Detunable Transmit Array and Flexible Receive Array for 7T Shoulder Imaging

Ryan Brown[1], Bei Zhang[1], Cem M Deniz[1,2], Gene Young Cho[1,2], Cornel Stefanescu[1], Shumin Wang[3], Daniel K Sodickson[1], and Graham C Wiggins[1]

[1]Radiology, New York University School of Medicine, New York, NY, United States, [2]Sackler Institute of Graduate Biomedical Sciences, New York University School of Medicine, New York, NY, United States, [3]MRI Research Center, Auburn University, Auburn University, AL, United States

Introduction High field musculoskeletal imaging of the knee has been successful in part due to convenient encircling coil structures afforded by its shape and small size. In contrast, high field shoulder imaging poses unique challenges for RF coil designers due to its asymmetric location in the body which makes azimuthally symmetric transmit coils such as a birdcage unfeasible. This restriction, along with the requirements that the transmit coil accommodate a wide range of subject sizes, provide sufficient B_1^+ coverage, and allow imaging of either the left or right shoulder, complicates the transmit array design due to B_1^+ twisting and subject-dependent RF interference at 7T. These transmit array aims somewhat differ from those of a shoulder receive array in which tightly-fitting array to achieve high SNR is the primary aim and phase propagation can be disregarded. A close-fitting receive array makes conventional geometries on rigid formers less suitable and calls for a flexible domed array with pentagonal and hexagonal symmetries to allow overlapping between neighboring coils [1]. With these objectives in mind, we designed and implemented a custom eight-channel transmit array and 10-channel receive array for shoulder imaging at 7T and demonstrate substantial SNR improvement over 3T.

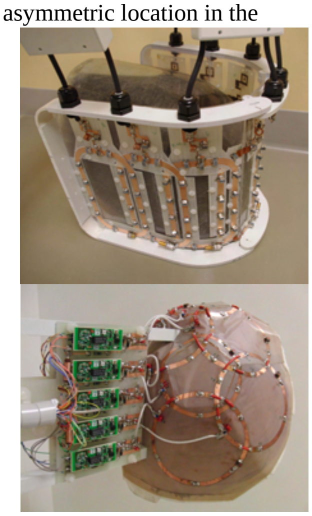

Fig. 1. Photograph of the eight-ch transmit-receive array and phantom (top) and 10-chl receive array (bottom).

Methods All images were acquired on a 7T whole body scanner (MAGNETOM, Siemens) using the developed shoulder coil or 3T scanner (TIM Trio, Siemens) using a four channel receive-only shoulder coil (small model, Invivo Corp.). The study was approved by our local IRB and three volunteers were scanned (one at both 3T and 7T, and two at 7T only) after informed written consent was obtained.

Transmit-receive array A U-shaped array consisting of eight rectangular coils (8.7 cm [transverse] × 14.5 cm [head-foot], partially overlapped in the azimuthal direction) was selected to provide regular coil geometry to simplify RF transmit phase requirements and to provide adequate coverage of the shoulder (Fig. 1). Two hinge points allowed the accommodation of a variety of subjects. Two PIN diodes in series with each coil allowed detuning when the receive array was active. B_1^+ maps and SNR maps were performed using birdcage-like excitation equivalent amplitude and phase steps of 45° between neighboring coils on a custom shoulder phantom and in vivo. The phantom was molded out of fiberglass to replicate the shoulder contour and filled with doped water to replicate composite shoulder dielectric properties at 7T: σ = 0.6 S/m, ε_r = 47. For in vivo imaging, the transmit voltage was calibrated in the deep cartilage (furthest point from the periphery).

Receive array A flexible 10-channel domed array was constructed with pentagonal and hexagonal symmetries to allow continuous overlapping of neighboring coils [1] and a tight fit to the shoulder in a variety of subjects (Fig. 1). Coils (8 cm and 9.6 cm in diameter) were etched on pyralux flexible circuit board. Coils were tuned and matched in the traditional manner using six distributed capacitors of approximately 6 pF. Active detuning during transmit was > 30 dB. Both neighbor and next-nearest neighbor coupling were approximately -10 dB while loaded due largely to shared electric fields in the sample.

