Per-Receiver Self-Positioning Error Awareness in Airborne Multistatic Passive Radar

Lost Without GPS? Silent Drone Navigation in Jammed Environments

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1. Background

- **Passive radar:** tracks targets using ambient Illuminators of Opportunity (IoO), staying silent.
- **Multistatic:** several spaced receivers localise better than one [1].
- **Airborne, GPS-denied:** receivers are mounted a drone swarm and self-localise from onboard sensors (IMU) and signals of opportunity, with *unequal* precision each.
- **Gap:** surveyed systems assume zero or uniform (IID) receiver-position error [2]. Heterogeneous per-receiver error stays unstudied.

2. Research Question

In an airborne multistatic passive radar, how does heterogeneous per-receiver self-positioning error affect target localisation and tracking?

(a) How does target positioning error scale with receiver count N and self-position noise σ_{Rx}?

(b) Does weighting each receiver by its own self-position error outperform the IID-modelled and self-position-error-blind weightings in a single snapshot?

(c) Does that advantage hold under drift in tracking (EKF)?

Does weighting each receiver by its own self-position error help?

Yes. In our simulation, a per-receiver-aware solver cuts median target error by ∼13% in snapshot and ∼28% in tracking, in comparison to a solver assuming IID self-positioning error.

Analogy: Ten lost hikers all spot the same tree but cannot place it on the map. Three hikers who each know their own position well pinpoint it better, so the whole group should listen to them more than the others.

References

[1] Y. E. Sagduyu, K. Davaslioglu, T. Erpek, S. Kompella, G. Anderson, and J. Ashdown, "MULTI-SCOUT: Multistatic integrated sensing and communications in 5G and beyond for moving target detection, positioning, and tracking", in *MILCOM 2025 — 2025 IEEE Military Communications Conference*, Los Angeles, CA, USA, 2025, pp. 693–698.

[2] L. Rui and K. C. Ho, "Elliptic localization: Performance study and optimum receiver placement", *IEEE Transactions on Signal Processing*, vol. 62, no. 18, pp. 4673–4688, 2014. DOI: 10.1109/TSP.2014.2338832

[3] A. Noroozi and M. A. Sebt, "Target localization from bistatic range measurements in multi-transmitter multi-receiver passive radar", *IEEE Signal Processing Letters*, vol. 22, no. 12, pp. 2445–2449, 2015.

[4] M. Malanowski and K. Kulpa, "Two methods for target localization in multistatic passive radar", *IEEE Transactions on Aerospace and Electronic Systems*, vol. 48, no. 1, pp. 572–580, 2012. DOI: 10.1109/TAES.2012.6129656

