Algorithm and Demonstration of Fringe Fitting for DOR Tones in Geodetic VLBI

First International Workshop on VLBI Observations of Near-field Targets

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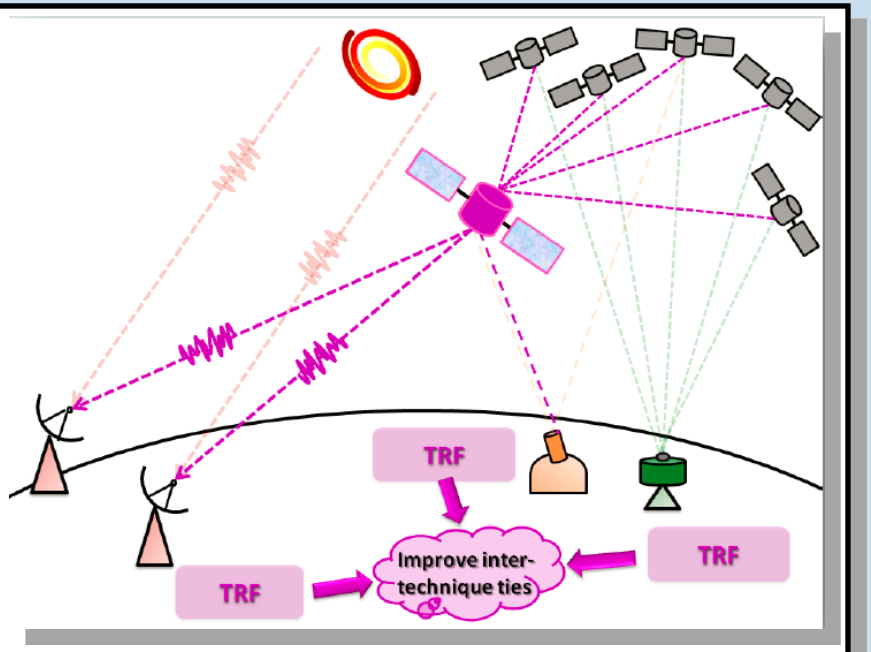
Table of Contents

Introduction

- Geodetic VLBI has been used to improve the frame ties between ICRF realized with VLBI observations of extragalactic quasar and spacecraft orbits realizing celestial frames. (Haas 2014; http://vlbi.geo.tuwien.ac.at/sorts/abstract/)



Plank, 2014

- DOR (Differential One-way Ranging) tone transponder is usually deployed by spacecraft for high accuracy interferometric tracking.(CCSDS; Border,2015)

- **DOR Tones narrow spectrum is totally different from quasar continuum spectrum.**

Algorithm and Analysis

- Interferometric phase output by FX type correlator can be expressed through first-order expansion. (Reynolds,2007)

$$\Delta\emptyset_{t,v} = \emptyset_0 + \frac{\partial\emptyset}{\partial v}\Delta v + \frac{\partial\emptyset}{\partial t}\Delta t$$

delay

rate

- Processing that estimates the delay and rate residuals is referred to as fringe fitting.

fringe-fitting in *fourfit*

- 2 steps
  - coarse grid search
  - refinement of parameter estimates
- grid search done via FFT's:
  - over frequency to find delay
  - over time to find fringe/delay rate
  - over "lag" to find single-band delay
- refinement
  - counter-rotate data and coherently sum:

$$\mathbf{g}(\tau,\dot{\tau}) = \sum_f \sum_t \boldsymbol{V}(f,t) e^{-2\pi i(f\dot{\tau}t + f\tau + \delta\phi)}$$

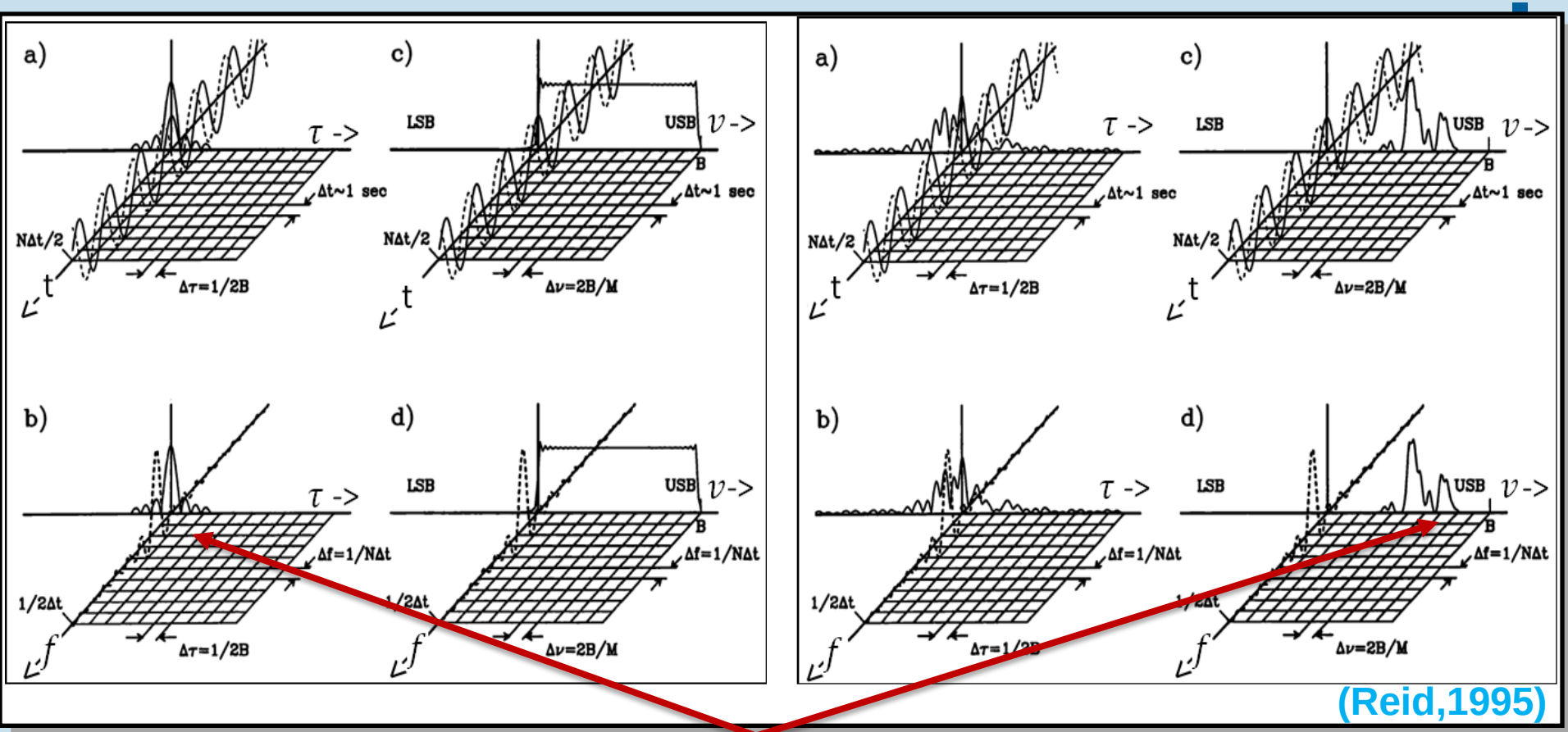
  - interpolate from closely-spaced grid-points

