Development of a non-shielded PatLoc gradient insert for human head imaging

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Today's limitations of gradient performance in human MRI are predominantly determined by the imaged body. To overcome the limitation of peripheral nerve stimulation (PNS) a multi-channel, non-linear PatLoc (parallel acquisition technique using localized gradients) gradient coil [1] was proposed. This gradient coil uses multipolar fields for in plane encoding [2] and is most promising to be used as a head gradient set. Therefore this abstract discusses the first design of a gradient system for human head imaging using multipolar gradients. The new system is designed for a Siemens 3T Tim Trio to be used in addition to the existing linear gradients.

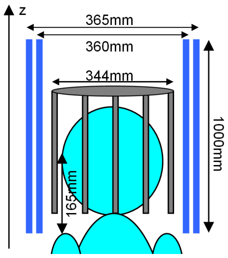

Fig. 1 view from top

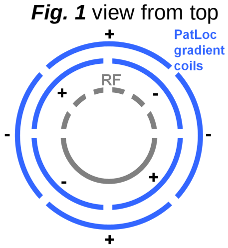

Fig.2 axial section

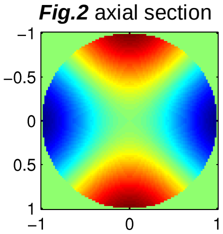

Fig.3 magnetic field [a.u.]

Materials

Because the multipolar PatLoc fields are closely related to shim fields of second order, it appears feasible to use these shim fields for PatLoc imaging. At present there are two alternatives: to use the shim coils of the AC 84 gradient system (Siemens Medical Solutions, Erlangen, Germany) or to build a dedicated PatLoc gradient coil system. The major reasons for building the gradient system are that the shim coils of the AC 84 can only be driven with 20A max. current and their inductivities are high (400-600µH). The other main advantage of the self build PatLoc gradient system is that we can use optimized fields rather then the pure spherical harmonic fields of the shim coils.

Methods

The non-shielded PatLoc gradient coil system will consist of 8 individual coil elements on two layers. One element per layer is optimized, and the other three elements are then simulated by symmetry conditions. The size and shape of the coil elements are determined by the manufacturing process and the final size of the gradient coil system. The individual coil elements are realised by winding wire around pins on a turning table. For mechanical stability each rung consists of 3-5 wires. This number of wires in each rung, the position of these rungs in z direction and the arc length of the coil element are optimized to match the target field [3]. The return paths are densely packed and one sided for open head accessibility. In the initial design the return paths were moved to a possible remote position provided by the former. The individual coil elements will be placed and mounted on a cylindrical former with a diameter of 36cm and cast under vacuum in epoxy resin after a water cooling system was integrated. Fig. 1 shows how the implementation of the PatLoc gradient coil for human head imaging will be realised. In grey, the human head RF-coil with 344mm diameter and in blue the gradient Patloc gradient coil elements on two layers with 360 and 365mm diameter. The overall length of the PatLoc coil, based on the former, is 1000mm where the isocenter is defined to be at z=0mm. The individual elements in each layer will be switched in series with polarities indicated in Fig. 2. The magnetic field in Fig. 3 is the magnetic field of the coil elements on the outer layer. Note, that this system will be implemented on a 3T Tim Trio with 6 independent gradient channels to combine linear and PatLoc gradients.

Results and Discussion

The coil elements of the PatLoc coil on the inner layer (36cm diameter) are 27cm wide and 1m long and 28cm wide on the outer layer (36.5cm diameter) and both are built up of 32 windings per coil element. Equal number of windings for the coil elements in both layers is preferred, because the sensitivity, inductance and resistance are then similar. Compared to the industrial product AC 84 from Siemens this self build gradient coil has a much higher sensitivity and lower inductivity. Due to the length of the wire for each coil element of around 60m the resistance is very large. Also the maximum constant current that the gradient coil can be driven with is five times larger. All figures of the PatLoc coil in the table are calculated for all four coil elements in one layer connected in series.

Measure	Siemens AC 84 (A22 / B22)	Self build PatLoc gradient coil (inner / outer layer)	Units
Sensitivity	620-700	1629 / 1621	$\mu T/A/m^2$
Inductance	430-440 / 625-631	52 / 60	µH
Resistance	730-750 / 675-690	5276 / 5320	mΩ
Max. current	20	100	A

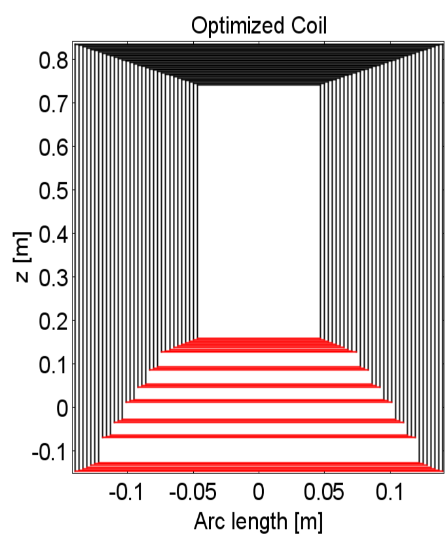

Fig. 4 optimized coil element of the outer layer

Conclusions

Although PatLoc imaging with shims of AC 84 is in principle possible and can be used as a proof-of-principle, the switching rate will be a limiting factor. The dedicated PatLoc coil is expected to withstand pulsed currents of around 200A resulting in roughly a factor 20 higher gradient strengths. Low inductivity implies a notably faster switching rate of the dedicated PatLoc coil. The position of the return paths will be subject of further optimisation to reduce resistance and inductivity for even better performance. Availability of a high performance PatLoc gradient coil will open new perspectives for rapid MR imaging.

[1] Hennig et al, ISMRM, Berlin, p.453 (2007), [2] Hennig et al, MAGMA 21(1-2):5-14 (2008), [3] Liu et al, ISMRM, Toronto, p.1164 (2007)

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