

3D GRADIENT SYSTEM FOR TWO B_0 FIELD DIRECTIONS BY USING CONCOMITANT FIELDS IN EARTH FIELD MRI

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Introduction:

One main part of NMR imaging hardware is the gradient system containing three coils for spatial encoding. These gradient fields in- or decrease the magnetic field components parallel to the B_0 field and vary linearly with position. Maxwell's equations indicate that every gradient is accompanied by perpendicular gradient fields called concomitant fields [1]. Gradients normally are designed for one static B_0 field direction. For our home build earth field scanner ($B_0=46\mu\text{T}$) the orientation of the coil system and the direction of B_0 field are not fixed.

In this work the use of concomitant fields as an additional perpendicular gradient system allowing the same imaging experiments for two different B_0 field directions is presented (see Fig. 1 for the two orientations). Earth field NMR needs a prepolarization coil to enhance the magnetization to measureable values. This method was first demonstrated by Packard and Varian [2]. The gradient system (cylindrical) is matched to the prepolarizing coil to realize a compact geometry. It is benefiting to have the opportunity to orientate the prepolarizing field parallel (Fig. 1a) and perpendicular (Fig. 1b) to the B_0 field. This choice of directions allows to acquire images with either adiabatic [3] or nonadiabatic [3,4] shutdown of the prepolarizing field [5]. The need to rotate the prepolarization coil relatively to the B_0 direction implies the need to have a gradient system which also works in both positions.

Materials and Methods:

We built a gradient system which is capable of encoding three dimensions for two presented B_0 orientations. The system requires four coils in total: three Golay coils and a Maxwell pair. Two coils can be used for both directions. The other two coils are used only for one direction. Fig. 2 exemplarily show one coil used for the two B_0 field directions. Fig. 2 a) represents the case where the B_0 field and coil geometry line up parallel, b) shows the case for perpendicular geometry. Simulations and " B_0 field mapping" measurements have been carried out to characterize the gradient performance for different B_0 field directions. The measurements are made with a 1.5T clinical scanner and a spherical head phantom of 20cm diameter.

Results:

The simulations, the " B_0 field mapping" measurements and imaging experiments verify this built gradient system. Fig. 3 presents the field measurements of the two gradient configurations shown in Fig. 2 a) and b). The gradient strength and region of 5% linearity are almost the same, only the sign reverses, the usable field-of-view does not change. Data for the second gradient used for two B_0 directions are not shown, but measurements show a similar behavior. Both gradient strength and region of 5% linearity are on the same order of magnitude. The difference in gradient strength can easily be compensated by the driving current. The size of the 5% linearity region is larger for the perpendicular case (2) and smaller for the parallel case (1) than for the presented gradient, but the imaging region is still within the 5% linearity.

Conclusion:

We built a gradient system with four coils which is capable of dealing with two B_0 field directions. With the help of the concomitant fields we reduce the number of necessary coils by two in comparison to two independent gradient sets for 3D imaging. These gradients can even be used for further B_0 field directions and therefore this promise new applications and results in more compact setups.

References:

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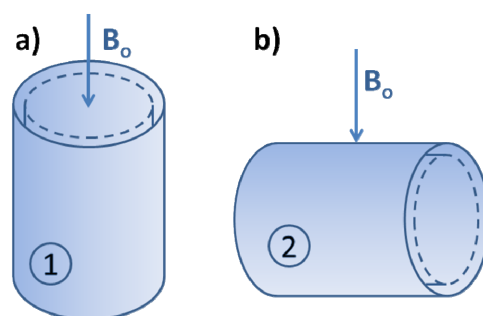


Fig. 1: Schematics of cylindrical gradient system. a) Orientation parallel to B_0 field, case (1) and b) perpendicular to B_0 field, case (2). The prepolarization coil (broken line) is matched to the gradients.

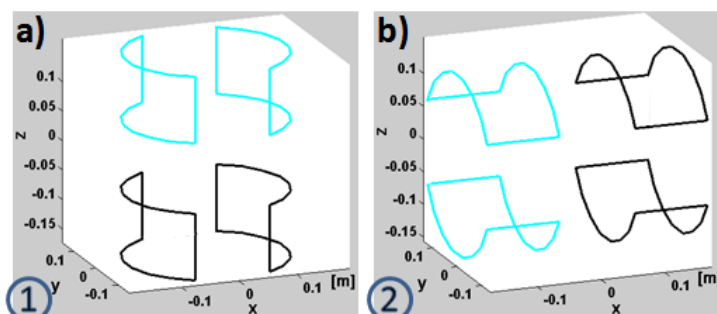


Fig. 2: The Golay coil of the x-gradient for, a) cases (1) and b) case (2).

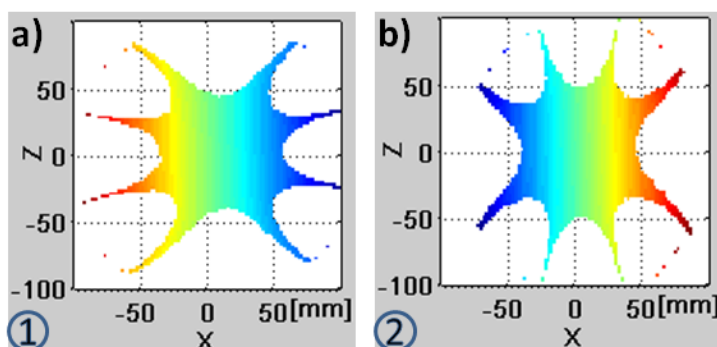


Fig. 3: B_0 Field map measurements of the x-gradient coil (see Fig. 2), a) for the parallel case (1), b) for the perpendicular case (2). The data are cropped with a 5% linearity mask. The measurement was carried out with a 1.5T clinical scanner via " B_0 field mapping". It was used a spherical head phantom of 20cm diameter.