- Analysis in the domain of "**delay – fringe rate**" through Fourier Transform;
- 3-D search (Single Band Delay Multi Band Delay fringe-rate)

(Cappallo, IVS VLBI School, 2016)

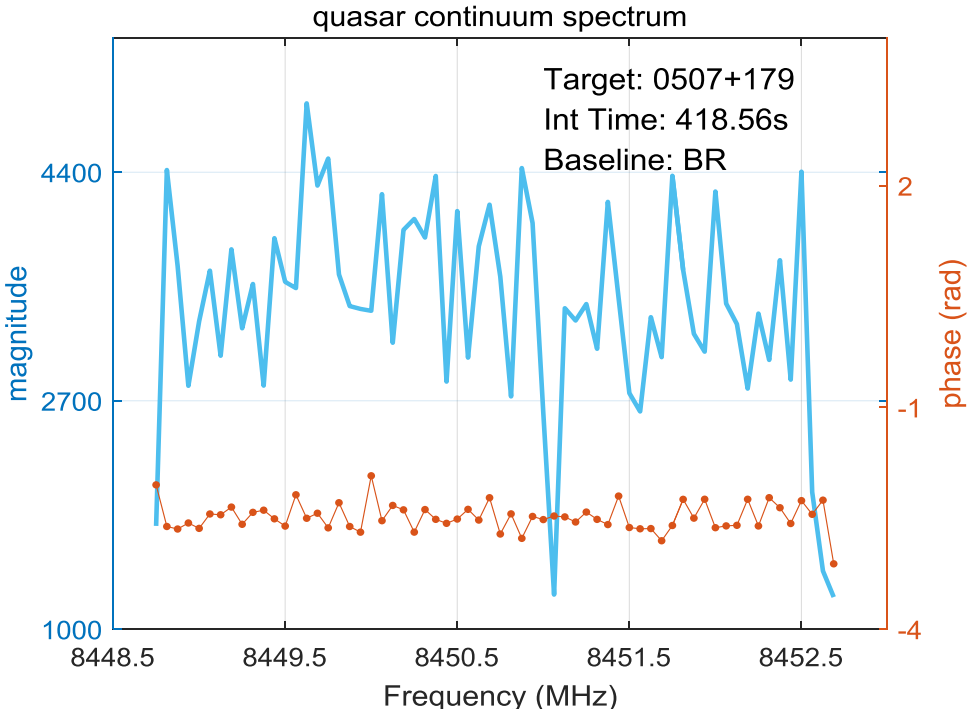
Algorithm and Analysis

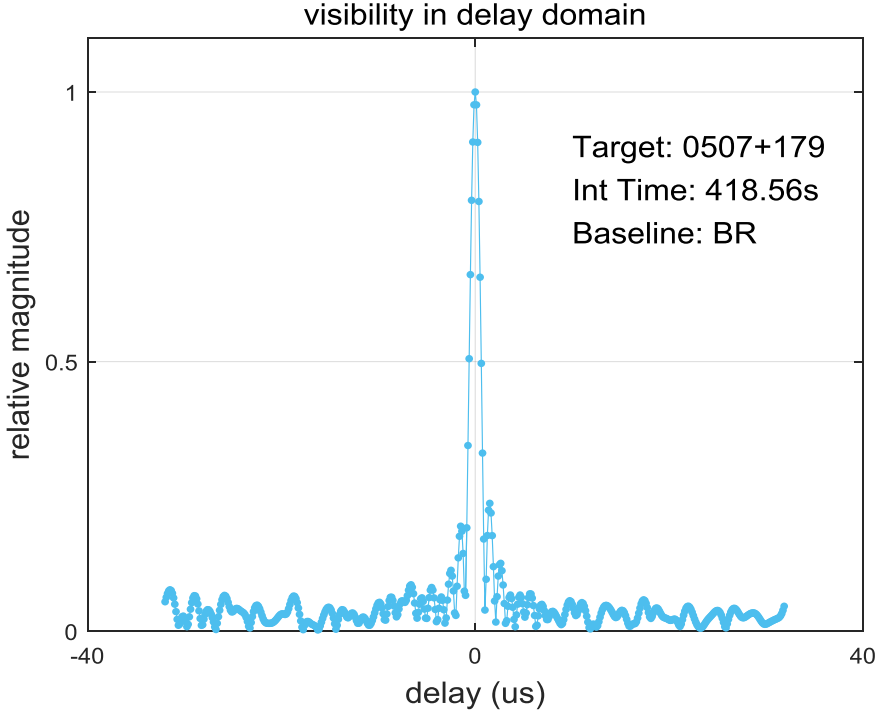
frequency(v) ⇄ delay(τ) time(t) ⇄ fringe rate(f)

