Measurement Accuracy on Indoor Positioning System Using SS Ultrasonic Waves for Drone Applications

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Resume

Tatsuki Okada

- Educational Background
  - Iwate Prefectural University , Iwate , Japan
    - Apr 2016 – Mar 2020: Faculty of Software and Information Science
    - Apr 2020 – present : Graduate school of Software and Information Science
- Field of study
  - Robotic systems
  - Sensor

Background

- As unmanned aerial vehicles (UAV) , drone can take off and land vertically in small spaces.

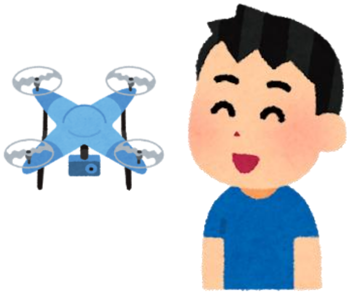
- Example

Outdoors

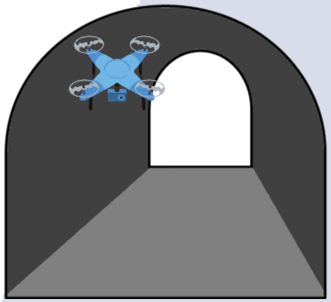
Autonomous search and rescue operations

Logistics

Indoors

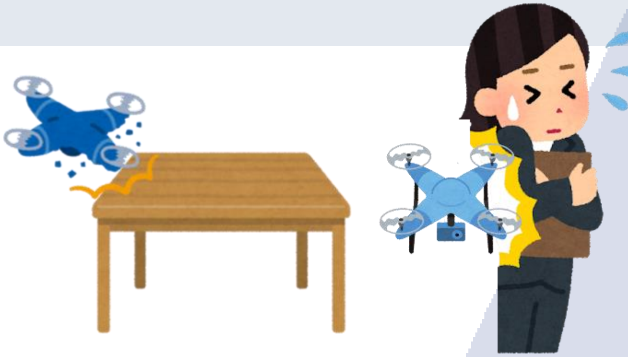


Communication robots



Inspections to detect aging degradation

Background



It is more dangerous to use drones indoors than outdoors.

It is essential to determine the absolute coordinates in space of the drone in relation to other objects.

- GNSS signal is difficult to detect indoors.
- In Simultaneous localization and mapping (SLAM) cause large errors.
  - The flight path of routine inspections is often in a dark place.
  - The walls do not always follow a uniform pattern.

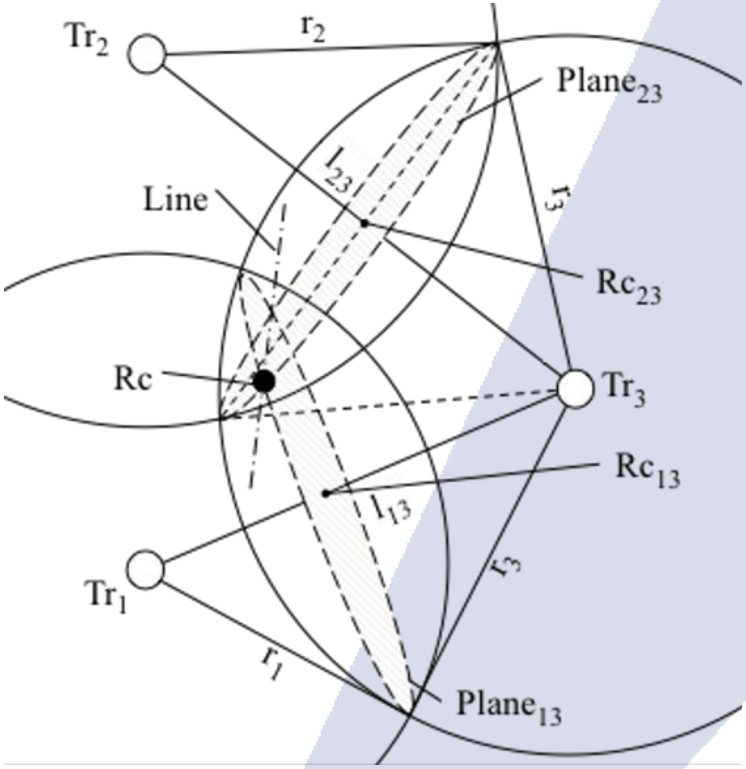
Propose

- We develop an indoor positioning system for drones to obtain 3D coordinates in areas where SLAM is not available.
  - We use spread spectrum (SS) ultrasonic waves, which are expected to acquire 3D coordinates with an accuracy of 10 cm.
  - However, noise from the propellers or downwash of a drone may lower this accuracy.

