

Along-Track GEO-MIMO SAR Formations: impact of atmosphere on the performance

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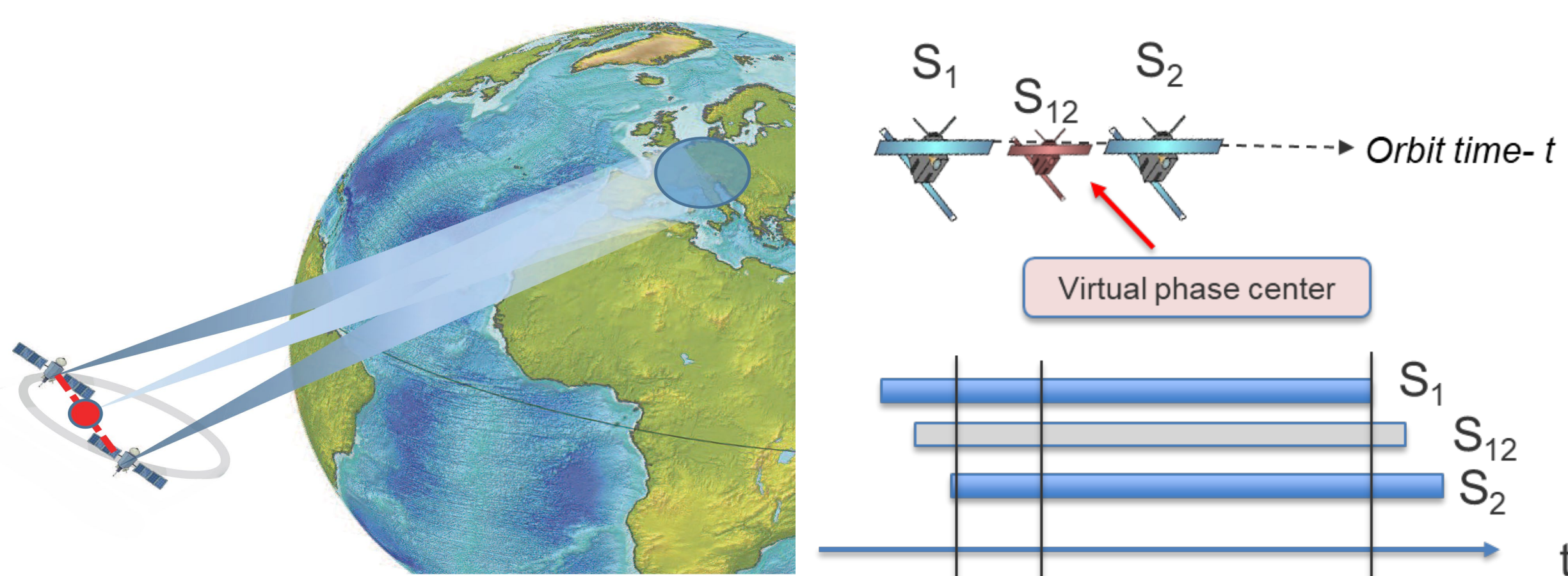
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Introduction

Short-revisit X-band SAR systems provide critical near-real-time monitoring for tactical surveillance, structural health monitoring of infrastructure, and persistent disaster management, leveraging the synergy between high spatial resolution and continuous temporal sampling. These capabilities are further enhanced by along-track MIMO formations to achieve High-Resolution Wide-Swath (HRWS) imaging despite the challenges posed by Atmospheric Phase Screen (APS).

