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A Comprehensive Overview of Gravity Measurement Utilizing a SQUID

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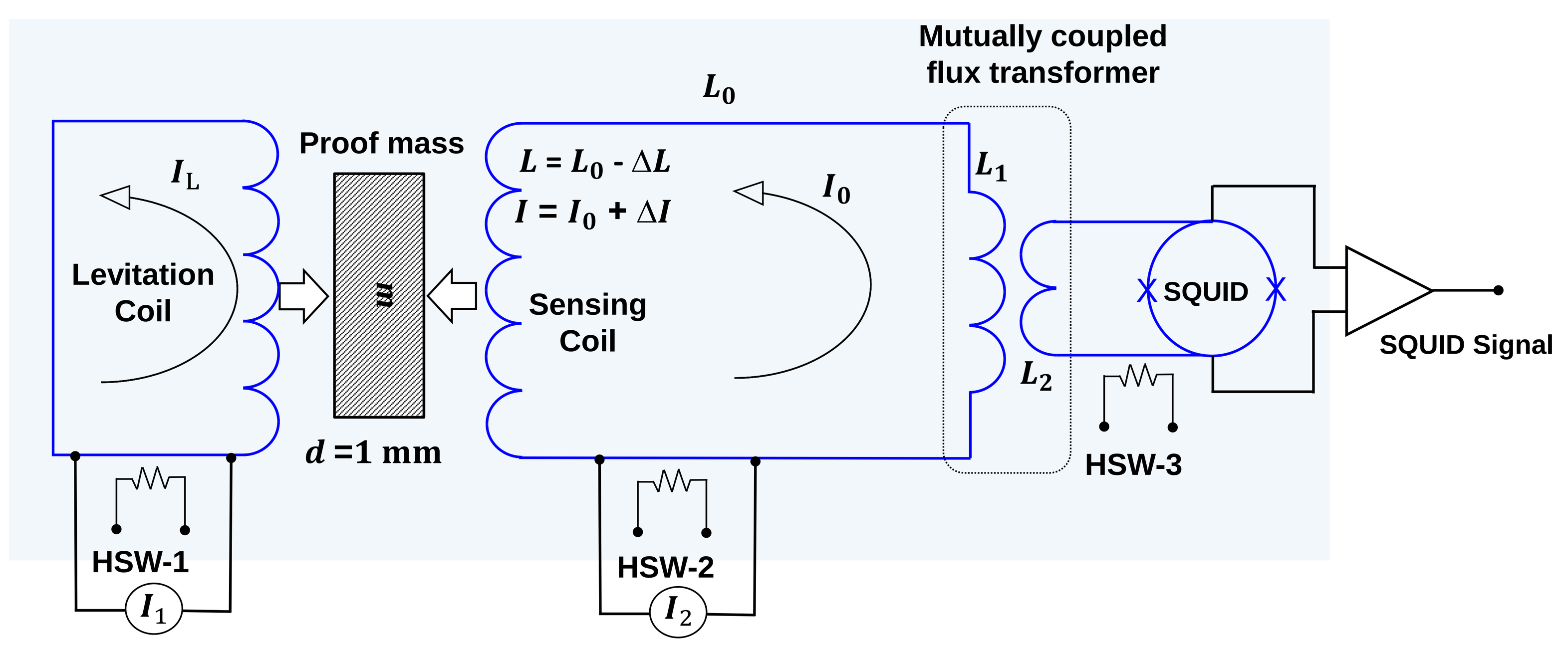
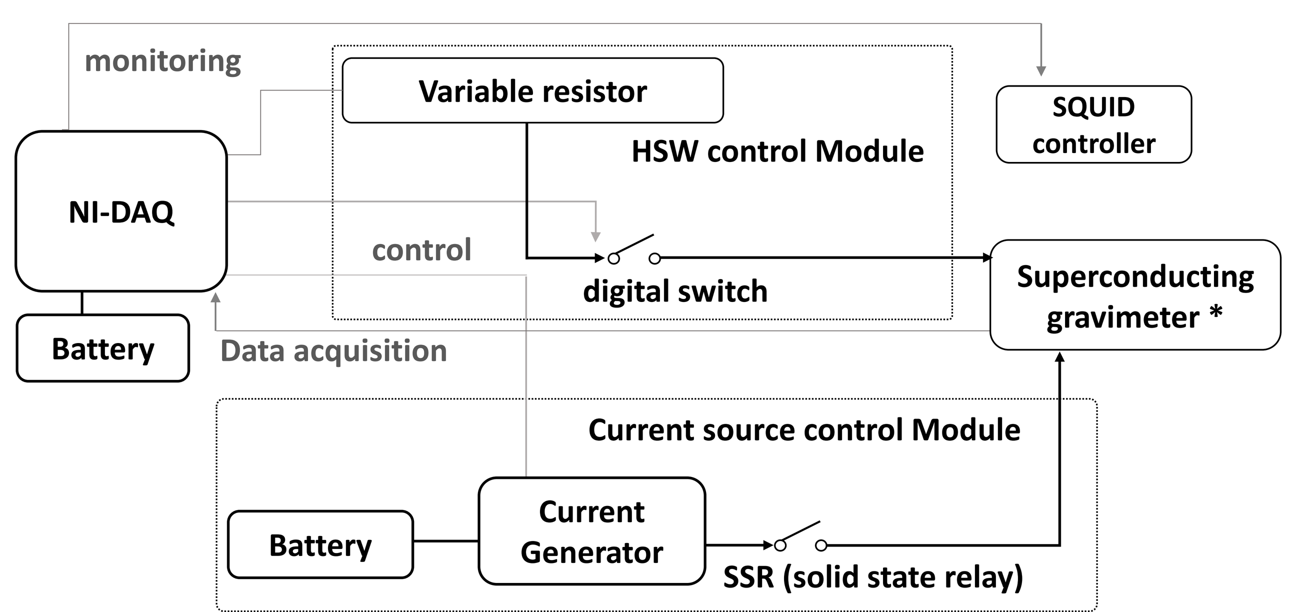
In this study, we present a comprehensive overview of gravity measurement method utilizing SQUID (Superconducting QUantum Interference Device) at cryogenic temperatures, along with the associated equipment. The measurement of gravity is an exceptionally delicate process, susceptible to real-time changes influenced by environmental factors. Therefore, a highly stable and high-resolution measurement system is crucial. To dachieve stable measurements at cryogenic temperatures, we engineered a magnetically shielded liquid helium cryostat. Meticulously designed to ensure optimal magnetic shielding through a superconducting magnetic shield, this cryostat exhibits remarkably high efficiency in maintaining a cryogenic liquid reservoir. Due to the low value of the first critical field (Hc1) of niobium, the cryostat is enveloped by traditional high-permeability materials, μ-metal, serving as the primary shielding within the external housing. A superconducting gravimeter is a device designed to detect minute displacements of a proof mass levitated in a superconducting environment, responding to changes in gravity. The proof mass in the superconducting gravimeter module, uniquely developed by KRISS, is levitated through electromagnetic force, with the current in the levitation coil set to persistent mode. We demonstrate the equilibrium position of the levitated proof mass by evaluating the change in the coil inductance. Additionally, we discuss the gravimeter and its superconducting circuits, presenting preliminary results from Earth Tides measurements.* **mookin@kriss.re.kr**