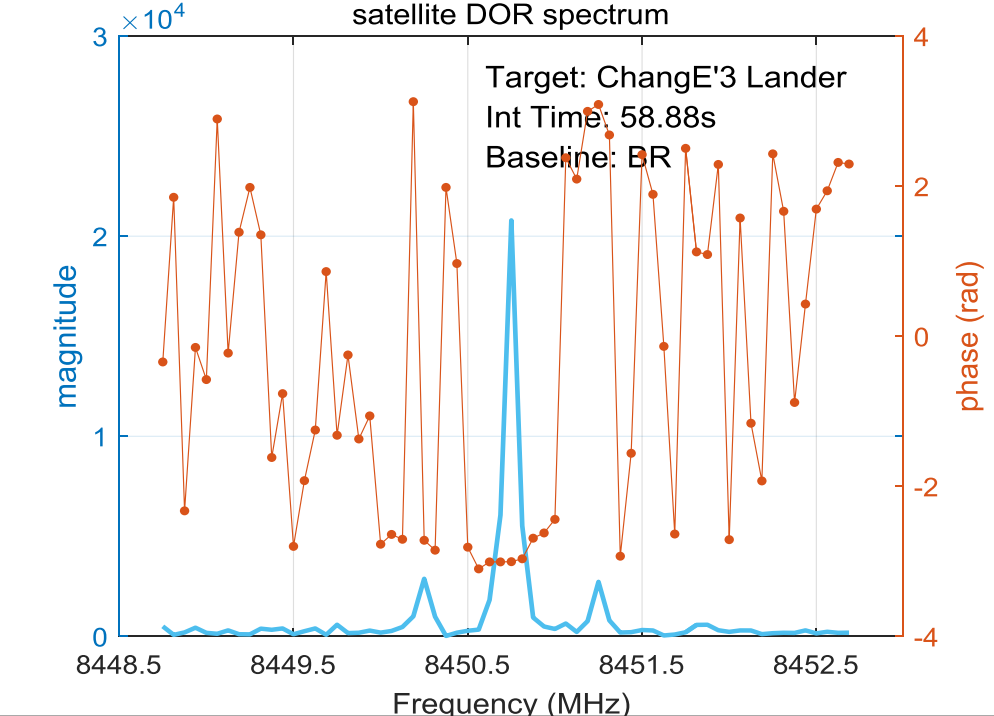


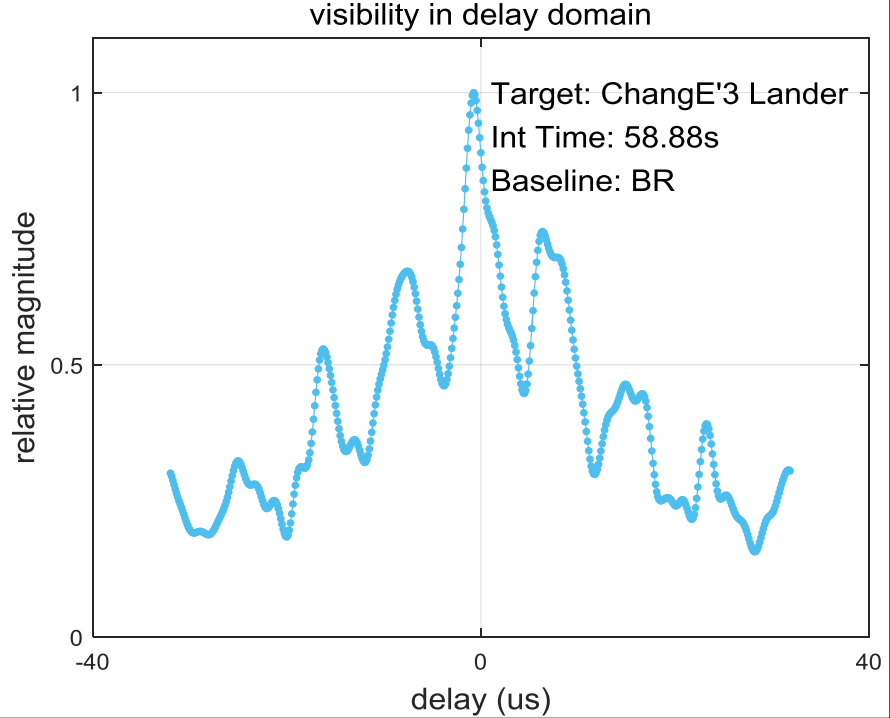
(Reid,1995)

visibility amplitude peaks sharply in both axis and most easily detected.


quasar continuum spectrum
Target: 0507+179
Int Time: 418.56s
Baseline: BR
magnitude
phase (rad)
4400
2700
1000
2
-1
-4
8448.5
8449.5
8450.5
8451.5
8452.5
Frequency (MHz)


visibility in delay domain
Target: 0507+179
Int Time: 418.56s
Baseline: BR
relative magnitude
1
0.5
0
-40
0
40
delay (us)


satellite DOR spectrum
×10^4
Target: ChangE'3 Lander
Int Time: 58.88s
Baseline: BR
magnitude
phase (rad)
3
2
1
0
4
2
0
-2
-4
8448.5
8449.5
8450.5
8451.5
8452.5
Frequency (MHz)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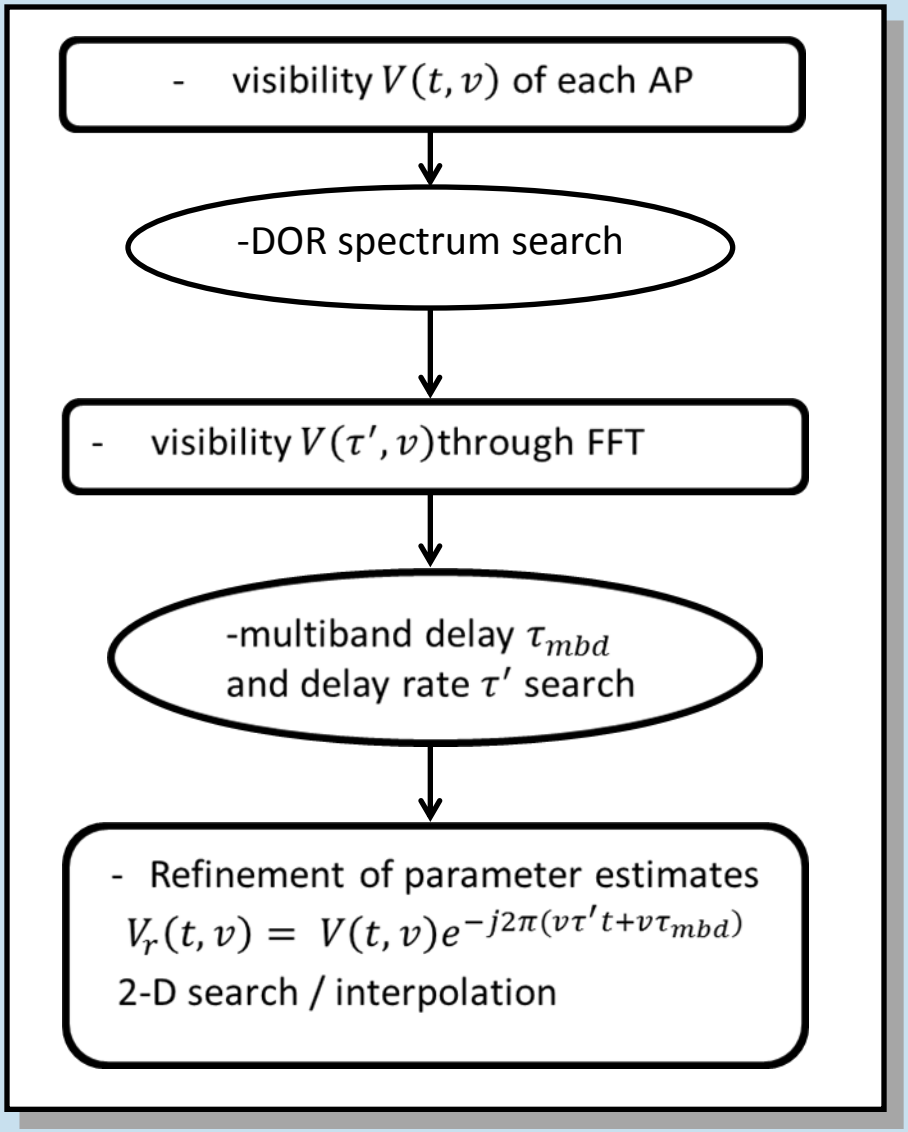
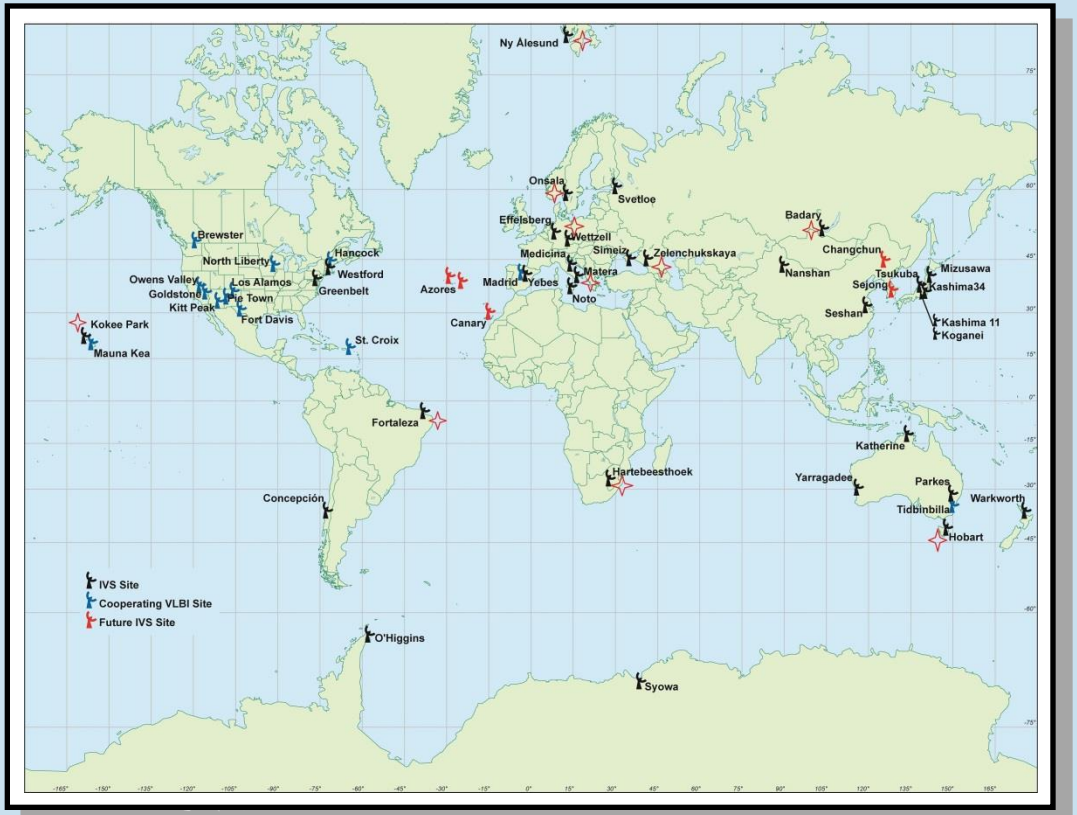
Algorithm and Analysis

