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 B1-field and high signal-to-noise ratio (SNR). However, there is an intrinsic trade-off between B1-field uniformity and high SNR in the configuration of RF coil; a large RF coil tends to generate a more uniform B1-field but lower SNR, because it collects a greater amount of RF noise from the volume it illuminates. Coils designed to balance this trade-off are 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 23Na 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 23Na coil and 1H 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).

23Na surface Tx coil combined with 4-ch Rx array coils

The 23Na coil design was adapted from a Unicoil 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.

1H surface coil

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

MR imaging

For 1H localizer MR imaging, gradient-echo sequence (TR/TE = 20/5 ms, TA = 10 s, flip angle = 40°, BW = 180 Hz/pix, slice thickness = 8 mm, FOV = 280 × 280 mm², matrix = 144 × 192) was used (Fig. 3). For 23Na 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 mm³, FOV = 300 × 300 mm², matrix = 64 × 64, and acquisition time =~3 min). High-SNR 23Na images (~40) of the spine and kidney were acquired with eight averaging and within ~25 min (Fig. 4).

Results and Discussions

In this study, we have developed a dual-tuned 1H and 23Na body RF coil at 3T by utilizing the Unicoil concept and coil geometry to improve the SNR and RF penetration depth. The coil allowed us to acquire 1H and 23Na 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.

References


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

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

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

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