) were 12x12 cm^2 and built with ten 12pF capacitors (American Technical Ceramics, Huntington Station, NY) distributed along the 13 mm wide planar conductor. For extended cerebellum coverage the two transmit coils located near the posterior (Tx #'s: 2 & 3) were lengthened to 14x12cm^2 and included twelve 10pF capacitors. An RF shield optimized for minimal eddy currents (Sheldahl, Northfield, MN) was placed at a distance of 2.5 cm from the Tx array for reduced interaction with the HGC and stabile coil tune and match [1, 2]. Serial PIN diodes (M/A-com, Lowell, MA) in each Tx coil loop were used for active transmitter detuning. In the current configuration the coil housing accommodates up to sixteen element receive arrays. For the first prototype nine receiver coils were realized on the former with two additional channels to allow for flexible receiver coils. All receive coil elements (~8cm) where built from silver-plated copper wire (2 mm), matched with a lattice balun network and included both active and passive detuning trap circuits [3]. Preamplifier decoupling was achieved using a combination of $\lambda/4$ length coaxial cables and lumped element phase shift networks connecting each coil element to a low-noise preamplifier (Microwave Technologies, Fremont, CA) [4, 5]. All experiments were performed at 7 Tesla utilizing a 36 cm i.d. Head Gradient Coil capable of maximal 80mT/m (AC84, Siemens, Erlangen, Germany).

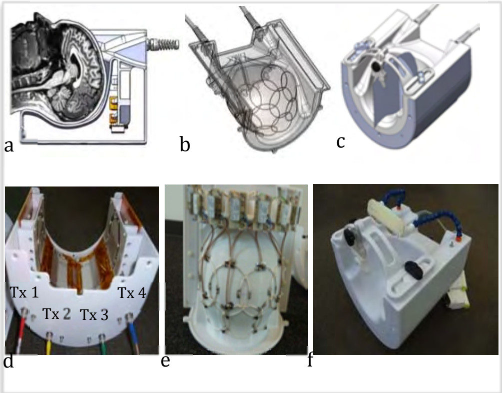

Fig. 1 Concept (a-c) and realization (d-f) of the modular open faced holder design.

Results and Discussion

The 'open face' appearance of the coil housing significantly improved both task presentation and patient comfort. The incorporation of the RF shield into the coil resonance structure was critical for reliable RF performance at 7T inside the HGC. All receive loops had excellent Q_u/Q_l ratios of 8 to 10 and achieved high SNR and low noise correlation <0.2. Due to the lower Q of loop coils (compared to striplines) all experiments could be performed without subject specific tune/ match re-adjustments, which significantly reduced setup time. To achieve optimal transmit efficiency and RF homogeneity the Tx array allows for full flexibility in terms of B_1^+ shimming [6], however we observed that an experimentally determined average phase distribution and equal RF amplitude can be used in practice (Fig.2). With an appropriate RF splitter this could further simplify the experimental setup and allow for broader use of the coil in more common single channel transmitter systems. The desired extended cerebellum coverage was achieved with the larger Tx coils placed near the posterior (Fig. 3). The transmit array supported spin inversion in the FOV seen by most of the receive array coils, however the difference in B_1^- and B_1^+ profiles leads to an asymmetry in efficient coverage of the left compared to the right auditory cortex (Fig. 3) [7]. The coil is routinely used for SE and GE EPI studies (example Fig. 4). For future design improvements we plan to increase the number of transmit as well as receive array elements- particularly along the z-axis- for increased B_1^+ control, brain coverage, higher SNR and parallel imaging performance.

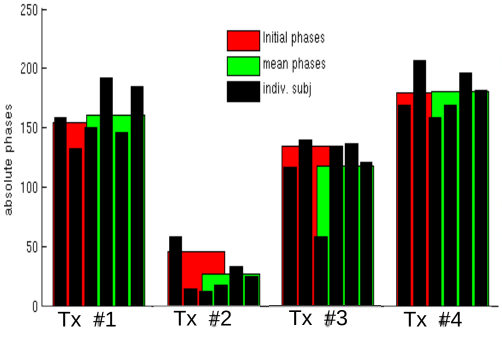

Fig. 2 Subject dependency of the optimal RF phase per coil for 6 Subjects (red – start phase, green- mean all subjects, black- optimal phase for subject).

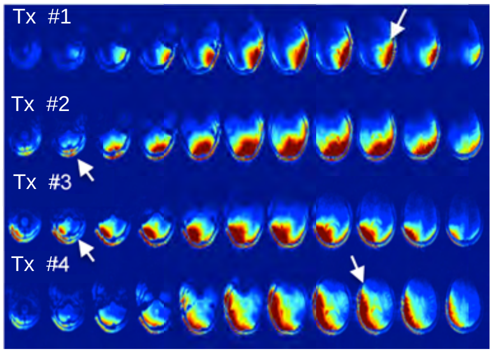

Fig. 3 Axial slices showing coverage of the four transmit coils. Note the extended cerebellum coverage achieved with Tx #'s 2 & 3 and the B_1 asymmetry between Tx #'s 1 & 4.

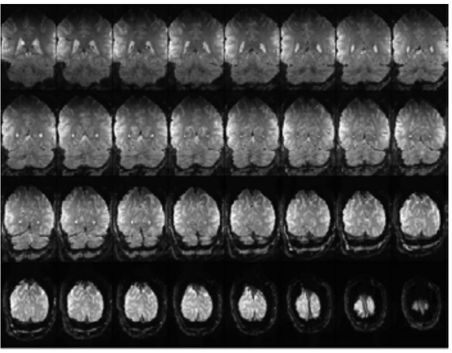

Fig. 4 Coronal EPI imaging example demonstrating coverage and excellent eddy current performance: GE EPI, iPAT=2, 1mm isotropic

References: 1. Vaughan, J.T., et al., *MRM*, 1994. **32**: p. 206-218. 2. Avdievich, N.I., et al., *MRM,* 2009. **62**(1): p. 17-25. 3. Wiggins, G.C., et al., *MRM*, 2006. **56**(1): p. 216-23. 4. Reykowski, A., *MRM*,1995. **33**(6): p. 848-52. 5. Roemer, P.B., et al., *MRM,* 1990. **16**(2): p. 192-225. 6. Van de Moortele, P.F., et al., *MRM*, 2005. **54**(6): p. 1503-18 7. Wiggins, G., et al., *Proc* 17th ISMRM, 2009: p. 393.

Supported by NIH P41 RR08079, U54MH091657, S10 RR026783, P30 NS057091, EB006835, EB007327, R21 EB009133, W.M. Keck Foundation