SQUID based Superconducting Gravimeter (SSG)

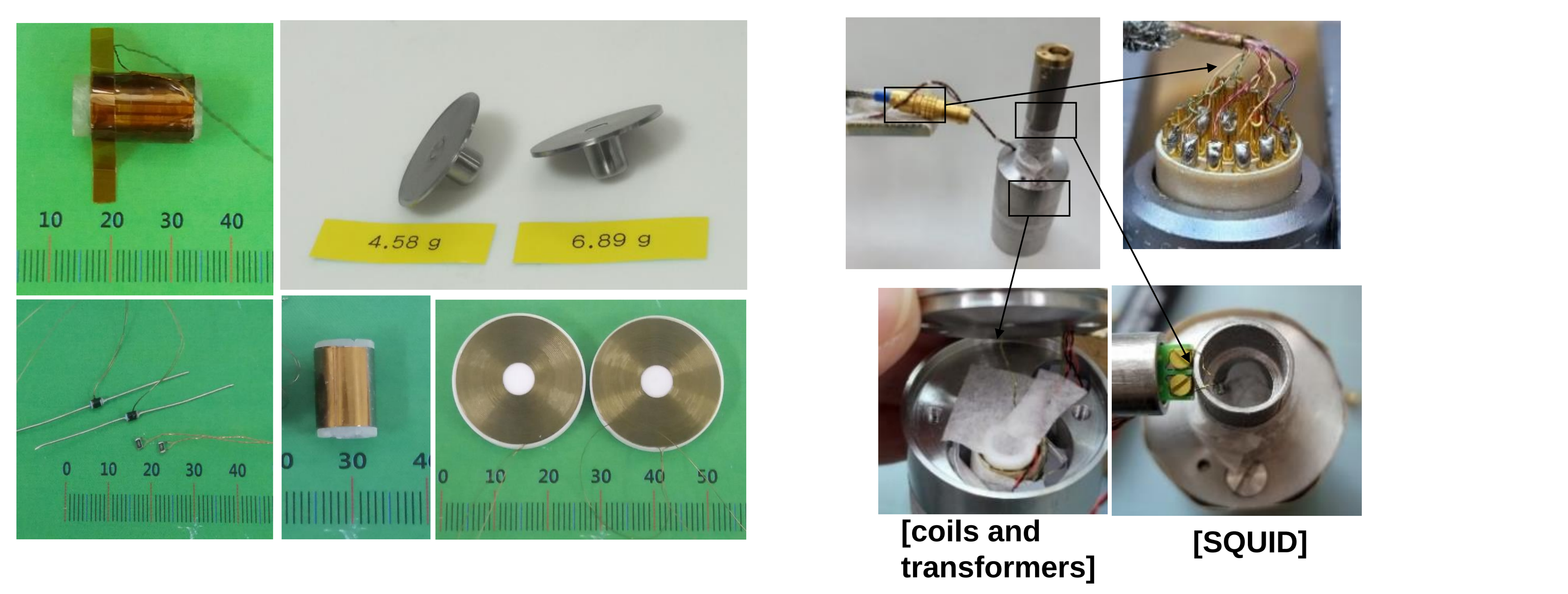
- **Schematic diagram of the SSG**

