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Enhancing Vibrotactile Feedback Clarity with Resonant Beam-Structured Sensor Mount in a Leader-Follower Robot System

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***Abstract*—In teleoperated robots, vibrotactile feedback from the robot's chassis can convey subtle information beyond vision or force feedback. However, self-generated vibration noise (ego-noise) degrades tactile clarity. This study proposes a method to enhance the signal-to-noise ratio (SNR) by using mechanical resonance amplification, using a beam-structured sensor mount combined with a perceptual intensity-based conversion method.**

***Index Terms*—Teleoperation, Ego-noise suppression, Vibrotactile feedback**

I. Introduction

Vibration feedback based on vibration sensing of robot's chassis provides subtle information not captured by visual or force-based feedback. However, ego-noise—vibrations generated by the robot's own motion often mask meaningful feedback. Our idea is to amplify the frequency range outside the ego-noise band, where the SNR is relatively high. Our approach is based on the idea that a specific frequency band can preserve the original contact information. However, conventional software-based filtering struggles with real-time processing, especially with noisy signals. To address this, we propose a beam-structured vibration sensor mount combined with human perception-based signal processing for clear tactile feedback.

II. Method

A. Beam-Structured Sensor Mount

To improve the SNR of vibrotactile feedback, we designed a sensor mount using a beam structure. This mount mechanically amplifies vibrations in a specific frequency range by exploiting structural resonance. The resonance frequency is tuned to match the frequency band where ego-noise is relatively low, thus improving the SNR at the hardware level by emphasizing informative vibrations.

B. Intensity Segment Modulation(ISM)

While mechanical amplification improves the physical signal, the resonant frequency may not always lie within the human-sensitive frequency range. To address this, we apply Intensity-based Sensory Modulation (ISM), which transforms the amplified high-frequency signal into an amplitude-modulated waveform centered on a frequency that is more perceptible to human skin [1]. This ensures that the operator can perceive the enhanced signal more clearly.

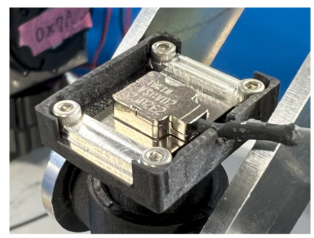

Fig. 1. Beam-structured sensor mount.

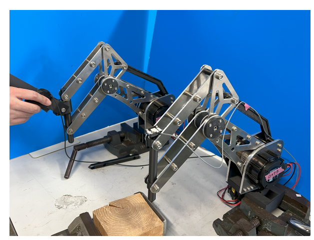

Fig. 2. Demonstration setup.

III. Demonstration

We applied the beam-structured sensor mount to a 3-DoF leader-follower robot, attaching it to the robot's chassis. In a demonstration, you can feel force and vibration while clearly emphasizing the tactile information.

References

[1] K. Yamaguchi, M. Konyo, and S. Tadokoro, "Sensory equivalence conversion of high-frequency vibrotactile signals using intensity segment modulation method for enhancing audiovisual experience," in *Proc. IEEE World Haptics Conf. (WHC)*, 2021, pp. 674–679.