北京科技大学自动化学院
School Of Automation And Electrical Engineering
1959

Development of an Autonomous Flapping-Wing Aerial Vehicle

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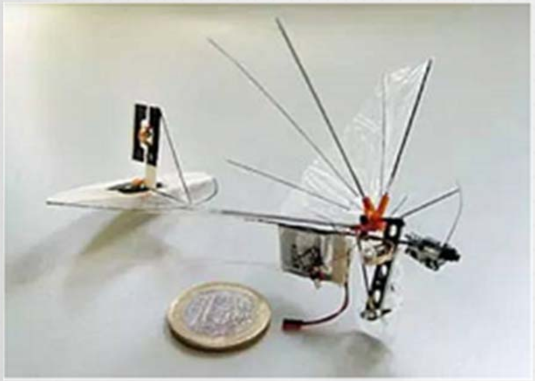
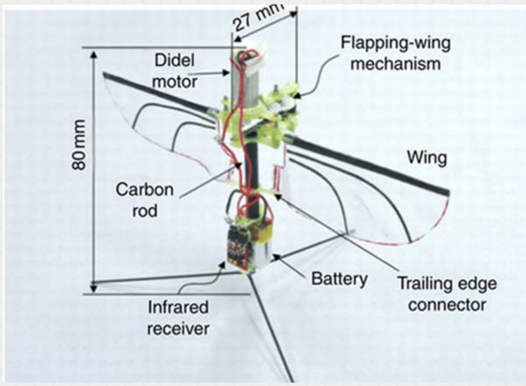
1 Introduction

Festo-SmartBird

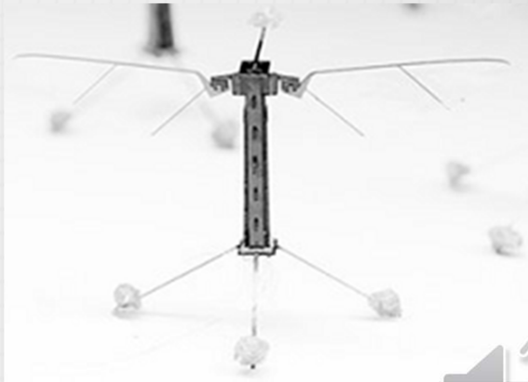
H2bird



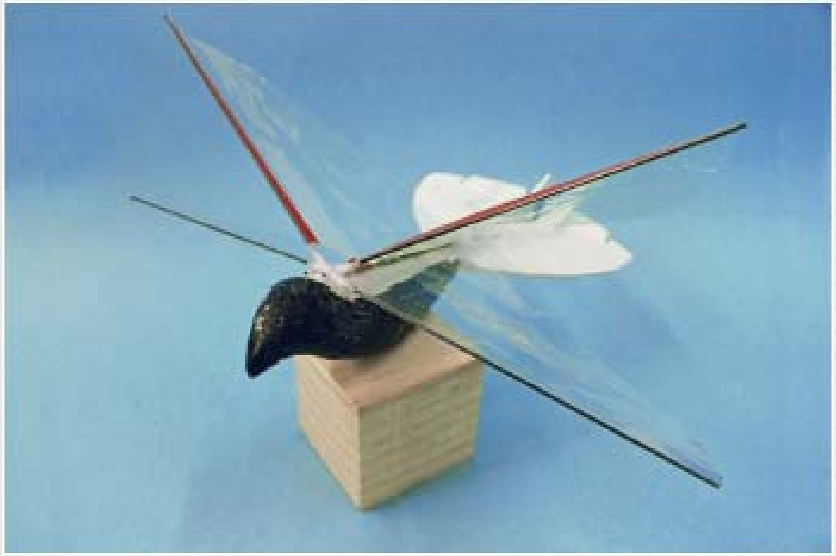
Delfly



FWAV of Konkuk University



1 Introduction

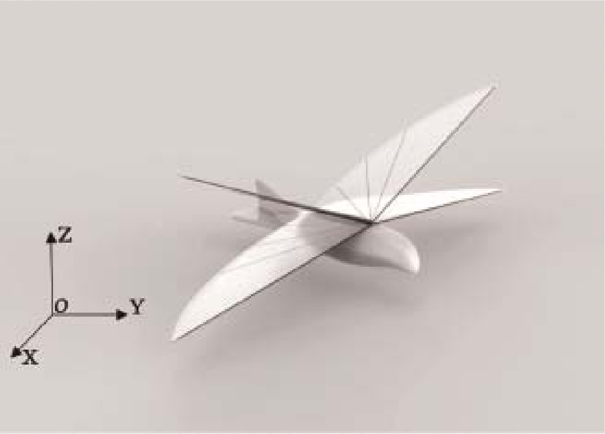


We design an FWAV with a weight of 14.1g and X-wing span of 20cm.

