Interferometric Carrier Observations and the Potential for GNSS-R Altimetry

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Abstract

The large number of radio signals transmitted from GNSS satellites provide observations with a global coverage. Therefore GNSS signals are used for Remote Sensing in different fields of Earth Observation. GNSS Radio Occultation receivers on a Low Earth Orbit measure signal refraction in different layers of the Earth’s troposphere and ionosphere. Vertical profiles, e.g. of the temperature and water vapour in those layers can be derived. Dedicated receivers and tracing algorithms have been developed to track GNSS carrier observations when signal propagation is affect by refraction.

Next to the Radio Occultation technique, GNSS reflectometry techniques reveal valuable observations for Remote Sensing. Reflections have been investigated to study the ocean surface, sea-ice or soil moisture. Different GNSS observables are affected by reflections. For altimetry the code delay can be used. The longer path travelled by the reflected signal causes a time delay in the code domain. Its application is mainly restricted due to the coarse precision of the code modulation.

The precision of the carrier phase is on the cm level. Changes in the carrier phase can be related to changes of the reflecting surface. This method, which is called phase altimetry, requires a tracking of the phase. For signals reflected off the ocean a tracking of the reflected phase is usually disturbed by ocean roughness. In order to facilitate the tracking interferometric approaches have been used, however, applications of phase altimetry are still limited.

The potential of interferometric carrier observations is not restricted to phase tracking. A precise model of the interferometric path is achieved by ray tracing calculations. This model is adopted from a Radio Occultation method which was extended to reflected rays. The unknown height of the reflecting surface is a free parameter in this model. Signal refraction is determined in the model using ancillary meteorological data. The interferometric path can then be predicted not only for single observations but for the whole evolution of a reflection event. The interferometric path model
is adjusted for the reflection event to obtain estimations of the height parameter. A representation of the event in the frequency domain permits retrieval of heights even if the surface is not smooth. In this paper we will show that this altimetric method can be applied to a ground-based experiment and an airborne experiment.

The ground-based experiment was conducted during the sea-ice campaign of ESA’s GPS-SIDS project. GPS reflections were recorded in the winter period 2008/2009 in the Disko Bay at the western coast of Greenland. Two different reflectometry receivers were set up about 700m above the ocean. The GOLD-RTR (GPS Open Loop Differential Real Time Receiver) from IEEC/CSIC and the JAVAD based GORS (GNSS Occultation Reflectometry Scatterometry) receiver from GFZ. For several weeks daily recurring reflection events from 31 GPS satellites were recorded. Interferometric phase observations were sampled at 200Hz. They were provided on two carriers L1 and L2 using C/A code and L2C code respectively. Observations were restricted to slant elevation angles between 5 and 15deg. The tropospheric bias was minimized by the ray tracing model. A long time series of ocean heights resolve semidiurnal tides. A detailed analysis of the tropospheric and ionospheric bias predicts a residual error of up to 20cm.

The flight experiment was conducted during a campaign with a Zeppelin airship. GNSS reflections were recorded during two flights over Lake Constance in autumn 2010. Two different reflectometry receivers were mounted, the JAVAD based GORS receiver from GFZ and the GSOC reflectometry receiver from DLR. One up-looking (RHCP) and two down-looking antennas (RHCP/LHCP) were set up at the rear of the airship. The trajectory of the airship was derived from dual frequency phase observations acquired by the up-looking antenna at a sampling rate of 10Hz. Interferometric phase observations were recorded using the up-looking and the down-looking antenna for the L1 and the L2 carrier. The interferometric sampling was at 200Hz. Initial results of the determination of altimetric heights of the lake surface are presented and discussed.