A Prepolarized MRI Scanner

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Introduction

Prepolarized MRI (PMRI) is a new MRI architecture based on field-cycled electromagnets that is suitable for low cost extremity imaging. In PMRI, a highly inhomogeneous polarizing magnet pulsed over 0.25 T generates magnetization, but the FID is acquired in a low field homogeneous pulsed electromagnet. The pulse timing is shown in figure 1. Here we outline the system design of our prototype, and demonstrate our first pre-polarized MRI images of the human hand and wrist.

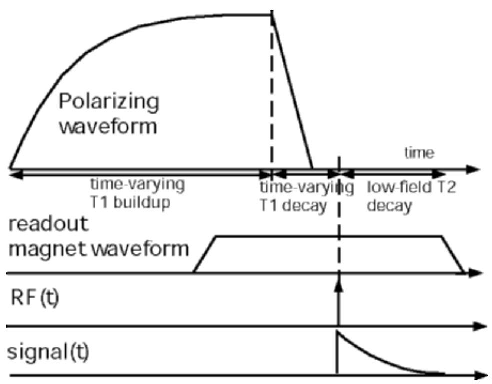

Figure 1. PMRI pulse sequence.

System Design

The cross section of the PMRI prototype assembly is shown in figure 2. The readout, gradient, polarizing and RF coils are arranged concentrically.

Readout Sytem: Our first resistive homogeneous magnet was a varient of the classic 6-coil design [1] with a 24-cm diameter free bore and 20-cm spherical homogeneous volume. For a readout frequency of 1 MHz, this 110 kg magnet required about 13 A and dissipated 2 kW. This magnet was pulsed on only for 200 ms during each TR. Two Techron 8607 gradient amplifiers, configured in a master-slave mode provided the readout magnet power. The control circuitry was upgraded to use a current transducer, and the feedback control loop was modified to perform 3rd order critical damping to minimize the field stabilizing transients.

Gradient System: Because of the small diameter needed for extremities, PMRI does not require high power gradient coils. We constructed a 3-axis gradient coil set using our new linear programming constrained optimization gradient design algorithm [2]. The coils were 22.5 cm diameter, 29 cm long, and produced a gradient of 2.6 mT/m for 10 A. Power was supplied by Techron 8607 amplifiers but our requirements could be met by power op-amps.

Polarizing System: We inserted a wrist-sized polarizing magnet (L=65 mH, R=1 ohm) in the readout bore[3]. The polarizing magnet (13 cm id, 22 cm od, 21 cm length) creates a 0.4 T field with 100 A and dissipates 10 kW. The polarizing field is applied for 0.5 to 2 s and rises exponentially with tau=L/R. During rampdown, the switched resonant power electronics opens 4 IGBT switches causing the coil energy to rapidly transfer to a capacitor-resistor bank within 35 ms[4].

RF System: We constructed an 9 cm dual transmit-receive wrist saddle coil for these experiments. The coil (1725 strand 48 awg litz wire) included a 13 cm dual slotted RF shield suspended inside the polarizing coil. During transmit, a crossed-diode-resistor network reduced the transmit Q below 13. We used a Delta-Sigma Inc. 300 W RF amplifier, despite needing only 3 W for a 1700 Hz nutation frequency at 1 MHz. In receive mode, coil Q was 260. The receive port was impedance matched for bandwidth expansion [5] and connected to a feedback damped JFET cascode preamplifier.

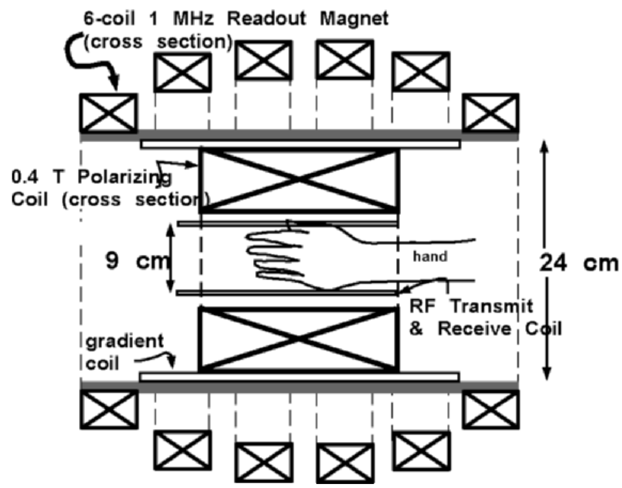

Figure 2: Prototype 9cm bore PMRI scanner

Results

Our first PMRI images used a polarizing interval of 400 ms and no averaging. The readout larmor frequency was 1 MHz. We used a Tecmag console for pulse sequence control. A gradient echo sequence acquired a 64x64 image matrix zero-filled to 256x256, 10 cm FOV, 1cm slice, 12.6 ms echo time for a total scan time of 56 s. Figure 3a shows an in vivo 0.25T polarized image of an axial slice through the left wrist near the base of the thumb. The polarizing interval produces T1 contrast between fat and muscle. The metacarpal bones and flexor tendon are readily visualized. Figure 3b shows a 0.4T polarized axial slice through the wrist at the base of the hand. Both flexor and extensor tendons are visible. At present, our image quality is limited by field drift of the readout magnet and supply. Water cooled magnets [6] and new precision reference electronics for the Techron supplies will be needed.

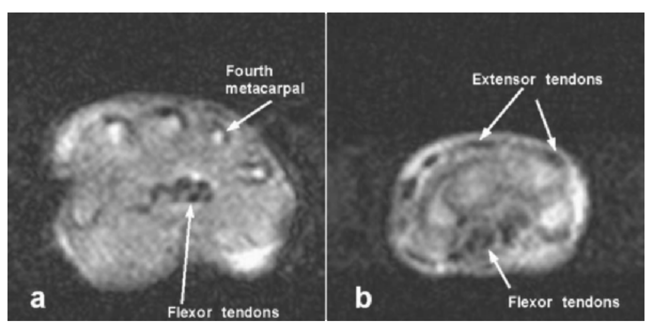

Figure 3: PMRI wrist images. a) 0.25 T polarized image near base of thumb. b) 0.4 T polarized of wrist near base of hand.

Conclusions

Our prototype component costs, excluding the console, were under $50,000 so a PMRI system can be extremely low cost. The PMRI design is well suited to extremity imaging yet offers new approaches to achieving field-cycled contrast.

References

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