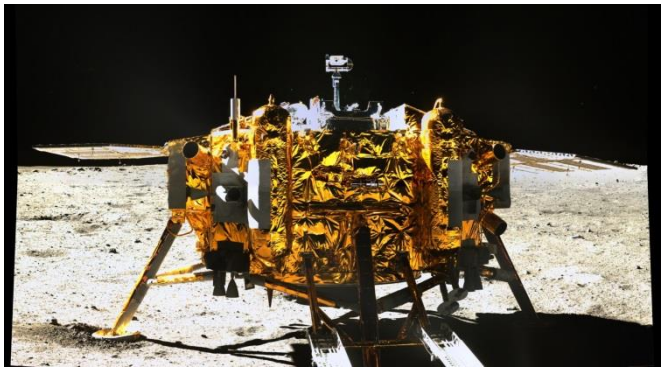


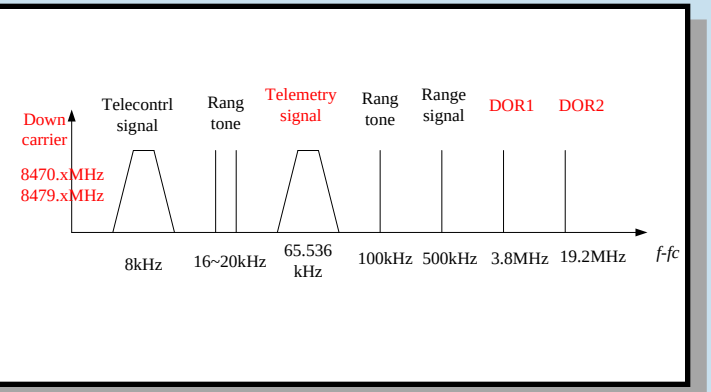
flow chart of our algorithm

Experiment and Comparison

- **OCEL(Observing the Chang'E-3 Lander with VLBI)** project has been conducting jointly by IVS and BACC, a global IVS R&D network augmented with two China Deep Space Stations was configured for OCEL.