To achieve autonomous height keeping flight of the FWAV, we adopt an external vision-based localization system as an altitude sensor.

2

FWAV Platform

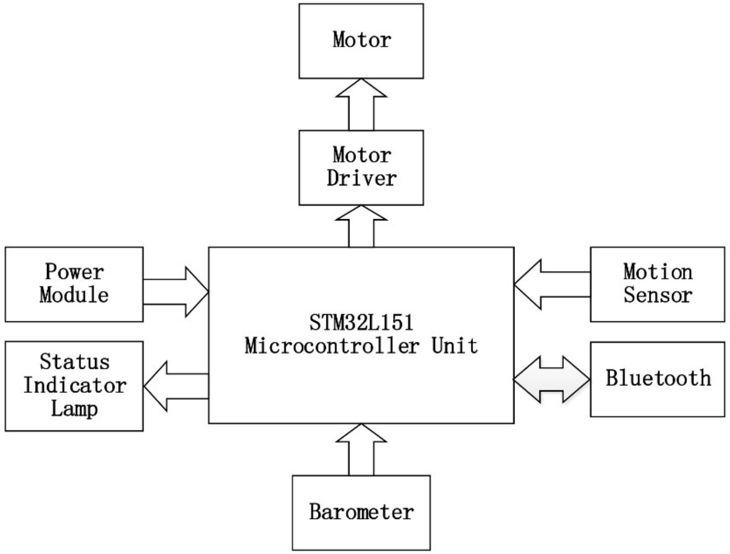


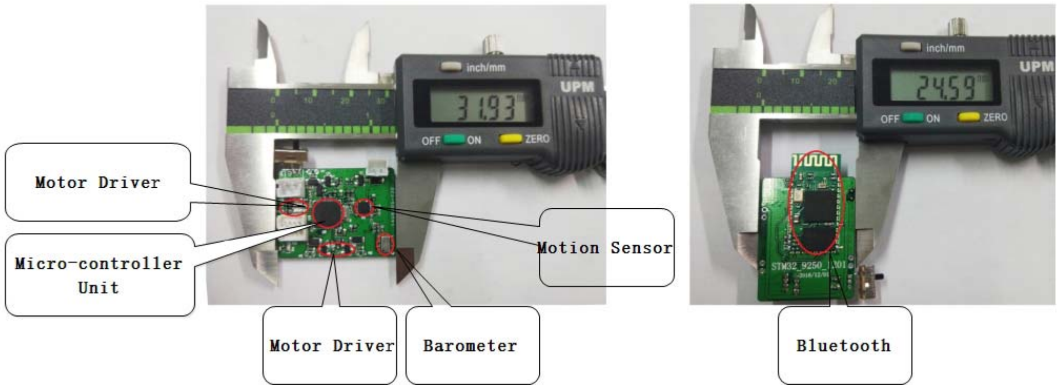
FWAVs with X-wing has lower power requirement compared to FWAVs with a single pair of wings or two wings in tandem and it gives minimal rocking amplitude, therefore the FWAV model in our work is equipped with X-wing configuration.

- **We design a circuit board with a 32 bit STM32L151 micro-processor to control the flight of the FWAV.**
- **Limited by the constraints of mass and size, its PCB is designed as small as a coin.**

FWAV Platform

The components and communication of the circuit board.





