1H/23Na dual-tuned RF Unicoil for human body MR imaging at 3T

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[Introduction]

When a radio frequency (RF) coil is designed and built for MR imaging, its performance is judged on the basis of achieving uniform imaging B_1-field and high signal-to-noise ratio (SNR). However, there is an intrinsic trade-off between B_1-field uniformity and high SNR in the configuration of RF coil; a large RF coil tends to generate a more uniform B_1-field but lower SNR, because it collects a greater amount of RF noise from the volume it illuminates (1). Coils designed to balance this trade-off is a surface receive (Rx) coil array combined with volume transmit (Tx) coil that produces a high SNR and uniform field distribution. In this Rx/Tx coil configuration, the size of Rx coil is determined by that of Tx coil; typically smaller than Tx. This restriction is problematic in body imaging since adequate RF depth penetration is required to achieve a high SNR deep in the body. Particularly, the problem can be exaggerated in sodium MR imaging because the SNR is low due to an inherently low biological sodium concentration and low MR sensitivity. Therefore, to improve the performance of a surface-volume Rx/Tx coil for ^{23}Na body imaging at 3T, we have developed a 'Unicoil' where one Tx and four Rx's were integrated into a single coil to maximize the size of Rx to the same dimension as Tx. Finally, the ^{23}Na coil and ^{1}H coil were combined and operated in a dual-tune mode.

[Material and Method]

All scans were performed using a 3T scanner (Siemens Medical Solutions, Erlangen, Germany).

^{23}Na surface Tx coil combined with 4-ch Rx array coils The ^{23}Na coil design was adapted from a Unicoil (1,2) which consists of integrated Tx and Rx coils combined into a single coil. In this coil, PIN diodes are turned on during the transmission to link the Rx loops thus becoming a single large Tx coil while the crossed PIN diodes detune the Rx coil loops (Fig. 1A). Conversely, during the reception, the PIN diodes are reversely biased which allows each individual Rx loop to receive a signal independently (Fig. 1B). To decouple the Rx coil loops, the overlapping distance was adjusted for the neighboring Rx loops, while a pre-amp decoupling method was used for the non-neighboring Rx loops. The Tx and Rx coils were tuned at 32.58 Mhz with S11 parameter below -20 dB.

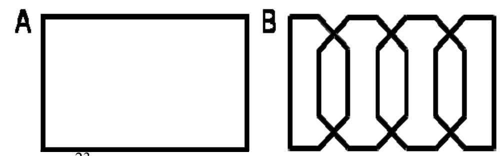

Fig. 1 ^{23}Na coil diagram during transmission (A) and reception (B).

^{1}H surface coil A single loop Tx/Rx coil was tuned at 123.2 Mhz for a transceiver coil. The ^{1}H coil was positioned 20-mm higher than the ^{23}Na coil (Fig. 2). A passive detuning circuit was inserted to minimize signal loss due to coupling of ^{1}H and ^{23}Na coils. Given a large separation in frequency in the ^{1}H and ^{23}Na signals, no additional elements were inserted between ^{1}H and ^{23}Na coils.

MR imaging For ^{1}H localizer MR imaging, gradient-echo sequence (TR/TE = 20/5 ms, TA = 10 s, flip angle = 40°, BW = 180 Hz/px, slice thickness = 8 mm, FOV = 280 × 280 mm^2, matrix = 144 × 192) was used (Fig. 3). For ^{23}Na imaging, a series of FID using 1-ms duration RF pulse were performed with different RF power to obtain a correct 90°-flip angle in the region of interest. 3D spiral trajectory sequence was used (TR/TE = 110/0.27 ms, BW = 215 Hz/pixel, isotropic resolution = 4 mm^3, FOV = 300 × 300 mm^2, matrix = 64 × 64, and acquisition time = ~3 min). High-SNR ^{23}Na images (~40) of the spine and kidney were acquired with eight averaging and within ~25 min (Fig. 4).

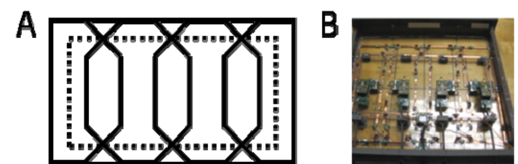

Fig 2. Schematic diagram of ^{1}H (*dotted line*) and ^{23}Na (*solid line*) coil (A) and the dual-tuned coil (B).

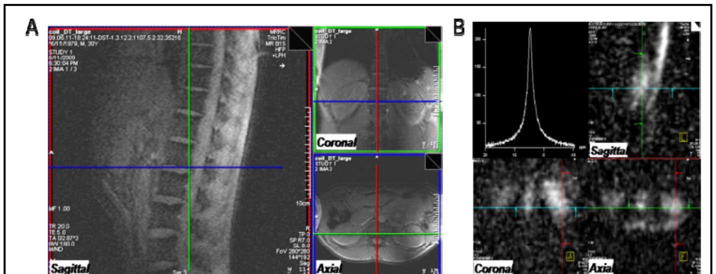

Fig. 3 ^{1}H (A) and ^{23}Na MR imaging of abdomen (B). ^{23}Na signal spectrum and three orthogonal views in B.

[Results and Discussions]

In this study, we have developed a dual-tuned ^{1}H and ^{23}Na body RF coil at 3T by utilizing the Unicoil concept and coil geometry to improve the SNR and RF penetration depth (2). The coil allowed us to acquire ^{1}H and ^{23}Na images of the spine and kidney resulting in excellent image quality. Future studies include the development and generalization of the Unicoil concept with other body parts as well as comparative evaluations with other coil designs.

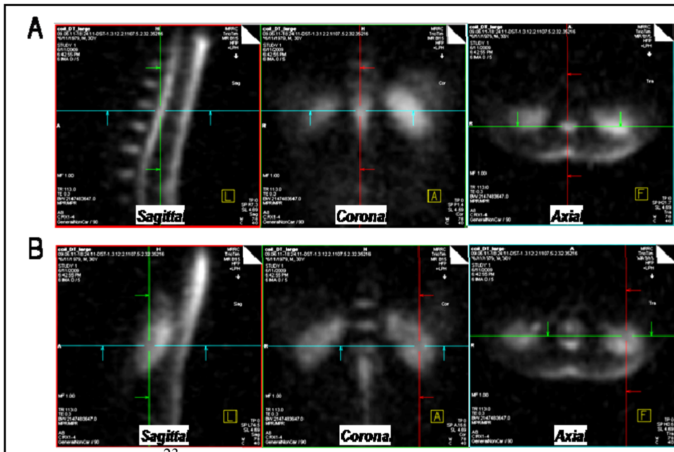

Fig. 4 In vivo ^{23}Na MR imaging of spine (A) and kidney (B). Each image was averaged with eight times.

[References]

[1] Jin, *Electromagnetic Analysis and Design in MRI*, CRC press, p198-202, 1999. [2] Jin and Perkins, *ISMRM processing*, p1116, 1994.