# A B0 Compensation Coil of a 0.3T Permanent MRI System

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## Synopsis

A B0 compensation coil is developed to compensate for the field drift of a 0.3T permanent MRI magnet caused by temperature shift. The Integral Equation Method (IEM) is firstly employed for the coil design, emphasizing on the optimization of the coil structure. By use of the two-dimensional (2D) Finite Element Method (FEM) code of "ANSYS" the optimization results are verified and modified to obtain better performances. Both design and experiment data show that the temperature drift is compensated effectively and the drift of the field uniformity caused by the compensation coil is in a reasonable range.

## Introduction

MRI magnets are required to produce a field with high spatial uniformity and temporal stability [1]. Through optimization design and passive shimming for a 0.3T permanent MRI magnet, a field homogeneity of 26ppm on a 30cm DSV (diameter spherical volume) is finally obtained [2].To meet the requirement of temporal stability, a B0 compensation coil is developed to compensate for the field drift caused by temperature shift. The coil is required to provide field of sufficient strength as well as high field homogeneity to avoid introducing great uniformity drift. This paper describes the development of a flat multi-turn circle-shaped compensation coil of a 0.3T permanent MRI magnet for temporal drift.

## Method

A simplified configuration of magnet and compensation coil is shown in Fig.1 [2]. According to the system parameters the coil design requirements are set as: the largest frequency drift which the coil is expected to compensate for is 30 KHz corresponding to the field strength about 7.046 Gauss and the field uniformity drift is less than 5ppm. The peak values of the voltage and current of the source are limited to 70V and 45A. The compensation coil is of a flat multi-turn circle-shaped structure. The turns are connected in series. The conductor wire has a thin strip structure which thickness and width are 0.8mm and 7.5mm. The number of turns and sizes of each turn are obtained from optimization design.

### *Optimization Design by Integration Equation Method (IEM)*

To make the design quick and convenient, a self-developed electromagnetic optimization design code is firstly used, which is based on the IEM method. The effect of the pole plates is equivalent to an infinite boundary with an infinite high magnetic permeability by which the coil is mirrored for five times. The optimal target is the field homogeneity on a 30cm DSV while the constraint conditions are the field strength, coil inductance as well as a series of location limitations. Through optimization calculation the configuration of the compensation coil is obtained which is shown in Fig.2. It consists of 18 turns in series. With reference to Fig.2 the current direction of the turns in red color is opposite to that of those in blue.

### ***2D Electromagnetic Calculation by** Finite Element Method* ***(FEM)***

The results of the IEM optimization design are validated by the 2D axisymmetric commercial FEM code "ANSYS". The agreement between the IEM optimization outcomes and FEM calculation results indicates that the simplified IEM optimization is acceptable. However, since the FEM model is closer to the real structure, if some small corrections of the coil structure are made on the basis of the IEM results the electromagnetic performances can be further improved.

## Results

The coil structure parameters optimized by IEM and modified by FEM model are listed in Table I. The calculation results by FEM show that a 30 KHz drift can be compensated by applying a current of 35.8A to the coil while the field uniformity drift is about 4.5ppm. The magnetic field distribution of 1/4 arc on the 30cm DSV is given in Fig.3.

Based on the electromagnetic optimization design a real B0 compensation coil is constructed. Before each scan a standard sphere phantom is excited by a RF transmit coil to observe the central frequency drift, from which the compensated current to be applied to the compensation coil can be derived. For usual experiments, the frequency compensation range from about -5 KHz to 5 KHz is in common use. An experiment is carried out to compensate for a field drift of 4372Hz on the 0.3T magnet. Through analyzing the spectrum of the resonance signal of an excited 30cm sphere phantom a central frequency drift as high as 4372Hz is compensated and the field uniformity drift about 1.882ppm on 30cm DSV is derived from the Frequency Width Half Maximum (FWHM) of the spectrum.

## Discussion and Conclusion

The electromagnetic design procedure for a B0 compensation coil is presented. To make the design quick and convenient the IEM method is firstly employed for the design of the coil structure. The FEM method is used to verify and modify the calculation results. The experiments show that the coil can effectively compensate for the temperature drift without introducing great field uniformity drift in sample region.

## Reference

[1] W. Denis Markiewicz, et al., IEEE Trans. on Applied Superconductivity, Vol.12, No. 4, pp.1886-1890, 2002.

[2] Xiaohua Jiang, et al., presented on 18th International Conference on Magnet Technology, 2003

TABLE I THE RADIUS OF EACH TURN OF THE COMPENSATION COIL OPTIMIZED BY IEM AND MODIFIED BY FEM

| Turn order | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roptim(m) | 0.2285 | 0.2914 | 0.3009 | 0.3104 | 0.3199 | 0.3294 | 0.3389 | 0.3750 | 0.3845 | 0.3940 | 0.4035 | 0.4130 | 0.4225 | 0.4320 | 0.4415 | 0.4510 | 0.4605 | 0.4700 |
| Rcorrect(m) | 0.2285 | 0.2922 | 0.3017 | 0.3112 | 0.3207 | 0.3302 | 0.3397 | 0.3750 | 0.3845 | 0.3940 | 0.4035 | 0.4130 | 0.4225 | 0.4320 | 0.4415 | 0.4510 | 0.4605 | 0.4700 |

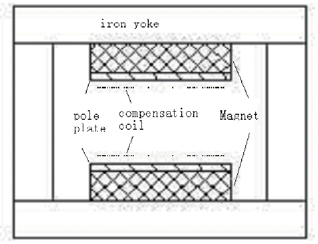

Fig.1 Simplified configuration of Magnet and Compensation coil

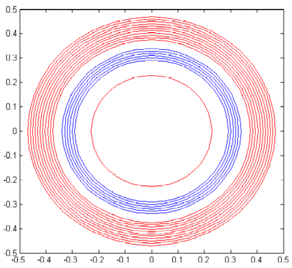

Fig.2 Configuration of the Compensation coil by IEM

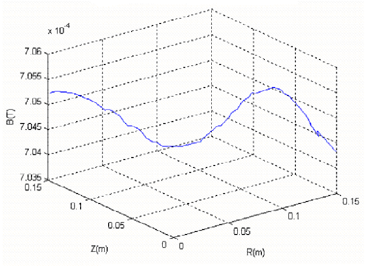

Fig.3 Magnetic field distribution of 1/4 arc on 30cm DSV