Transceive Field Probes for Magnetic Field Monitoring at 7T

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Introduction

Despite continued advances in MR hardware, imperfections in the magnetic field evolution during MR scans still hamper numerous MR procedures. Field perturbations are caused by mechanisms such as eddy currents, limited gradient bandwidth, and heating effects. To address these errors by means of signal processing they must be accurately known. Reproducible field perturbations can be determined approximately by preparatory measurements (1, 2), or, as has recently been proposed, by monitoring the relevant field evolution directly during each actual scan using NMR field probes (3) consisting of small droplets within closely-fitting solenoid detector coils. Previous implementations relied on excitation by the same volume transmit coil used for exciting the imaging object. Consequently, independent excitation of probes and object is not possible. In other situations a volume transmit coil may not be present, or it may not provide sufficiently uniform excitations among the field probes. Additional problems arise from the difficulty of completely eliminating signal contamination from the object, which we address here by completely shielding the probes, making them independent units.

Materials and Methods

Probeheads were constructed using 0.8 mm Pyrex capillaries surrounded by 7-turn copper solenoids, cast into paramagnetically doped epoxy for susceptibility matching in a geometry similar to that proposed in ref. (3). Each capillary contains 400nℓ of cyclohexane (C_6H_{12}) doped with a concentration of 9.0 mM of $Cr(dpm)_3$ to reduce its T_1 to approximately 340 ms, while leaving T_2 largely unchanged. The cyclohexane was confined between D_2O plugs doped with manganese chloride to match their susceptibility to that of the doped cyclohexane (**Figure 1**). Each probehead was connected using a standard T/R RF coil topology to tuning and matching capacitors having small dimensions and magnetic susceptibilities to minimize their effects on B_0 homogeneity within the droplet. No additional components are required at the probe, thus facilitating the task of miniaturization. The probe circuits were tuned to the Larmor frequency of protons at 7T (298MHz), matched to a double-shielded 50Ω coaxial cable and wrapped in a continuous copper foil shield that was grounded to the shield of the coaxial cable. Shielding effectiveness was better than 50dB.

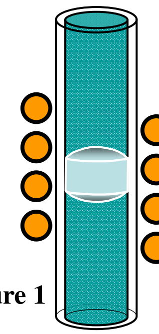

Figure 1

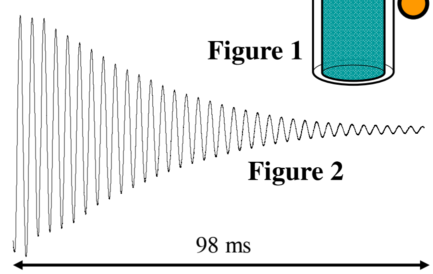

Figure 2

A hexagonal arrangement (~20 cm in diameter) of 6 field monitoring probes was used to perform a simultaneous monitoring and imaging experiment using a spiral k-space trajectory. A square 6×6 cm^2 T/R surface coil was used to excite and receive signal from a 500 ml cylindrical water phantom. Excitation to all coils was provided by splitting a single power RF signal into two, one to excite the surface coil and the other, after attenuation by 50dB and further 8-way splitting (two outputs were terminated), to excite the probes. Further individual attenuations ranging between 0 and 7 dB were introduced using variable attenuators to equalize the flip angles in the probes. These 7 power signals were routed to the respective coils through T/R switches custom built in-house for use within the magnet bore close to the probes for optimal SNR.

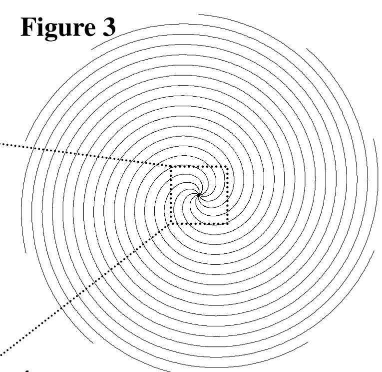

Figure 3

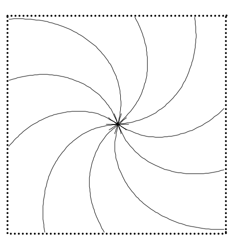

Figure 4

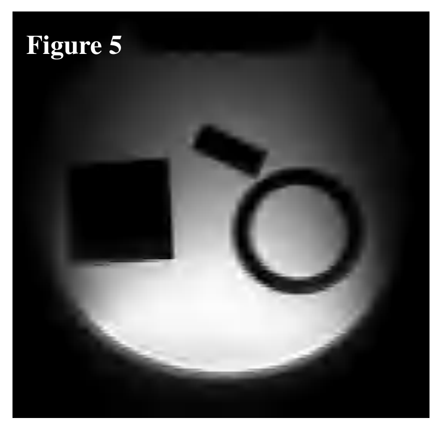

Figure 5

Results

All measurements were conducted on a Philips 7T Achieva. A typical probe FID in the absence of field gradients is shown in **Figure 2**. A longevity better than 50ms is readily achieved (a significant challenge even at lower field strengths), thus allowing monitoring of sequences with long readouts.

An 80-segment spiral trajectory with $T_{acq} = 98$ ms, $T_R = 1000$ ms, matrix size = 288, FOV = 240 mm was monitored during an image acquisition and is shown in **Figure 3** (every eighth arm shown for clarity). Absence of signal from the imaging phantom in the probes' signals is proven by the regularity of the spirals during the first few ms of acquisition (**Fig. 4**) when the largest signals from the center of k space are picked up by the surface coil. This is significant since the volume of excited material is more than 10^5-fold greater than that in the probe droplets and only a few centimeters away, thus validating the shielding approach. Image reconstruction was performed from the surface-coil data by gridding. The resulting image (cropped) is shown in **Figure 5**.

Conclusion

The transceive design, along with shielding and careful selection and combination of materials, solves key problems and enables robust field monitoring at high field strengths as demonstrated at 7 T.

References

(1) SB Reeder et al. MRM 1997;38:429-439. (2) JH Duyn et al. JMR 1998;132(1):150-153. (3) De Zanche et al. ISMRM 2006 #781.

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