Investigation of Element Designs and Construction of a Reconfigurable 8 Channel Tx, 16 Channel Rx Torso Array for 7T

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Introduction: Improved signal-to-noise ratio (SNR) has led the drive for high magnetic field scanners. While substantial progress has been made toward exploiting high field benefits for head imaging, high field torso imaging has been hindered by non-uniform B1+ distribution and inadequate B1+ in the center of the torso. Stripline coils have become the preferred method for RF excitation at 7T due to their spatially distinct sensitivity profiles, self contained E-fields and lack of transverse current. Striplines have shown promise for torso imaging [1], and striplines in conjunction with local B1 shimming has facilitated 7T cardiac imaging [2]. Despite these encouraging studies, conventional loop coils have not been compared to the stripline in the context of torso imaging. One interesting option is to use the loop in conjunction with the stripline to create a circularly polarized excitation field as proposed in [3] to potentially enhance B1+ in the central torso. To address these topics, we measured B1+ generated by an unshielded loop, shielded loop, stripline, and stripline/loop combination coils. Further B1+ mapping was performed with an array of eight stripline/loop coils.

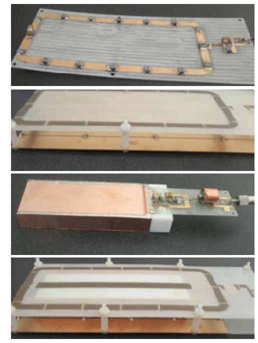

Fig. 1. Prototype coils: unshielded loop, shielded loop, stripline, and stripline/loop combination.

Methods: Four candidate coils were constructed and tested (Fig. 1): 1) an unshielded 8x20cm^2 loop, 2) a 8x20cm^2 loop with solid copper shield 2cm above the loop, 3) a stripline with 15cm length, 5cm wide ground plane, 2 cm wide active element, 2 cm thick teflon dielectric and 2cm sidewalls as proposed by [4], and 4) stripline/shielded loop combination coil. Loop coils were tuned to 297.2MHz using 16 distributed capacitors (~12 pF each for the unshielded loop, 15pF each for the shielded loop, and 16pF each for the loop/stripline combination coil) and capacitively matched to 50Ω while loaded with a torso phantom [roughly 22cm (A/P) × 31cm(L/R)] doped with NaCl and alcohol to mimic the dielectric properties of muscle at 7T (ε_r≈58, σ≈0.77S/m.) Striplines were tuned using two 4.3pF capacitors at opposing ends of the active element and capacitively matched to 50Ω while loaded with the torso phantom.

Though single-element coil experiments may provide insight into baseline coil performance, a realistic torso array calls for multiple elements to surround the sample [1,2]. To this end, an array of eight stripline/loop coils was constructed with approximately 4cm gap between elements. Multi-element experiments were performed with either eight loops or eight striplines with unused elements terminated with 50Ω loads. During transmit, elements were connected to independent RF amplifiers with phase roughly equal to the azimuthal position of the element with respect to the center of the phantom. Some effort was made to reduce signal nulls caused by destructively interfering RF standing waves. During receive, elements were connected to independent preamplifiers via coaxial cable of appropriate length for preamplifier decoupling.

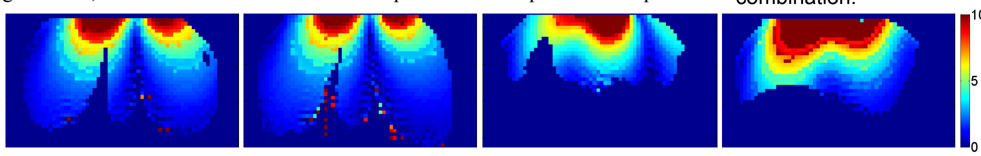

Fig. 2. FA maps for a 150v excitation for the unshielded loop, shielded loop, stripline and stripline/loop combination (scale in radians.)