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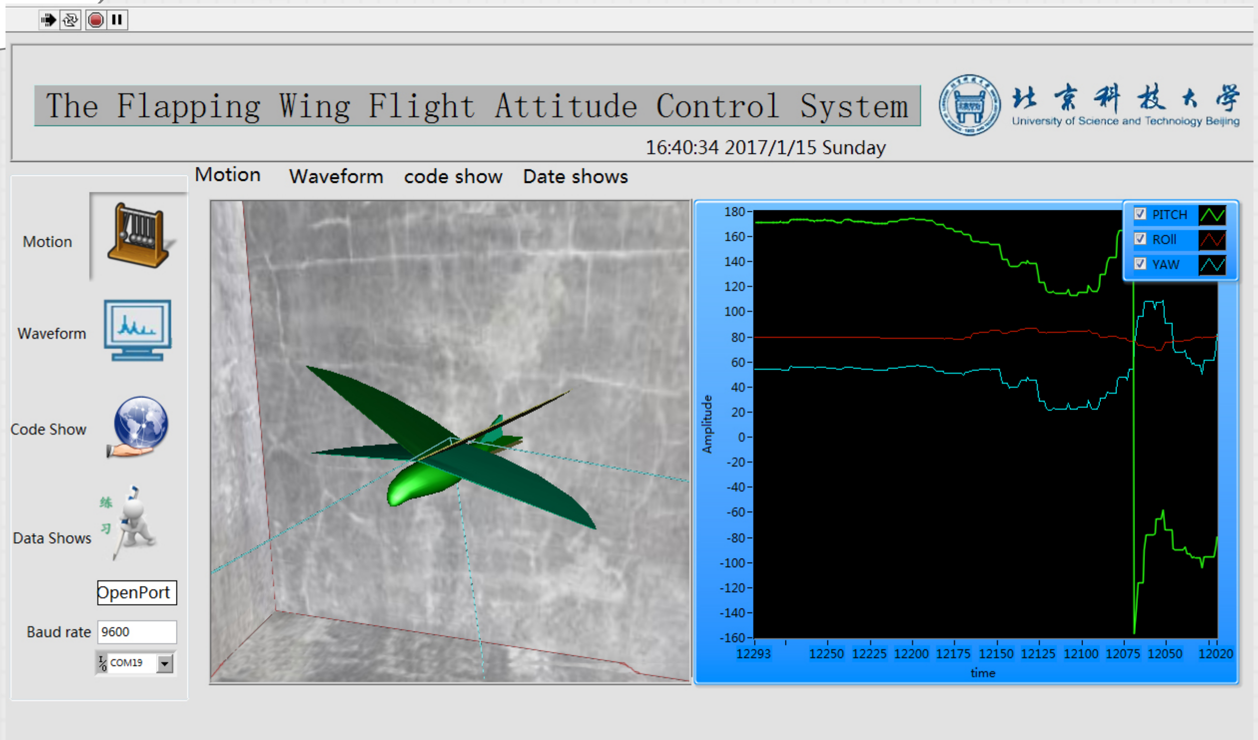
FWAV Platform



The visualization plug-ins can display a 3D modeling and receive real-time data such as sensor output, quaternion and Euler angle after operation, motor output state estimation and control input signal through the Bluetooth.

3 Control Design

- **The dynamics of FWAV about attitude and position control is described by the following equation:**

$$M(q)\ddot{q} + C(q,\dot{q})q + G = R(q)u_c(t) + d(t) \quad (1)$$

- **We just take consideration of the position and the equation can be described as:**

$$M_t(q_t)\ddot{q}_t + G_t + d_t(t) = R^{IB}(q_r)u_t \quad (2)$$

- **The model-based controller is proposed as:**

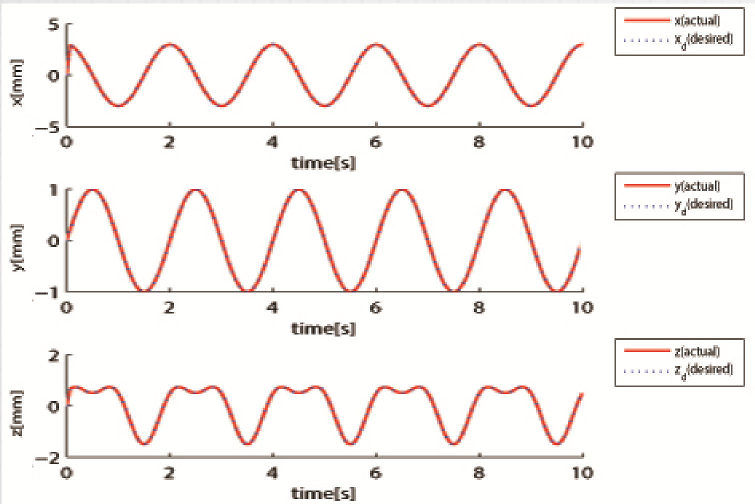
$$u_t = (R^{IB}(q_r))^{-1}[-z_{ti} - K_2 z_{t2} - sgn\left(z_{t2}^T\right)\bar{d}_t(t) + G_t + M_t\dot{\alpha}_{t1}] \quad (3)$$