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3. Method

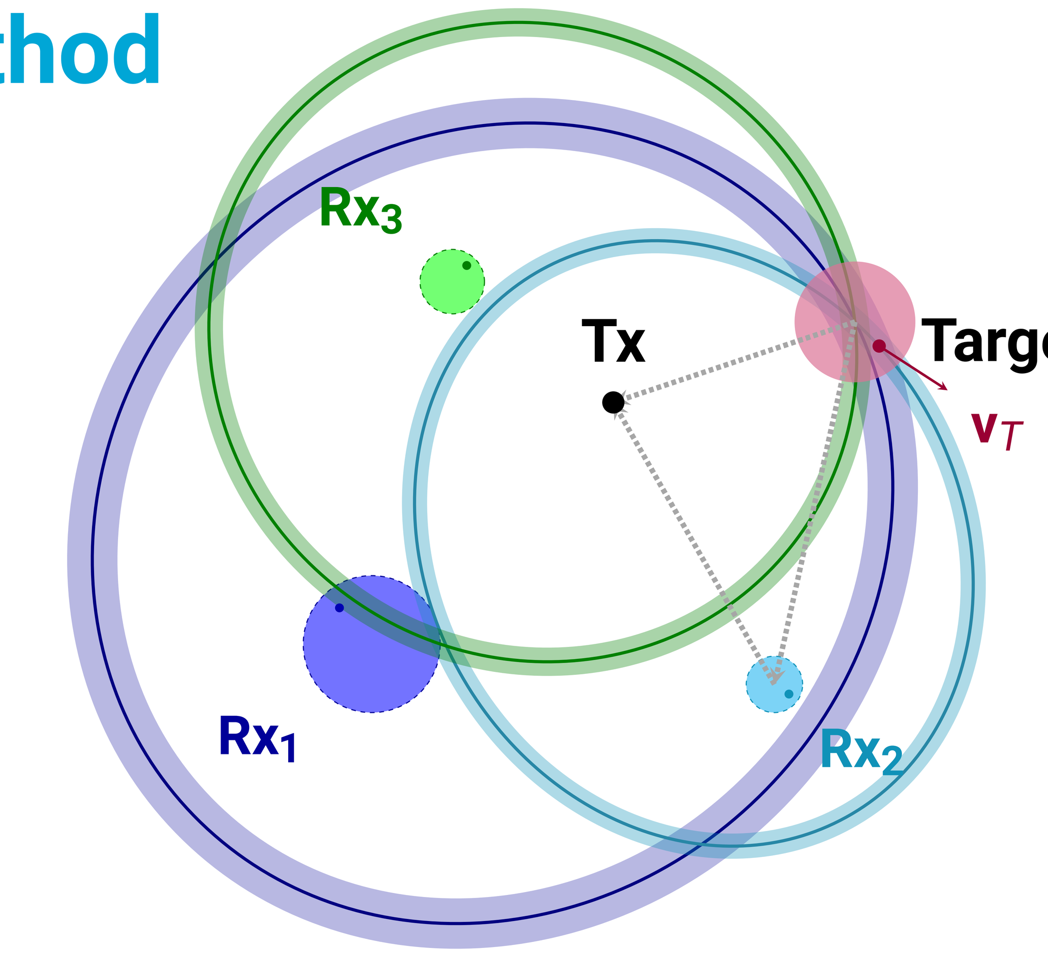

Figure 1. *A multistatic system with three receivers, one transmitter (IoO), and a target.*

Measurement model. Each bistatic range B_i (one per Tx–Rx pair) confines the target to an ellipse E_i. The target lies near their intersection.

Noise. Bistatic measurement noise grows with distance $\sigma_{B,i} \propto R_{r,i}$.

Combining measurements. Target position by weighted least squares (WLS) solvers [3], [4]. Bistatic range i gets weight W_i the solvers differing only in the self-position term σ_{Rx}:

$$W_i = \begin{cases} 1/(\sigma_{B,i}^2 + \sigma_{\mathrm{Rx},i}^2) & \textbf{per-Rx}\text{: each receiver's own measured } \sigma_{\mathrm{Rx},i} \\ 1/(\sigma_{B,i}^2 + \bar{\sigma}_{\mathrm{Rx}}^2) & \textbf{iid}\text{: one shared average } \bar{\sigma}_{\mathrm{Rx}} \\ 1/\sigma_{B,i}^2 & \textbf{blind}\text{: self-positioning error ignored} \end{cases}$$

Tracking. For tracking, an EKF additionally accounts for per-Rx drift (rate $\sigma_{\mathrm{drift},i}$) by carrying each receiver's offset as state.

Setup. Monte Carlo, 10^4 trials per cell (layout in Fig. 2). We sweep receiver count N and average self-positioning noise.

