

## Error budget of GNSS-R altimetry on a multicopter

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Upward and downward GNSS receivers are deployed onto a multicopter in order to measure the path delay between the GNSS signals directly received and reflected at the water surface, which can be converted to the antenna height above the water surface ( $H_a$ ) by assuming a simple geometry. The height of the water surface in a geodetic coordinate can be obtained by extracting the obtained  $H_a$  from the precise position of the multicopter in the given geodetic coordinate. Experimental flights have been conducted in Hirado Bay and at Lake Biwa, in which the multicopter was hovering about 130 m above the water surface for more than three minutes. In general, the estimated  $H_a$  changes in good accordance with the altitude of the multicopter, but  $H_a$  includes significant high-frequency variations of the order of several meters whose periods are several seconds. These periods are similar to those of wind waves, suggesting that the reflection point was displaced due to the slope of the water surface caused by wind waves, which deviates from the assumed simple geometry. After removing these high-frequency variations by temporal averaging, the estimated height of the water surface agrees well with the reference height independently observed by a gauge with only 0.07m difference. However, this accuracy depends on not only  $H_a$  but also the precise positioning of the multicopter that requires a reference site on land for differential GNSS, which may limit the applicable area of the GNSS-R altimetry on a multicopter.

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