Quantum Design

MPMS Application Note 1014-209

Environmental Magnetic Shield—Option M107

Introduction

The MPMS Environmental Magnetic Shields were designed for our customers whose laboratories are located in environments with excessive magnetic noise. These shields provide an attenuation of approximately -38dB over the entire response range of the $MPMS_2$ and up to 5.0 tesla for the MPMS, degrading to -25dB at 5.5 tesla. The shields also serve as a return path for the magnetic field from the MPMS superconducting solenoids, allowing the system to be run in close proximity to other sensitive instruments.

The Magnetic Shields

The magnetic shield developed for the MPMS comprises an inner layer with a 16.5 inch diameter cylinder (closed at the bottom) that fits around the outside of the MPMS dewar. The outer shield has a similar design and fits around the outside of the inner shield. The high permeability inner shield absorbs the fields produced by the MPMS magnet while the outer layer attenuates the incoming noise.

The magnetic shield developed for the 1.0 Tesla $MPMS_2$ has a single layer design, which does not saturate in the 1.0 Tesla field. The shield is a mu-metal cylinder (closed at the bottom) that fits around the outside of the $MPMS_2$ dewar.

Performance

Attenuation and small signal sensitivity measurements were performed on both types of shields. For the attenuation measurements, a test fixture was built to simulate a low frequency (0-10 Hz) "noise" field. "Noise" was produced by a calibrated dipole coil so that both longitudinal and transverse fields could be simulated. That is, the dipole could be oriented longitudinally or transversely to the second derivative gradiometer. The input noise signal was adjusted to deliver noise levels that have been found in worst case environmental situations on an unshielded MPMS. The output voltage of the SQUID was monitored and recorded. The same test was performed with the shield in place. A shielding factor was calculated using the following equations:

$$S(\text{dB}) = 20 \log(A)$$

$$A = \frac{V(\text{Shielded})}{V(\text{Unshielded})}$$

where V = ½ peak-to-peak SQUID output voltage.

Shielding Factor for the MPMS

Characterization of the shields was performed as a function of field to determine saturation fields. A plot of the shielding factor S(dB) is shown in Figure 1 for the 5.5 tesla MPMS. Note that at high fields, saturation began to reduce the attenuation of the outer shield of the MPMS 2-layer design.

Shielding Factor for the 1.0 Tesla $MPMS_2$

A plot of the shielding factor S(dB) is shown in Figure 2 for the 1.0 tesla $MPMS_2$. This shield saturates at a field well above the maximum $MPMS_2$ field.

Standard Deviation versus Applied Magnet Field for the MPMS

Small (10mg) samples of copper wire were used to measure the small signal performance of the MPMS at magnetic fields greater than 2500 gauss. For fields less than 2500 gauss and for the $MPMS_2$, a 5mg Pd sample was used to determine performance. The standard deviation of three measurements, consisting of 5 scans each, was used as the parameter describing typical system noise. Measurements were taken 15 minutes after a field change, and the magnet charging was done in the oscillate mode.

A slight improvement in performance at all fields was noted with the shield. A small gain in performance was due to the normal laboratory environment at Quantum Design's test facility (for example, no high-intensity, low frequency environmental noise present). The improvement in performance demonstrated that there should be little or no degradation of small signal sensitivity.

Standard Deviation versus Applied Magnet Field for the $MPMS_2$

Figure 3 illustrates the standard deviation versus applied magnetic field for the $MPMS_2$. Again, the slight improvement in performance with the shield indicates no degradation in small signal sensitivity.

Measurement of Environmental Noise

The development of the Environmental Magnetic Shields was motivated by the need to reduce background environmental noise when using the MPMS. Common contributors to this background noise are elevators, motors, and other electromechanical devices. The other main contributor is magnetic field sweeping instruments that are located in close proximity to the MPMS.

Figure 1. Shielding Factor for the 5.5 Tesla MPMS

Figure 2. Shielding Factor for the 1.0 Tesla $MPMS_2$

Figure 3. Standard Deviation versus Applied Magnet Field for the $MPMS_2$

Techniques

A number of techniques, for determining if external noise is causing difficulties with measurements may be used. Internal techniques using the MPMS included simple observations of erratic behavior in small signal measurements that may depend on the time of day or local activities near the instrument. External surveys may be implemented using fluxgates or other vector magnetometers.

Reduction of High Frequency Noise

Our experience has shown the MPMS systems usually work properly in typical laboratory environments. The second derivative gradiometer pickup coil is designed to reject noise from far field, and a number of steps have been taken to reduce high frequency noise. However, in those locations where environmental noise interferes with the instrument, the Environmental Magnetic Shield may provide a substantial improvement in system performance.