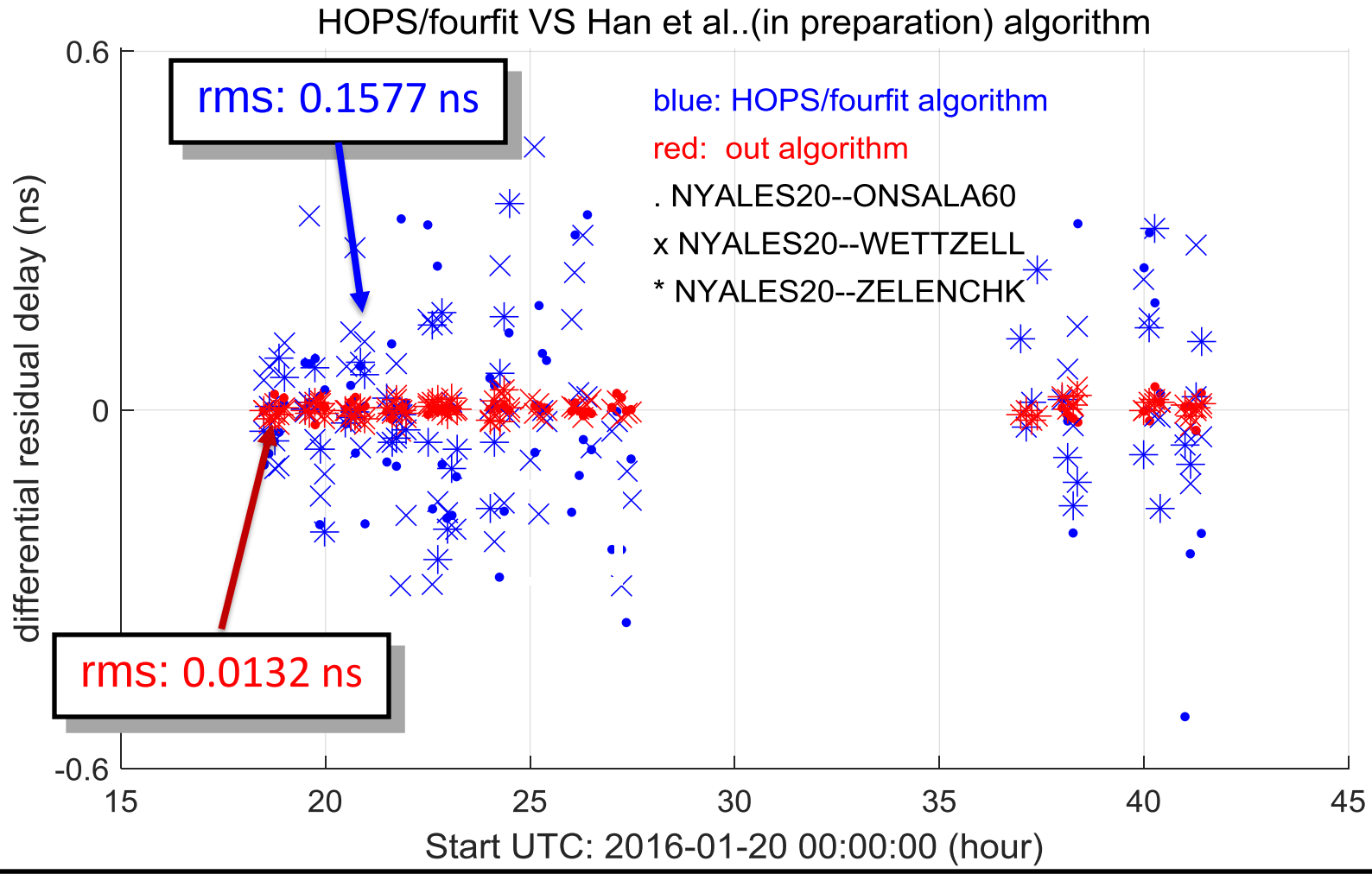




Stations in rd1601

Experiment and Comparison

- Results of the algorithm adopted for spacecraft navigation (Kikuchi,2004; Tang,2012) are deemed as true reference value.



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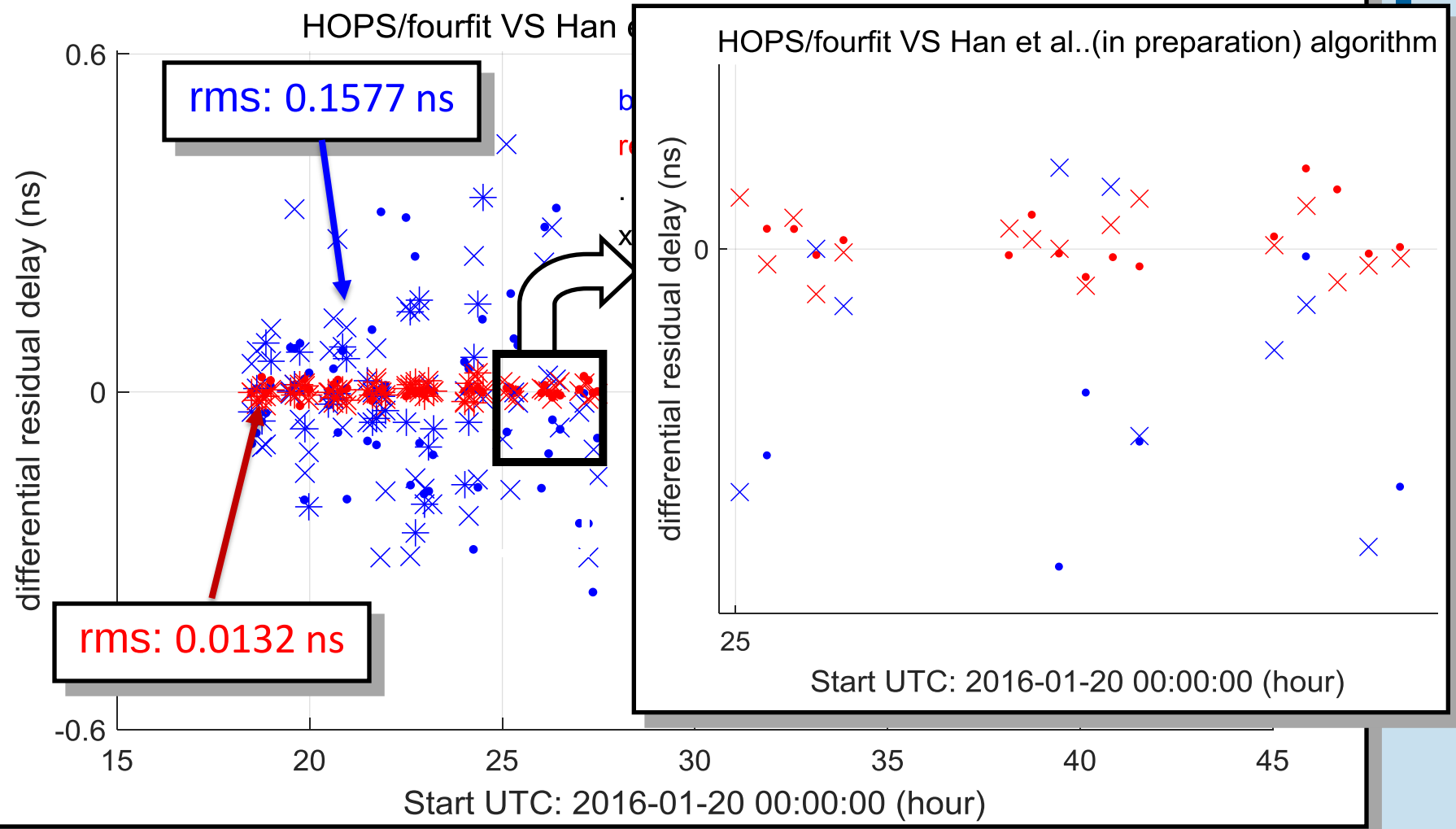