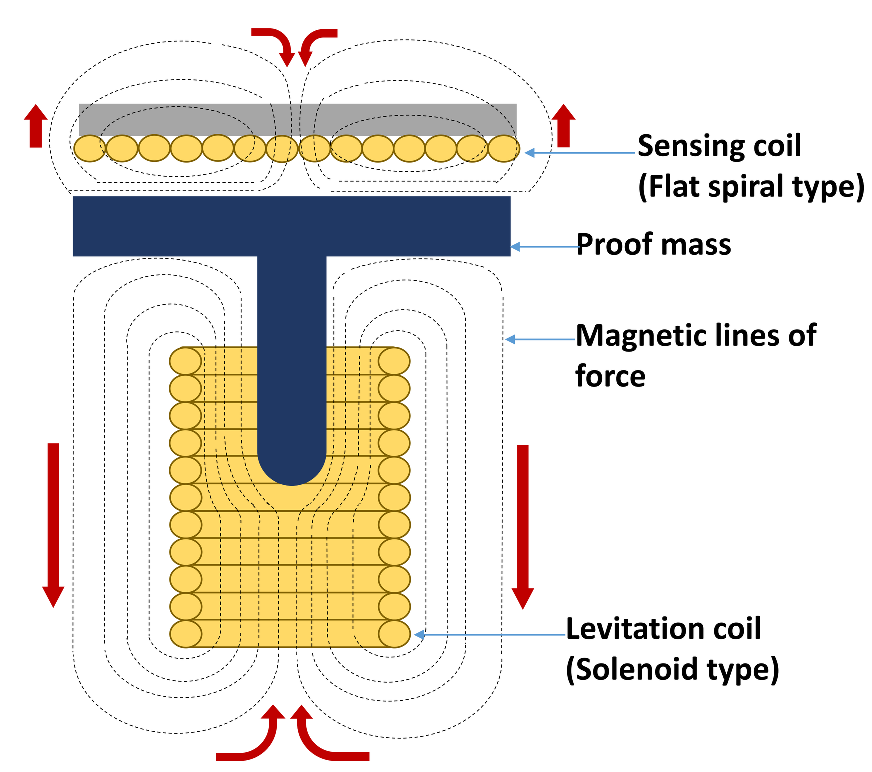


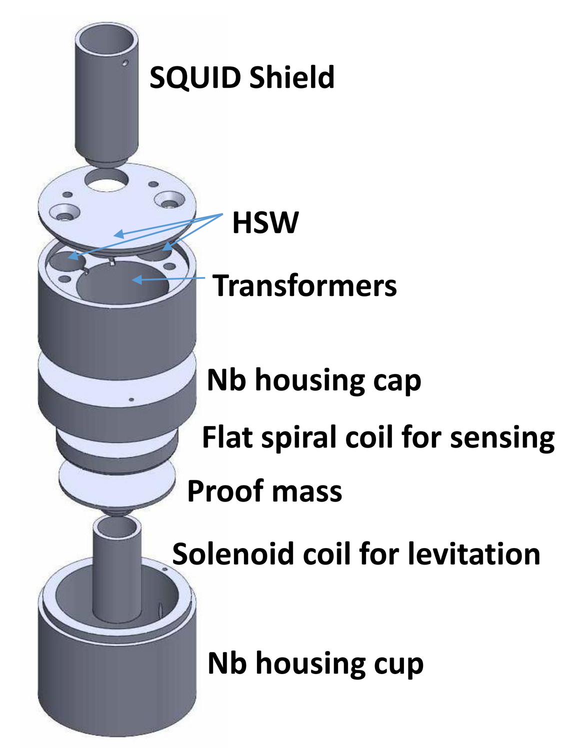
- **Schematic diagram of electronics for SSG**



