# Active compensation for separate shell magnetic shields used in biomedical applications

Abdelmomen, Mahgoub Usama Ahmed



出版情報：九州大学, 2014, 博士（学術）, 課程博士
バージョン：

氏　　名：**Mahgoub Abdelmomen Usama Ahmed**

論文題名：**Active compensation for separate shell magnetic shields used in biomedical applications**
**(生体磁気に用いる分離型磁気シールドの能動補償)**

区　　分：甲

## 論　文　内　容　の　要　旨

Many advances have been witnessed in the applications related to the field of biomagnetism and magnetic biosensors in the last decades. The principle idea is based on sensing tiny magnetic fields (in order of pico-Tesla) emitted from the human body using highly sensitive sensors. Although a variety of magnetic sensors are capable of measuring such small magnetic fields such as SQUIDs and, fluxgates, measuring biomagnetic fields is still challenging as these tiny magnetic fields are contaminated with the environmental magnetic fields that is three orders of magnitude larger than the biomagnetic fields. Hence, magnetic shielding is indispensible to provide a magnetically quiet environment for the sensors to work within. Examples for applications that need a magnetic shielding for their measurements are magnetic nano-particle (MNP) detection and Magnetocardiography (MCG).

Conventional magnetic shields consist of many layers of magnetic materials. As a consequence, the cost and weight of such shields are very high. These two disadvantages hinder applications that depend on measuring biomagnetic fields from being widely used. One solution is to use active compensation techniques aided with separable passive shields in order to reduce the amount of magnetic material utilized in the shield.

A new active shielding system is proposed in this thesis with two identical separated magnetic shells: cap shell and cup shell. The shield provides an axial symmetric magnetic shielding efficiency. This shielding can be utilized in MNP detection. One can characterize magnetic signature of samples by measuring the axial component of the magnetic field emitted from them. The samples can be provided using a rotating table. Hence, the shielded area needs to be easily accessed. So the separate shell magnetic shield will suit this kind of applications. The numerical simulations are conducted to explain the operating principle and to show the shielding efficiency. Those simulations are then confirmed by the experiments. A shielding factor of 3162 at frequency of 1 Hz at 10 cm separation between shells and a shielding factor of 4466 at 14 cm separation at r = 7.5 cm are reported.

Similarly, large-scale separate shell magnetic shield utilizing the principle of active compensation aided with separate magnetic shells was introduced previously. The performance of the system was investigated previously. As reported previously, along the y-axis, without active shielding the shielding factor was as low as 20 with magnetic noise of 100 pT/√Hz at 1 Hz. With such level of magnetic noise, MCG measurements cannot be conducted. Hence a new strategy using two independent controllers to cancel both static and time varying magnetic fields is proposed. Two sets of coils are utilized for active compensation in y-direction. The system shielding efficiency is measured and effect of different parameters. In addition a new strategy is proposed to reduce magnetic field gradients and ensure spatially flatter shielding efficiency using over compensation technique. For the case of two independent controllers, the gain of the controller can be increased from $K_p$ = 1 in case of using one controller to $K_p$ = 10 improving shielding performance at 15 cm separation to 20 pT/√Hz at 1 Hz with noise floor of 3 pT/√Hz for frequencies above 20 Hz. The shielding factor increased from 20 in case of passive shield to about 800 at low frequency. With overcompensation technique, the magnetic field inside the shield is maintained at 60 nT, improving the resultant magnetic field gradient inside the shield from 25 nT/cm to less than 1 nT/cm