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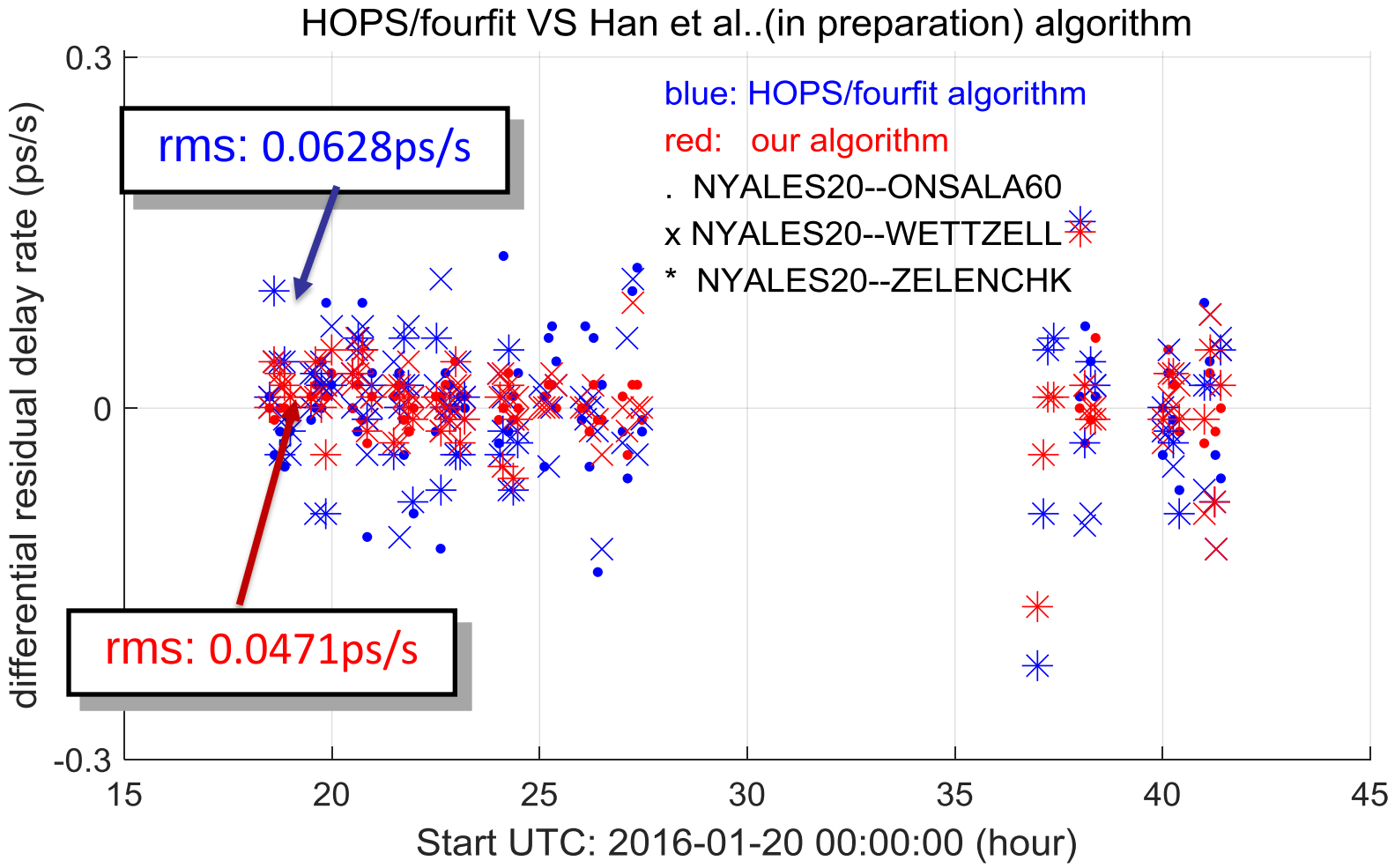

