Common-mode differential-mode (CMDM) method for quadrature transmit/receive surface coil for ultrahigh field MRI

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Introduction Quadrature transmit/receive coils have been demonstrated to be an efficient method to reduce the excitation power and to increase the signal-to-noise ratio (SNR) up to 41% theoretically [1]. The coupling between two quadrature channels is a major factor that decreases the SNR improvement by quadrature coils. Current studies on double tuned coil design indicate that the common-mode (CM) differential-mode (DM) method provides two orthogonal EM field distributions by the two resonance modes in one coil element. The two modes are intrinsically decoupled electromagnetically [2, 3]. In this work, we propose a CMDM 2-channel quadrature transmit/receiver surface coil design for 7T MR imaging. A prototype coil is designed and fabricated for proof of concept studies. The two modes of the CMDM coil are tuned and matched at 298MHz separately. Both workbench tests and water phantom MR imaging experiments at 7T are carried out to evaluate the coil performance. GRAPPA reconstructed images have been acquired to evaluate the parallel imaging performance of the proposed coil.

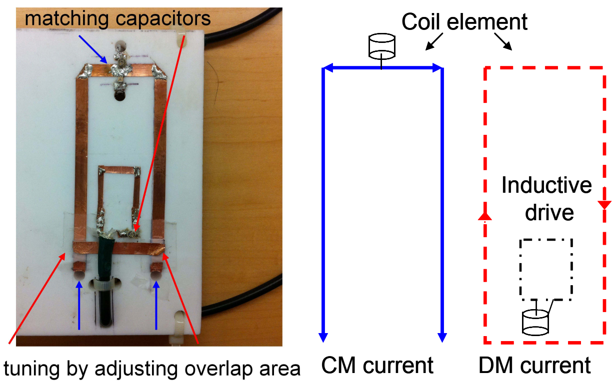

Fig. 1: (a) the prototype quadrature CMDM surface coil; (b) diagram of the CMDM coil, the solid line denotes the common-mode current and the dashed line denotes the differential-mode current.

Methods As shown in Fig. 1(a), the dedicated square surface coil with 4cm width and 9.4cm length was fabricated by 6.35mm width copper strips on 1.27cm thickness Teflon board. The opposite side of the board was cover by copper shield served as ground. The CM was driven capacitively by coax cable. In this mode the copper strips were realized as split microstrips with the same current direction. The CM was tuned by 91pF terminated capacitor on the driven end and overlap copper lines with Teflon insert on the other ends, which utilized as trimmer capacitors. The DM was driven inductively by a small square loop with matching capacitor. In this mode the coil worked as a shielded square surface coil and the current of parallel copper strips was of opposite directions. The DM was tuned by adjusting overlap area as shown in Fig. 1 as well. Since the magnetic field of the two modes was orthogonal, the CM cannot be driven by the small loop, whilst the DM cannot be driven by the driving cable of the CM due to the symmetric geometries.

The two modes were tuned to 298 MHz corresponding to the proton Larmar frequency at 7T and matched to 50 Ohm separately. Workbench test on the resonance modes and isolation were carried out on the network analyzer (Agilent E5070B). The water phantom MR imaging experiments were performed on the General Electric (GE) whole body 7T scanner. The two channels were driven quadraturely. The images of CM and DM were acquired and reconstructed separately. The axial and sagittal MR water phantom images were acquired by gradient echo (GRE) image sequence with the parameters: flip angle = 10^o ; TE = 5 ms; TR = 800 ms; slice thickness = 5 mm; FOV = 14×14 cm^2; 256×256 image matrix; NEX = 1.To evaluate the parallel imaging performance of the CMDM coil, GRAPPA [4]was used for image reconstruction. 32 Auto-Calibration Signal (ACS) lines in the center of the k-space were used to estimate the missing lines. The GRAPPA reconstruction with acceleration factor of 2 was performed to L/R direction in axial plane and to S/I direction in sagittal plane.

Results The S21 of the two modes was measured by network analyzer. The intrinsic decoupling of the two modes, which was better than -36 dB at resonance frequency, was demonstrated by the bench test. The result indicated that the two modes were decoupled sufficiently. Fig. 3 showed the MR phantom sagittal and axial images acquired by each mode, the combined images and the GRAPPA reconstruction images. The images showed the CM and DM of the surface coil provided similar B1 coverage, which indicated the SNR improvement could be achieved in the whole region of interested. The SNR of the combined images increased 24% and 69% of that of the DM and CM images respectively on the surface region of the phantom. At the center of the phantom, the SNR of the combined image was 10% and 103% higher than that of the DM and CM images respectively. The GRAPPA reconstruction images showed the parallel imaging performance was still good although there were some artifacts in the accelerated images.

Discussion The results of bench test and MR phantom experiments demonstrate that the proposed CMDM method is a feasible and efficient technique for quadrature surface coil design for ultra-high field. The intrinsic decoupling between the CM and DM, which is due to the symmetric geometries of the surface coil and the orthogonal magnetic field distribution of the two modes, provides one of the major advantages of the CMDM design. SNR improvement can be realized in the whole region of interested. In addition, compared with conventional quadrature approach, its compact, robust and simple design would be beneficial to array coil designs for parallel imaging and make array coils with the quadrature feature possible and practical. The impressive parallel imaging results attained by using the two modes of the CMDM coil as two independent channels demonstrate the feasibility of the CMDM quadrature coils for parallel imaging [5].

References 1) D. I. Hoult. *Magn. Reson. Med*, 1984, 1:339-353; 2) Z. Xie, *et al. 16th annual meeting of ISMRM*, 2008, p2985; 3) Z. Xie, *et al. 17th annual meeting of ISMRM*, 2009, p2964; 4) M.A. Griswold, et al. *Magn. Reson. Med.*, 2002,47:1202-1210; 5) J. V. Hajnal, *et al. 8th annual meeting of ISMRM*, 2000, p1719.

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Fig. 2 Bench test result. The intrinsic decoupling phenomenon leaded to S21 better than -36 dB at resonance frequency.

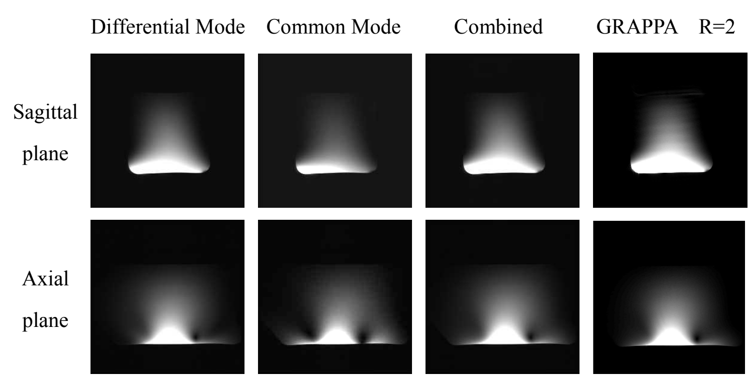

Fig. 3 Water phantom images. First two columns: acquired by the two channels respectively; Third column: combined image without acceleration; Fourth column: GRAPPA reconstructed images.