Title:	Modeling and Simulation of a Spinning Spherical Test Mass for Modular Gravitational Reference Sensor
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Abstract

In a drag-free spacecraft, the spacecraft computer uses input from displacement sensors to fly at a constant distance from a free-floating test mass inside the spcaecraft. Optical sensors offer higher resolution and zero stiffness compared to capacitive sensors, but the small spot size makes them much more sensitive to test mass surface irregularities. Except for these residual geometric irregularities, the sphere is orientation invariant. Consequently, with a spherical test mass, we can eliminate electrostatic suspension for orientation control, which can cause unwanted forcing of the test mass. Spinning a sphere spectrally shifts the surface irregularities as well as the mass center offset from the geometric center out of the desired sensing band. Given that the outof-roundness and mass center offset of a sphere can be 105 larger than the desired resolution, special care must be taken to avoid aliasing spin frequency information into the science band. An analytical model for the output of a drag-free sensor using a spherical test mass including all first order contributions is developed. With this model, we evaluate systematic errors in the mass center measurement due to geometric variations which place requirements on spacecraft attitude and test mass dynamics. We also present a fast and reliable algorithm for recovering the mass center location and spin frequency of the test mass, in real-time, to picometer level from the sensor data. This algorithm involves fitting and removing the spin harmonics from the sensor output and uses the phase of the fitted harmonics to track the test mass spin frequency in real-time. A numerical simulation is developed to compared this algorithm to other possible data processing methods including a straight-forward tuned digital filter and a surface mapping algorithm. The computational complexity of each algorithm is analyzed since in there is limited CPU power on a satellite, and there is insufficient bandwidth for transmitting the data to the ground. The simulation can also be used to assess the performance of these algorithms as well as examine requirements on physical hardware systems such as sampling rates, quantization bits, and non-linearities.

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