3T Transceiver Quadrature Surface Coil Design for Cervical Spine Spectroscopy

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Introduction: MR spectroscopy (MRS) provides noninvasive quantification of the metabolite within a region of interest, aiding diagnostic measurement of morphological images [1]. MRS in the cervical spinal cord (C-spine) is particularly challenging because of the small size and deep anatomical location, limiting the signal available and placing stringent demands on the accuracy of spatial localization [2]. Due to the use of high bandwidth refocusing pulses and the inclusion of additional water suppression, an MRS sequence running with body coil transmit is SAR demanding, and may be hampered by the maximum B_1^+ magnitude available. Motivated by the need for a local transceiver coil optimized for C-spine spectroscopy, a new design of 3T TR quad surface coil is presented, and its efficiency performance is evaluated on the in-vivo images, compared to the commercial head-neck receive coil.

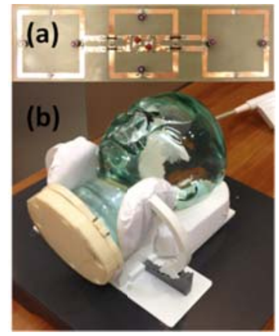

Fig.1 (a) 3T TR Quad surface loops (b) packaged coil

Methods: The TR quad coil consists of one middle loop and a symmetrical saddle loop (fig.1a). Each loop is of identical size, 7cm square for the location of the C-spine assuming 12cm average diameter of human neck. Full wave simulations were performed to determine optimum dimensions for the coil elements, targeting efficiency and uniformity over the region of interest. Ergonomic factors were also considered in designing the loop (open structure in a tilted position, fig.1b) to comfortably fit around subjects. The middle and the saddle loops are electrically and geometrically decoupled each other, with S_{12} less than -20dB. Each side of the saddle loop was individually tuned and matched at 100 ohms in parallel with loading to form 50 ohms at the feed network connected to one port of the quad hybrid. Circular polarization was achieved by putting a quarter wave phase delay between the saddle feed and the quad hybrid to balance the phase relation between the middle and the saddle loop, noting that the lattice balun on the saddle loop itself provides a 90 degree phase shift. The coil incorporates a TR switch assembly that integrates the quad hybrid, PIN diode switch network with the high power dummy loads, and the 50 ohm preamp. Using a tissue equivalent gel phantom, temperature maps were generated for a high SAR sequence using proton resonance shift MR thermometry [3], A hot spot was identified close to the middle loop, and the SAR parameter was set based upon the maximum temperature rise in that region. Three plane flip angle (FA) and SNR maps were generated as Tx/Rx efficiency metric, compared to the commercial head neck coil (Siemens, TIM trio) with the body coil transmit. The required pulse voltage was manually calibrated targeting at 90 degree in the region of C-spine using the pre-saturation based B1 scout sequence [4], whereas the Siemens coil was set by the auto calibration by the scanner. For the multichannel combined SNR image the sum of square method was used [5]. High resolution T2 FLASH axial images were obtained to locate the white and grey matter within the C-spine.

Results: 3 plane FA images using both the 3T body coil (fig.2a) and the TR quad coil (fig.2b) show the target flip angle distribution in the C-spine region, noting that the broader uniform excitation was obtained with the body transmit. To achieve a 90 degree flip angle in the spinal cord a 500 μs hard pulse with 278 volts was required with the body coil, and 77 volts with the T/R neck coil. The estimated excitation power required for the target flip angle using the local TR quad is roughly one 13^{th} of the body transmit, but at the expense of a smaller FOV and lower uniformity. On receive side, SNR improvement was observed by factor of 1.34 in the target region (35 vs. 47), compared to the Siemens head-neck coil in fig.3. The zoom of the axial T2 flash images in figure 4 demonstrates the clear SNR benefits of the proposed coil.

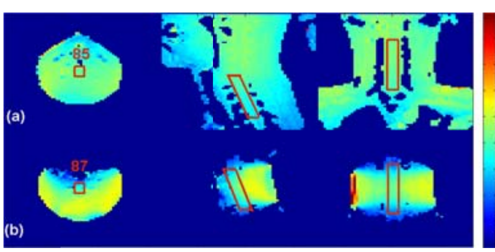

Fig.2 Three plane FA images, (a) Siemens Head-Neck (b) TR Quad. Note - target FA achieved in the ROI (rectangle area)

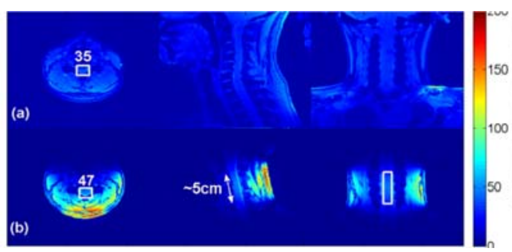

Fig.3 Three plane SNR images, (a) Siemens Head-Neck (b) TR Quad. Note - 34% SNR improvement in the ROI with the TR Quad

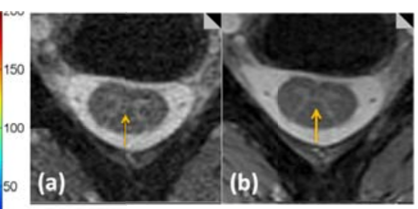

Fig.4 Axial T2 Flash images, (a) Siemens Head-Neck (b) TR quad. Note - clear delineation of the white and grey matter due to the superior SNR with the TR quad

Discussion: The local TR coil designed for a target anatomy has achieved improved SNR in the ROI. Regarding transmit, a higher maximum pulse bandwidth can be achieved with the TR coil, which enables better spatial localization. However, the SAR limit for the TR coil turns out to be more conservative than the body coil, constrained by the maximum temperature rise of the local hot spot. The center feeding of the saddle loop through the lattice balun produces the constructive B1 at the center, creating common mode current on each loop, which is analogy to the series feeding butterfly loop. Special care is needed to tune and match each of the saddle loop, which is critical to achieve the balanced current distribution, hence creating the optimal field at the center.

Reference: [1] MRM58:880-885 [2] JMRI 26:1101-1105 [3] JMRI 12(4):525-33 [4] NMR Biomed. 2010; 23: 368–374 [5] MRM 54:1439–1447