# Coastal Altimetry Using Ku/Ka-Band Signals of Opportunity: Results From a Recent Experiment at Platform Harvest

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## Abstract

Coastal altimetry can provide important measurements supporting storm surge prediction, development of realistic wave models, and improved forecasts of wave setup and overtopping processes. Current satellite altimeter data has significant limitations near the coasts, due to land contamination, rapid tidal variation and atmospheric effects.

Over the last two decades, ocean altimetry using signals of opportunity (SoOp) has been demonstrated using transmission from the Global Navigation Satellite System (GNSS). Recently, techniques first developed for GNSS have been expanded to digital communication signals with the promise that the wider bandwidth and higher power would enable sea surface height (SSH) retrievals at a scientifically useful precision.

A reflectometry experiment was conducted at Platform Harvest (NASA's altimetry calibration and validation site) in August, 2017. Direct broadcast satellite (DBS) transmissions in Ku-band and K-band, from a commercial geostationary satellite (DirecTV), were recorded from a height of about 27 m above sea surface. SSH was determined from the differences in electromagnetic path delay between the reflected and direct signal, found by cross-correlating the two signals and computing the delay from the specular point. These retrievals were compared with the sea level reported from a tide gauge located at Platform Harvest.

A preliminary analysis showed a SSH precision of 2.6 cm, when using 5 sec of data with a 4 ms coherent integration. An error analysis, based on the integration time of the cross-correlation, signal-to-noise ratio (SNR) of the received signal, and the signal bandwidth predicted a theoretical error of 1.5 cm, root-mean-square-error (RMSE). The findings from this experiment demonstrate the feasibility of processing the full broadcast spectrum, composed of multiple independent data channels, as a single wide-band (400 MHz) signal and validate an error model that could be used in satellite mission studies.

## Experimental Description

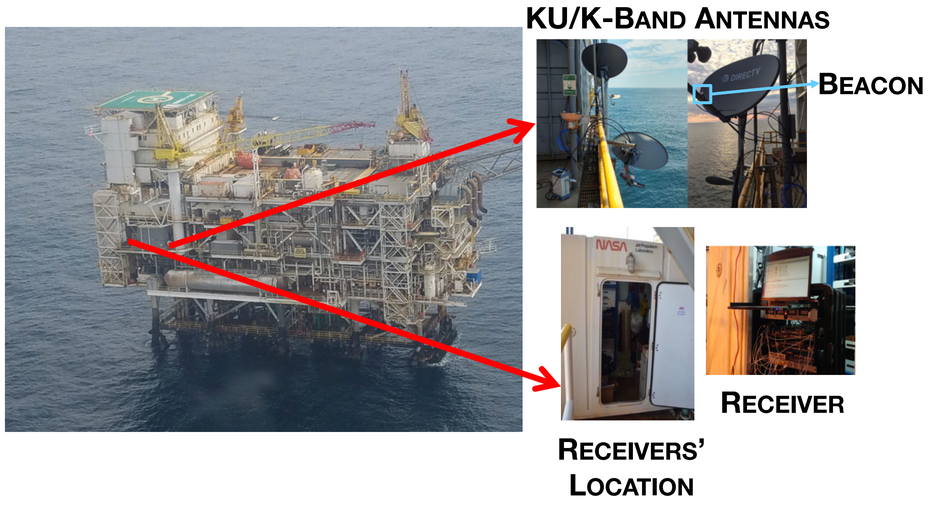


**Figure 1:** This figure shows the location of antennas and receivers at Platform Harvest. The antennas are located at approximately 27 meters above the ocean surface.

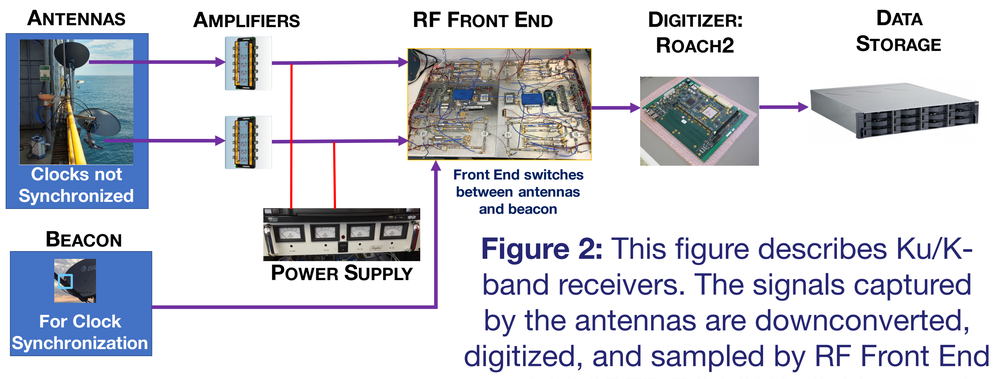


**Figure 2:** This figure describes Ku/K-band receivers. The signals captured by the antennas are downconverted, digitized, and sampled by RF Front End and CASPER ROACH2 digitizer, and transferred to hard drives for storage.

