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# De-noising GNSS-Reflectometry Measurements from a Freshwater Surface

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Global Navigation Satellite System Reflectometry (GNSS-R) is a form of bi-static radar in which the GNSS signal reflected off a surface can be used to remotely sense the surface from which it reflects. It is a low-cost, all-weather sensing method in which a GNSS receiver specifically measures what would typically be considered multipath rather than rejecting it. This technique has the potential to be extremely useful in monitoring phase changes between water and ice in the crysophere, as the signal scattered power and Doppler shift is function of the surface conditions. The power collected as a function of time delay and Doppler shift is often represented on a Delay-Doppler Map (DDM).

In prior work we had designed and built a GNSS-R sensor suite consisting of a direct GNSS antenna and receiver, a downward-looking reflection-receiving GNSS antenna and receiver, and for validation data a collocated lidar, camera, and weather station. The design and coordination of the sensors were described in [1,2]. With post-processing we had generated DDMs for reflected signals collected from ice and water surfaces using an incoherent integration method.

In this paper, we present the updated coherent signal processing method to compute the Delay Doppler Maps (DDMs) for studying the fresh water surface using Global Navigation Satellite System (GNSS) exploiting reflected signals from our latest Lake Michigan data campaign. In addition to the incoherent integration signal processing method [3], a coherent signal processing method, that is inspired by [3], is studied to compute the DDM. Moreover, due to the natural noise in the sample data a moving average filter is applied to smooth the scattered power and finally the noise floor is removed from the DDM to reduce the residual noise.

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3. R. Parvizi, H. Sabbagh Zadeh, L. Pan, B. Pervan, and S. Datta-Barua, "Multi-sensor Study of Lake Michigan's Surface using GNSS-Reflectometry," *Proceedings of the 31st International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2018)*, Miami, Florida, September 2018, in press.