Low Frequency motion estimates of the BSC-ISI

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1 Summary

A simple model of the stage 1 BSC-ISI performance below 2 Hz has been made. It is based on the simple HAM analytic modeling code (*HAM ISI Modeling Abstract*, Brian Lantz, T0810042-v1), and the analytic expressions used to predict platform motion (*Simple Calculation of Active Platform Performance*, Brian Lantz, T080119-01).

We show that the sensor noise, per se, does not limit the motion of stage 1 below 1 Hz, but rather that the motion of the ground (and HEPI), and in particular the tilt motion of the ground, limits the performance for the blend filters used. The performance plots here are all generated by the matlab script BSC_modelv0.m, and the blend filters are all contained in the function make_complementary_filters_BSCPDR_090927.m.

2 Caveats

The mechanical model is the one developed for the HAM-ISI, and so is completely unsuitable above the first resonance frequency of about 1 Hz. The sensors used to do the noise coupling calculations are in the locations of the displacement and GS-13 sensors for the HAM-ISI, and so are not quite in the final locations. The L-4Cs are not included at all. Since we plan to use these for the inertial sensors for stage 1 of the BSC-ISI above a few hertz, we do not continue the noise plots above 2 Hz. We plan to achieve most of the isolation performance below 0.5 Hz on the first stage, but at 1 Hz, we expect to get significant performance from stage 2. Thus, the isolation from the second stage should be expected to make the 1 Hz performance much better, and make the performance around 0.5 Hz worse by as much as a factor of 2.

Below 0.5 Hz, the loop gains are large (much more that 100), so the performance of the system is dominated by sensor noise, the blend filters, and the input noise, and the performance is not really impacted by the shape of the open loop transfer functions. Thus, the estimates here should be useful to help understand the low (sub 0.5 Hz) performance of the system.

3 Sensor Noise

The noise we use as the input to the sensors is the measured noise of the +/- 1 mm ADE capacitive displacement sensor, and the measured noise of the T240. These curves are included in figure 1.

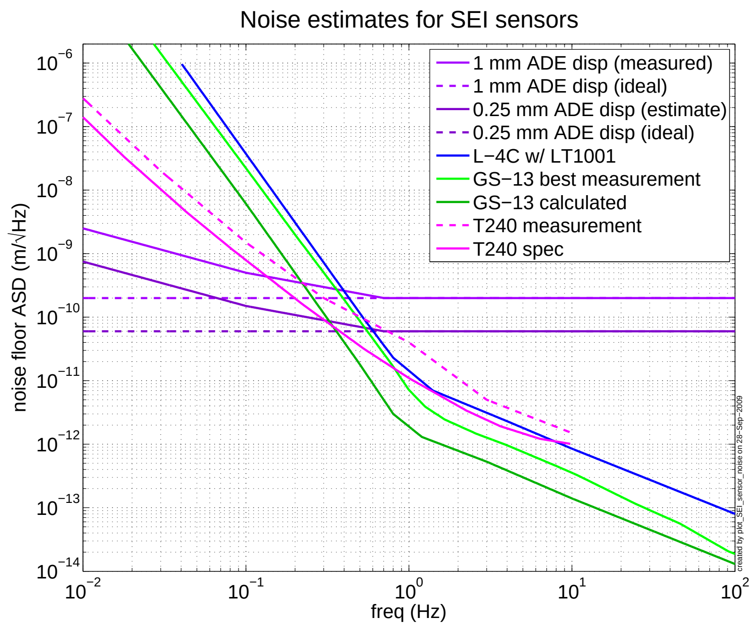

Figure 1: Noise estimates for the various SEI sensors.

4 Motion in RZ

The simplest DOF is RZ, the rotation about the vertical axis. HEPI doesn't give any performance in RZ below 0.5 Hz, and there are no interesting cross couplings. The blend filter we use

