

A high-performance head gradient coil for 7T systems

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Introduction

Diffusion Tensor Imaging (DTI) [1] and Diffusion Spectral Imaging (DSI) [2] require long duration gradient pulses for diffusion weighting. As the signal to noise (SNR) increases with decreasing TE, shorter TE is therefore advantageous for a SNR limited technique such as DTI and DSI. This is only possible when using larger gradient pulses. However, the limits in using a whole body gradient coil with high gradient amplitudes, G_{max} , in combination with high slew rates, SR, are dictated by the peripheral nerve stimulations (PNS) [3] and the available current and voltage applied to the coil [4, 5]. To overcome the PNS limits, higher gradient performance can only be used when using smaller gradient coils, such as head sized coils. Reducing the radius, r , of such a coil also helps because the performance of a gradient coil scales with r^5 therefore allowing an increase in G_{max} and SR.

Design constraints

Head gradient coils are used either (a) in dedicated head scanners or (b) as add-ons to whole-body systems. This poses certain constraints on size, shielding, force and torque compensation.

Performance

The most important aspect in gradient coil design is obviously gradient performance. Our design was set to achieve a gradient strength of 80 mT/m and a slew rate of 400 T/m/s.

Size

Both use cases (a) and (b) limit the outer diameter, therefore 670 mm is taken as a good compromise that will fit both. The inner diameter should be as small as possible for optimal performance, and as wide as possible to leave enough room for a noise cover, which can also hold a RF transmit coil, as in whole-body systems. The inner diameter was set to 400 mm, leaving 20 mm radial space for a cover to achieve a 360 mm patient bore, as in existing systems. The most severe limitation, however, is the distance from shoulder to field-of-view (FOV). Our design incorporates shoulder cut-outs (see Figure 1) which allow the gradient coil to extend further towards the patient. This breaks the Z symmetry of the transversal gradients. Using the additional space between the shoulder cut-outs will also break the rotational symmetry of the Z gradient.

Passive Shim

Since the gradient coil will be used in small-bore head scanners, it will have to support an option for passive shimming. 16 slots for shim trays are provided (see Figure 1). The slots are located between the primary and shielding layers of the gradient coil, utilizing empty space.

Active shim

Higher B_0 strength requires higher performance from the second order shims. Our design provides a $7000 \mu\text{T}/\text{m}^2$ second order shim strength. Inductive coupling between gradient and shim coils in conventional designs [7] vanishes because of symmetry. Breaking the symmetry on the gradient coil introduces inductive coupling. We use a novel asymmetric shim design concept which gives the freedom to minimize coupling between gradient and shim coils without compromising efficiency.

Force and torque compensation

The head gradient coil is designed to work in both dedicated head scanners and whole-body systems. The total force in both cases is limited to an acceptable level of less than 200 N for all gradient axes. Asymmetric gradient coils are not symmetrically torque balanced. Torque on all axes is limited to an acceptable of less than 75 Nm.

Technical Data

Field of view: 250×220 mm ($r \times z$)

Axis	X	Y	Z	A20	A21/B21	A22/B22
Sensitivity	178 $\mu\text{T}/\text{A}/\text{m}$	178 $\mu\text{T}/\text{A}/\text{m}$	178 $\mu\text{T}/\text{A}/\text{m}$	700 $\mu\text{T}/\text{A}/\text{m}^2$	700 $\mu\text{T}/\text{A}/\text{m}^2$	700 $\mu\text{T}/\text{A}/\text{m}^2$
Inductance	460 μH	465 μH	190 μH	1265 μH	185 μH	550 μH
Resistance	80 m Ω	82 m Ω	54 m Ω	4.1 Ω	300 m Ω	600 m Ω
Max. Power Loss	16.3 kW	16.6 kW	10.8 kW	410 W	30 W	60 W

This information about this product is preliminary. The product is under development and not commercially available in the U.S., and its future availability cannot be ensured.

References

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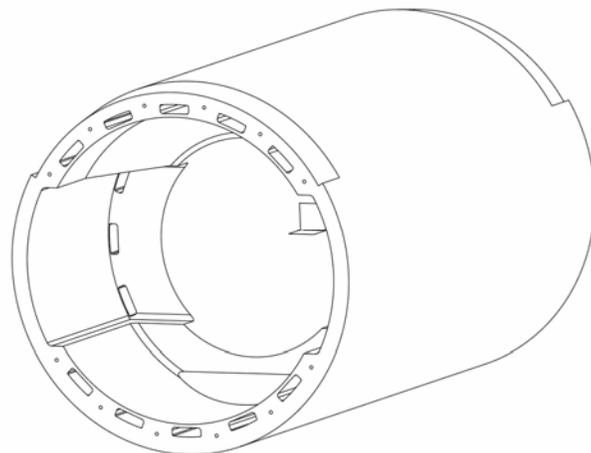


Figure 1: Isometric view of the head gradient coil