This study conducts an experiment to evaluate the positioning accuracy of drone flights during a periodic inspection.

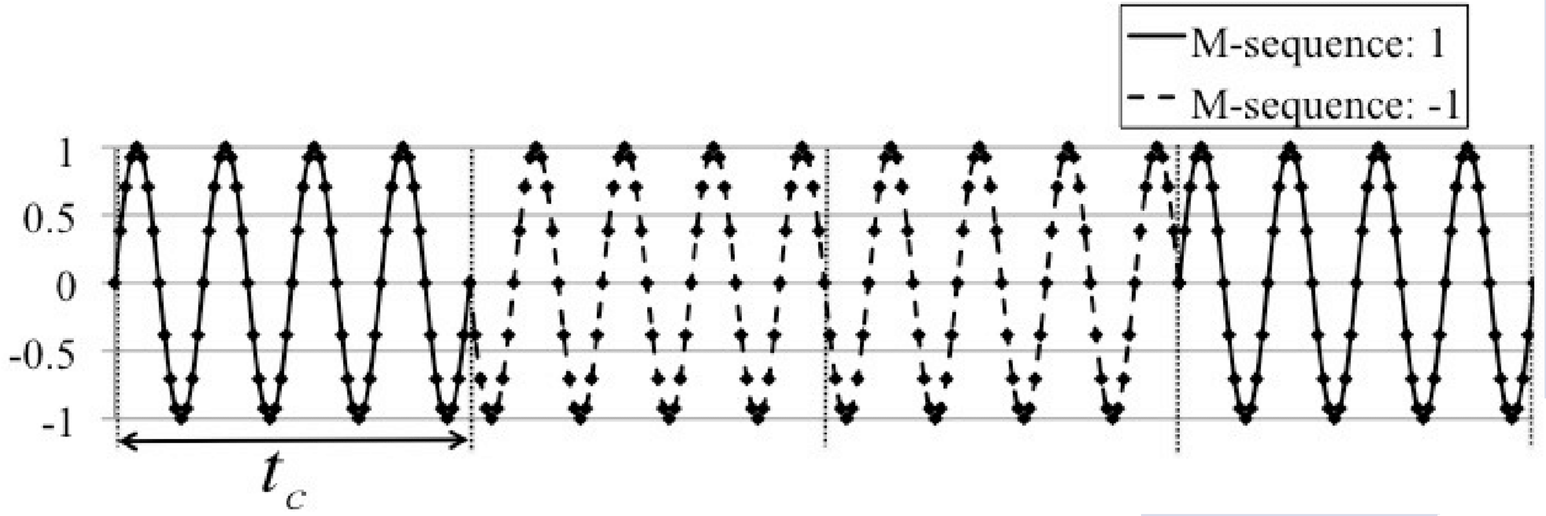
A method for positional calculation

1. Distance (r_1,r_2, r_3) between the receiver Rc and each transmitter are obtained.
2. Three spheres whose radius is (r_1,r_2,r_3) are generated.
3. The planes ($Plane_{23}, Plane_{13}$) from the pairs of Tr_1 and Tr_3, and Tr_2 and Tr_3 are solved by simultaneous equations.
4. Line of intersection is obtained from the two planes.
5. The Two points at the intersection of the line with an equation of an arbitrary sphere are solved.
6. One solution becomes outside of the room. The other solution is the position Rc of the receiver.

