8 Channel Transmit and 16 Channel Receive Constellation Coil for 7T MRI

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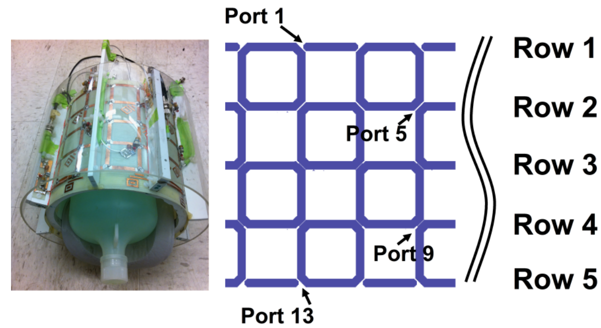
Introduction Constellation coil [1-3] is a new concept of parallel transmit/receive array, which consists of a continuum structure to support most flexible current path control, simplify coil fabrication and improve robustness. Theoretical and simulation analysis have demonstrated ultimate coil performance can be approached by accommodating various current patterns on an enclosing surface [3]. Compared with conventional array design, constellation coil offers alternative structures with higher scalability. In this work, we present an 8 channel transmit/16-channel receive constellation coil for 7T MRI to support highly parallel Tx/Rx. Both transmit and reception performance have been investigated and compared with high density commercial arrays.

Methods As shown in Fig 1(a), the proposed 1-layer mini-loop transmit/receive constellation coil was adapted from 2-layer mini-loop constellation coil shown in reference 2. The coil consisted of 4-by-16 mini loops. Each loop was 4.6 cm by 4.6 cm and made of 6 mm width copper. The conductors were fabricated on a flexible PCB and wrapped on the 18.4 cm length and 23.5 cm diameter holder. Fig 1(b) showed the configuration of a quarter of the coil. The blue lines indicated the copper conductors. 6.8 pF chip capacitors were located between the gaps of the conductors in Fig 1(b). There were 4 ports on each of Rows 1, 2, 4 and 5. In imaging experiments, 8 of the total 16 ports were chosen as transmit/receive ports while the other 8 ports were receive-only. All the ports were matched to 297.2 MHz corresponding to the proton Larmar frequency at 7T.

Water phantom MR imaging experiments were performed on a Siemens whole body 7T Magnetom scanner. The 7.3 L cylindrical water phantom containing 1.25 mg/L $NiSO_4{\cdot}6H_2O$ and 4 mg/L NaCl with 15 cm diameter was utilized for RF excitation and reception measurements. Flip angle maps were experimentally measured for each transmit channel and then phase shimming [4] was performed. The center coronal images were acquired by gradient echo (GRE) image sequence with the parameters: flip angle = 20^o; TE = 4 ms; TR = 2000 ms; slice thickness = 5 mm; FOV = 252×252 cm^2; 128×128 image matrix; Average = 1. Signal-to-noise ratio (SNR) was calculated from raw data with GRE and noise acquisition according to the Kellman method [5]. For comparison, the same measurements were carried out by using commercial NOVA 24 channel array and QED 28 channel array. The SNR of constellation coil and commercial coils were normalized by flip angle to remove impact of transmit field variations, and then compared to evaluate the reception performance of the 16 channel constellation coil.

In order to investigate transmit performance of the constellation coil, 3 different transmit port combinations have been studied, which are ports on Rows 1 and 5, ports on Rows 2 and 4, and ports on Rows 2 and 5. Phase shimming was carried out on the center coronal plane and total transmit power was measured to evaluate transmit efficiency.



(a) Constellation Coil (b) Coil Configuration

Fig. 1 Photo and Configuration of proposed constellation coil

Results The GRE images, flip angle maps and normalized SNR of 16 port constellation coil, 28 channel QED array and 24 channel NOVA array were shown in Fig. 2. Although the inner diameter of the constellation coil was about 40% larger than that of QED array, which is around 16 cm, the normalized SNR of constellation coil at center region is comparable with QED array. Compared with NOVA array, the constellation coil provided better imaging coverage while maintained similar reception performance at center region. 1D profiles of the normalized SNR at the vertical center lines on coronal planes were shown in Fig. 3, which demonstrated the three coils provided comparable normalized SNR in the deep region of interest.

