EGU21-11577
https://doi.org/10.5194/egusphere-egu21-11577
EGU General Assembly 2021

High-rate GNSS Reflectometry Estimates for Airborne Soil-moisture Detection

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Soil moisture remote sensing on a global scale has been an active area of research over the past few decades due to its essential role in agriculture and in the prediction of some natural disasters. In this regard, GNSS-Reflectometry (GNSS-R) is proven as an efficient tool for the measurement of soil moisture content using remote sensing techniques. GNSS-R is a bi-static radar technique that uses the L-band GNSS signals as sources of opportunity to characterize Earth's surface, due to the fact that the reflected signals are often affected by the properties of the reflecting surface. In the context of this work, it is important to detect and fastly reach the area of interest (reflecting surface) for which the soil moisture content shall be monitored. A GNSS-R setup onboard a gyrocopter meets all the requirements of our application. This paper is dedicated to the study of airborne GNSS-R techniques for soil moisture monitoring using a low-altitude airborne carrier with a high rate (1ms for GPS C/A) carrier-to-noise ratio (C/N_0) observations.

To cope with the rapid displacement of the satellites footprints along the receiver trajectory, high rate (1000 Hz rate) C/N_0 observations are processed. For this purpose, real flight experimentation has taken place on October 19, 2020 for 45 min. During the flight, the gyrocopter maintained a low-altitude of approximately 315m above the ground with an average speed of 95 km/h. Based on that, the size of the major axis of the first Fresnel zones that constitute the detected footprints ranged between 1,316m for a minimum elevation angle of 3° and 15m for a maximum elevation angle of 75°. Concerning the temporal resolution of the application, the raw data were sampled at a frequency of 25MHz and the C/N_0 estimates were realized at a rate of 1000Hz.

During the flight, an average of 9 GPS satellites have been detected of which 4 GPS satellite signals were extensively analyzed to observe the reflectivity corresponding to land, beach, and sea reflections. After analyzing the Delay Doppler Maps which provides an image of the scattering cross-section in terms of time and frequency and consequently tracking the corresponding signals, the 1ms C/N_0 estimations were derived using the in-phase components of the signals as

observations. The reflected signals are then linked to the footprints of the satellites and thus to the reflecting surfaces from which each processed signal has reflected using the GPS time, attitude, and position provided by onboard sensors and the GPS time extracted from the digitized GNSS signals. The ultimate aim of this study is to obtain reflectivity measurements from high rate C/N_0 observations in order to provide a soil moisture mapping of the studied area, where we notice that the signals reflected from the beach had the best reflectivity followed by sea then land reflections.