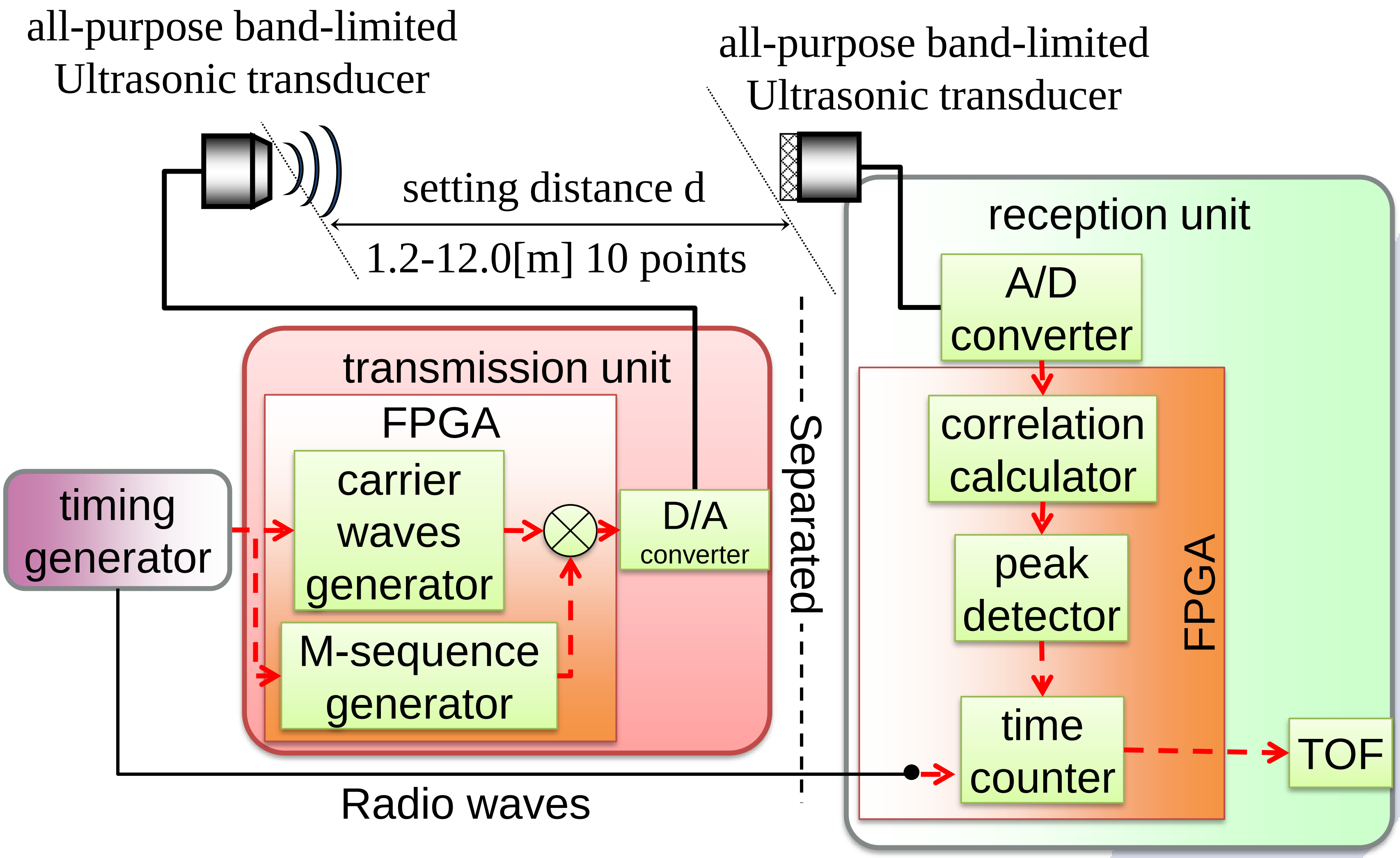


SS signal

- The SS signal is modulated by binary phase shift keying.
  - M-sequence
    - A pseudorandom code sequence, with a direct sequence method.
  - $t_c = 4/f$ (t_c is defined as the time required to describe 1-chip of the M-sequence , f is carrier frequency.)
  - The length of SS ultrasonic signals becomes $2^9 - 1 = 511$ [chip] due to a 9-bit shift register for the M-sequence.