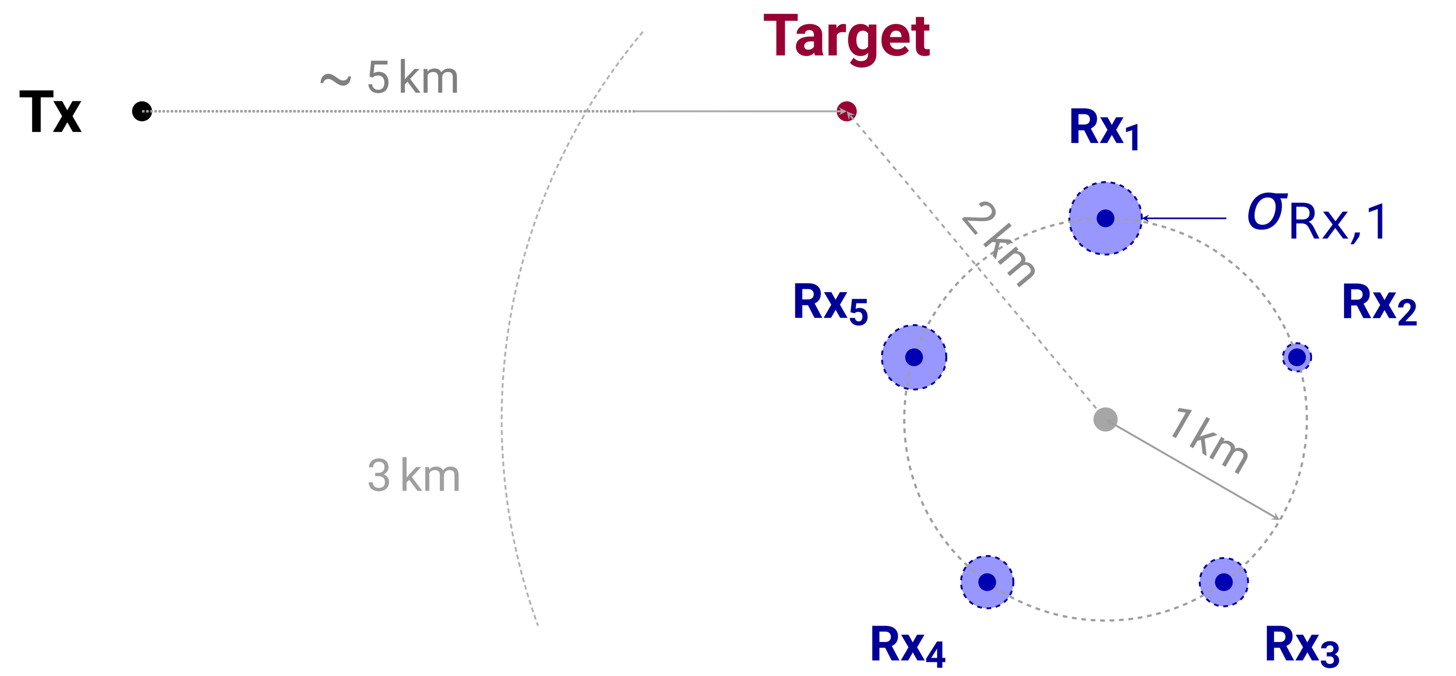

Figure 2. *Example layout. N=5 receivers on a 1 km ring, target within 3 km, Tx at ∼ 5 km. Discs show each $\sigma_{\mathrm{Rx},i}$.*

4. Results

Q: Does weighting each receiver by its own self-position error improve radar performance?

A: Yes. Error ordering is: per-Rx < iid < blind across the sweep. At N=10, σ_{Rx}=5 m the median target error falls by ∼13% (snapshot) and by ∼28% (tracking) comparing to iid.

