Investigation optimum ports' location for multi-nuclear constellation coil

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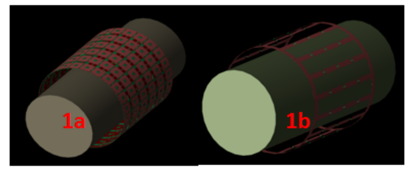
INTRODUCTION: The essence of constellation coil transmit and/or receive performance optimization can be described as one of maximizing |B1±|/|E|, quantities that track flip angle-to-SAR ratio (spin excitation) and signal-to-noise ratio (signal detection). It uses an approximately continuous RF structure as well as multiple distributed ports to support generally sophisticated RF current patterns responsible for the ultimate performance with multi-channel transmit and receive[1]. And the transmit and receive ports' location are very critical to the ultimate performance. The present study investigated optimum ports' location for multi-nuclear imaging with FDTD simulation.

METHODS AND RESULTS: Single helix constellation coil can be used to transmit and receive for 7T proton (297.2MHz) and sodium(78.6MHz) imaging without any de-tuned or de-coupled circuits was previously demonstrated. And the SNR performances were comparable with other coils[2]. 8 ports were roughly located in the structure separately azimuthally by 45° in the mid section (proton) or in the center ring (sodium) without prior optimization design. Compared with combined SNR map, individual channel SNR maps indicated that some port contributed nearly 80%, while some other ports' contribution were almost negligible. For a constellation coil structure, ports' location are very critical to the Tx efficiency and SNR performance. Since each port requires its own receiver and data acquisition hardware, practical considerations limit the receive ports can not be infinite. In consideration of our hardware support capability, the study will be performed on 16 ports for proton(297.2MHz) and sodium(78.6MHz). The purpose of this investigation is to find the optimum 16 ports for proton and sodium separately. FDTD simulations were used to do the evaluation.



In this study, a mini-patches constellation knee coil was modeled in FDTD simulation (Remcom XFdtd 7.12) for proton and sodium, which has two layers of mini patches sandwiching a 10 mil-thick substrate of εr=10. The mini patches are of size 24 mm x 27mm, and each is capacitively coupled to its four immediate neighbors on the other side of the substrate. The same 32 ports, which located in equally spaced 4 rings, and each ring with 8 ports separately azimuthally by 45°, were added to simulate at 297.2MHz and 78.6MHz. As reference, a 16-rung birdcage knee coil with the same size was also modeled and simulated(Fig.1b).

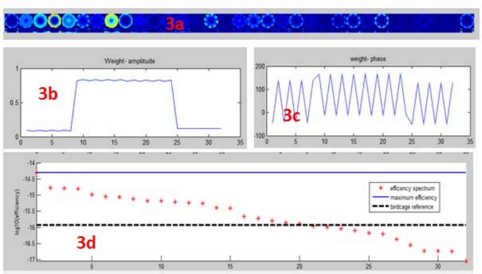


Table.1: The relative weights (amplitude) of 32 ports for maximum efficiency-proton								
Ring1 (port 1to8)	0.0922	0.0872	0.0922	0.0872	0.0922	0.0872	0.0922	0.0872
Ring2(port 9 to 16)	0.817	0.8326	0.817	0.8326	0.817	0.8326	0.817	0.8326
Ring3(port 17 to 24)	0.8139	0.8293	0.8139	0.8293	0.8139	0.8293	0.8139	0.8293
Ring4(port 25 to 32)	0.1234	0.1249	0.1234	0.1249	0.1234	0.1249	0.1234	0.1249

For parallel receive array, an interesting hypothesis is to assess sensitivity squared per unit noise power. Especially for any linear operator-based image reconstruction, a reconstructed image can be equivalently expressed as weighted summation of multi-channel MR signals[3,4]. Depending on the reconstruction weights of multi-channel MR signals w, a multi-port coil operates at a range of efficiency levels, as quantified by the metric, equivalently expressed as $\eta = w^H \Gamma w / w^H \Phi w$, which uses of B1- values in constructing Γ and uses of noise correlation calibration in obtaining Φ.

Maximum and minimum exist that bound the efficiency range. One can approach efficiency assessment with the eigen-modes. The largest eigenvalue and its corresponding eigenvector represent, respectively, the maximum receive efficiency and the corresponding reconstruction weights w. Other modes deliver less efficiency and can also be readily identified. The efficiency of the eigen-modes, were shown in Fig.3d for 32-port proton receive. And B1- profiles corresponding with different eigen-modes were shown in Fig.3a. The maximum efficiency mode which was marked with a blue line in Fig.4d, outperformed the birdcage knee coil in CP mode (marked with a black dotted line). Amplitudes (Fig.3b) and phases (Fig.3c) of combination weights for 32 ports were calculated at the mode-1,which corresponding to the maximum efficiency. And the amplitude information were shown in Table.1, which indicating that the ring 2 (port 9 to 16) and ring 3 (port 17 to 24) were the optimum ports for 16-port proton receive. The same investigation was performed for sodium with the same 32 ports. The results were shown in Fig.4a-d. Be different from proton, the trend of amplitude information of combination weights, which corresponding to the maximum efficiency was opposite (Table.2), which indicating that the ring 1(port 1 to 8) and ring 4(port 25 to 32) were the optimum ports for 16-port sodium receive.

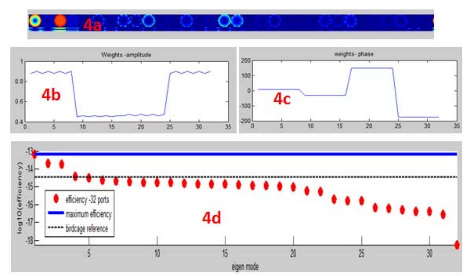


Table.2: The relative weights (amplitude) of 32 ports for maximum efficiency-sodium								
Ring1 (port 1to8)	0.8804	0.9009	0.8804	0.9009	0.8804	0.9009	0.8804	0.9009
Ring2(port 9 to 16)	0.4501	0.4576	0.4501	0.4576	0.4501	0.4576	0.4501	0.4576
Ring3(port 17 to 24)	0.4587	0.4724	0.4587	0.4724	0.4587	0.4724	0.4587	0.4724
Ring4(port 25 to 32)	0.8768	0.9019	0.8768	0.9019	0.8768	0.9019	0.8768	0.9019

DISCUSSIONS: The optimum ports' location were investigated for proton and sodium imaging based on the same constellation coil by FDTD simulation. For 16-port receive, ring 2 (port 9 to 16) and ring 3 (port 17 to 24) were the optimum ports for proton, while ring1 (port 1 to 8) and ring 4 (port 25 to 32) were the optimum ports for sodium.

In practical implementation, inadaptable ports match and imperfect supported hardware, such as pre-amps' noise and electronic loss in the coil will make the results deviation from the simulation results. Further, the investigation will be continued on phantom and volunteer test on a Siemens 7T scanner.

REFERENCES: [1] Y.Zhu, 19th ISMRM.2011 [2] X.Yang, 20th ISMRM.2012 [3] Y. Zhu, *18th ISMRM*, p 46, 2010. [4] Y. Zhu, *18th ISMRM*, p 1518