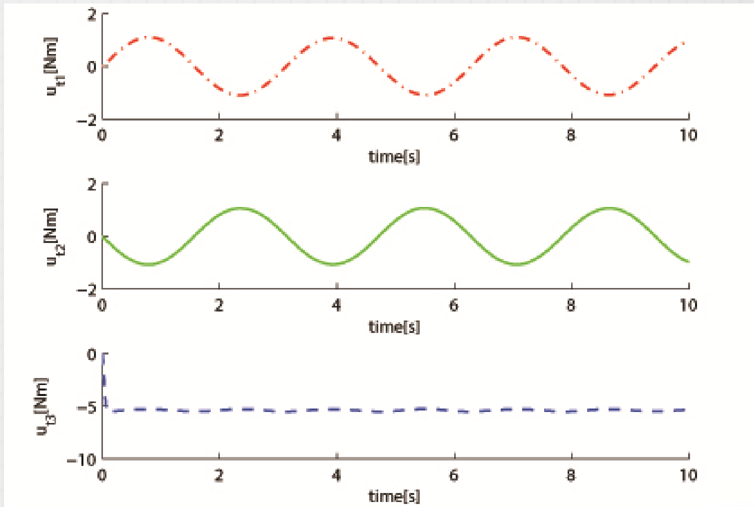
3 Control Design
-MATLAB Simulation

We set the desired trajectories of x_{t1} as follows:

$$\begin{cases} x_d = 3\cos(\pi t) \\ y_d = \sin(\pi t) \\ z_d = \sin(\pi t) + 0.5\cos(2\pi t) \end{cases}$$

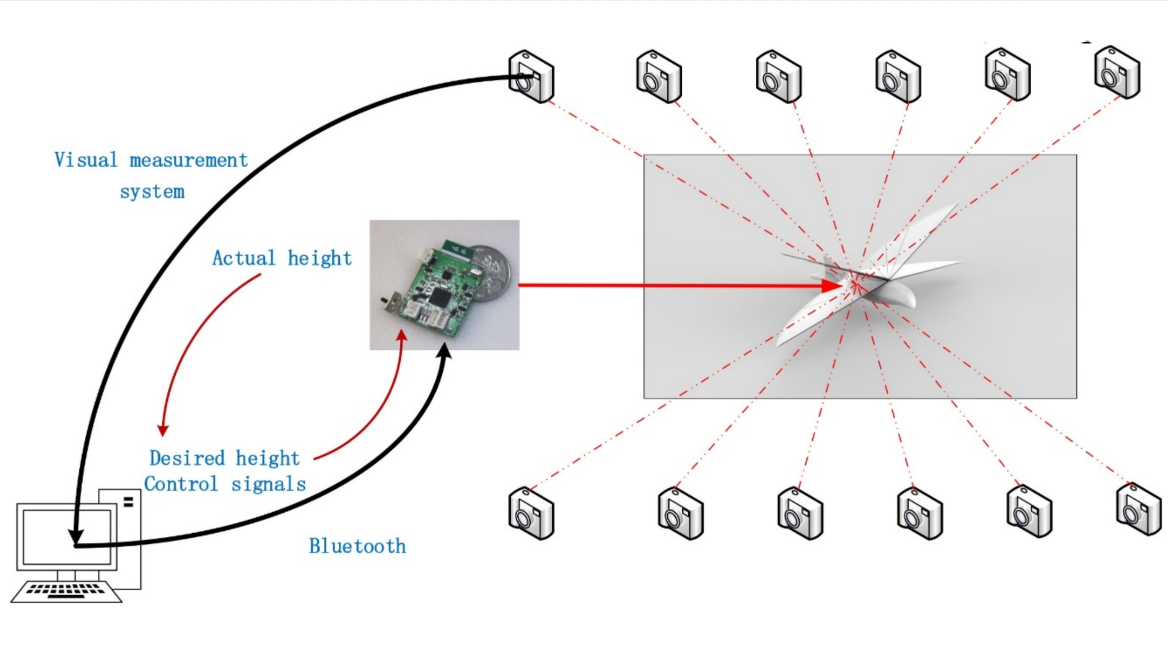
And the simulation results are:





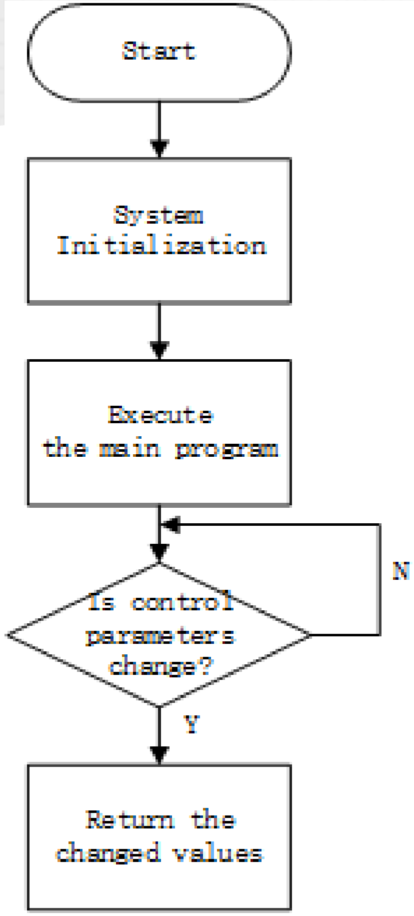
4 Experiment

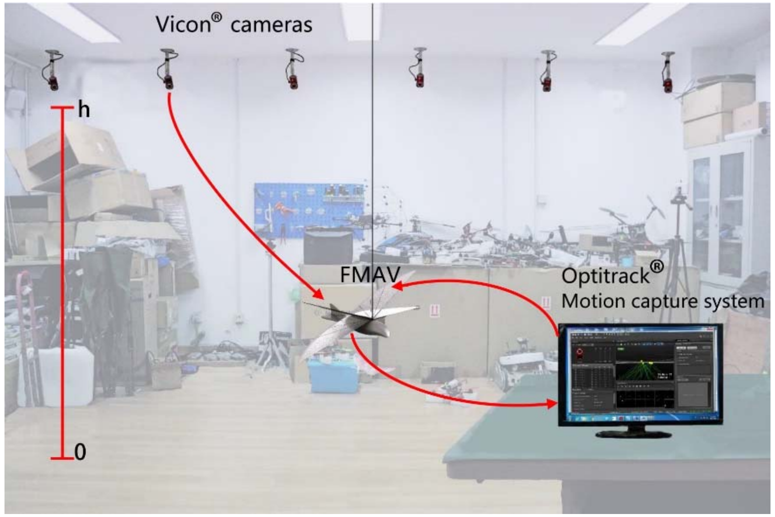
- To verify the effectiveness of our developed FWAV platform, an indoor flight test is conducted on the FMAV.
- The Bluetooth is used to communicate with the external vision-based localization system and the control board of FMAV.



