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High Precision Target Localization Using a Sub-Nyquist Super-Resolution Radar

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Drones are becoming increasingly used in the modern world, from toys to shooting movies, from delivering pizzas to surveillance. They also pose a severe security concern particularly when they enter forbidden zones such as airports and defense installations. Drones are typically much smaller than combat aircrafts, which makes it imperative to develop specialized radar systems that can detect and localize drones with unprecedented precision. From a signal processing perspective, this places the problem within the paradigm of accurate signal modeling and super-resolution of targets in the delay-Doppler plane – the present contribution is aimed at meeting these criteria. We address the problem of estimating target locations that are sparse in a pulse-Doppler radar's unambiguous region by sampling the received signal at sub-Nyquist rates. The received signal is modeled as a finite-rate-of-innovation (FRI) signal, and the problem of estimating the delays in a single transceiver radar is formulated as one of recovery of sparse common-support (SCS) FRI signals [1], which arises in the context of channel estimation in multiple input, multiple output (MIMO) communication systems. The delays are estimated by the SCS-FRI reconstruction method. We present a new method termed *delay focusing* to estimate the Doppler shifts. To obtain overall performance gains, we also present an extended method called *dual focusing*, which combines both *delay* and *Doppler focusing* schemes, and has the capability to super-resolve targets in the delay-Doppler plane. The performance of the recovery methods in the presence of noise is also analyzed. By means of simulation studies, we demonstrate that the proposed estimation methods are robust to noise. Monte Carlo performance analysis in the presence of noise shows that the dual focusing method accurately resolves closely spaced targets and yields a significant decrease in normalized mean-square error (NMSE) of up to 10 to 20 dB for the estimated Doppler shifts. We also simulate the scenario where multiple targets are in a *formation*, that is, when they are closely spaced along both delay and Doppler axes, and show that the dual focusing method achieves a hit-rate of nearly 100% at a much lower signal-to-noise ratios (SNRs) than that required for Doppler focusing [2].
The presentation will be based on our recent publication in this direction [3] and some ongoing work since that publication.

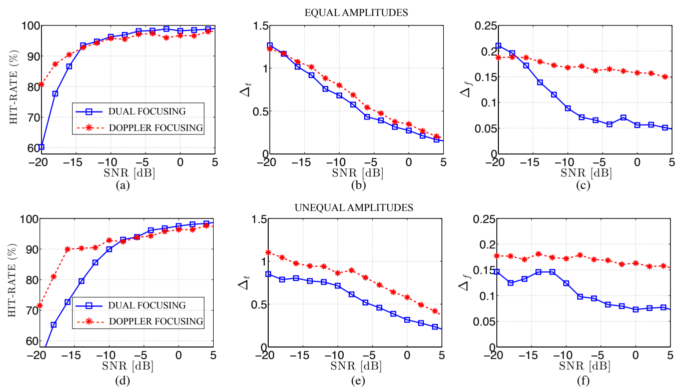

Figure 1. Performance of dual vs. Doppler focusing methods for targets in two clusters, with two targets each. (a) and (d) Hit-rate (in %); (b) and (e) RMSE in delay estimation; and (c) and (f) RMSE in Doppler estimation. The top and bottom rows correspond to targets within a cluster having magnitudes $\{1,1\}$ and $\{1,0.5\}$, respectively.

References

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[3] S. Rudresh and C. S. Seelamantula, "Finite-rate-of-innovation-sampling-based super-resolution radar imaging," *IEEE Trans. Signal Process.*, vol. 65, no. 19, pp. 5021–5033, 2017.