4.2.4 Project: Field gradient variation outside a 3T Trio scanner

Aim

Safe scanning of certain MR-conditional medical implants is contingent on meeting restrictions on the maximum spatial field gradient experienced by the patient (displacement force being related to the first derivative of B_0). It is therefore important to have an understanding of how both the stray field and its gradient vary around the magnet. In this experiment, I aimed to determine the variation in the spatial field gradient in the z direction (dB_0/dz) outside the bore of the 3T Siemens Trio Scanner at NHNN and estimate the maximum field gradient.

Method

I used a Hall Probe Element and GM08 Gaussmeter to measure and display the magnetic field strength respectively. The Hall Probe Element consists of slab of semi-conductor material. Current passes from one end of the slab to another and the voltage on both sides is the same when no external magnetic field is present. In presence of an external magnetic field, a force is exerted on the charges of one sign, causing separation and build up of positive charges on one side of the slab and negative charges on the other side of the slab. This generates a voltage across the sides of the slab which is proportional to the strength of the magnetic field. The Hall Probe is connected to a Gaussmeter which amplifies and digitises the voltage signal and displays the results on the screen. The signal measured will vary depending on the orientation of the probe with respect to the magnetic lines of flux. The Hall element within the probe must be at right angles to the magnetic flux lines.

The Hall Probe was calibrated before use. This is done by zeroing or nulling the current reading so that any offset is set to zero for subsequent measurements. The probe was shielded from the earth's magnetic field by placing it in a zero Gauss can.

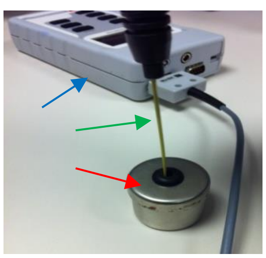


Figure 4.2 Calibration of the Hall probe (green arrow) using a zero gauss can (red arrow). This involves zeroing the current reading before use which can be monitored using the GMO8 Gaussmeter (blue arrow)

Due to active shielding in the magnet, there is a steep field gradient just outside the bore. Hence measurements must be made at frequent 5cm intervals for accurate calculations of gradient strength near the bore. A long piece of thread was taped to the couch and 5cm intervals were marked for a distance of 120 cm after which measurements were taken at 20 cm intervals. Measurements were made along the z axis, at a height which was roughly at the centre of the bore. The reference point was chosen at a point inside the bore (roughly 50 cm from the couch) as shown in figure 4.3**.**

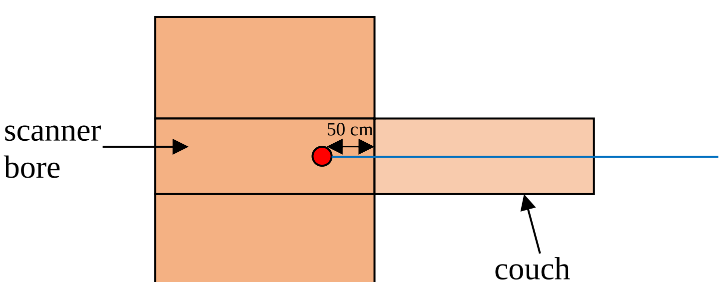


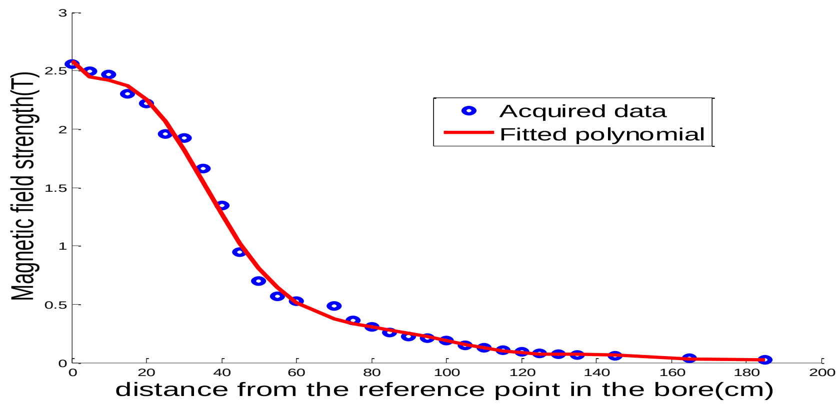
Figure 4.3 The location of the reference point (indicated by the red dot, located 50 cm from the couch) for carrying out magnetic field strength measurements along the z axis (blue line) of the Trio 3T system at NHNN.

Ideally measurements for the transverse, longitudinal and vertical components of the magnetic field should be made for each point and the absolute field strength calculated from these components.

However, this procedure is very time consuming and difficult to perform without the availability of a suitable jig. Hence the absolute magnetic field was measured by placing the Hall Probe perpendicular to the magnetic field lines and tilting it till a maximum reading was recorded on the display screen. This maximum reading was taken as the measure of the absolute magnetic field strength at that point.

Results and Conclusion

a)



b)

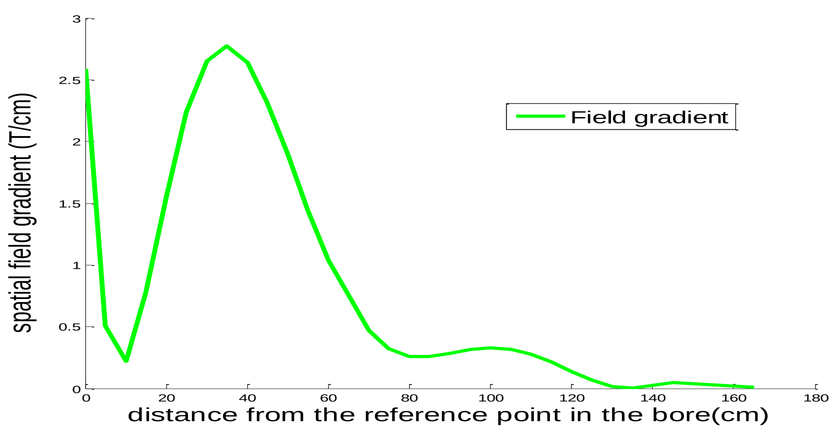


Figure 4.4 a) Variation of the magnetic field strength along the z axis measured from a height of 114 cm from the floor at the centre of the bore. b) Plot of spatial gradient (T/cm) vs. distance (cm) from the origin. Both plots were produced using code in MATLAB

The plot in figure 4.4(a) shows the variation in absolute field strength from the bore along the z axis at a height of 114 cm from the floor (roughly the centre of the bore). Using code written in MATLAB (appendix B3), a polynomial is fitted to the data and then differentiated to give the field gradient (T/cm) plot as shown in figure 4.4 (b). The spatial gradient and hence force (which is a proportional to the product of B_0 and spatial gradient of B_0) rises considerably in the vicinity of the bore entrance. Here a peak gradient of 2.7 T/cm was calculated at 37 cm from the reference point i.e. close to the entrance of the bore (figure 4.4 (b)). The spatial gradient drops to being negligible after approximately 1.3 m from the reference point in the bore. This may be due to the short bore size and active shielding in the Trio system.