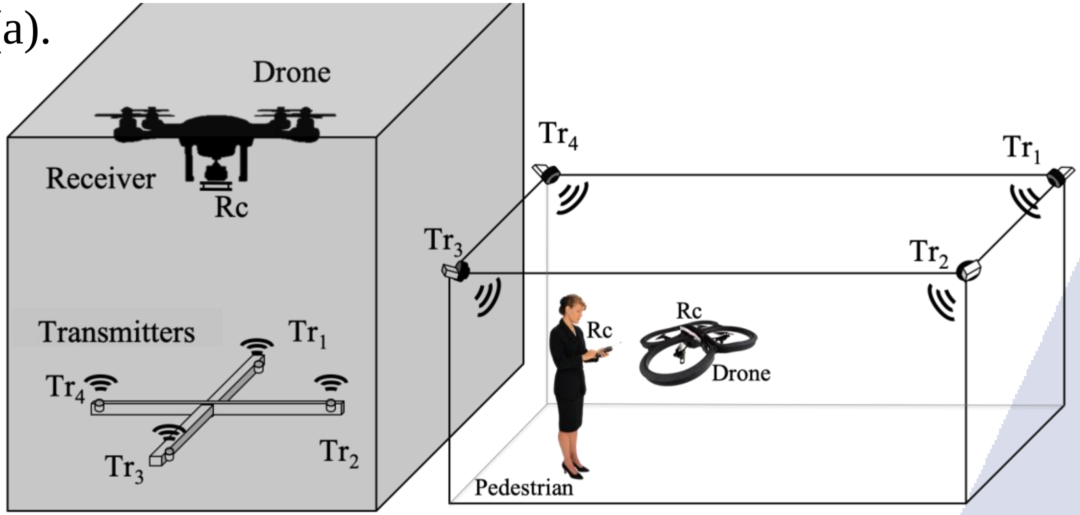


Hardware structure of a positioning system using SS ultrasonic waves



Our proposed indoor positioning system

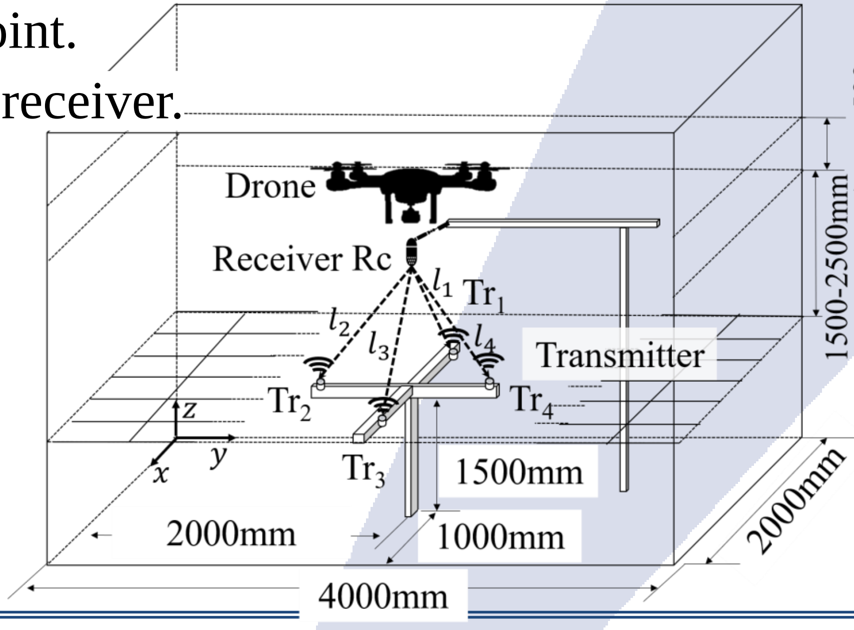
- The figure below shows the layout of the transmitter and receiver.
  - (a): A periodical inspection at a plant.
  - (b): A communication drone.
- (a) has the transmitter mounted on a cross-shapes. (b) is mounted in four corners of a room.
  - In (a), considering the Dilution Of Precision (DOP), the larger the mount size, the more accurate the expected positioning accuracy.
  - In (b), the transmitters are more difficult to install, but DOP is better than the situation in (a).



