Asymmetric head gradient coil for imaging and spectroscopy at 7T

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Introduction

The push to higher field strengths in MR is driving the need for greater performance from gradient systems. In general, the most demanding applications require large gradient amplitudes and fast switching. The use of smaller diameter asymmetric head-only coils [1] has allowed these needs to be met within the constraints imposed by the available power supplies and the onset of peripheral nerve stimulation in the subjects. However, some sequences (T_2^*-weighted methods, rapid gradient echo sequences and spectroscopy) are very sensitive to magnetic field inhomogeneity, a problem exacerbated at high field. It is usually the job of the gradient system to provide sufficient homogeneity control with integrated active and passive shims. It has been shown that homogeneity may be further improved by using dynamic shimming methods [2], but this places additional constraints on the shim coil designs. Here we describe the development of a head-only asymmetric actively-shielded gradient set with shims optimized for imaging and spectroscopy applications at 7T.

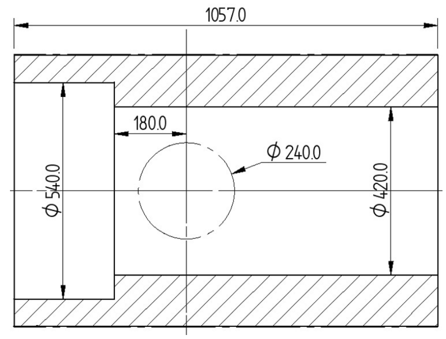

Figure 1: Gradient dimensions

Design

The gradient was designed with an outer diameter of 675mm, enabling it to fit inside an actively-shielded 7T magnet with 680mm diameter room temperature bore. A large inner diameter of 420mm was chosen to allow a variety of array coils to be used, whilst maintaining a comfortable patient bore. At the patient end, this diameter increases to 540mm to accommodate the shoulders. A spherical field-of-view of diameter 240mm, offset 180mm from the shoulder cut-out, was chosen.

Since the gradient is intended for use in short, shielded 7T magnets, it was considered necessary to integrate passive shim trays in order to correct any deviations in the bare magnet homogeneity. The assembly therefore comprises 24 slots, positioned between primary and shield coils.

To correct for inhomogeneities caused by the subject, the gradient also contains room temperature (active) shims. The inhomogeneity caused by differences in magnetic susceptibilities is greater at high field, and it has been shown [3,4] that there can be significant benefit from including channels up to 3rd order for global shimming. The assembly therefore contains these orders, the target strengths for which were guided by previous work [3]. To accommodate the possibility of dynamic shimming it was necessary to keep the inductances of the shim coils as low as possible. This constraint is particularly difficult for the 3rd orders, which are naturally inefficient, and so for these coils the peak current was doubled to 20A. To maintain the highest flexibility for shimming it was necessary to ensure that all channels could sustain their peak currents continuously: the shim coils therefore feature extra water-cooling which is independent from the gradients. Based on previous observations [5] it was decided to actively-shield the Z^2 as well as the Z^0 shim to reduce eddy current effects during dynamic operation. All shim coils were inductively decoupled from the main gradients; capacitive coupling was minimized by ensuring sufficient thicknesses of dielectric between layers.

Figure 2: The completed gradient set

Methods

The magnetic design was accomplished by composing the current distribution of a series of basis functions and minimizing a weighted sum of the deviation from the desired field profile, power dissipation, and inductance. Coils were CNC machined and attached to a fiberglass former. The assembly was vacuum impregnated with epoxy resin and alumina filler.

Results and discussion

Table 1 summarizes the technical data for the designed coil. The requirement of a large patient bore results in relatively modest performance of the gradient coils, although the maximum strength and slew-rate are still sufficient for most applications. The additional space required to cool the multitude of shim coils reduces the amount of cooling dedicated to the gradients, which in turn impacts the achievable duty cycle. Figure 3 shows the first test image obtained from the gradient coil at 7T.

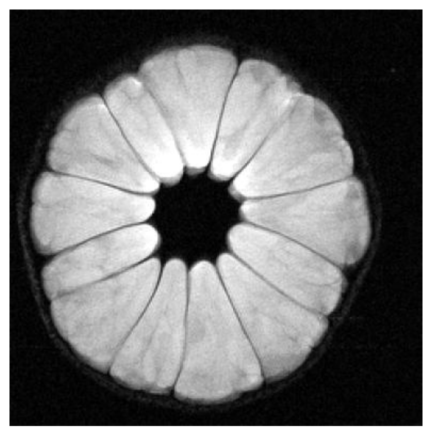

Figure 3: First image of an orange

	Strength	Inductance	Resistance	Max. heat dissipation
X	0.1 mT/m/A	312 µH	80 mΩ	2100 W
Y	0.1 mT/m/A	286 µH	80 mΩ	2100 W
Z	0.1 mT/m/A	290 µH	100 mΩ	2600 W
RT shims	-	-	27 Ω (tot.)	7700 W

Table 1: Gradient coil performance

References

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