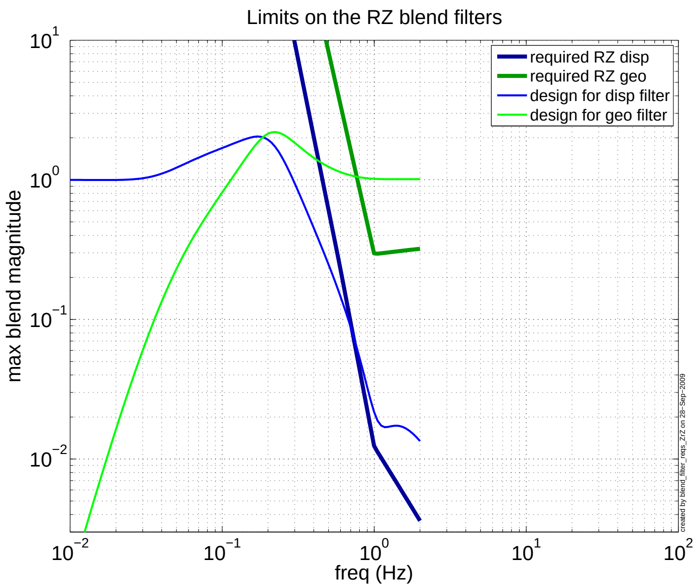

Figure 2: Complementary blend filter used for the RZ model. Thin lines are the blend in use, and thick lines are targets we try to stay below.

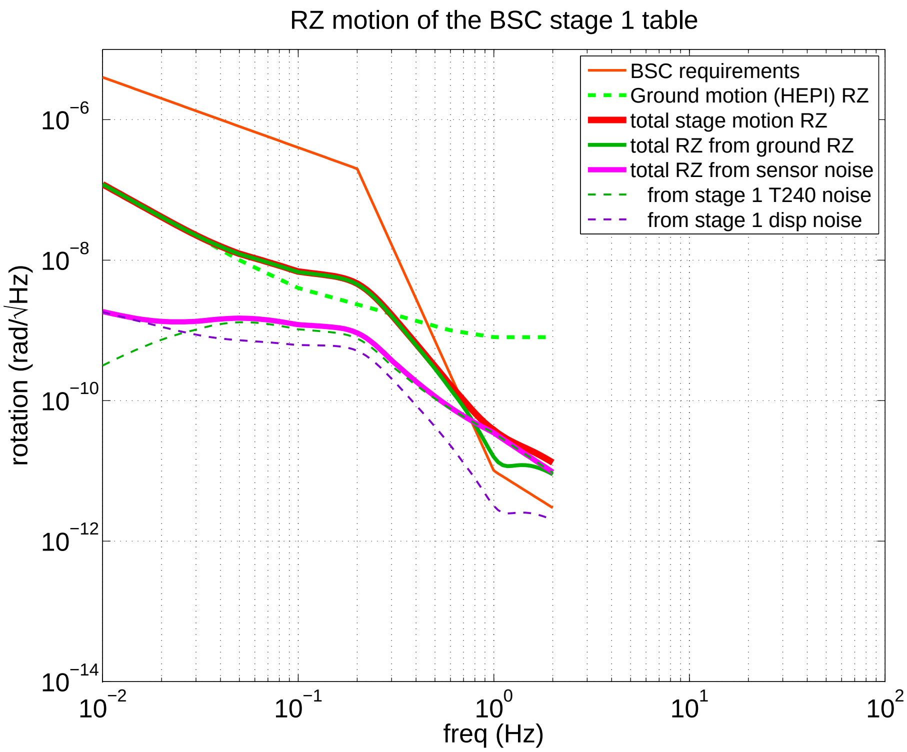

Figure 3: Estimated performance of stage 1 of the BSC-ISI in the RZ (rotation about Z axis) DOF. The thick red line is the total estimated motion, and the magenta line is the motion caused by sensor noise.

5 Motion in Z

Motion in the vertical (Z) direction is also reasonably simple. Here we use the old LLO ground motion estimate, and assume that HEPI is helping from 0.1 to 10 Hz. The large jump at 0.1 Hz results from the FIR filter shape.

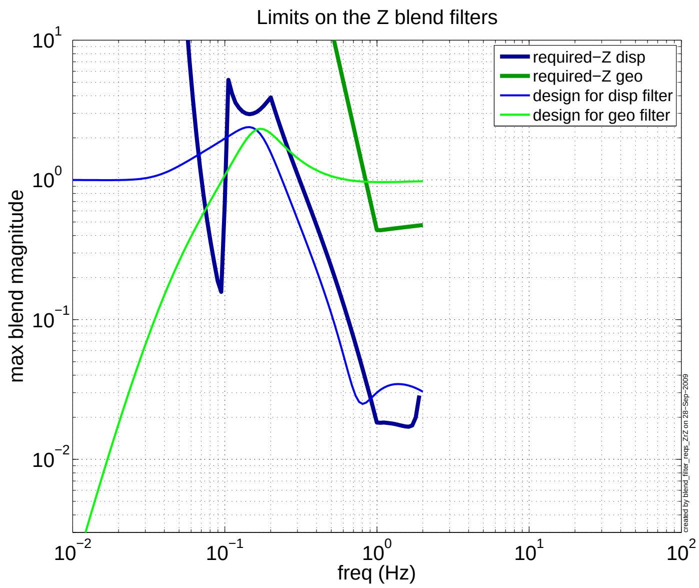

Figure 4: Complementary blend filter used for the Z model. Thin lines are the blend in use, and thick lines are targets we try to stay below.

