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Thermal and Magnetic Issues with the Magnetic Pre–Isolator (MEPI)

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Two basic concerns have been brought up regarding the magnetic pre–isolator; expansion due to heating of the housing from ohmic losses in the coils, and magnetic coupling from the field created by the actuator to both the L4C seismometers and directly to the test masses. This note is to comment on work done to both characterize and, where appropriate, discuss possible solutions to these issues.

Thermal Expansion

Thermal expansion was characterized by putting in the maximum current that the actuator could be expected to draw for the time that it could be drawn and measuring the temperature on the actuator housing. Correction of tidal motion could require up to 50 microns of motion. Using the spring constant from Ken Mason's design for the EPI structure, the horizontal spring constant is about $1\ 10^{6}$ N/m per pier. The required 50 microns of motion would mean 50 N of force. Using the actuator manufacturers transduction value of 21 N/A, means the actuator would draw 2.4 A. This force could be required to be maintained for multiple hours.

To check the heating that would result from this, 3 A of current were put into the actuator, and the temperature monitored over 2.5 hours. The total temperature rise during this time was 6 C. With a coefficient of thermal expansion for steel of $1.5\ 10^{-5}$/C , this represents a 5 micron expansion. A heat sink was then attached to the actuator, with a resulting 1.3 C temperature increase and a 1 micron expansion. This heat sink is now used on all the actuators installed at LASTI.

Magnetic Interaction with Geophone

An L4 geophone was placed near the actuator and signals from it coherent with current into the actuator were compared with expected seismic signals. The response from the geophone was found to be linear in current into the actuator, linear in frequency, and inverse square in distance between the actuator and the geophone. Using this information to make a model, the size of the expected geophone signal from seismic excitation was compared to the magnetic noise from the actuator acting against the same seismic signal. The seismic signal out of the geophone was found to be four orders of magnitude higher than the noise from magnetic coupling.

Magnetic Interaction with Test Masses

The magnet field around the actuator was measured with a wire coil so that an estimate could be made of the effect of on the test masses. The field was found to be linear in input current to the actuator, inverse square in distance away from the actuator, and to have a pole at 100 Hz in frequency. An additional pole at 20 Hz was assumed for the field inside the chamber to try to model the effect of the chamber walls. This is based on results from Serge Lefranc in T990027–00–D.

Using this model, an input current spectrum necessary to counteract seismic noise was assumed as an input. The resulting magnetic field noise at a distance of 2 meters, the scale of distance between the installed actuators and the test masses in the chamber, was compared to the background field measured at Livingston by Shourov Chatterji.

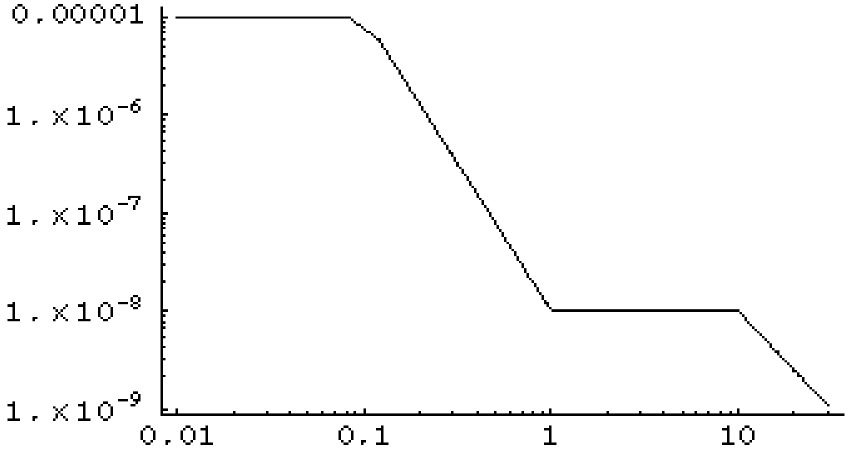

Figure 1 – Assumed Livingston seismic noise spectrum. Seismic noise in m/Hz$^{1/2}$ vs Frequency in Hz.

