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Effect of coherent integration on target detectability using reflected GNSS signals

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Global Navigation Satellite System Reflectometry (GNSS-R) is a remote sensing method using navigation signals of opportunity in a bistatic geometry. This method has gained recent research interest as it successfully predicts sea state and wind speeds, soil moisture [1]. Its ability to accurately detect an oil tanker has been shown to be viable on an airborne platform [2]. Current studies assess the feasibility of ship detection using spaceborne signal integration parameters. However, inherent weak signal strength of GNSS signals limits its feasibility for target detection. This research studies the impact of coherent and incoherent integration times on overcoming these limitations using airborne platforms.

Conventional GNSS acquires the delay of a complex signal to produce the auto-correlation function (ACF) of known pseudo-random Gold code to then compute the navigation solution. For a reflected GPS L1 C/A signal, the ACF is spread on a delay-Doppler map (DDM) with the shape defined by Woodward's Ambiguity Function (WAF) [3]. The signals' ability to extract information is dependent on multiple factors; this study will focus on coherent integration time, receiver altitude, surface topography and target radar cross-section (RCS). Due to the bistatic nature of GNSS-R, a target reflection can be summarised by the bistatic radar equation:

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi)^3 (R_{TP} R_{PR})^2} . \langle T_i \Lambda(\Delta\tau) S(\Delta f_D) \rangle^2 . \sigma_P \tag{1}$$

Where the WAF for a coherent target reflection can be simplified to be dependent on coherent integration (T_i^2). The RCS (σ_P) of sea vessels have been documented for monostatic cases, therefore a comparison with GNSS-R would address the backscattering geometry. There would be minimal sea clutter reflection, and the noise floor would be dependent on system temperature and the noise bandwidth ($kT_{sys}B_N$).

In comparison with experimental proof by [2], simulation shows that the coherent integration and receiver distance lie within the detection region. This is shown in Figure 1, where the green region indicates the detection range for typical cargo vessel or oil tanker RCS. These results highlight the potential of using GNSS-R to detect large sea vessels.

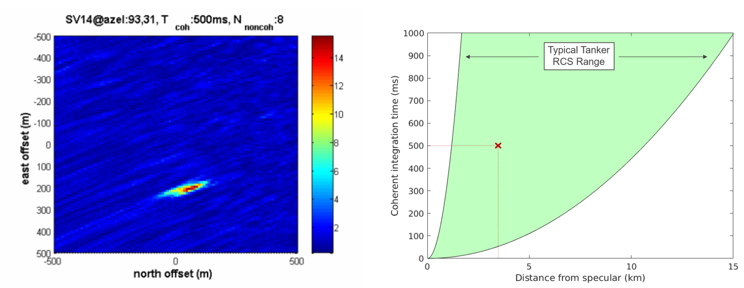

Figure 1. Reflection of an oil tanker (left) with detection parameters marked with "x" (right) for scenario in [2].

References

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