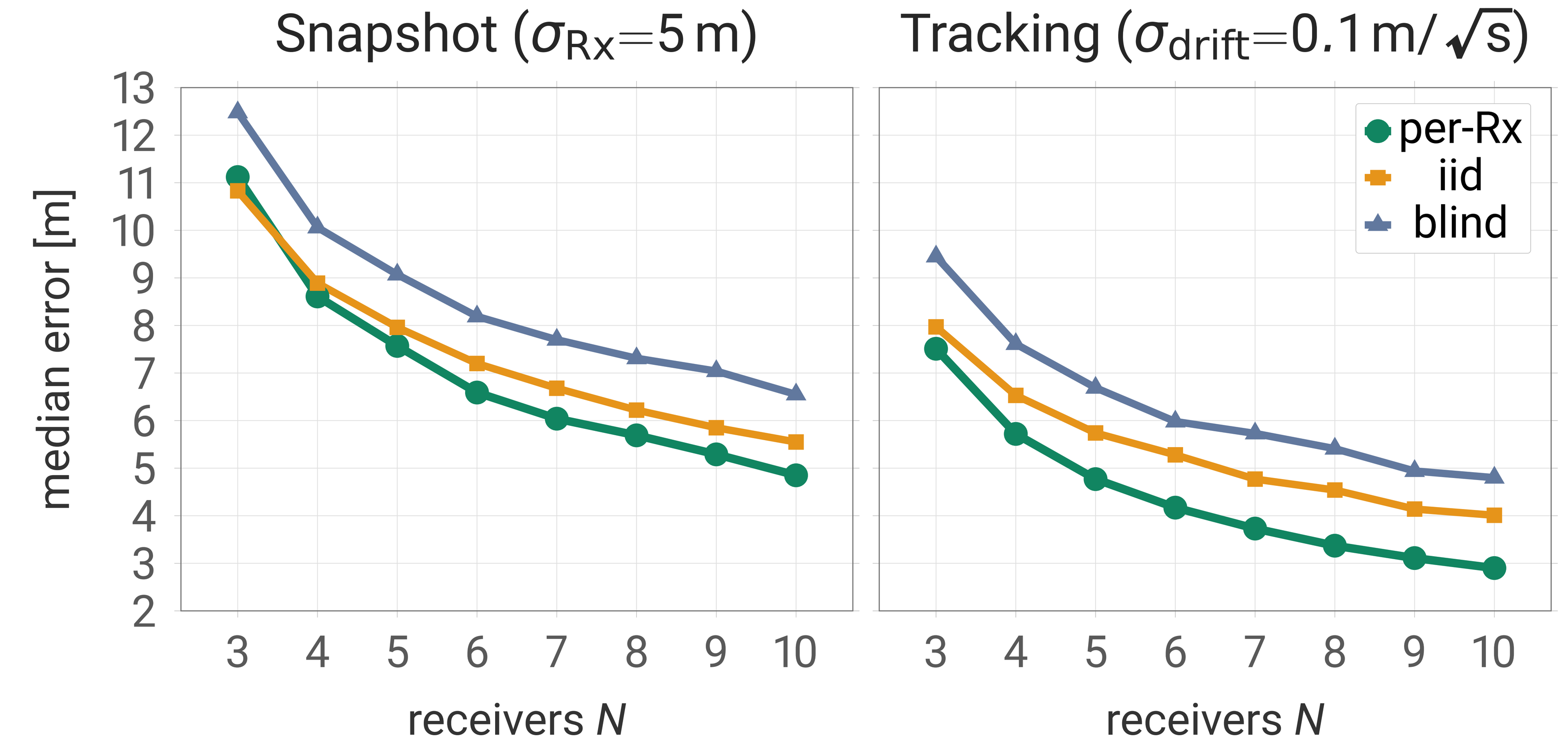

Figure 3. *Median target error vs. N for the three solvers. Left: snapshot WLS. Right: EKF tracking. per-Rx stays below iid and blind throughout.*

Q: How do receiver count and self-position noise affect target positioning error?

