

Novel concepts in magnetic shielding

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1 Introduction

VTT Automation and Euroshield Oy has developed a new concept for magnetically shielded rooms. For an enclosure size of 3 x 4 x 2.5 m³, the shielding factor exceeds 60 dB at low frequencies, increasing to above 90 dB at frequencies beyond 10 Hz. The concept, based on double aluminium and mumetal shields and an active shielding stage, incorporates several new techniques for increasing the cost-effectiveness of traditional shielding. A magnetically shielded room based on this concept was constructed for MEG studies at the Low Temperature Laboratory of Helsinki University of Technology in 1998.

2 Methods

2.1 Passive shielding

The passive shielding consists of two shells with 150 mm interspace. Each shell has a 2 mm mumetal and an 8 mm aluminium layer as shielding materials. The aluminium profile frame and the aluminium shielding layer are prefabricated into modular elements from which a shield of desired dimensions can easily be assembled. A special assembly technique assures that the transfer resistance between adjoining aluminium plates does not markedly exceed the resistance of a continuous plate.

The sliding door is, when opened, completely hidden inside the wall. When closed, it is pneumatically tightened against the shields providing continuity of both mumetal and aluminium layers.

Demagnetization of the magnetic shielding structure after assembly was performed using demagnetization coils, surrounding each edge of each mumetal shell. The total number of coils is 24.

2.2 Active shielding

Active shielding is accomplished by compensating the disturbing fields with locally generated opposing fields. Local fields are generated by feeding currents through coils surrounding the passive shielding structure. The currents must be actively related to the disturbance fields. This is accomplished with the

aid of magnetic sensors, which generate a signal proportional to the local magnetic field.

Most magnetometer sensors used in active shielding designs measure the field in practically a single point in space, either positioned on the surface of a wall or at a distance from the room. Thus, they are sensitive to local distortions caused by ferromagnetic and conducting objects, or their movements. Lower sensitivity to local effects is obtained by spatially integrating sensors, which measure the average signal over a larger volume of space.

In the present design, the demagnetization coils, fixed right onto the passive shielding structure are used as magnetic sensors. Each coil encloses only the edge of one mumetal shell, not the entire room. The position of the sensor coils is schematically shown in Fig. 1.

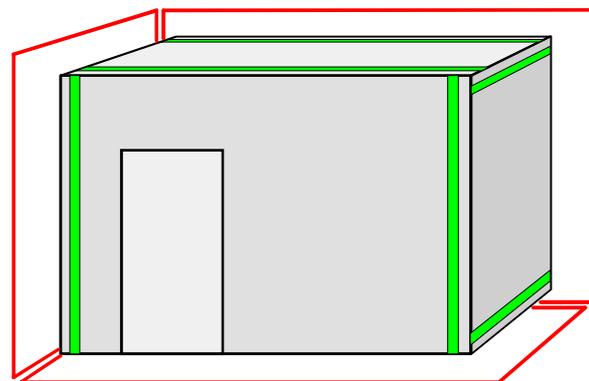


Figure 1: Location of compensation coils (outside the room, 3 of 6 shown) and measurement coils (around the mumetal elements, 6 of 24 shown).

Variations in the external magnetic field sets up changes in the magnetic flux inside the ferromagnetic shells. Since the sensor coils are wound around sections of these shells, they act as induction coil sensors for external disturbances. At very low frequencies the ferromagnetic material provides a large volume high permeability core for these coils. Thus, the sensors are able to operate down to frequencies in the mHz region using low-noise preamplifiers. The noise voltage density of the amplifiers is 0.8 nV/ $\sqrt{\text{Hz}}$ with a 1/f corner frequency

of 0.3 Hz. With twelve coils per mumetal shell, all three orthogonal field components can be measured, as well as their gradients in the same directions. The control system comprises the twelve sensors, data acquisition electronics, a PC-based digital controller, power amplifiers, and compensation coils as shown in Fig. 2. The twelve sensor signals are weighted to produce input signals for the six controllers. Optimization of the elements of this 6×12 weighting matrix is not trivial. In this design, a programme based on the simulated annealing algorithm was used. In this process normal external noise was used as the driving input signal, and the matrix was optimized for minimum flux variations at the twelve sensors. Due to the random nature of the excitation signal, i.e. the external noise, the rate of convergence of the algorithm must be kept low. The results presented here are based on an optimization run that took about one day to accomplish. After optimization the parameters are fixed and used for noise control in operation.