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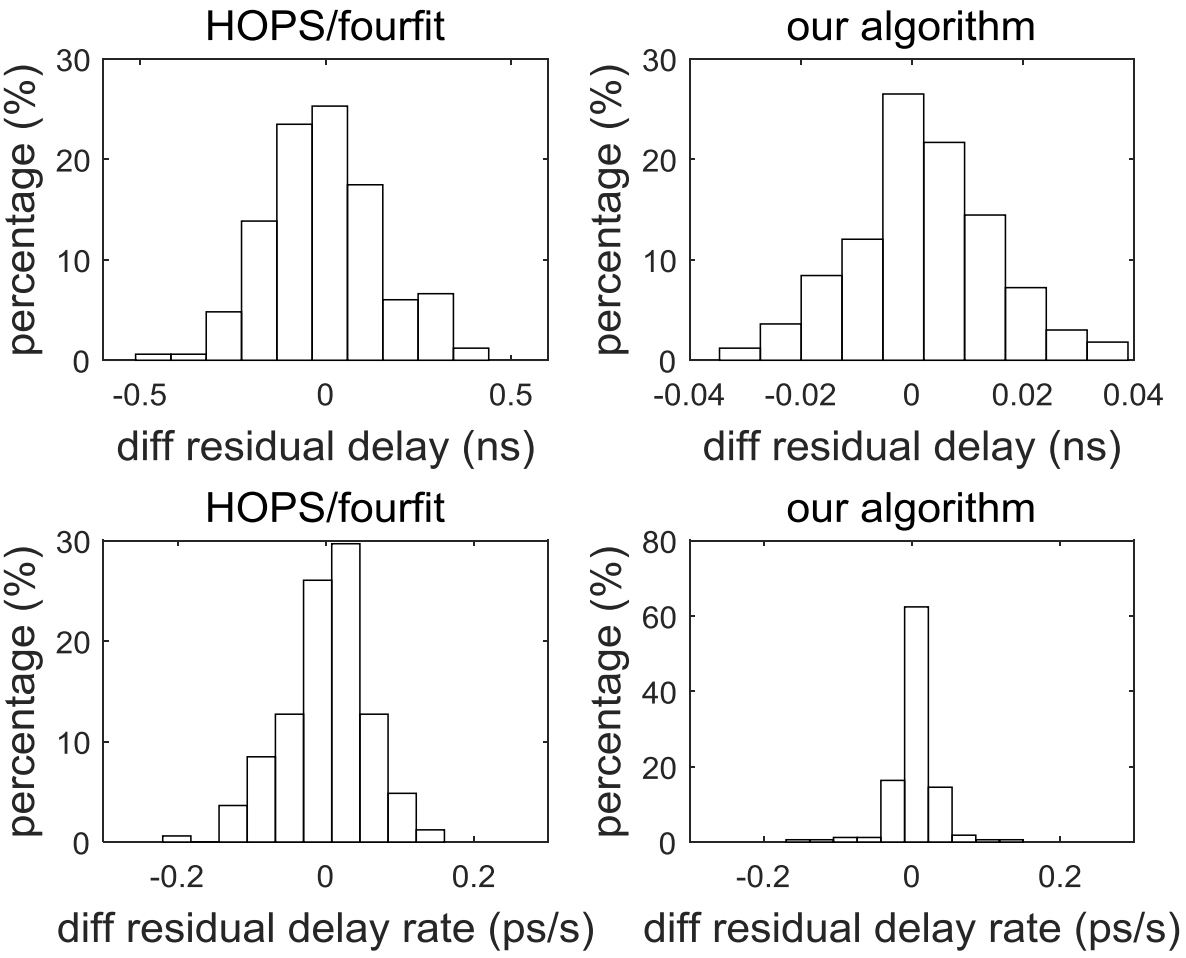
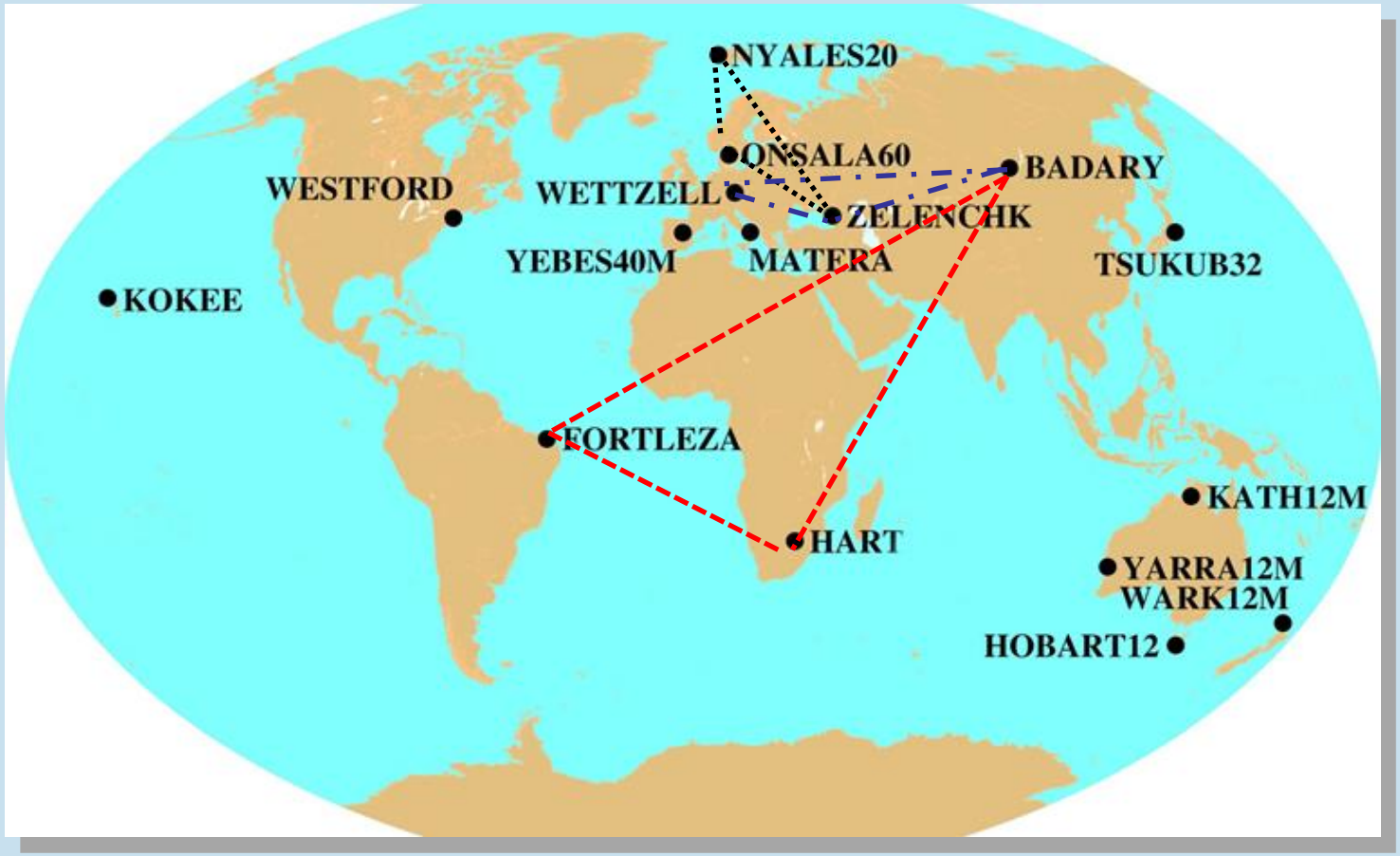