AT GEO Formation

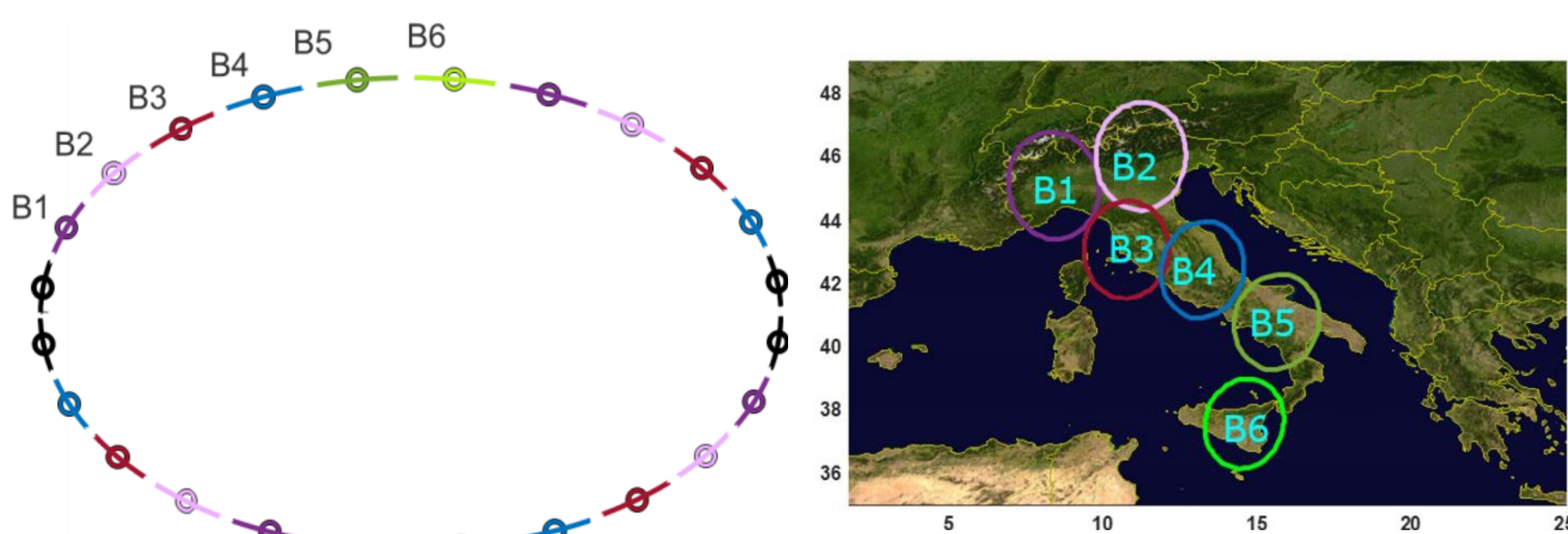
This study investigates a Near-Zero Inclination (NZI) GEO-SAR configuration, where a slight orbital eccentricity is exploited to synthesize the synthetic aperture. The long integration times compensate the severe path loss associated with the $\sim 37,000$ km slant range.



The exploitation of a MIMO formation of 2 GEO satellites introduces a series of advantages with respect to a single satellite and a constellation:

- Enhances the Signal-to-Noise Ratio (SNR) by a factor 4
- Allows to obtain short revisit multiple interferograms

The daily orbit is partitioned into 1-hour slots to ensure full national coverage of Italy. Utilizing a dual-satellite formation in each slot enables High-Resolution Wide-Swath (HRWS) imaging, doubling the coverage area without sacrificing spatial resolution.



A close-formation GEO-SAR configuration enables persistent and highly coherent interferometry, unlocking new capabilities in near-real-time change detection while effectively compensating for tropospheric and ionospheric artifacts.

