# Combined Transmit-Only Asymmetric Birdcage and Receive-Only Endorectal Surface RF Coils

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**Target audience:** Scientists with interests in multinuclear RF hardware development, sodium imaging and prostate cancer.

**Introduction:** Determination of tissue sodium ($^{23}$Na) concentration (TSC) in human prostate with MRI may provide important information on changes in prostate morphology and metabolism associated with malignancy. However, $^{23}$Na MRI is challenging with lower SNR in comparison to conventional $^{1}$H imaging [1, 2] due to the low sodium concentration in human tissues and the lower gyromagnetic ratio of the $^{23}$Na nucleus. To overcome these disadvantages, it is necessary to develop optimized RF hardware for sodium imaging. The purpose of this work is to present a rigid endorectal receive-only RF coil tuned to $^{23}$Na, and for the purpose of image quality comparison, an identical dual-frequency $^{1}$H and $^{23}$Na receive-only RF coil. These receive coils were separately integrated with a dedicated unshielded asymmetric quadrature birdcage transmit-only RF coil and operated in Transmit Only Receive Only mode (TORO) for $^{23}$Na imaging at 3T.

**Methods:** For the endorectal coils, the tuning and matching circuits were built into the distal end of the probe (see Figure 1). For the dual-tuned $^{23}$Na – $^{1}$H coil, pole insertion was used to include a second resonance at the proton frequency. For both dual- and single-tuned coils a decoupling circuit was implemented to decouple the coils during RF transmission. Three vials of varying $^{23}$Na concentration (150, 90, 30mM) were integrated inside the probe to calibrate observed sodium concentration and to provide landmarks for subsequent image analysis. The geometrical design of the asymmetric bird cage coil followed the method reported in [3] and can be split into two halves to allow easy access for the subject. The coil is a 16-rung, high-pass design, and it was built to utilize the maximum space in the bore of a 3T MR imaging system (GE Discovery-MR750). End-ring capacitance values were evaluated based on analytical mesh inductance estimates [3] in order to provide tuning to the resonant frequency (33.78 MHz). TORO operation was implemented utilising scanner bias current during transmission to decouple the receiver, with further internal decoupling provided by the T/R switch. The SNR of each receive coil was measured with a 0.9% saline phantom using a 2D FGRE sequence FOV = 14 x 14, matrix size = 32 x 32 TE/TR=1.7/80ms. $B_1$ transmit inhomogeneity was measured using the double flip angle method [4]. Subject images were acquired with a 3D FGRE sequence optimized for short TE; 14 slices and acquisition parameters similar to 2D images.

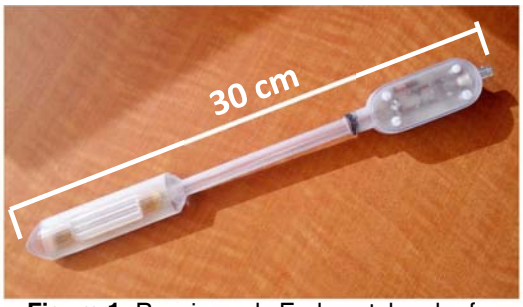


**Figure 1:** Receive only Endorectal probe for $^{23}$Na MRI

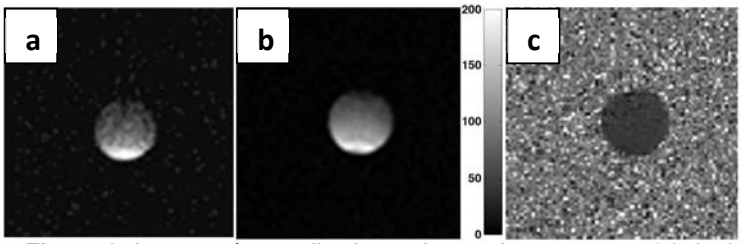


**Figure 2:** Images of a small saline solution phantom using (a) dual- and (b) single-tuned endorectal RF coils operating with an asymmetric bird cage in TORO mode.(c) Mean flip angle ± S.D. = 45.4° ± 3.6°.

**Results:** Using a saline phantom, the measured SNR for the single-tuned probe was found to be 1.5 times greater than for the dual-tuned probe (see Figure 2). $B_1$ transmit inhomogeneity measured from the flip angle inside the phantom was less than 5% (see Figure 2 c). *In vivo* SNR was measured in a ROI near the probe was 33.6 ± 1.6 for a single six-minute acquisition with the 3D FGRE pulse sequence (Figure 3).

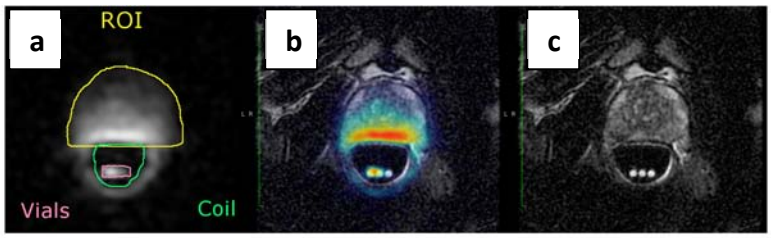


**Figure 3**: *In vivo* sodium imaging of the prostate. The sodium image of a prostate (a) is co-registered with a $T_2$-weighted $^{1}$H image (c) and displayed in panel (b). Osirix was used for the rigid co-registration.

**Discussion/conclusion:** A single-tuned receive-only endorectal RF coil was integrated with an unshielded, asymmetric quadrature transmit-only birdcage coil for $^{23}$Na MRI of the prostate. The TORO system is optimized for improved SNR capable of in vivo sodium imaging.

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**References:** [1] D. Hausmann et al., Radiology & Volume 47, No. 12, 2012 [2] F. Wetterling et al., Phys. Med. Biol. 57 (2012) 4555–4567
[3] A. Farag et al., 20th ISMRM, Melbourne, Australia, 2012 [4] Insko EK, Bolinger L. J Magn Reson A 1993; 103: 82–85