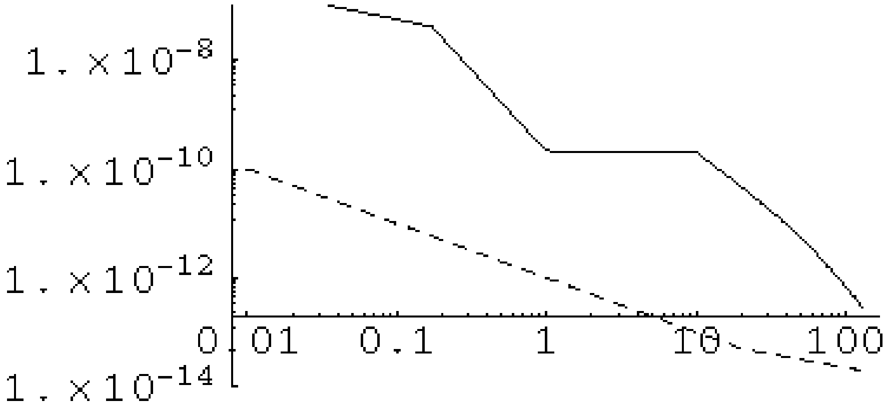

Figure 2 – Magnetic field noise in T/Hz$^{1/2}$ vs Frequency in Hz. The dotted line is the measured background at Livingston and the the solid line is the expected noise from the actuator.

Coupling to the test masses was calculated by assuming a 10% difference in the dipole moments of the mirror magnets. The force on the test mass was calculated from the field and the net dipole moment, then the response to this force was compared to the science requirement document, E950018−02−E, noise.

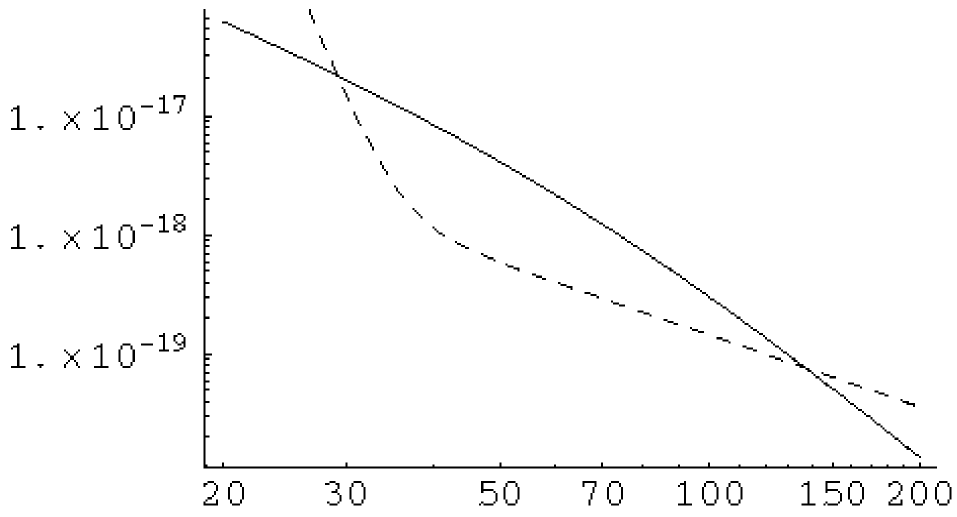

Figure 3 – Test mass position noise in m/Hz$^{1/2}$ vs Frequency in Hz. The dotted line is the SRD noise and the solid line is the predicted noise from the actuator magnetic effect.

An attempt was made to test this model by placing the actuator next to BSCs at both Livingston and Hanford. The actuator was driven with 10 A at various frequencies between 0.1 and 100 Hz. The model indicated that, if the assumptions were correct, the magnetic effect of the actuator on the test masses should be seen above the noise as of August 2002, when the tests were carried out. No effect was observed in either AS_Q or AS_I at either site. Clear coupling was seen to optical lever channels, however.

The effect of added shielding was then examined, to reduce the noise at the test mass. This was deemed desirable, despite the negative results at the sites, because of the size of the predicted noise in Figure 3. A continuous metal box was imagined surrounding each actuator. To reduce the noise to 1/10 the SRD value, 5 mm thick steel would be needed, or only 4 mm thick steel if the magnetic field noise from the actuator was reduced to the background field level at 40 Hz. If mumetal is used rather than steel, the equivalent wall thicknesses are 0.25 mm and 0.2 mm receptively. The field immediately outside the actuator when 3 A of current is drawn is about 12 T, well above the saturation field for mumetal. A 2.5 mm thick steel box would bring the field down to about 0.6 T, just below the saturation of mumetal. A 100 micron mutmetal box could then reduce the field well below the level necessary to reach the SRD.