Gradient echo images on a 7T whole body scanner equipped with an eight-channel parallel transmit system (MAGNETOM 7T, Siemens Healthcare, Erlangen, Germany) were acquired over a range of RF excitation voltages with a 10ms slice-selective pulse. FA mapping was then performed using the procedure outlined in Ref. [5]. For multi-element experiments, individual FA profiles were calculated by acquiring an additional image I_n in which excitation was generated by only the n^{th} element at a low transmit voltage (10v) and applying $FA_n = \sin^{-1}(I_n/A)$ [5].

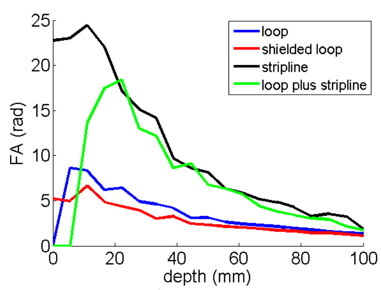

Fig. 3. FA profiles through L/R center of Fig 2.

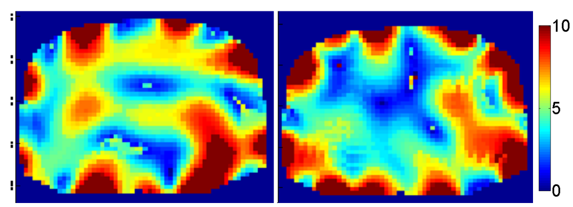

Fig 4. FA maps for a 150v excitation for the 8-element loop array and 8-element stripline array (scale in radians.)

Results: FA maps for the four candidate coils showed that the stripline coil provided the most efficient excitation near the surface and maintained a strong excitation directly beneath the element (Figs. 1, 2). Characteristic high-field transmit and receive nulls can be seen in the loop coil FA maps, which were less efficient than the stripline near the periphery but comparable at depth. Note that the loop z-coverage is likely greater than the stripline due to increased length. The stripline/loop combination coil did not improve efficiency directly below the element though improved L/R coverage was observed. Shielded and unshielded loops provided comparable excitation efficiency. The eight channel loop array showed a moderate advantage in the phantom center compared to the eight channel loop array (Fig. 4). FA profiles from the individual elements composing the eight channel arrays reveal typical loop and stripline B1 patterns, as the striplines generated a spatially concentrated double-lobe pattern and while the loops generated a wider triple-lobe pattern due to B-field twisting.

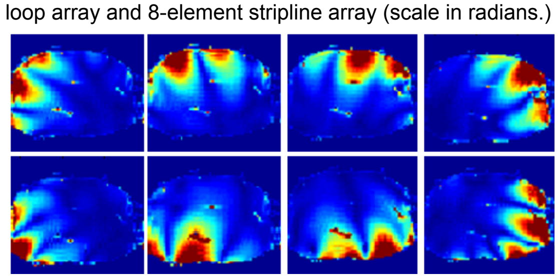

Fig 5. Individual element FA profiles for the 8-element loop array.

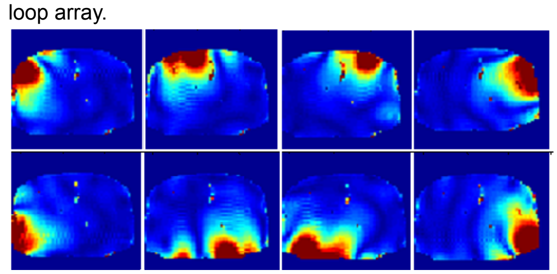

Fig. 6. Individual element FA profiles for the 8-element stripline array.

Discussion: This work illustrates the feasibility of torso imaging at 7T using either conventional loop or stripline coils for excitation. The constructed array of eight stripline\loop combination coils has the potential for eight-channel parallel transmit and 16-channel receive to improve SNR over the eight-channel design tested here. The array can therefore be utilized as a workhorse for parallel transmit experiments with the goal of evaluating coil-dependant metrics such as RF pulse acceleration, SAR, and B1 shimming.

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References: 1) Orzada, et al. Proc ISMRM p.2999 (2009). 2) Snyder, et al. MRM 2009. 3) Kumar and Bottomley. Magn Reson Mater Phy 2008. 4) Akgun, et al. Proc ISMRM p. 2619 (2009). 5) Setsompop, et al. MRM 2008.