Architecture of the FWAV platform

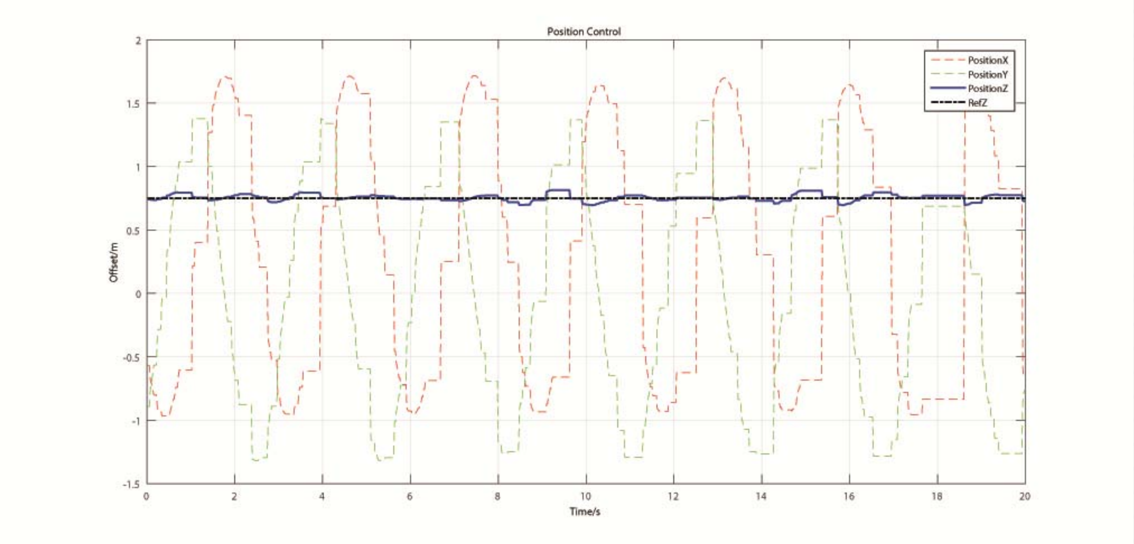
4 Experiment
-Flow chart of program





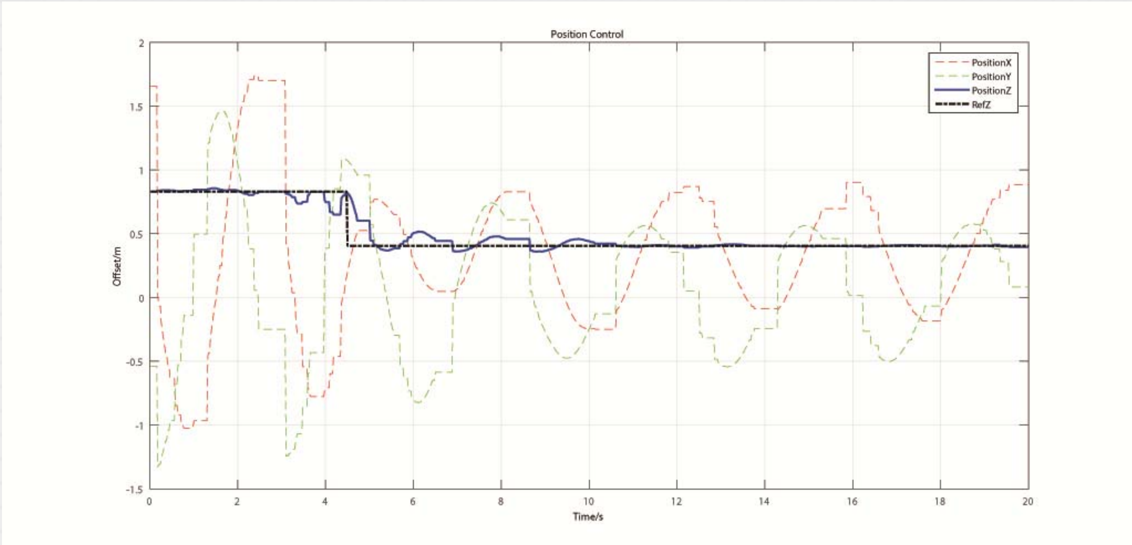
The vision-based localization system we used as an altitude sensor is from Canada named optitrack. We put three marks on the bird's body which can be identified by 12 cameras and return the location information to the computer.

4 Experiment



We only control the position z, that is height keeping flight of FMAV. In this figure, the red and green dash lines represent the x and y position, respectively. It can be observed that they change periodically since the FWAV is hovering in the space.
The blue line is the position z. The black dot and dash line is the setting altitude $z_d = 0.75m$. Within $20s$, the actual altitude coincides the setting values well with the acceptable fluctuations.

4 Experiment



Furthermore, there is a step signal of setting height z_d that change from $0.83m$ to $0.4m$ at $4.5s$. The actual height Z reaches the set point within $0.6s$, and it gets smoothly and steadily at $t = 10.5s$.

4 Experiment

5

Conclusion

✓An FWAV platform is developed.
✓A model-based control law is given theoretically.
✓Experiment on the height keeping flight control of the FWAV through PID shows a good performance.

Future work

✓Focus on adopting more advanced control algorithm such as adaptive neural network control .
✓Try to control not only the position but also the attitude of the FWAV.
✓Vibration control is also one of the issues we are considering in future.

Thank you!

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