A Prepolarized MRI Knee Scanner

T. Grafendorfer[1], N. I. Matter[2], R. D. Venook[2], S. E. Ungersma[3], G. E. Gold[4], N. J. Giori[5], B. A. Hargreaves[4], J. M. Pauly[2], A. Macovski[2], G. C. Scott[2], and S. M. Conolly[6,7]

[1]GE Global Health, CA, [2]Electrical Engineering, Stanford University, CA, [3]Stanford University, CA, [4]Radiology, Stanford University, CA, [5]Orthopedic Surgery, Stanford University, CA, [6]Bioengineering, UC Berkeley, Berkeley, CA, United States, [7]Electrical Engineering, Stanford University, Stanford, CA, United States

Introduction: Prepolarized MRI uses a pulsed strong (but inhomogeneous) *polarizing* magnet and a separate, homogeneous low-field *readout* magnet during image acquisition (see Fig. 1) to dramatically decrease system cost. SNR efficiency and contrast with a 3D-RARE pulse sequence is nearly identical to conventional midfield MRI scanners [1]. Susceptibility artifacts are significantly mitigated with Prepolarized MRI [2] due to the low-field during imaging. Here we present the first *in vivo* data, including normals with metal implants, from our knee Prepolarized MRI scanner.

Methods: A 4-coil homogeneous water-cooled readout electromagnet (up to 0.2T) [3] and an insert polarizing solenoid designed with hollow copper wire were constructed (Stangenes Industries, Palo Alto, CA) to accommodate the knee. Total polarizing field strength was 0.4 T and readout field strength was 0.06T (2.55 MHz). A 25 mT/m gradient coil was constructed with copper wire inlaid into a plastic former with pattern from [4]. A litz wire receiver coil was constructed to optimize sensitivity [5]. The polarizing coil used a switched power supply [6]. Fig. 1 shows the knee scanner, which was controlled by a Tecmag Apollo console. Prepolarized MRI studies on normals (including two normals with metal implants or a total knee replacement) were compared to a GE 1.5 T Signa MRI with a 3D spin-echo (RARE) sequence with matched resolution (192x192 matrix with 0.7x0.7x4mm resolution) and matched scan time (4minutes).

Results: Figure 2 compares knee images from a normal volunteer on the 0.4T/0.06T PMRI scanner and the 1.5 T scanner. Note the excellent definition of the cartilage. As expected, the SNR is about a factor of 5 better for the 1.5 T MRI scanner. The water/fat shift was not noticeable with 0.06T readout field. Figure 2 shows a comparison between MRI and Prepolarized MRI in a normal volunteer with stainless steel screw implants (susceptibility = ~1000 ppm). Note the significant improvement of susceptibility artifacts with PMRI acquisition.

Discussion: Prepolarized MRI image quality near metal implants is significantly better than conventional MRI. SNR efficiency using 3D RARE is excellent [1]. With a modest increase in cost, 1.0 T polarizing will be feasible, and further litz coil optimization will also double the SNR [5]. This combined 5x increase in SNR will render PMRI comparable to 1.0T conventional MRI. The total magnet cost, including the readout, polarizing, gradients, and RF was less than $30,000. Hence, PMRI shows great promise for high-quality MRI in developing nations.

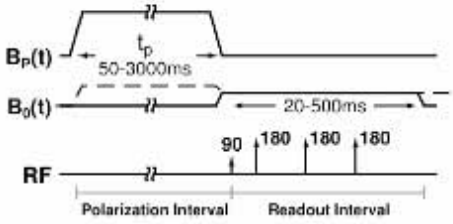

Figure 1 (left) Photo of 0.4T/0.06T Prepolarized MRI knee scanner. (Right) Timing diagram for Prepolarized MRI scan.

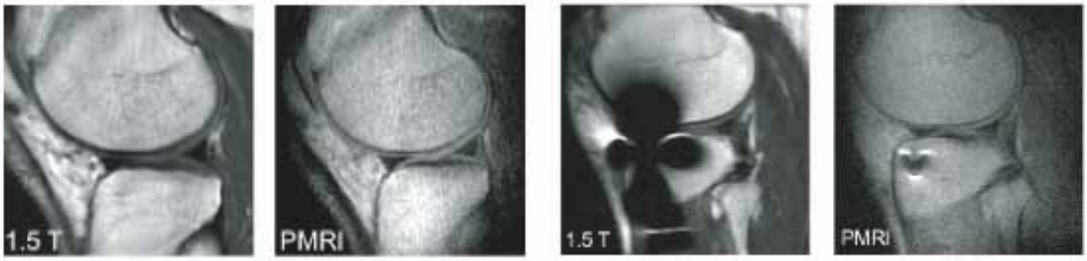

Figure 2 (left) Comparison study of normal knee images from a 1.5 T GE scanner and from our new knee-sized PMRI scanner (right). Both images are from 3D RARE volumetric scans with 4 mm slice thickness, 50 kHz readout bandwidth, and 4 minute scan time. The 1.5 T image has 14.4 cm FOV, while the PMRI image has 16 cm FOV with 0.4 T polarization field and 0.06 T readout field. Note that the excellent visualization of the articular cartilage and lateral meniscus in the PMRI scan. **Figure 2(Right)** Comparison of normal with stainless steel screws in knee. Note that PMRI shows significant improvement near metal.

References:

[1.] N. I. Matter, et al., Magn Reson Med. 56, (5) pp: 1085-1095, 2006. [2.] R. D. Venook, et al. Magn Reson Med. 56(1):177-86, 2006. [3.] Hao Xu, et al, IEEE Trans. on Magnetics, Vol. 36, No. 2, 2000. [4.] S. E. Ungersma, et al. Magn. Res. Med., 52(3):619–627, 2004. [5.] T.Grafendorfer, et al. , "High Q Litz wire receiver coils up to 8 MHz," Proc. 14th ISMRM, May 2006 [6.] N.I. Matter, et al., IEEE Trans Med Imaging, 25(1):8493, Jan 2006.