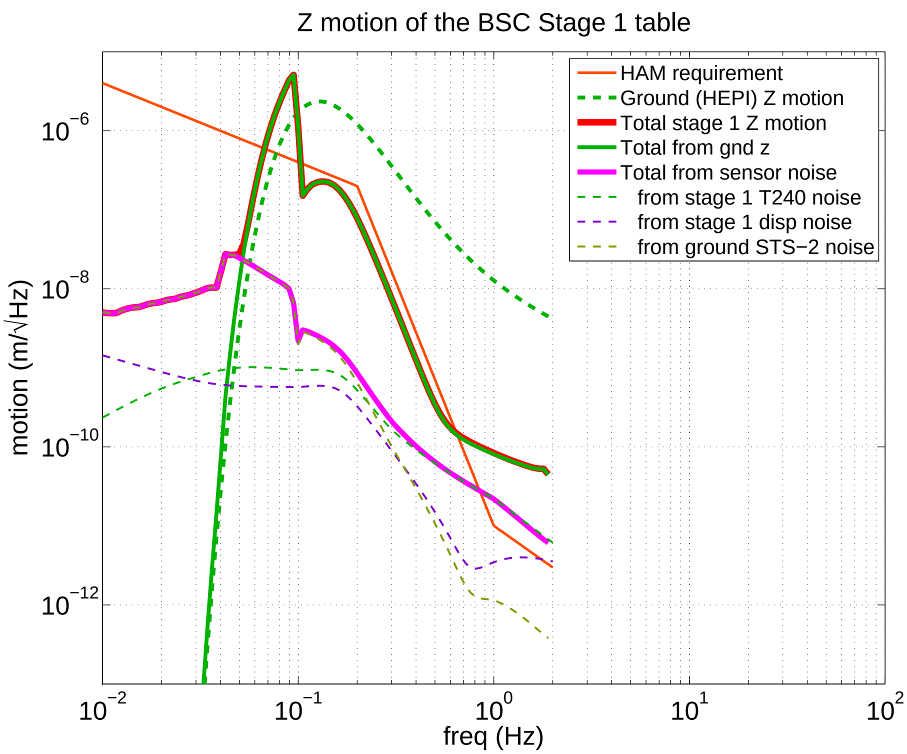

Figure 5: Estimated performance of stage 1 of the BSC-ISI in the Z (vertical) DOF. The thick red line is the total estimated motion, and the magenta line is the motion caused by sensor noise. The ground motion is causing the majority of the motion below 0.5 Hz, and the limits from sensor noise (again in magenta) are not the reached. The filters here are essentially the same as those put into the HAM, and there is clearly room for optimization.

6 Tilt Motion (RY)

Tilt motion of the table (RY) is reasonably simple, but causes cross-coupling to the horizontal direction. In figure 7 we see the estimated tilt performance of the table, which is well below the BSC-goal curve. The motion of the table is shown as before, with the red curve being the total tilt motion, and the magenta curve representing the component which comes from tilt. A look at the blending in figure 6 shows that the blend frequency is about 0.65 Hz, and the filters are designed to roll off the inertial sensor at f^3 below about 0.040 Hz. This blend corner is about a factor of 2 in frequency below the blend for RY on the HAM tables, and the lower blend is enabled by the quieter vertical sensors (the T-240s) used on the BSC. The dashed red curve shows how a horizontal inertial sensor will (mis)interpret the tilt motion. Since the dashed red curve crosses the requirement curve at about 0.14 Hz, we can guess that, in order to keep the tilt motion of the table from violating the horizontal requirement, we need to have the blend frequency for the *horizontal* direction be at 0.14 Hz or above. We can also see that the sensor noise is not the main contributor to the motion, but that below 30 mHz, the noise of the inertial sensors is almost as large as the estimated ground tilt (this input estimate is from data on a windy = large tilt day). Hence, if we were to continue to lower the frequency of the blend below 0.65 Hz, we would decrease the tilt at 0.1 Hz, but increase it at 10-20 mHz.

