SCIENCE FREQUENCY ANALYSIS OF TEMPERATURE SENSORS FOR THE LASER INTERFEROMETER SPACE ANTENNA (LISA)

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Introduction

The present experiment was designed to achieve high resolution temperature measurements for the LISA Pathfinder space mission, which aims to detect gravitational waves from massive black holes and galactic stars in the frequency range of 0.1 mHz to 1 Hz within our Galaxy, the Milky Way, and by massive black holes in distant galaxies. Temperature changes due to internal factors of the spacecraft as well as external phenomena can exert an influence on the highly sensitive gravitational waveform sensors onboard. The task of detecting temperature changes with high resolution, accuracy and precision is essential. In the same manner, it is of primary importance to identify the noise characteristics introduced by the sensors and their frequency content on the spacecraft spectrum.

Purpose and Hypothesis

Temperature sensing is required to measure temperature changes to an accuracy of three digits or higher (μK) and remove noise to levels in the order of pK. The ability to do this depends on the capacity of detecting and minimizing the noise floor of the signal. An apparatus was built for this purpose: a highly accurate sensor capable of detecting temperature increments at the level of the LISA requirements. Thermistors (temperature sensors) were connected in a Wheatstone bridge configuration to produce an electrical signal proportional to temperature variations. Efforts were made to isolate or minimize the source of electrical noise, reducing its influence over the measurements. Temperature data was collected, recorded and properly analyzed. An evaluation of the sensing and noise reduction achievements was completed, as well as suggestions for sensor design/construction of resistive sensors for the LISA mission.

Materials and Methods

Mechanical/electrical integration was optimized for noise reduction. Data from the sensor was processed, analyzed and displayed accordingly:

- **Electrical Design:** Wheatstone bridge with a small, common DC-current excitation to minimize self-heating. All components and software were commercially available. Design driven: high resolution, sensitivity, response time, small asynchronous fluctuations (random errors) and small systematic errors. Low pass filter incorporated to isolate harmonics from the power line, as well as any electrical noise outside of the spectrum of interest.

- **Mechanical Design:** PCB assembly integrated into aluminum chassis for EMI shielding.

- **Test:** Several 50/72 hr. tests were conducted to identify the apparatus' capabilities and performance in terms of voltage noise.

- **Calibration:** Two-part: (a) high sensitive/ high dynamic range thermocouple sensor (0.55 mK resolution) used to establish a coarse reading of the temperature of the test plate and (b) cross calibration among the four thermistor sensors to establish stability resolution. Curve fitting with the least-squares regression method.

Conclusions

The active excitation (TEC) of the system was necessary for calibration. The curve fitting method was used for the temperature estimation. The results of this experiment show that the nature of the data may make it necessary to use different estimation models for different types of data. The curve fitting method utilized to estimate temperature has the advantage of providing a continuous calibration. Thermistors perform with high accuracy and stability. Uncertainties cannot be eliminated from measurements but at best, only minimized. Signal to noise ratio (S/N) was optimized with an adequate balance of thermistor values, low bandwidth amplifiers (U1) and signal booster/voltage follower (U2) (software used: Multisim from Electronics Workbench).

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Bibliography

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http://lisa.pl.nasa.gov/