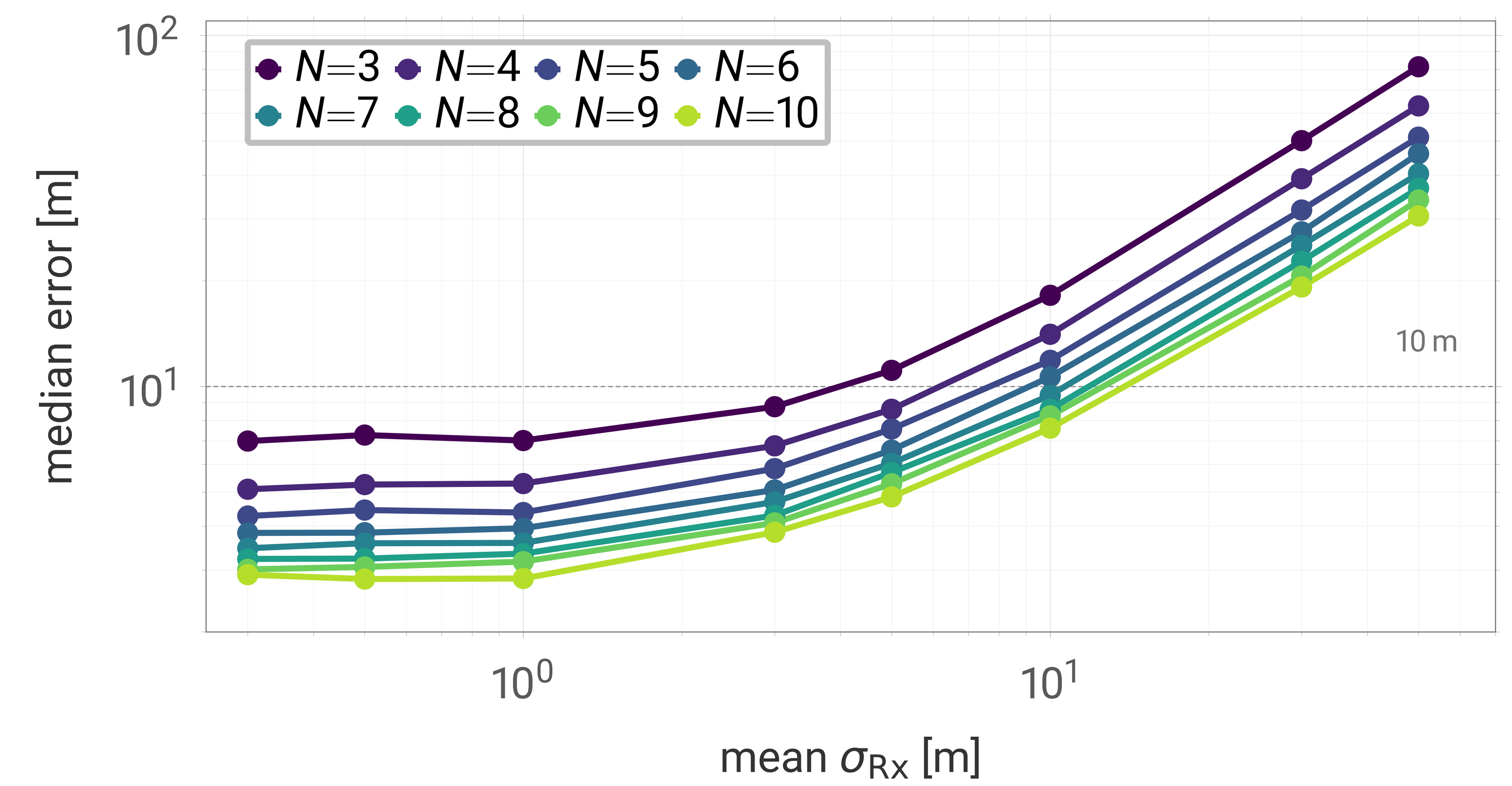

Figure 4. *Per-Rx median error vs. σ_{Rx}, one line per N (lighter – more receivers).*

A: Extra receivers help most below a knee at $\sigma_{\mathrm{Rx}} \approx 5$ m (region dominated by measurement noise), above which the returns diminish.

5. Limitations

- No experimental validation against real data [4].
- 2D, single transmitter, constant-velocity linear path target only, quasi-static receivers.
- Per-Rx $\sigma_{\mathrm{Rx},i}$ assumed reported exactly by the onboard filter.