Results The 7T eight channel transmit-receive array and 10 channel receive array provided 73% and 113% respective SNR gains in the deep cartilage over the commercial 3T array (Fig. 2). Greater SNR gains were observed in superficial regions. The birdcage-like phase relationship among transmit elements resulted in surprisingly uniform B_1^+ in the left shoulder (Fig. 3). This uniformity allowed successful application of clinically relevant TSE sequences for delineation of the shoulder cartilage (Fig. 4, left). Reduced B1+ uniformity was observed in the right shoulder (Fig. 4, right), which we expect to be mitigated with a unique RF shim.

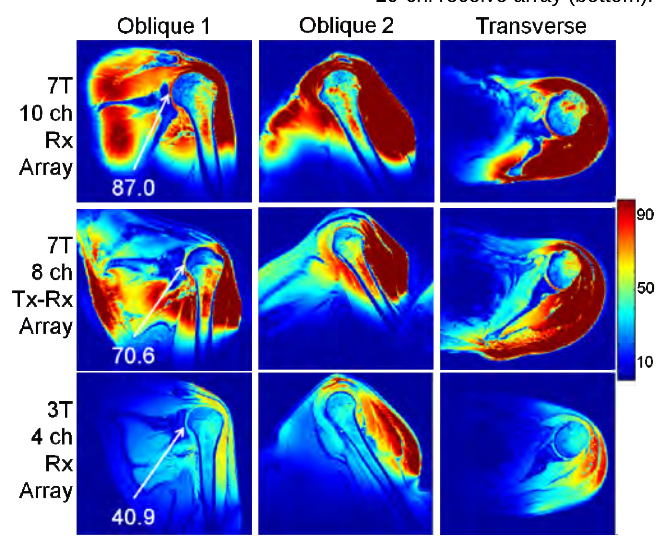

Fig. 2. 7T and 3T SNR maps in the left shoulder. Deep cartilage SNR is noted in the left panels.

Conclusions The developed detunable transmit array and separate geometrically tailored receive array for 7T shoulder imaging showed substantial SNR gains over a commercial 3T receive array in the deep cartilage, a region in which high SNR has been difficult to achieve. The 7T array provided high B1+ uniformity in the left shoulder with a convenient birdcage shim, while additional phase alterations are needed in the right shoulder.

References [1] Wiggins MRM 2006;56(1):216-23

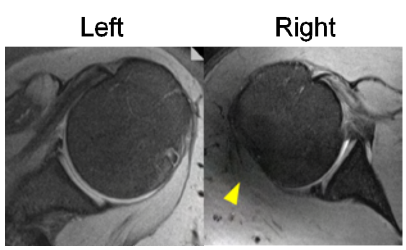

Fig. 4. 7T TSE proton density fat sat. images of the left and right shoulder. RF inhomogeity leads to signal dropout in the right shoulder (arrowhead). Parameters: 0.36 x 0.36 x 3mm^3, TE/TR = 26/1800ms, BW=245Hz/pixel, turbo factor = 5, 25 slices, TA = 4:44.

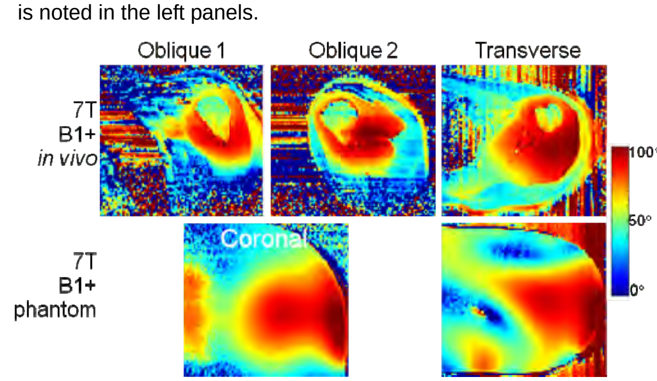

Fig. 3. 7T flip angle maps in the left shoulder and phantom.