An independent spectrometer and coil insert for research on clinical MR systems

M. N. Paley[1], E. Krjukov[1], J. M. Wild[1], P. D. Griffiths[1], M. Lamperth[2], and I. R. Young[2]
[1]Academic Radiology, University of Sheffield, Sheffield, Yorkshire, United Kingdom, [2]Mechanical Engineering, Imperial College, London, United Kingdom

INTRODUCTION

Most clinical magnetic resonance systems do not have access to ultra-short echo time, multi-nuclear or magic angle spectroscopy and imaging (1-3) which all have the potential to improve clinical utility. The aim of this project was to develop a fully independent imaging insert for clinical MR systems to provide these new research applications without disturbing routine operation. The initial clinical targets are improved orthopedic imaging and the enabling of hyperpolarized 3-He imaging for neonatal and pediatric lungs.

METHODS

The insert system uses only the magnet and patient handling system of the clinical MR system and provides all other required hardware and software to enable the advanced techniques discussed above. A spectrometer and software system based on National Instruments hardware and Labview software (NI, UK) has been developed and integrated with a 1.2KW RF amplifier (Tomco, Au), 100V, 92A gradient amplifiers (Analogue Associates, UK) as shown in Figure 1 and an insert gradient and RF coil system to provide the completely independent imaging system. The new data acquisition system is based on a PXI chassis with an embedded Windows XP controller which can acquire 32 channels simultaneously at 14 bit resolution at up to 2.5 MS/s. 8 channels of 16 bit D-A conversion provide the control, RF and gradient waveforms at a maximum output rate of 1 MS/s. The RF spectrometer is based on modular RF components from Mini-Circuits and is capable of broadband operation from 250KHz up to 200 MHz (limited by the synthesizer) using frequency doubling and digital quadrature detection. A novel 3 axis cubic gradient coil set consisting of a rectangular 'Maxwell' pair for Z with biplanar coils for both the X and Y axes was modeled in 3D using the Biot-Savart law in Matlab. Each coil half was wound with 28 turns of 2mm magnet wire on a rigid 300mm access square section former, large enough to accommodate the adult head and knee. The mean spacing of the Maxwell pair was 270mm. The biplanar coils were wound with the return path forming a continuous rectangular solenoid for each coil half (Figure 2). The measured resistance of the Maxwell pair was 0.5 Ohms and the biplanar X and Y coils was 0.4 Ohms. The assembled coil weight was 12 Kg so it could be easily lifted into the magnet bore. Gradient cables were filtered at the screened room waveguide and plugged into the gradients inside the screened room The insert gradient set was initially tested on a 3T MR system (Philips Intera, NL) with a 100mm circular T/R surface coil located at the centre of the gradient set. The gradient coil fits tightly inside the body coil to prevent motion.

RESULTS

Figure 3 shows the calculated Bz field in the axial plane at z=0 mm for the X coil. Figure 4 shows the assembled gradient coil with insulating covers in place.

Fig 1 

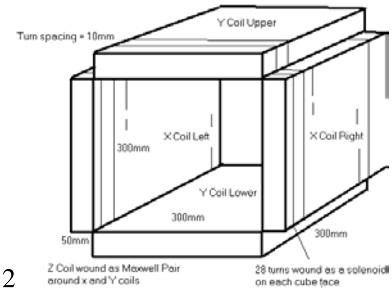
Fig 2 

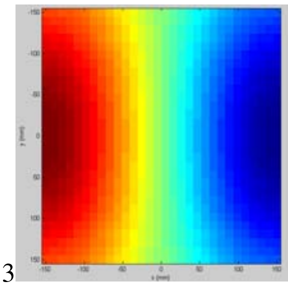
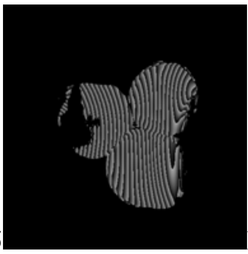
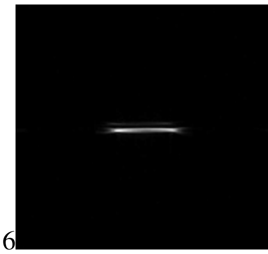
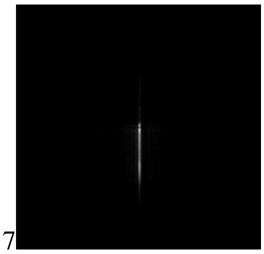
Fig 3 

Figure 5 shows a phase map of 3 large cylindrical uniformity phantoms inside the coil acquired at 3T (body coil) and a TR/TE=40/18ms gradient echo sequence with 5A DC applied to the X-gradient showing the appropriate phase banding. The dark regions are due to noise masking. Search coil measurements also showed the X, Y and Z coils are linear to within 2cm of the ends of the former. Figure 6 shows a coronal gradient echo image of a 90mm diameter cylindrical phantom acquired with the cube gradient insert and independent spectrometer system with TR/TE = 500/2ms, 160mmm FOV with only phase encode applied and fig 7 with only frequency encoding applied showing good phase stability and field homogeneity. The phantom/coil needed to be mounted independently from the gradients to avoid vibration.

Fig 4 
Fig 5 
Fig 6 
Fig 7 

DISCUSSION AND CONCLUSION

Preliminary testing has shown that a fully independent MR gradient insert and spectrometer system can be operated on a standard clinical imager with no permanent disturbance of normal operation and easy switchover. Further work will implement advanced methods for multi-nuclear imaging and spectroscopy. A LabView based MR compatible motion system is also in development, which will allow limbs to be rapidly moved to the magic angle under image guidance.