**Table 1:** Recording parameters for Experimental Campaign in August 2017

| Parameter | Ku-Band | K-Band |
|---|---|---|
| Center frequency, $f_c$ | 12.4 GHz | 18.5 GHz |
| Sampling frequency, $f_s$ | 400 MHz | |
| Sampling quantization | 8 bits complex | |
| Polarization | LHCP, RHCP | |
| Recorded data length | 5 sec | |
| Date recording period | Every hour from 0200 UTC on 08/4/2017 to 0200 UTC on 08/07/2017 | |

## Altimetry Using SoOp: Theory and Results

A code altimetry approach is used to retrieve SSH. The direct and reflected signals are cross-correlated to form reflected waveform and delay at the specular point is computed (Eq. 1). The delay is related to height, *H* (or SSH) by Eq. 1.

$$\textbf{Eq. 1:}\quad \tau_i(t) = \tau_{i,l}(t) + \tau_b = 2\frac{H(t)}{c}\sin\varepsilon + \tau_b$$

$H$ : Antenna Height Above Surface
$\varepsilon$ : Elevation Angle
$\tau_b$ : System Bias
$T_c$ : Chip Length (Data Rate)
$N_{IN}$ : Incoherent Integration
$SNR$ : Signal to Noise Ratio

The measurement noise, $\sigma_\tau$, in the estimation of delay is given by Eq. 2.

$$\textbf{Eq. 2:}\quad \sigma_\tau = \frac{T_c}{\sqrt{N_{IN}}}\sqrt{\left(1+\frac{1}{SNR}\right)^2 + \left(\frac{1}{SNR}\right)^2}$$

The standard deviation, $\sigma_H$, in the estimation of height is given by Eq. 3.

$$\textbf{Eq. 3:}\quad \sigma_H = \frac{\sigma_\tau}{2\sin\varepsilon}$$

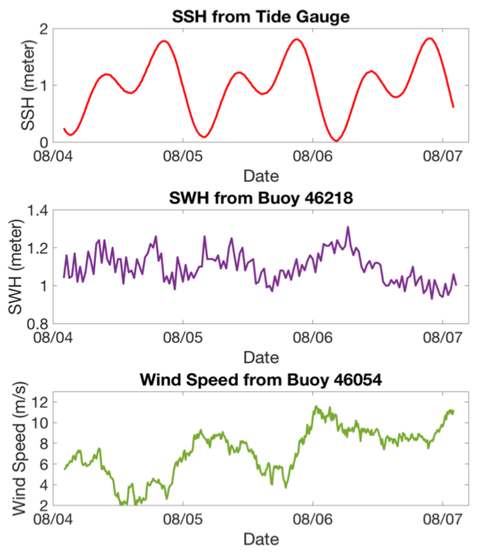


**Figure 3:** The figures show the sea condition during the experimental campaign. The top figure shows SSH from tide gauge. The middle figure shows SWH (0.9-1.3 m) and bottom figure shows wind seed (2-12 m/s).

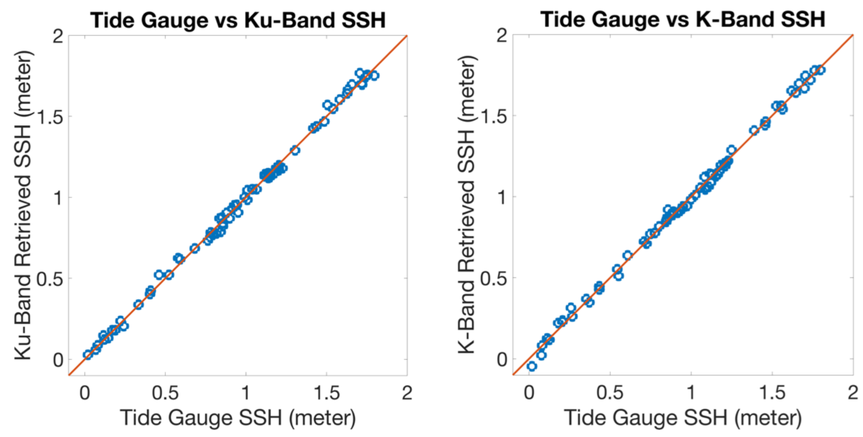


**Figure 4:** The figure shows scatter plot of retrieved SSH from Ku-band (left) and K-band (right) LHCP data and SSH from tide gauge. The error in retrieval of Ku-band and K-band is 2.69 cm and 2.61 cm, respectively.

**Table 2:** Summary of altimetric precision from LHCP Ku/K band signal

| | | Ku-band, LHCP | | K-band, LHCP | |
|---|---|---|---|---|---|
| Parameter | Avg. Time | Theoretical | Experimental | Theoretical | Experimental |
| SNR [dB] | 4 ms | 39.5 | 40.5 | 36.1 | 36.4 |
| $\sigma_H$ [cm] | 5 s | 1.53 | 2.69 | 1.50 | 2.61 |

## Summary

This poster shows preliminary results of an estimation of SSH using most of the available bandwidth (400 MHz) of Ku/K-band SoOp data from DirecTV. SSH was retrieved using a least squares approach. 5 sec of data was recorded over 6 min time period for each polarization, LHCP and RHCP. The precision of estimation of height was found to be 2.6 cm for LHCP data from both Ku/K-band. This is about 1 cm (more than expected) error which could be due to variation in ocean condition while the data was being recorded.

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