(a) Situation for a dark plant (b) Situation for a room

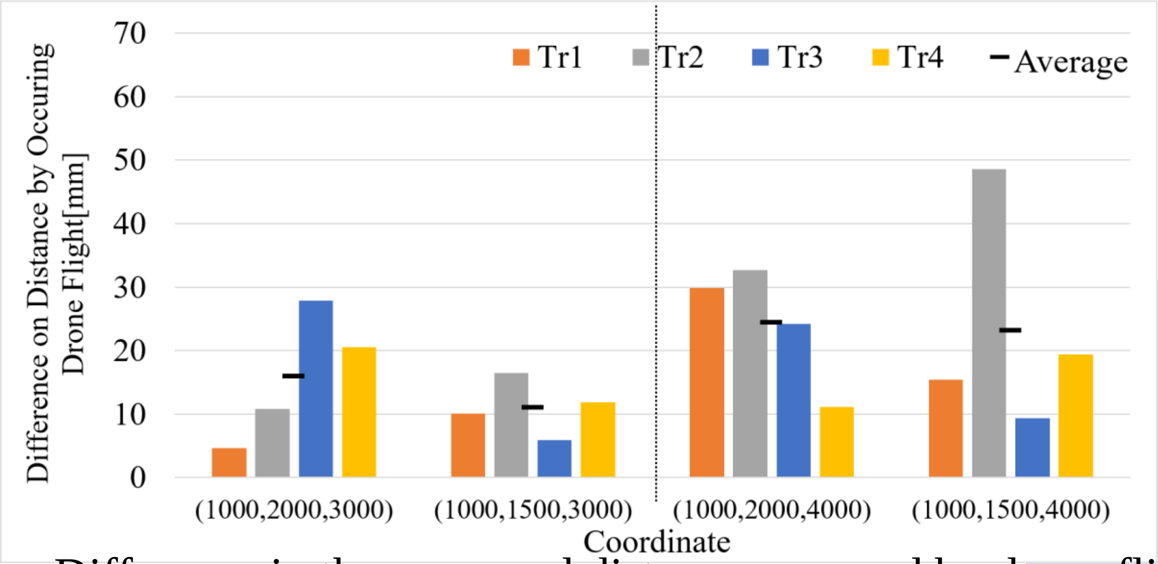
Positioning error by drone noise and downwash

- Purpose: To evaluate the effects of motor noise, wind noise, and downwash generated by the propeller during flight with SS ultrasonic positioning.
- The environment used for this experiment.
  - A room is 2000mm long and 4000mm wide.
  - Four transmitters Tr1–Tr4 were place.
    $Tr_1[mm] = (500,2000,1500)$ $Tr_2[mm] = (1000,1500,1500)$
    $Tr_3[mm] = (1500,2000,1500)$ $Tr_4[mm] = (1000,2500,1500)$
  - $l_1 - l_4$, are measured for each receiving point.
  - The drone hovers about 500mm above the receiver.
  - Video during the experiment: https://youtu.be/_LmJQrC1Wdw



Measurement error in distance

- The results of the experiment show that all measured distances are obtained when the drone is flying.
- A greater distance between the transmitter and receiver indicates larger measurement distance.
- The difference in the distance between Tr2 and Rc(1000,1500,4000), where above Tr2, is increased by the drone hovering.

