

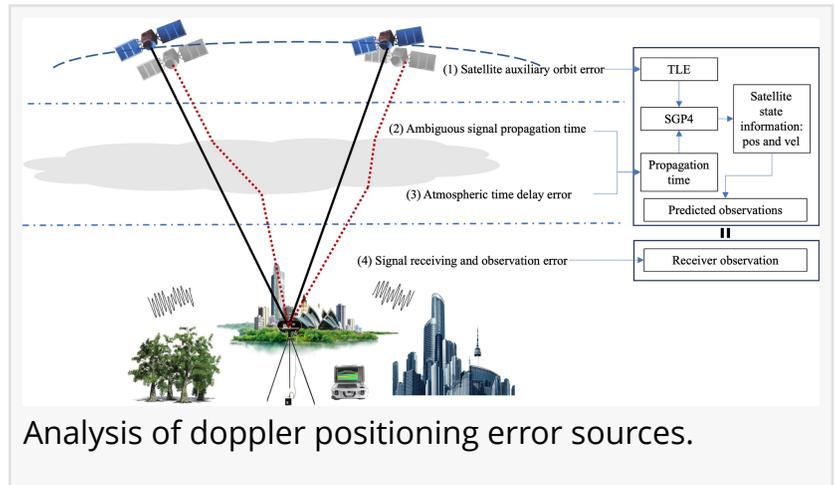
Sharper LEO navigation through outer-loop framework

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[/EINPresswire.com/](https://www.einpresswire.com/) -- As demand

grows for reliable positioning beyond conventional Global Navigation Satellite Systems (GNSS), researchers are turning to [Low Earth Orbit \(LEO\)](#) satellites as a promising backup. In the new study, a team developed an outer-loop positioning framework that explicitly accounts for signal propagation time in LEO Doppler observations—an often overlooked factor in signal-of-opportunity navigation. By introducing a geometric propagation-time model

into the observation process, the method improved three-dimensional position and velocity estimation while also producing more stable receiver clock corrections. The advance points toward more dependable navigation in dense cities, transport corridors, and other environments where traditional satellite positioning can struggle.



Positioning, navigation, and timing services are now essential for autonomous systems, logistics, and mass-market electronics, yet conventional GNSS remains vulnerable in urban canyons, tunnels, and other obstructed environments. LEO constellations such as Starlink, OneWeb, and Iridium have drawn growing interest because their signals are strong, plentiful, and fast-moving, making them attractive as backup or complementary navigation sources. But unlike GNSS satellites, many LEO platforms do not provide transmission timestamps or pseudorange-style observables, leaving signal propagation time uncertain. Previous studies have focused heavily on orbit-related errors, while the role of propagation time in state estimation has received far less attention. Based on these challenges, deeper research into propagation-time-aware LEO positioning is needed.

In 2026, researchers from the Universitat Autònoma de Barcelona reported in *Satellite Navigation* a new outer-loop positioning framework for LEO Doppler observations that explicitly accounts for signal propagation time, demonstrating improved accuracy and stability in both simulations and real Iridium measurements.

The proposed method combines an outer loop and an inner loop to better reconstruct the true geometry of LEO signal transmission. In the outer loop, satellite states are updated with TLE+SGP4, predicted Doppler observations are generated, and residuals are estimated through weighted least squares. In the inner loop, intermediate quantities—especially signal propagation time—are iteratively refined. The framework also introduces a finite-difference Doppler observation model that reduces the influence of atmospheric delay and better links Doppler drift to receiver position, velocity, and clock states. Experiments showed that the algorithm improved three-dimensional position accuracy by more than 15% and velocity accuracy by more than 25%, while significantly improving clock-related error estimation. In measured Iridium observations, point-positioning error fell by 13.4% compared with an existing coarse-time approach, and solution stability also improved. The study further identified a practical convergence limit: when the initial position error reaches 200 km, the tolerable receiver clock error drops below 50 ms, underscoring the importance of good initialization in real deployments.

The findings suggest that propagation time is not merely a secondary correction in LEO navigation, but a central factor that shapes the quality of the final solution. By treating it explicitly rather than absorbing it into a rough coarse-time estimate, the researchers showed that Doppler-based positioning can become both more accurate and more robust. The work also provides a clearer understanding of how spatial and timing uncertainties interact, offering valuable guidance for future receiver design and algorithm development.

The broader implications are considerable. As LEO constellations continue to expand, propagation-time-aware positioning could help build resilient navigation services for GNSS-challenged or GNSS-denied environments. The approach may prove especially useful for low-cost devices, mobile platforms, and Internet-of-Things applications that cannot rely on high-end atomic timing hardware. While further validation under more diverse real-world conditions will still be needed, this study establishes a practical and theoretically grounded route toward more accurate, stable, and scalable LEO-based navigation services in the years ahead.

References

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