- **Design of the SSG measuring apparatus and superconducting housing**

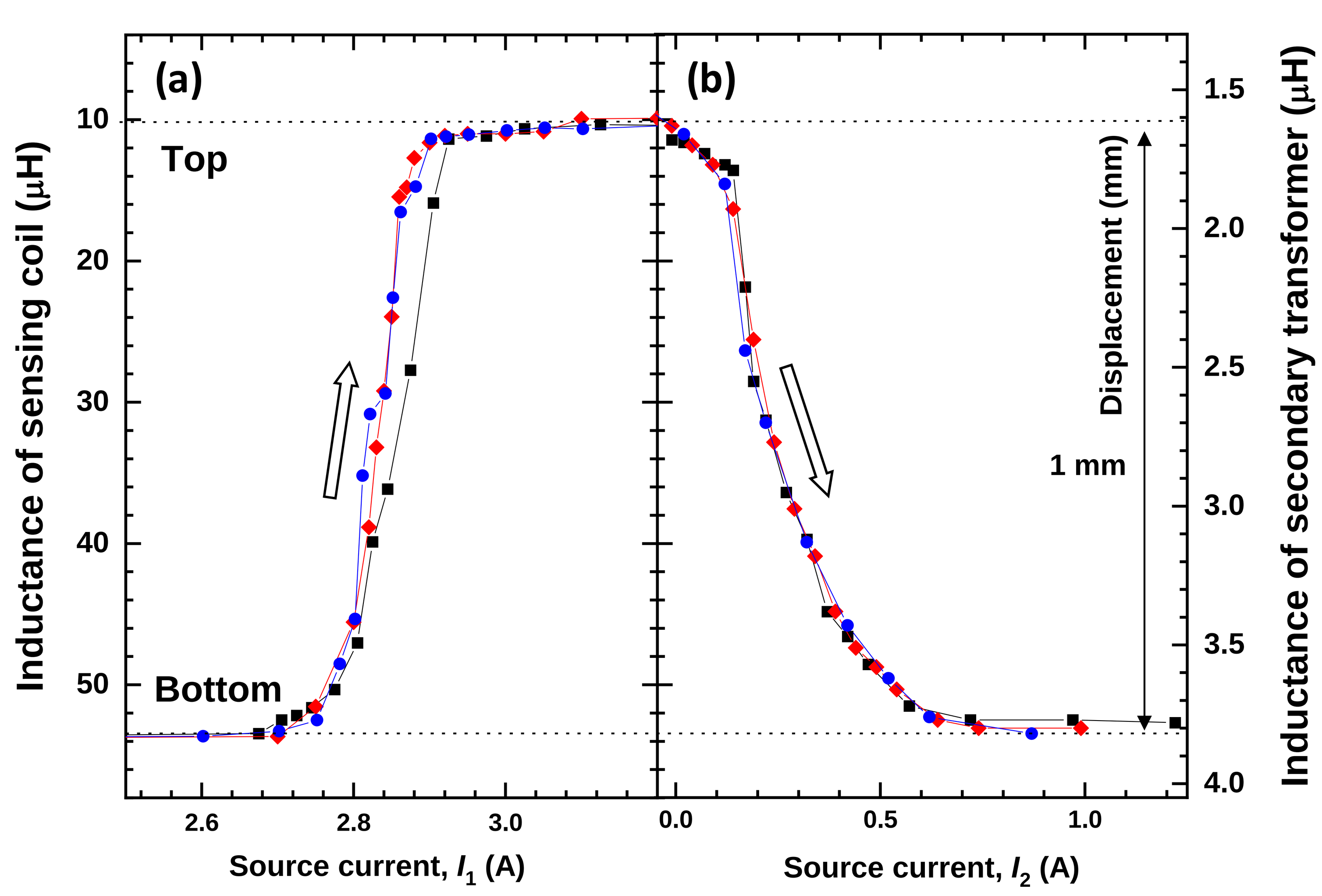


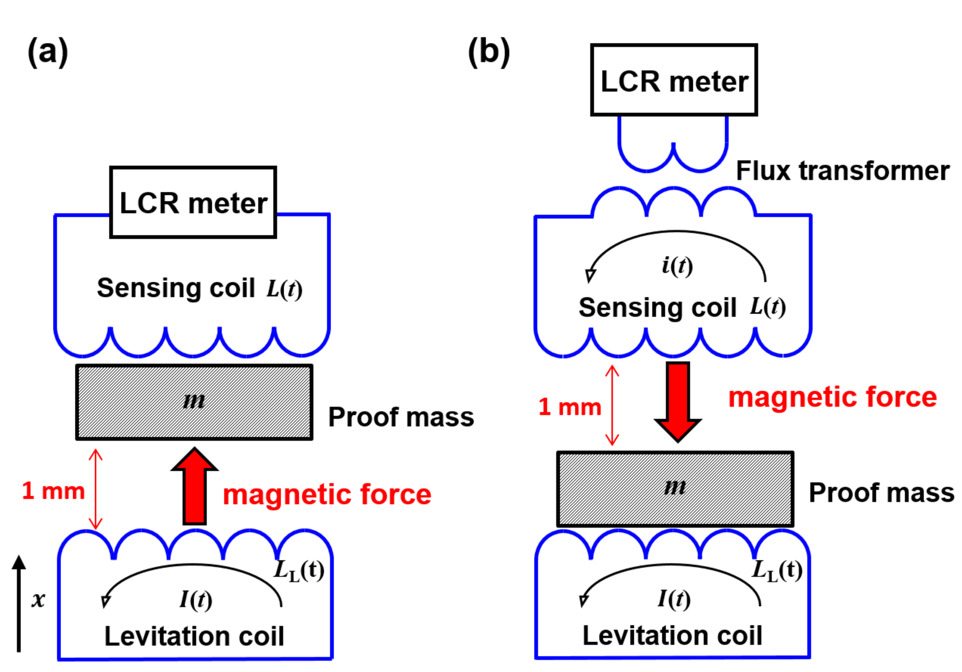




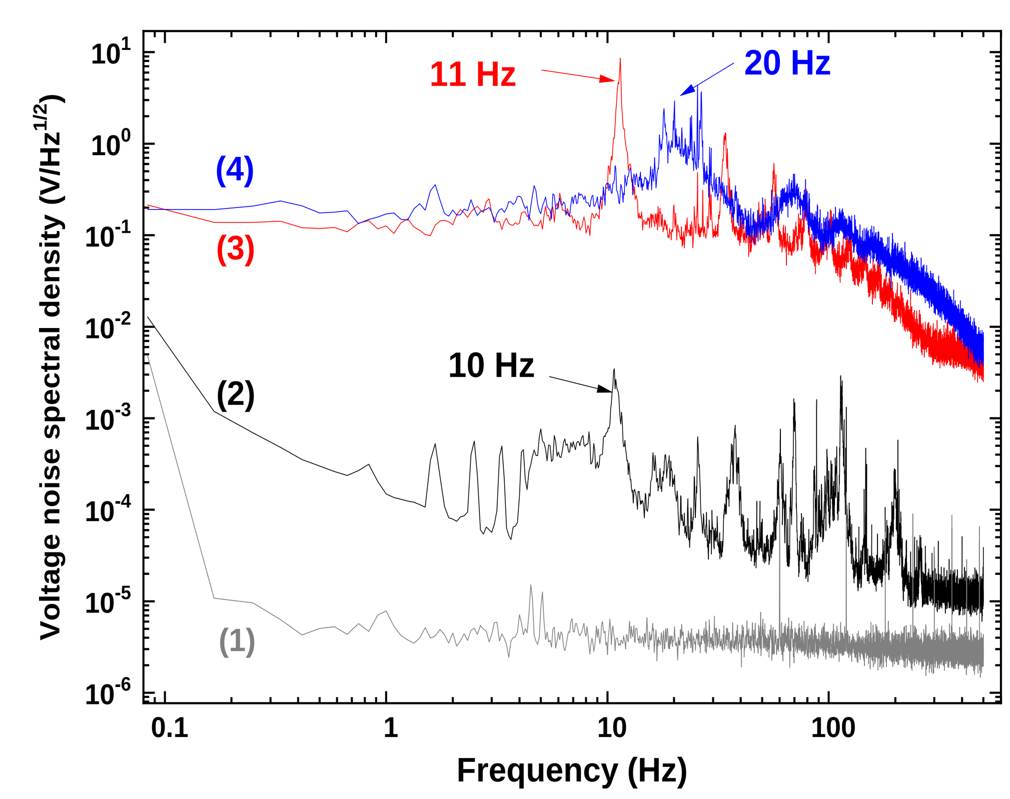
Results and Discussion

(a) Characteristics of the inductance values in the sensing coil
(b) Characteristics of the inductance values in the secondary transformer





