DEVELOPMENT OF NEW DUAL TUNED COIL AND ARRAY FOR MULTI NUCLEAR IMAGING

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Introduction: MR imaging of nuclei other than hydrogen has been used to investigate metabolism in humans and animals. However, MRI observable nuclei other than hydrogen are not as abundant and as a result the image SNR is low. Therefore, dual-tuned radio frequency (RF) coils are required for these studies, in which high-resolution structural images are acquired using hydrogen and metabolic information is acquired with the other nucleus. Using a dual-tuned coil, the experimenter avoids the inconvenience of moving the patient out and replacing the RF coil for imaging different nuclei [1]. However, the common scheme of using trap circuits for dual-tuned design results in increased coil losses as well as problems in obtaining optimal tuning and matching at both frequencies. Here, a new approach is presented using PIN diodes to switch the coil between two resonance frequencies. A conventional design dual-tuned birdcage coil is used to transmit RF power and a dual-tuned receive-only phased array is designed and built with the PIN diode circuit to switch between resonance frequencies. This design avoids the trap circuit and it is demonstrated that the performance is significantly improved at both frequencies compared to a coil with trap circuit for dual-tuned operation.

Methods: The resistance of RF coil circuit will cause energy dissipation in the form of heat and the amount of this dissipation determines the quality factor of the circuit. Therefore, the additional loss in a trap circuit as well as difficulties in obtaining good matching and tuning at both frequencies causes loss of efficiency in RF coils. In order to test that the PIN diode based dual-tuning improves coil efficiency, we first built two rectangular surface coils, one with the PIN diode switch and the other with conventional LC trap. Both coils had identical geometry for comparison (Length = 150mm and width= 136mm). The coils were operated in transmit/receive mode. A 0.5cm wide thin copper tape was used to construct the coils for 4T MRI. To operate the new design at 1H frequency (170MHz) the PIN diodes were reverse biased by applying -12V. Similarly, +12V was applied to forward bias the PIN diodes and tune the coil to sodium frequency (45.04MHz). The loaded and unloaded Q-factors of each coil were measured using a cylindrical phantom. This cylindrical phantom, filled with CuSO4 solution and 0.5g/100ml NaCl, and was also used for imaging. 1H imaging: gradient echo, TR/TE = 710ms/13.0ms, NEX = 1, Thickness/Gap = 5.0mm/0.5mm, Flip Angle = 25, Matrix = 256*192, FOV=230*230mm^2. Pulse sequence for Sodium: Gradient Echo, TR/TE = 80ms/5.0ms, NEX = 12, Thickness/Gap = 5.0mm/0.5mm, Flip Angle = 90, Matrix = 64*64, FOV=120*120. SNR was calculated using the equation: [(Signal Avg.-Noise Avg.) / Noise Std.Dev.]. The results are shown in table 1 and figure 2. We also constructed a dual–tuned, 4–channel phased array receive coil based on this new concept. The tuning frequency was switched using PIN diodes and passive detuning was used to decouple the coil during high power RF transmitted. Low noise amplifiers (LNA) with low input impedance (below 2Ω) and separate TR switches were designed and implemented for both operating frequencies separately. Dual-tuned, helmet shaped, conventional low pass birdcage coil with trap circuit was built for RF transmit [2-3]. It had 16 elements, 25cm inner diameter, and 25cm length. This coil is also unique in that both 1H and 23Na operations were driven with 4-port feeds in order to achieve more uniform B1 and reduced SAR, which is critical for high field MRI. 4 ports for 1H were fed at radial positions of 0º, 90º, 180º, and 270º and 4 ports for sodium image were fed from radial position of 45º, 135º, 225º, and 315º. Those ports are connected to 4way RF power splitters tuned to the relevant frequencies. Isolation between the birdcage and phased array coils was less the -30dB and the couplings among phased array elements were less than -20dB. The images of a cylindrical resolution phantom were acquired using the 4-channel phased array with PIN diode tuning and the same pulse sequences described above. The phantom had 20cm diameter and contained the same solution as the other phantom.

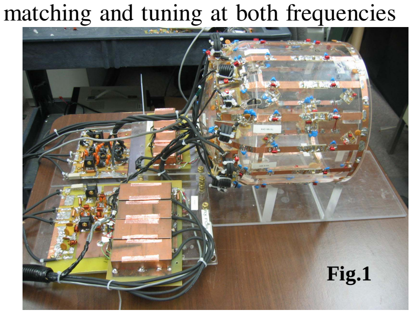

Fig.1

	Unloaded Q	Loaded Q	Ratio	SNR
New coil with PIN diode (1H)	111.94	23.172	**4.83**	**141.6**
Conventional design (1H)	55.318	13.669	**4.05**	**96.2**
New coil with PIN diode (23Na)	72.441	25.487	**2.84**	**15.2**
Conventional design (23Na)	34.644	17.124	**2.02**	**10.1**

Table1. Q-factor and SNR measurements for the two surface coils

Results and discussion: It is seen from table 1 that the surface coil with PIN diode tuning had almost twice as high unloaded Q as the conventional design (lower coil losses) and higher loaded-to-unloaded Q ratio (better sensitivity) for both operating frequencies. The substantial improvement in performance can also be seen from the SNR values. Our new design had SNR improvement of about 47% and 50.0% higher than conventional design at 1H and 23Na resonance frequencies, respectively. 1H and 23Na images acquired with the constructed 4-channel dual tuned array based on the new concept were shown in Fig.3.a and b. It can also be seen from Fig.3 that the coupling between the coil elements were minimal. Since the SNR is inherently low in imaging nuclei other than 1H, it is important to achieve the best possible sensitivity and minimize the coil losses. Here we presented a new dual-tuned RF coil design for MRI which offers lower coil losses and better tuning efficiency at both operating frequencies due to the elimination of trap circuit used in conventional designs.

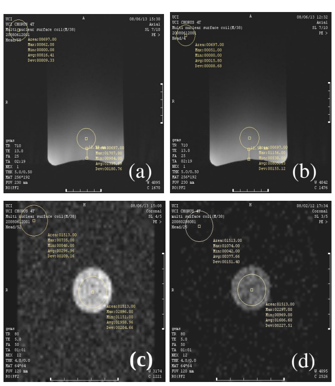

Fig.2 (a) 1H image with the new coil design. (b) 1H image with conventional coil. (c) 23Na image with new coil design. (d) Sodium image with conventional coil,

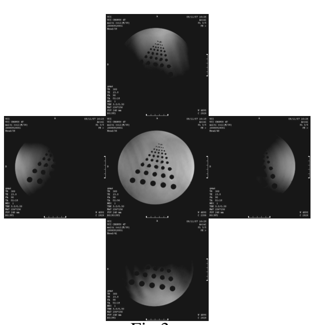

Fig.3a

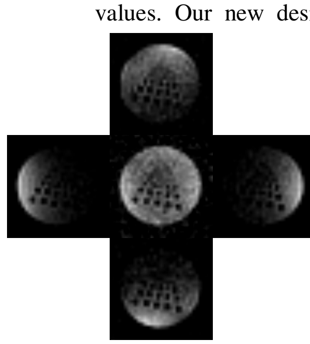

Fig.3b

Fig.3 (a) 1H image using 4-channel multinuclear phased array with PIN diodes reverse biased to operate at 170MHz. (b) 23Na image with PIN diodes forward biased to operate at 45MHz.

References: [1] Hayes et al., JMR 63, p622-628 (1985). [2] Shen GX et al., MRM 41, 268-275 (1999). [3] Ibrahim TS et al., ISMRM, p429 (1999)