Fig. 4 showed the flip angle maps and corresponding transmit power of the 3 different transmit port combinations. The transmit coverage and efficiency can be manipulated by alternating transmit ports and/or RF shimming strategy. These results suggest the constellation coil is potentially capable to optimize current distribution to achieve ideal transmit current pattern. The transmit power of QED and NOVA coils, each of which used an integrated birdcage coil to achieve the flip angle shown in Fig 2, were 250.5W and 151.3W respectively. Compared with the commercial products, the constellation coil appeared to be capable of maintaining high efficiency with larger size and coverage.

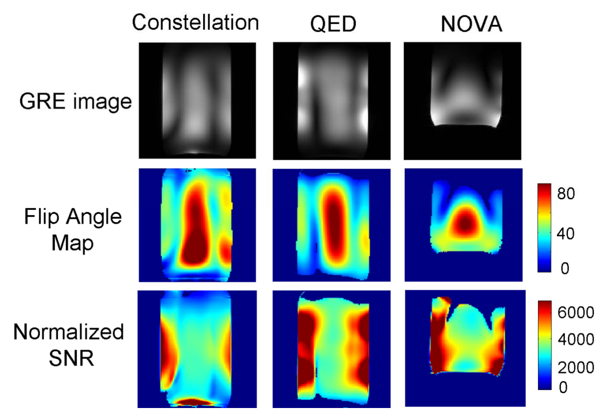


Fig. 2 Imaging results of constellation coil, QED 28 channel array and NOVA 24 channel array.

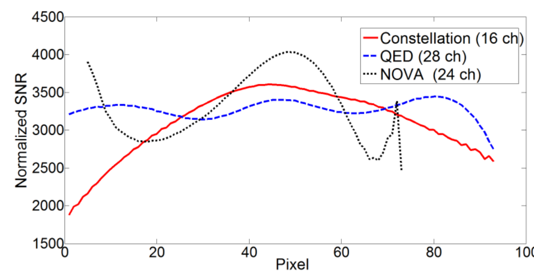


Fig. 3 Normalized SNR comparison at the center of the third row images in Fig 2.

Discussion The imaging results indicate that the proposed 8-channel transmit/16-channel receive constellation coil achieves comparable transmit and reception imaging performance at 7T with larger size and coverage, compared with commercial products. The capacitance variation and loss may be be reduced and robustness may be improved by replacing the present structure with a 2-layer mini-loop structure fabricated on using a quality PCB. Further investigation includes simulation-guided ports selection to optimize coil performance. In addition, this coil structure may also benefit multinuclear MR imaging [5].

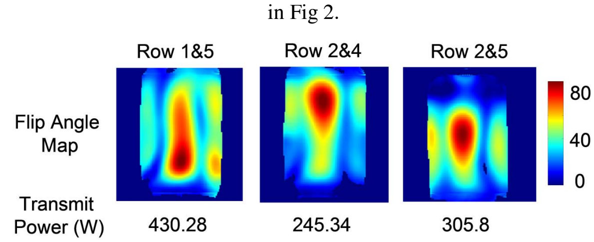


Fig. 4 Flip angle maps and transmit power of different transmit port combinations.

References 1) Y. Zhu, *18th ISMRM*, p 46, 2010; 2) Y. Zhu, *et al. 19th ISMRM*, p3840, 2011; 3) Y. Zhu, *et al. 12th ISMRM*, p432, 2012; 4) G. J Metzger, *et al. Magn Reson Med*, 2008,59: 396-409; 5) P. Kellman, *et al. Magn Reson Med*, 2005, 54: 1439-47; 6) X. Yang, *et al. 12th ISMRM*, p2819, 2012

Acknowledgments

This work was supported in part by grants from the NIH.