- **Flux noise spectra of the levitated proof mass**



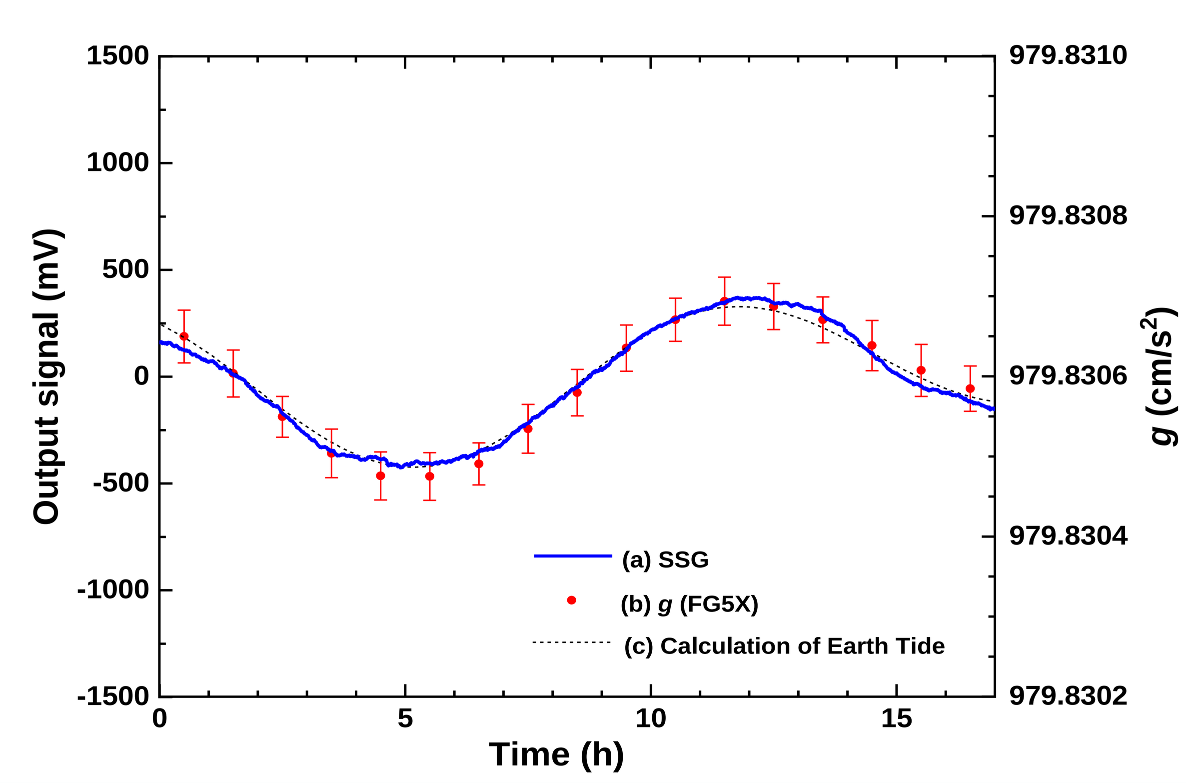
- **Transfer function:**

$$H_{gj}(\omega) \propto \frac{1}{\omega_0^2 - \omega^2}\frac{\Lambda}{L_1 + L_0} i$$

where,

$$\omega_0^2 = \frac{\Lambda^2 i^2}{m(L_1 + L_0)} + \frac{\Lambda_L^2 I^2}{m L_{L0}}$$

- **Comparison of the survey spectrum of gravity for 16 hours**



Summary

We designed and fabricated a SQUID-based highly sensitive gravity detection technique, which represents an intermediate stage of our ongoing SQUID-based gravimeter project. This technique involves levitating a proof mass using magnetic force and a self-centering structure. In a levitation experiment, we measure the inductance for sensing via a solenoid-type levitation coil. We also measure the displacement of the proof mass by injecting current into the solenoid and sensing coils. This displacement measurement is achieved through the inductance of a secondary coil within the flux transformer. From the experimental outcomes, we derive the initial flux values at the equilibrium position of the proof mass. Once we integrate the SQUID into the superconducting circuit, we gain the capability to monitor the movement of the proof mass. Upon optimizing the initial set values of the charged magnetic flux, we successfully measure the resonance frequency of the accelerometer. The results of our study not only confirm the feasibility of this approach but also identify certain challenges that will guide our next research step — developing a SQUID-based gravimeter.