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Ocean Reflection Interference in Low Elevation GPS Measurements

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Global Navigation Satellite System (GNSS) L band signals are used for timing and positioning purposes. Several error sources, such as atmospheric refraction and signal reflections, degrade the solution, but at the same time these can be investigated using the accurate knowledge of time and positions.

We present initial results of ocean reflection studies based on low elevation GPS measurements from Haleakala Summit, Hawaii, during October 2004. The GNSS Receiver for Atmospheric Sounding (GRAS) developed by Saab Ericsson Space AB, Sweden, is used in the experiment. The objective of this field test experiment is to establish experimental knowledge on the influence of signal multi-path interference and other signal disturbances caused by the atmosphere and surroundings as measured by the receiver.

Due to the ~3000 meter altitude of the observation site at the volcanic island, a free line-of-sight over the ocean to the horizon is available. Hence, when tracking satellites at low and negative elevation angles, ocean reflections of the signal will occur and interfere with the direct signal.

We study the spectral properties of the signals as received by the GRAS instrument simultaneously in both phase-locked mode (PL) and open-loop mode (OL) in separate receiver channels. The OL mode provides the in-phase and quadrature components of the signal at a sample rate of 1000 Hz. The instrument setup consists of separate L1 and L2 antennas both oriented with the main gain lobe toward the horizon. The signals are fed into a prototype version of the GRAS receiver, which is designed especially for operational atmospheric soundings from satellites. The instrument software is modified for ground based signal Doppler conditions. An ultra-stable rubidium frequency reference is used to control the receiver clock.

The characteristics of the reflected signal depend on the scattering properties of the sea surface and the footprint of the reflection. The footprint size and shape in turn depends on the signals incidence angle and the relative velocities of transmitter and receiver to the reflection point. The scattering properties of the sea surface are related to the roughness which depends on sea wave characteristics, which then could be investigated using this type of measurements.

For atmospheric profiling purposes the reflected signal is merely noise to the data. In low elevation measurements the reflected and direct signal is closely located in frequency and the difference in the direct and reflected signal delays approaches and becomes less than one code bit and hence the code correlation in the receiver will not diminish the reflected signals power in the data. In order to improve retrieval of atmospheric parameters close to the ocean surface, the interference of reflected signals has to be understood and accounted for.

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Ocean Reflection Interference in Low Elevation GPS Measurements

- initial results from a mountain-based Open Loop experiment

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Outline

- Experiment setup
- Characteristic Ocean Reflection Signature
- Code and Doppler Separation
- PLL vs. OL
- Can GRAS be useful in ocean studies?

Measurement setup

Quick Local Climate Guide

Error sources

- Turbulence
- Multipath (atmosphere, buildings, ocean,…)
- Thermal Noise
- Instrument Noise
- Interference (co-channel, other systems)
- Retrieval errors (phase unwrapping,…)

Previous Reported Ocean Reflection Observations

- G. Beyerle and K. Hocke 2001: Space based
- Martin-Neira et al. 2001: Ground based
- Lowe et al. 2002: Aircraft data
- …

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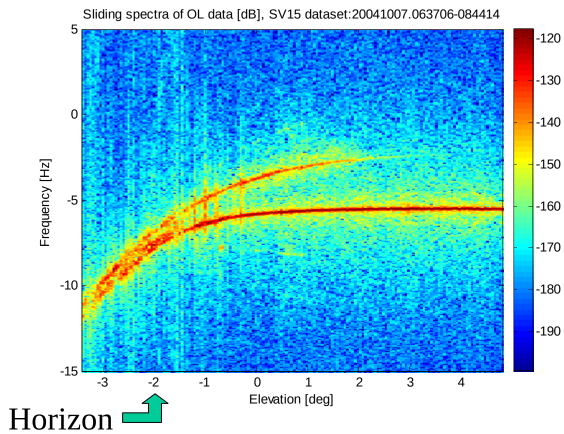
Spectral Signature



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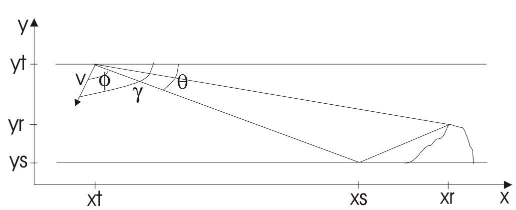
Code Separation, I



- **C/A and P(Y) codes are "pseudo random", hence the correlation with the replica C/A in the code loop (both PLL and OL) suppresses other than the tracked signal**
- **Optical path length difference in a flat Earth, no bending approximation is…**

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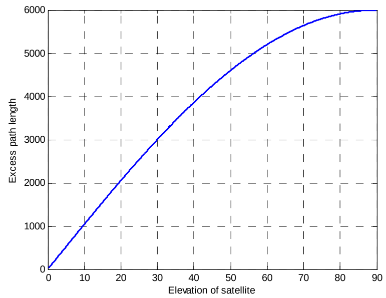
Code Separation, II



- C/A code chip is 300m which corresponds to ~3^o elevation
- I.e. code loop mitigates ocean reflections above ~3^o elevation
- …but can we separate direct and reflected signal below ~3^o?

