1T MR Imaging of Trabecular Bone at the Distal Radius using a dedicated RF Coil

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Introduction: Osteoporosis is a multi-factorial disease caused by reduced bone mineral density and trabecular architectural deterioration. Reduced signal-to-noise ratio (SNR) due to the required high resolution and the low field strength of our extremity scanner makes it challenging to produce acceptable trabecular bone images. In this study, a dedicated quadrature RF coil was designed to improve SNR for MR imaging of the distal radius on a 1T extremity MRI system.

Methods: A quadrature 12-element, low-pass, birdcage transmit-receive coil was designed for a 1T extremity MRI system (OrthOne, ONI Medical Systems, MA) using the "Birdcage Builder" software (Department of Radiology, Pennsylvania State University, PA). An in-house program was developed to predict full resonant spectrum of birdcage resonator in both unshielded and shielded cases. In this model, all self-inductances and mutual-inductances were considered and evaluated using Gaussian quadrature rules. The coil dimensions were 7.25cm long by 10.16cm in diameter to accommodate a human wrist. SNR and magnetic field homogeneity were evaluated through measurements of copper sulfate solution dissolved in 0.9% saline. In-vivo high resolution images (195μm×390μm in-plane resolution and 700μm slice thickness) were acquired using an SPGR sequence with identical parameters (TR/TE=37/18.1ms, flip angle=20^o) on a healthy young male subject and a postmenopausal female. 3D volume renderings were obtained using visualization software VolView (Kitware Inc., New York) by choosing a threshold value to segment bone and bone marrow.

Results and Discussions: The prediction results of resonant frequencies for both unshielded and shielded are shown in Tables 1 and 2. The quadrature birdcage wrist coil was tuned to resonant frequencies of 42.660/42.660MHz for two drive elements, and impedances were matched to 54.6/48.0Ω. The surface plot of B_1 homogeneity is shown in Figure 1; an inhomogeneity of 7% was measured within the imaging volume. The custom designed birdcage coil offers a 19% improvement in SNR compared to ONI's upper extremity coil. The axial wrist image of a healthy young male was shown in Figure 2. 3D volume rendering shows a marked difference in trabecular architecture between healthy young adult male and postmenopausal female subject (Figure 3).

Conclusions: We have successfully shown that fine trabecular structure can be imaged using a relatively low field (1T) extremity MRI. The potential exists to apply this technique to map the bone architecture and possibly predict risk of fracture in bone degenerative diseases such as osteoporosis.

Mode	BirdcageBuilder	Our Model	Measured
1	7.56	7.70	8.08
2	n/a	11.34	12.07
3	n/a	12.96	13.87
4	n/a	13.43	14.47

Table 1: Comparison of resonant frequencies (MHz) of unshielded lowpass birdcage coil (L=12cm,R=6.7cm,N=8,W_{leg}=W_{er}=1cm,C_{leg}=2000pF)

Mode	BirdcageBuilder	Our Model	Measured
1	8.27	9.67	10.00
2	n/a	12.21	13.88
3	n/a	13.51	15.25
4	n/a	13.90	15.7

Table 2: Comparison of resonant frequencies (MHz) of shielded lowpass birdcage coil (L=12cm,R=6.7cm,Rs=8cm,N=8,W_{leg}=W_{er}=1cm,C_{leg}=2000pF)

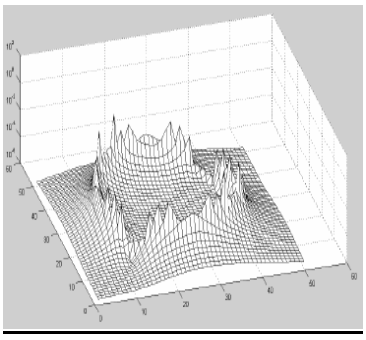
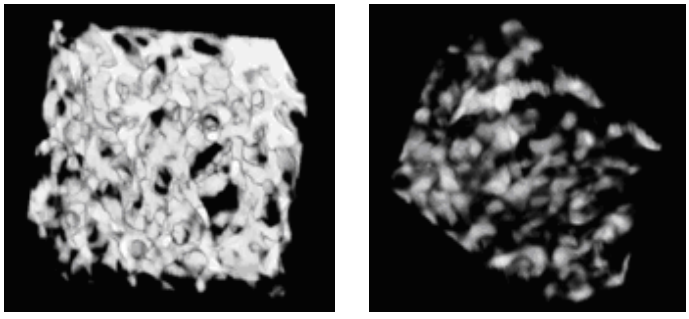


Figure 1: Axial B_1 homogeneity profile

Figure 2: Axial wrist image of a healthy young male.



(a) (b)

Figure 3: Volume rendering of trabecular bone structure at the distal radius. (a)Healthy young male; (b)Postmenopausal female.