Conclusions

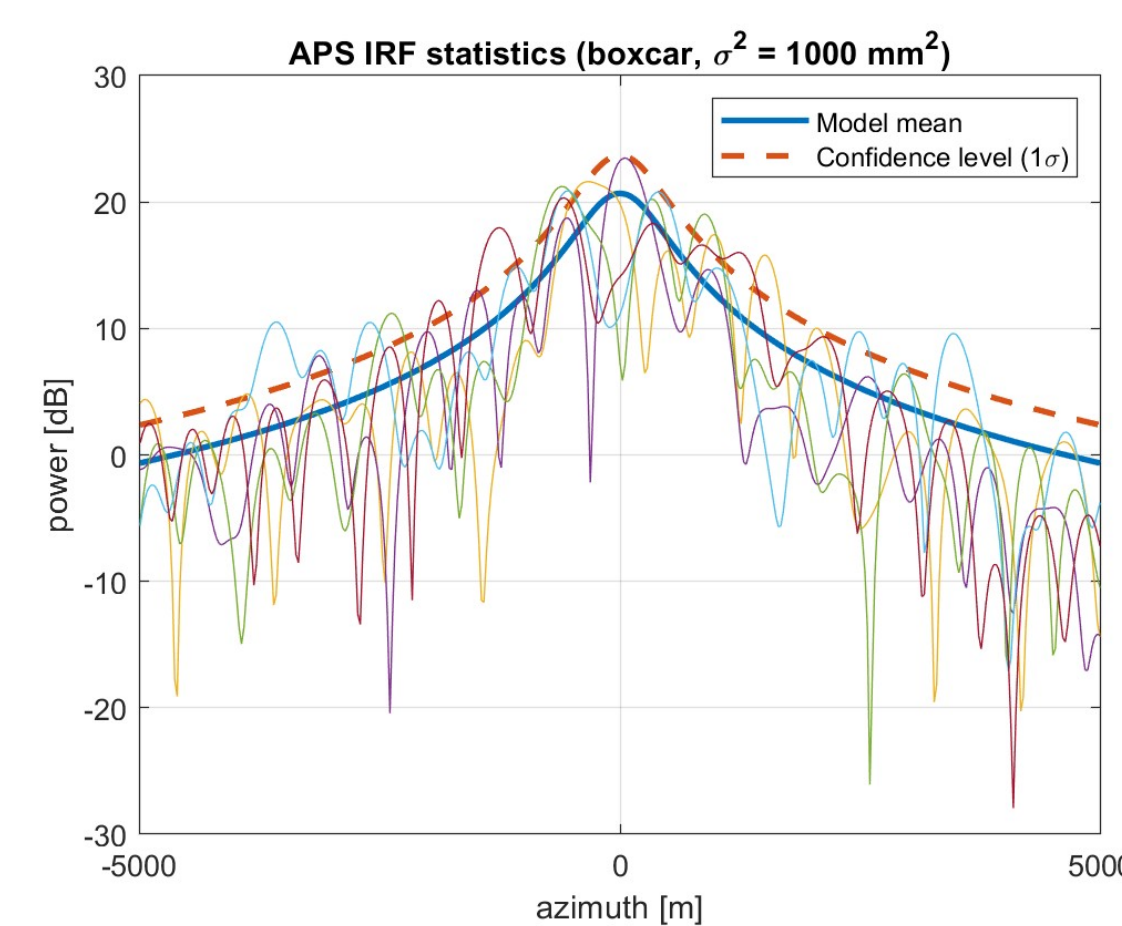
Along-track GEO-SAR in X-band combines the unique short revisit and wide coverage with fine resolution imaging. This needs an effective autofocus that in turn demands good coherence and higher power. A compact along-track MIMO-GEO formation would provide higher power, and very short revisit. MIMO images would generate multi-temporal baseline interferograms for an effective autofocus, but also for change detection.

Acknowledgments

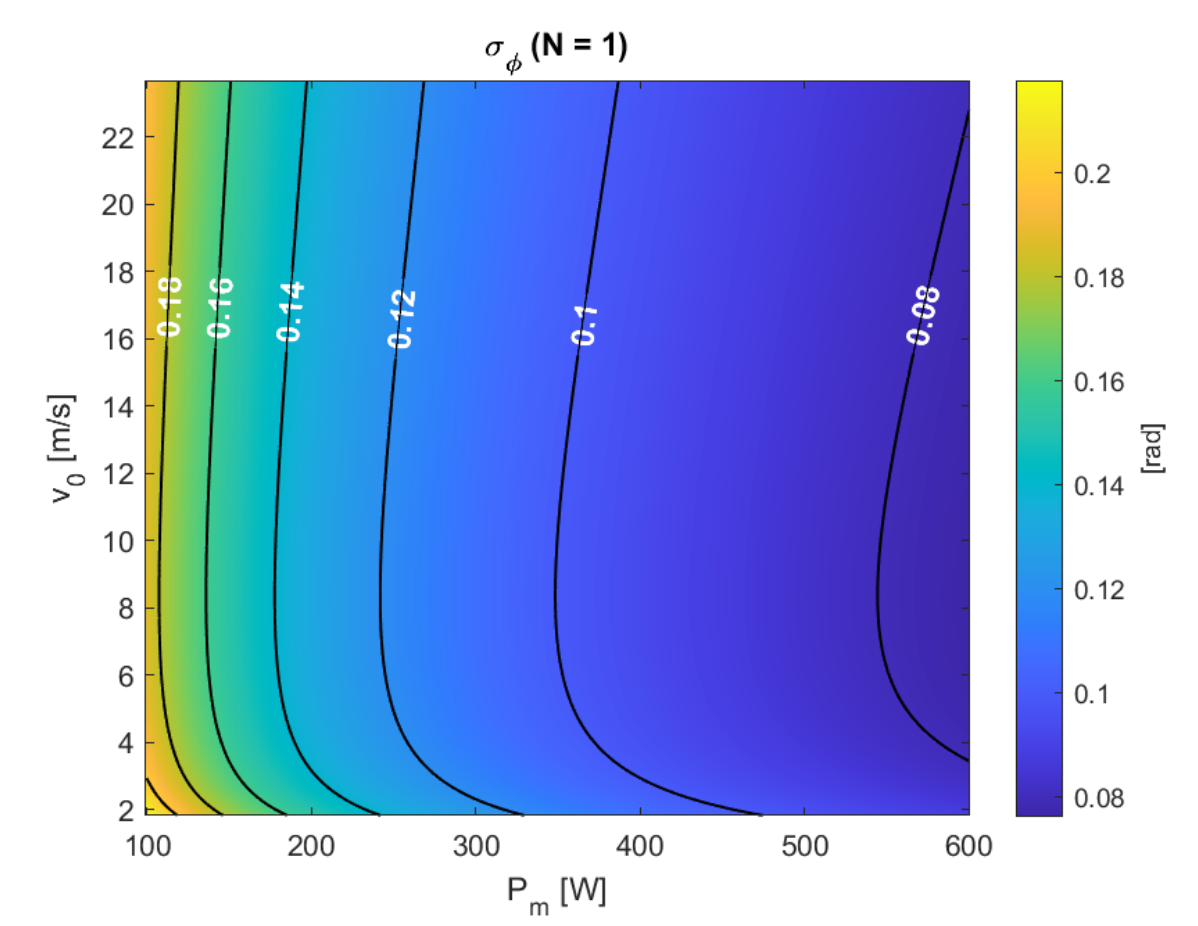
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Potentials and challenges