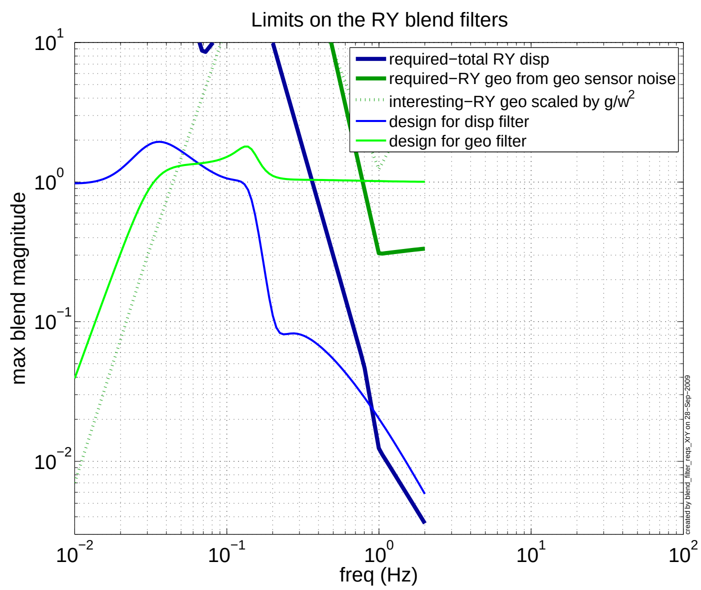

Figure 6: Complementary blend filter used for the RY model. The blend frequency is about 0.65 Hz.

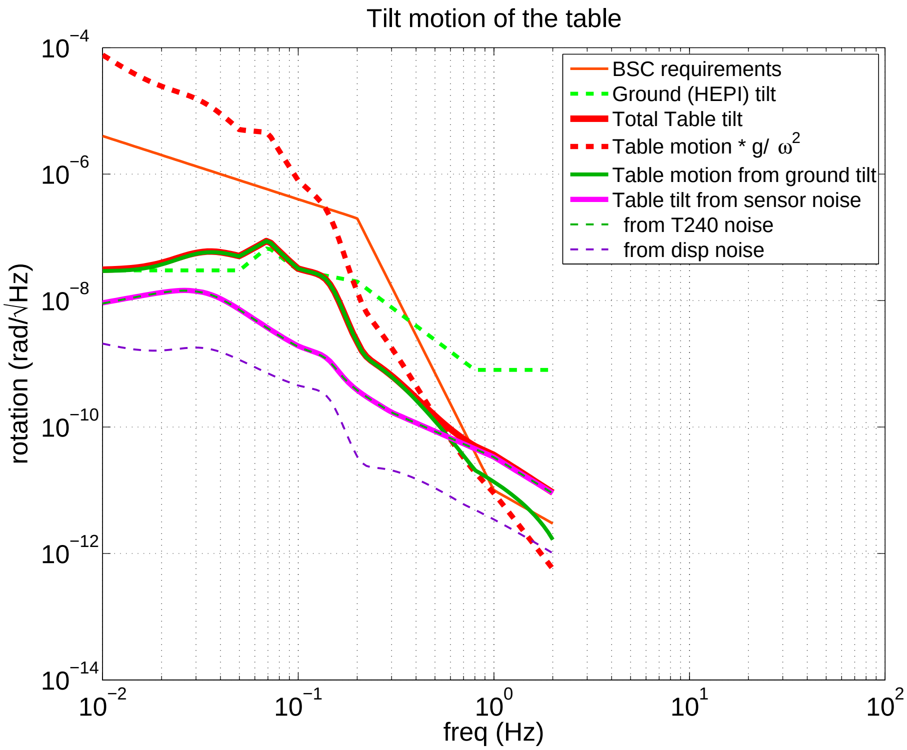

Figure 7: Estimated performance of stage 1 of the BSC-ISI in the RY (tilt) DOF. The thick red line is the total estimated motion, and the magenta line is the motion caused by sensor noise. The dashed red line, which crosses the requirement curve at 0.14 Hz, is tilt-horizontal confusion which the table tilt will cause a horizontal inertial sensor.