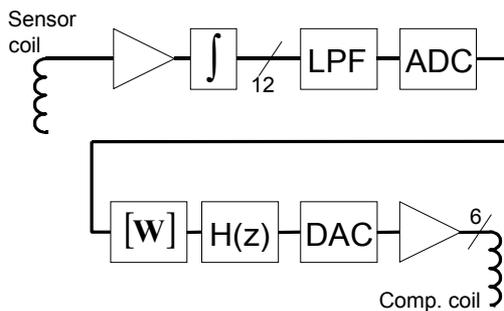


Figure 2: Simplified block diagram of the control system.

3 Results

The effectiveness of the shielding is given by the shielding factor, which is the ratio of the disturbance amplitude without shielding to the amplitude measured inside the shield. The shielding factor as a function of frequency is presented in Fig. 2. At low frequencies ($f < 0.2$ Hz), the shielding factor of the passive shield only is 30 dB, increasing to above 80 dB at 10 Hz. The active shielding system increases the total shielding factor to above 60 dB at frequencies above 10 mHz, and to 90 dB at 10 Hz. For comparison, two passive three-layer rooms are included in Fig. 3, Refs [1] and [2].

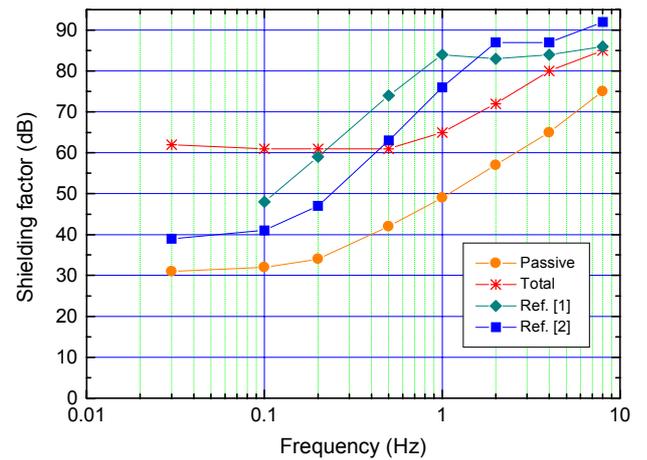


Figure 3: Passive and total shielding factors versus frequency.

4 Discussion

By combining active and passive shielding methods it has been possible to construct a cost-effective magnetically shielded cabin of large size. The modular construction of the passive shield allows fast erection of the structure and flexibility in dimensioning of the cabin. Novel methods of mounting and joining mumetal, together with the new door construction, assures very small degradation of the effective magnetic permeability of the complete structure as compared to that measured in separate mumetal sheets.

Future work will be focused on improving the active compensation in the range 0.5 – 10 Hz. A separate controller has been designed for attenuation of residuals at the mains frequency of 50 Hz.

The sensor signals of the inner mumetal shield, representing the residual disturbances, can be mapped to any point inside the room. The usefulness of this mapped residual disturbance signal for the MEG equipment will be investigated.

References

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2. M. Paavola, R. Ilmoniemi, L. Sohlström, T. Meinander, A. Penttinen, and T. Katila, "High performance magnetically shielded room for clinical measurements", *Biomag96, Proc. Of the 10th Internat. Conf. On Biomagnetism*, Santa Fe, 1996.