Geostationary SAR enables all-weather, continuous imaging with wide coverage and rapid access, but image formation is constrained by tropospheric and ionospheric variability. Coarse-resolution imaging has been demonstrated at C-band using interferometric autofocus. X-band systems could deliver finer resolution though higher power is needed, while stronger decorrelation poses significant challenges for autofocus.



Degradation of Impulse Response due to turbulence in C-band

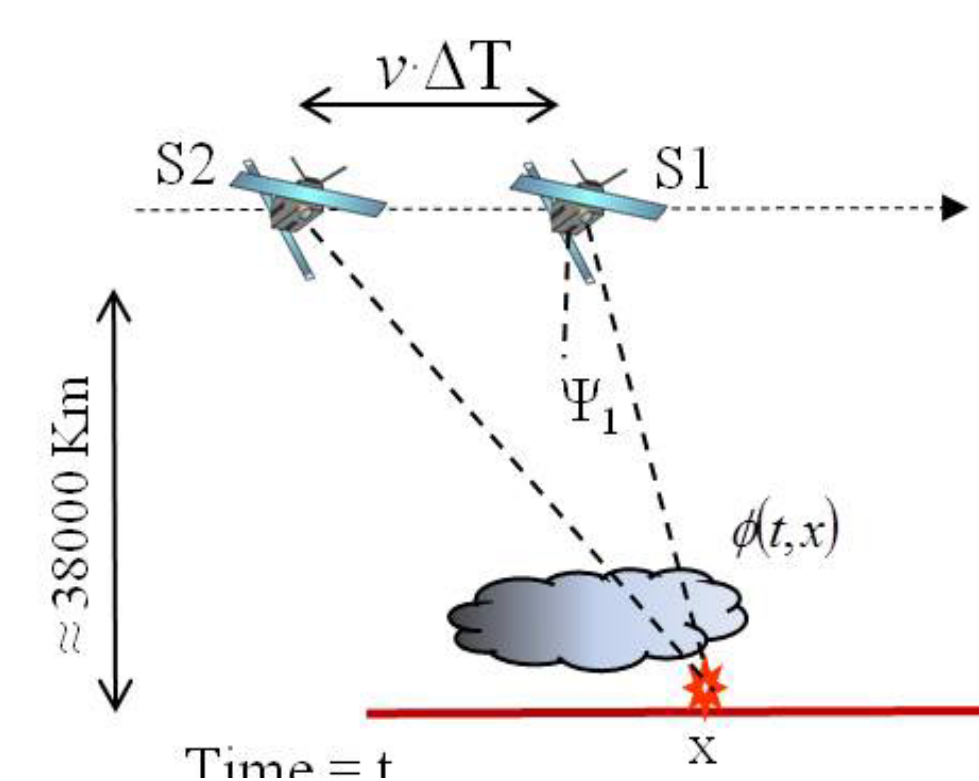


Performance achievable from a single C-band sensor, after autofocus

The way forward

An along-track close formation of 2 MIMO satellites along-track would enable effective autofocus thanks to the coherence in the short revisit, and fine resolution, thanks to the MIMO N^2 gain.

The feasibility is however subject to the effective turbulence of troposphere, much more than the ionosphere. To assess it, an entire year of water-vapor data generated by meteorological model has been processed.



The statistic analysis of the delay will enable the design of the formation, and, in turn, to assess the feasibility of the concept and derive achievable performance.