7 Motion in the beam direction (X)

We finally come to the good bit. We set the blend frequency pretty high (In figure 5

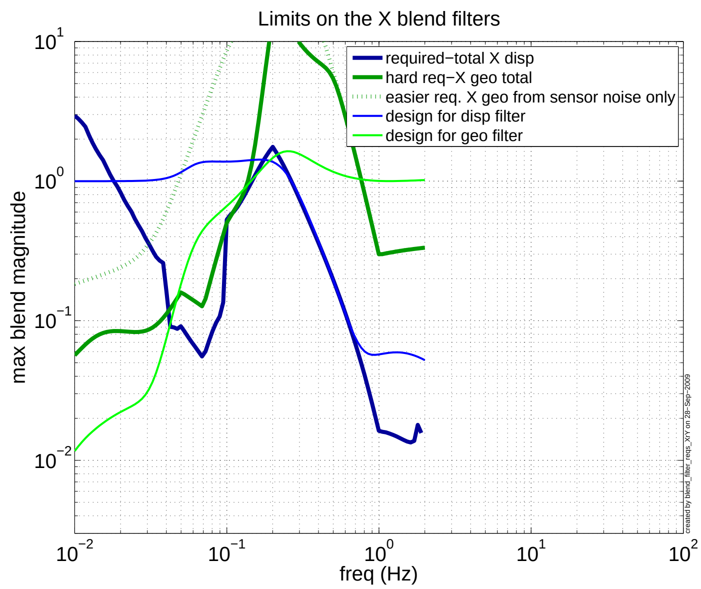

Figure 8: Complementary blend filter used for the X model.

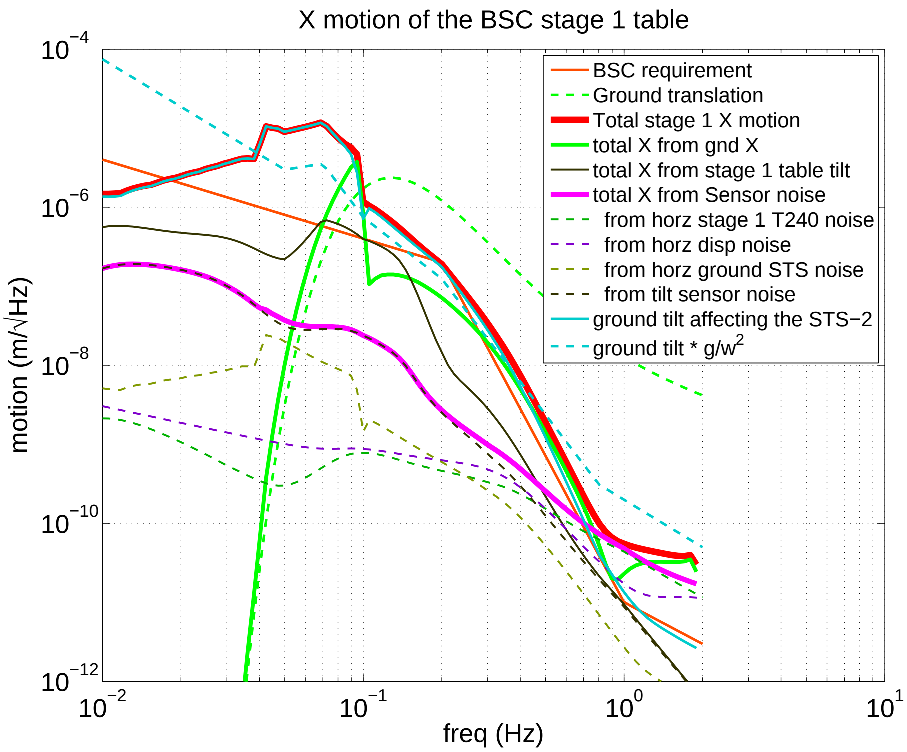

Figure 9: Estimated performance of stage 1 of the BSC-ISI in the X (horizontal, or beam) DOF. The thick red line is the total estimated motion, which looks pretty good (at or slightly above the requirement) at frequencies between 0.1 and 0.5 Hz.The magenta line is the motion caused by sensor noise, which is well below the requirements below 0.5 Hz. The table tilt coupling (dark brown) is pretty close to the requirements, too. However, The tilt of the ground on this windy day completely dominates the performance. The dashed blue curve shows what the STS-2 reads from the tilt, and the solid blue curve shows how the filtered STS-2 signal caused the platform to move too much below about 0.17 Hz. As we saw with HEPI, if we want good isolation in at the microseism, and it is windy, there will be a lot of motion below 0.1 Hz. This will be true until we can get either a good gyroscope or a auxiliary interferometers running between the tables.