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Direct and Reflected Signal Separation

- Shape of correlation waveform
- Detect both waveforms, if separated
- Polarization

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Polarization

- GPS signal is RHCP
- Reflected GPS signal polarization depends on incidence angle
- Above, at and below Brewster angle regimes

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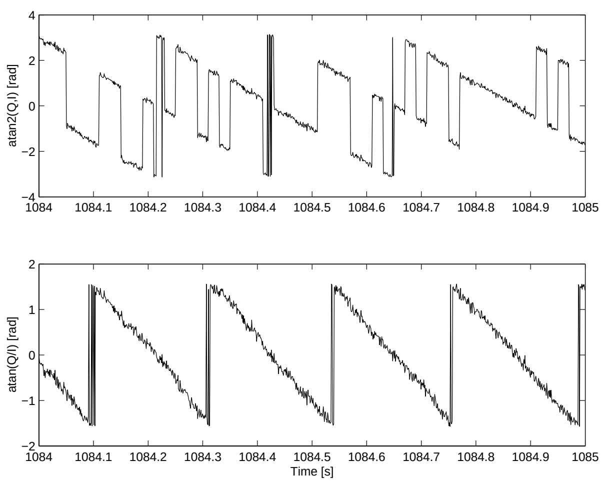
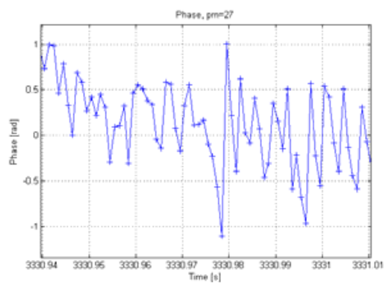
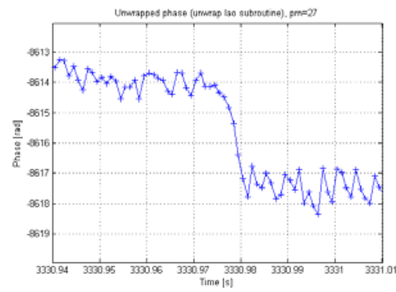
Phase

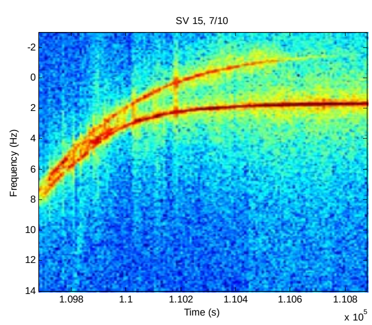


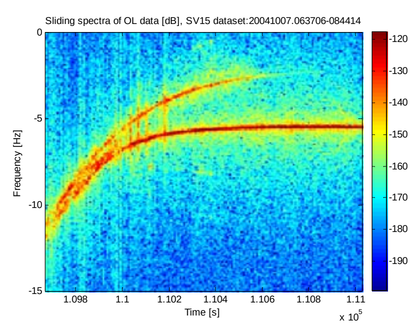
…in presence of strong noise





PLL vs. OL





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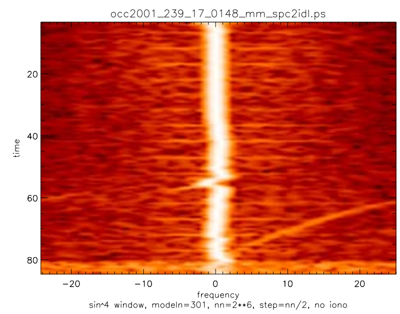
Space Based Occultation

- Champ data
- Ocean reflection ($62^oS,39^oW$)
- Horizontal lines due to clock settings?
- Beyerle & Hocke 2001 has reported reflection signatures in 28% of GPS/MET



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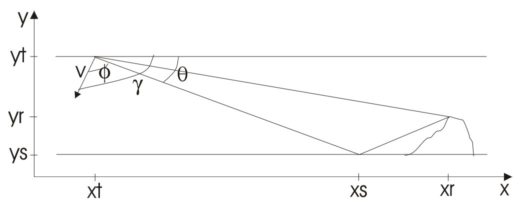
Altimetry



- We only capture reflected signal below a certain elevation limit.
- Is it possible to determine Sea Surface Height with only Doppler information of the reflected signal?
- …with a reasonable accuracy?

Summary

- General Problem: Very close in both frequency and delay when near the horizon
- We have frequency information for both rays
- We only have delay information for direct ray
- Separate vertical an horizontal polarization measurements could provide useful