Static B_0 field monitoring at 3 T and 7 T: An MRI Dosemeter

I. D. Cavin[1], J. Chauhan[2], R. Chettle[2], I. Taylor[2], M. Henini[2], P. M. Glover[1], P. A. Gowland[1], R. W. Bowtell[1]

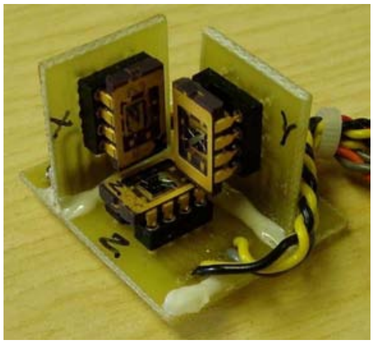
[1]Sir Peter Mansfield Magnetic Resonance Centre, School of Physics and Astronomy, University of Nottingham, Nottingham, United Kingdom, [2]School Of Physics and Astronomy, University of Nottingham, Nottingham, United Kingdom

Introduction

There is an urgent need for a dosemeter in MRI. This is because firstly, the lack of a dosemeter means that there is currently little information available on the nature of the magnetic field exposure of staff working in an MR environment. Secondly, the lack of a dosemeter hampers epidemiological studies of MR workers. Finally a dosemeter would be required to limit staff exposure, if this were considered prudent. Current guidelines are set to a 24 hour average of 200mT and peak of 2T [1-4]. Commercial logging dosemeters are available and studies of field exposure to radiographers have been conducted giving average exposure of 1.7mT over 8 hour shift using 1.5 T scanners [5]. The low sampling rate, 2T saturation limit (which may be exceeded close to a shielded 1.5 T magnet) and steel-clad batteries make the commercial unit used unsuitable for high field installations. The aim of this study was to design and construct a fully non-magnetic, rechargeable, MR compatible, pocket-sized, 3 axis, Hall-probe dosemeter capable of recording several hours of magnetic field exposure up to 7 T at a higher sampling rate. A prototype dosemeter has been used to record the static field exposure of MR workers in both 3 T and 7 T whole body magnet environments carrying out a set of typical tasks.

Experimental method

Three wafers of doped, GaAlAs semiconductor alloy (fabricated by the Molecular Beam Epitaxy unit of the School of Physics and Astronomy, University of Nottingham) were used as sensing elements [6]. Fabricating the Hall elements in this way has allowed the devices to be optimised for 7T maximum field strength whilst retaining low-field sensitivity. The elements are then separately packaged and mounted orthogonally to each other (Fig. 1). The magnitude of the B field may be calculated irrespective of the orientation of any one of the Hall elements. Outputs from the three Hall sensors were amplified and sampled at 4 Hz, using a 10 bit ADC. The data-logger was capable of recording 4 MBytes of data from the three Hall probes. At present the resolution is of the order of 100 milliTesla. At the end of exposure, the data can be downloaded to a computer via a USB interface for further analysis. The power consumption of the device was sufficiently low to allow data logging for up to 8 hours using a Lithium-ion plastic case rechargeable battery pack. In preliminary studies using the dosemeter, the static field exposure was recorded as five MR workers positioned a phantom into a 7 T (90 cm bore diameter) magnet using the manually operated patient bed. In a separate study two workers carried the dosemeter for a whole working day which involved putting volunteers and phantoms into a 3 Tesla whole body scanner. The dosemeter sensor elements were attached to the head.



Results

Table 1 shows the peak field experienced by 5 different MR workers whilst changing a phantom in a 7 Tesla magnet. Also shown is the integrated field exposure over time (for fields >0.2 T). The large variation in exposure was largely due to the amount of time each individual took to perform the task. Figure 2 shows the typical field experienced by MR personnel whilst loading and unloading a phantom in a 3 Tesla MR scanner. The peak field experienced by this individual was 2.3 Tesla. Routine patient and coil changes over a typical day for 2 MR workers gave integrated exposure values of 128.7 and135.5 Ts (giving 24 hour average of approximately 1.5 mT).

Subject	Peak Magnitude (tesla)	Integrated Exposure (tesla seconds)
1	0.9	23.4
2	1.4	19.9
3	1.9	44.1
4	1.5	76.6
5	0.8	38.7

Table 1: Phantom loading for 5 subjects at 7 Tesla.

Discussion and conclusions

The feasibility of monitoring static magnetic field exposure of individuals moving around an MR scanner has been demonstrated. Sensitivity of the Hall Probe can be improved to 5 Gauss by increasing the Hall current but linearity will be compromised. This can be overcome by dynamically controlling the Hall bar current. Future work will focus on reducing the system noise evident in figure 1. Surface mount components will further reduce the size of the dosemeter to credit card dimensions. Work is being carried out to combine this static field meter with a meter capable of measuring time varying magnetic fields. Further studies of the daily exposure of scanner operators working around 3 T and 7 T scanners is underway. These will be used to determine the range of exposures experienced by different workers performing a variety of tasks at different magnetic fields.

References

[1] *ICNRIP Statement, Health Phys.,* ***87****(2), 197-216, 2004;* [2]*National Radiological Protection Board (NRPB), Br J. Radiol.,1982; 56:974-977;* [3] *International Electrotechnical Comm.(IEC). International standard: part 2. CEI/IEC 601-2-33, 1995;* [4] Schenk, J.F.,*J. Mag. Res. Img*., 12, 2-19, 2000.; [5] Bradley J. *Institute of Physics and Engineering in Medicine – MR Safety update*, October 2005; [6] Ripka P. *Magnetic Sensors and Magnetometers*, (2001) Artech.

FIGURE 2: Static B_0 field exposure experienced by an MR worker loading and unloading a phantom in to 3 Tesla MRI scanner