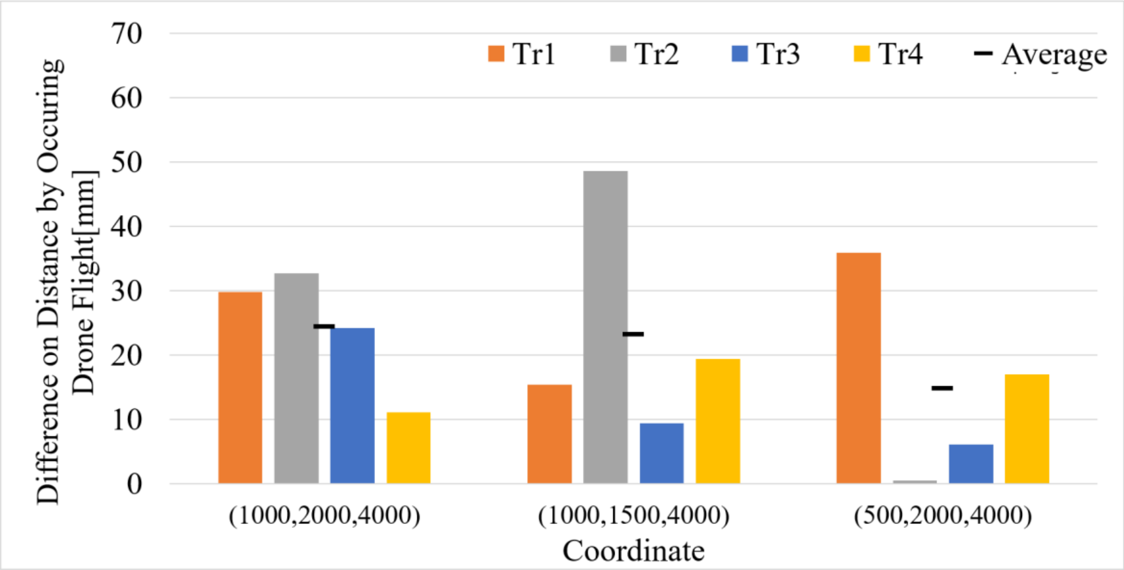


Difference in the measured distance occurred by drone flight. (center position vs.above Tr2)

Measurement error in distance

- It can be seen that the difference in the distance between Tr1 and Rc(500,2000,4000) increased by hovering the drone.
- Compared to Rc(1000,2000,4000) and Rc(500,2000,4000), the average difference decreases.

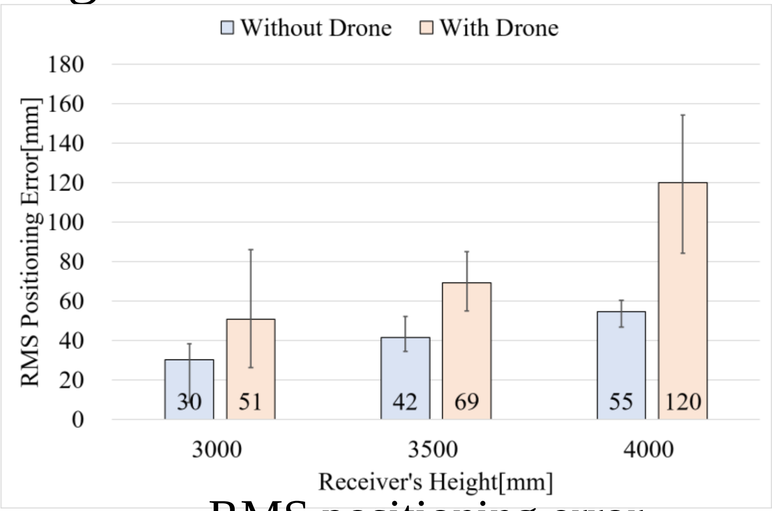
→ Indicate that a drone's downwash and noise have a significant effect on the measurement distance when the transmitter and receiver are facing each other.



Difference in the measured distance occurred by drone flight.
(at height of 4000mm)

Positioning error

- Positioning errors were evaluated using the Root Mean Square (RMS) of the difference between the results and the installed distances.
- The graph indicates that the positioning error increased when the drone is flying because of downwash and flight noise; however, the average errors are less than 15cm.
- The greater the distance between the transmitter and receiver, the larger the average RMS positioning error and variance.



RMS positioning error.
At the center position.(Rc(1000,2000))

Conclusion and Future work

■ Conclusions

- ➢This study proposed a positioning system using SS ultrasonic waves for indoor applications, such as drone communication and wall surface inspection, and evaluated the effects of the system against drone downwash and noise.
- ➢The experimental results for assuming an inner wall inspection by the drone shows that downwash increases the positioning errors.
- ➢But the errors are less than 15cm.

■ Future Work

- ➢We will evaluate the errors in positioning with multiple drones.
- ➢We will discuss their errors occurred by flight noise and downwash.