A novel gradient design: simultaneous generation of fast switchable linear and high order field gradient for MR imaging

S. Wintzheimer[1], F. Fidler[2], M. Ledwig[1], T. Drießle[1], D. Gensler[1], and P. M. Jakob[1,2]

[1]Department of Experimental Physics 5, University of Würzburg, Würzburg, Germany, [2]MRB, Research Center Magnetic-Resonance-Bavaria, Würzburg, Germany

INTRODUCTION

Shimming a magnetic field usually requires an additional set of complex coils which act independently from the linear gradient system used for MRI. Therefor a unique coil has to be developed for each field order, which is very extensive. In this study a novel matrix gradient design is presented, which is capable of generating both linear gradient fields for imaging and at the same time high order shim fields. The simultaneous generation of several orders can be achieved by using a set of individually driven coils. The complete gradient field results from the superposition of all these individual magnetic fields. This provides the possibility of creating a large variety of field profiles by driving each coil with a different current. This matrix gradient can not only provide strong linear gradients used for imaging but at the same time allows generating shim fields in order to compensate inhomogeneities in the main field. Driving the coils separately grants the advantage of switching shim and gradient fields very fast due to low inductivity of each single coil. With this new design it is possible to provide fast switchable imaging and shim gradients.

METHODS

In order to demonstrate the principle of the matrix gradients, a biplanar gradient system was simulated and built. It consists of 18 individual rectangular coils arranged in two opposite planes. For this special system we chose a distance of 2 cm between the planes and 4cm*4cm as dimension. The coils are arranged in each plane in two 3x3 matrices (figure 1). Each coil C_x is driven by the current I_x.

Multiple field profiles have been measured and simulated. The simulations were done with a Matlab (MathWorks) script using biot-savart's law. In lack of 18 gradient amplifiers experiments were performed by adjusting the individual currents with potentiometers.

By using this simple geometry it is possible to create linear as well as high order field profiles.

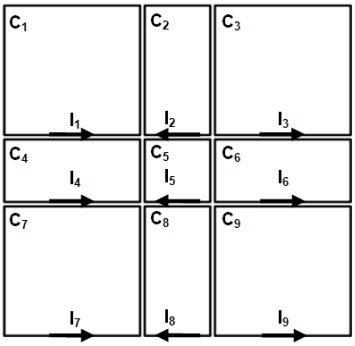

Fig. 1: One plane with 9 coils arranged in a 3x3 matrix. Each coil C_x is driven with a current I_x.

RESULTS

Exemplarily a simulation of the linear gradient field in x-direction is shown in figure 2. The gradient strength is about 25mT/m/A in a field of view of 1cm. To demonstrate the capability of creating higher field orders a measured quadratic shim field in x-direction is shown in figure 3. The field profile corresponds to the simulations. Thereby each coil has a low inductance of 1.4µH which makes very fast switching times of about 200ns possible. This short time applies to any arbitrary field profile, gradient as well as shim fields. Preliminary results are encouraging, since the novel design results in increased signal strength due to improved shimming capabilities while maintaing high performance linear gradients. Moreover it is possible to build an arbitrary matrix gradient system for almost every given geometry.

CONCLUSION

The proposed gradient system is able to create linear gradient fields as well as higher order shims simultaneously with fast switching times. Furthermore, the possibility to switch high order shims as fast as linear gradients is advantageous e.g. for individual slice shim in multislice experiments. The geometry is not restricted to planar gradient systems and the number of coils and their arrangement is free of choice. The major drawback, however, is, that for each coil a separate gradient amplifier is required but it is possible to switch multiple field orders with optimal speed.

REFERENCES

Patent Application DE1020080182656

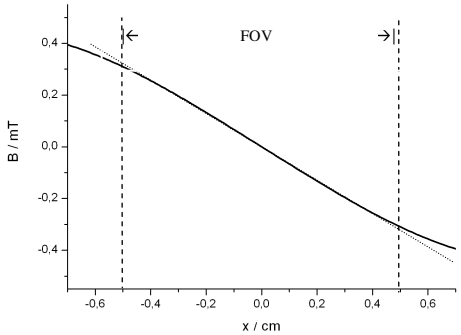

Fig. 2: Simulation of linear gradient field, exemplarily shown for the x-direction. Dashed lines mark the field of view, dotted line indicates the perfect linear gradient

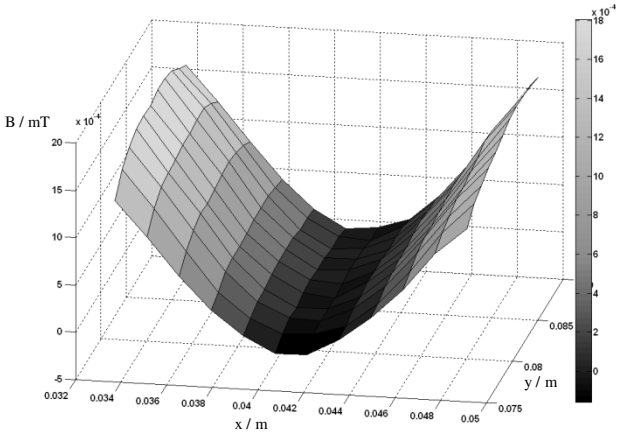

Fig. 3: Measured quadratic field profile