error distribution

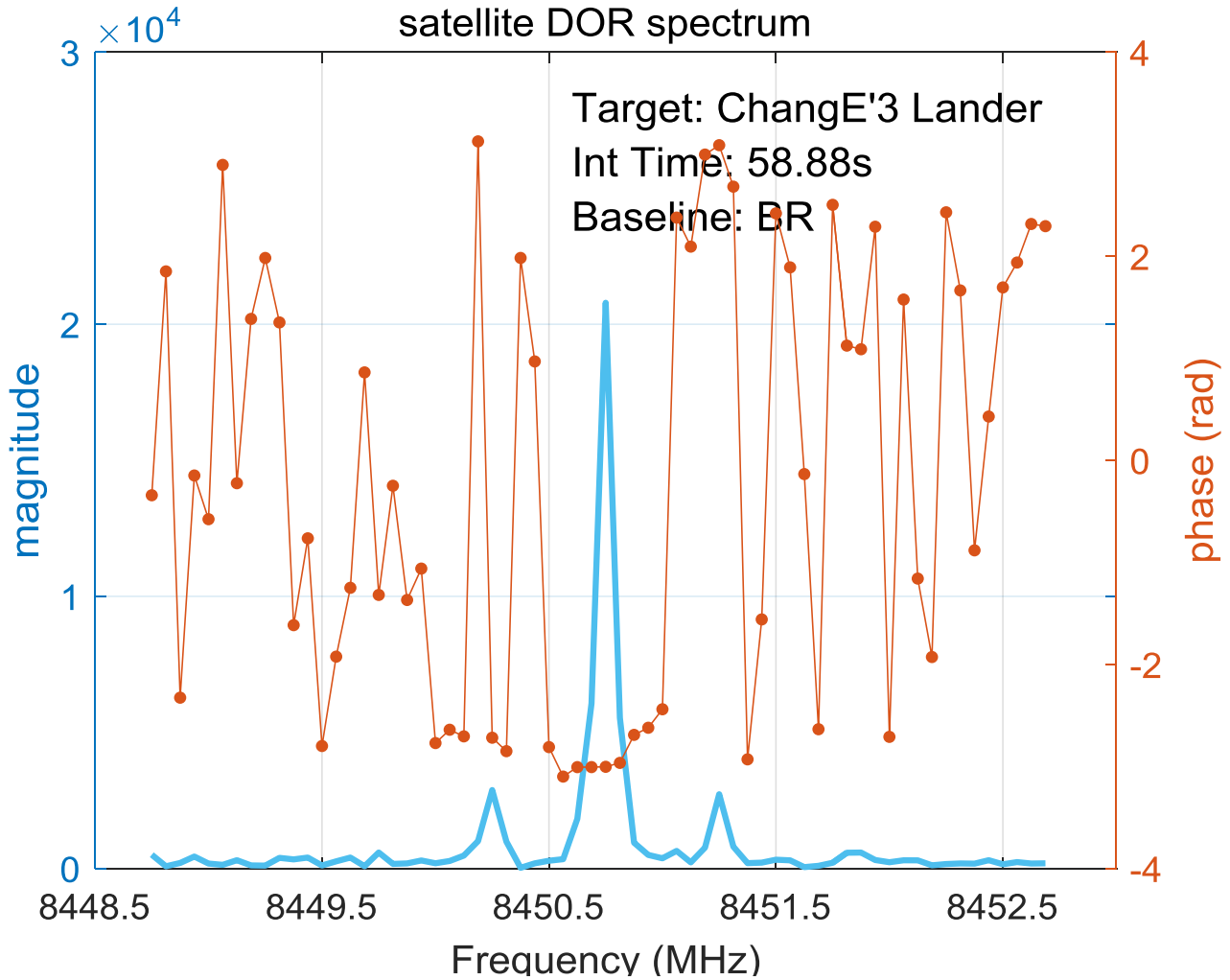
Experiment and Comparison



closure delay	Baseline Combination(3 examples..)		
rms(ns)	NY/ON/ZC	BD/FT/HH	BD/WZ/ZC
HOPS/fourfit	0.2748	0.4259	0.2598
our algorithm	0.0808	0.1057	0.0928

Experiment and Comparison

- Algorithm has better results than original algorithm, **why?**



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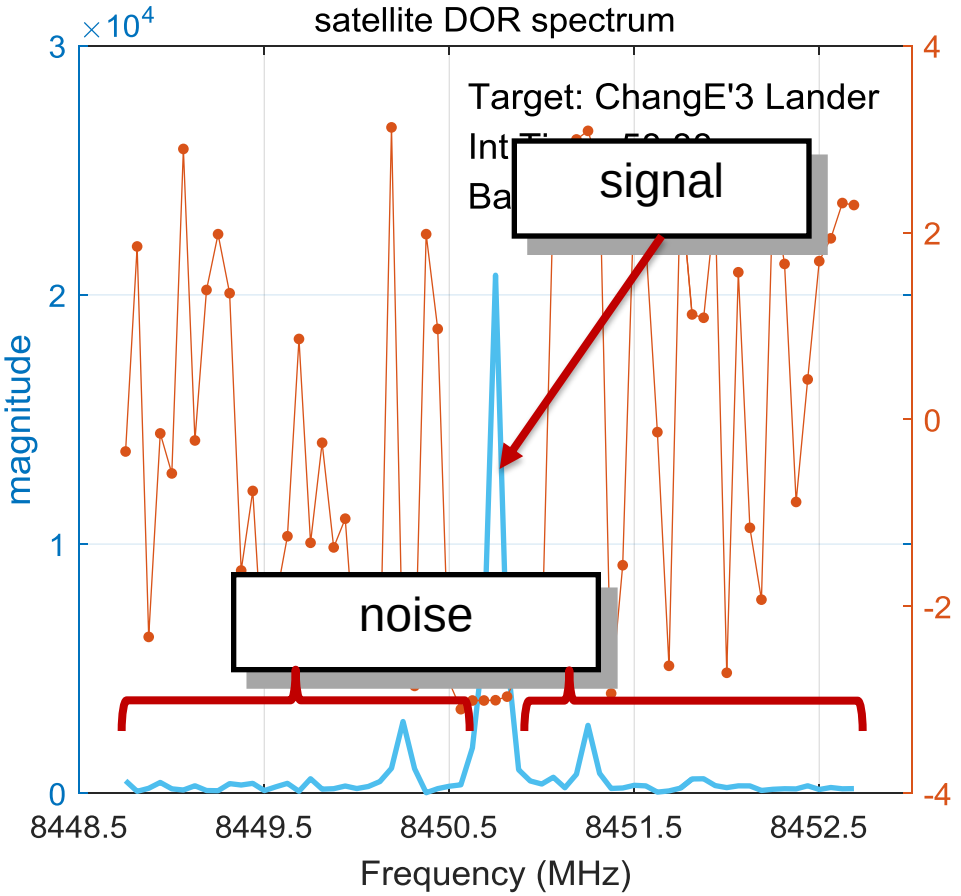

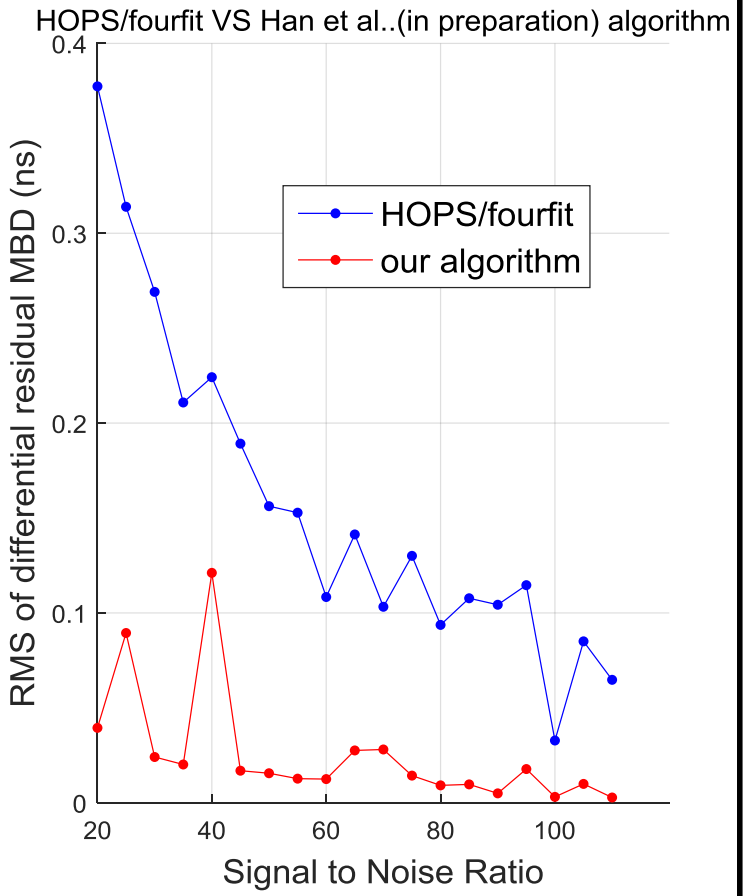

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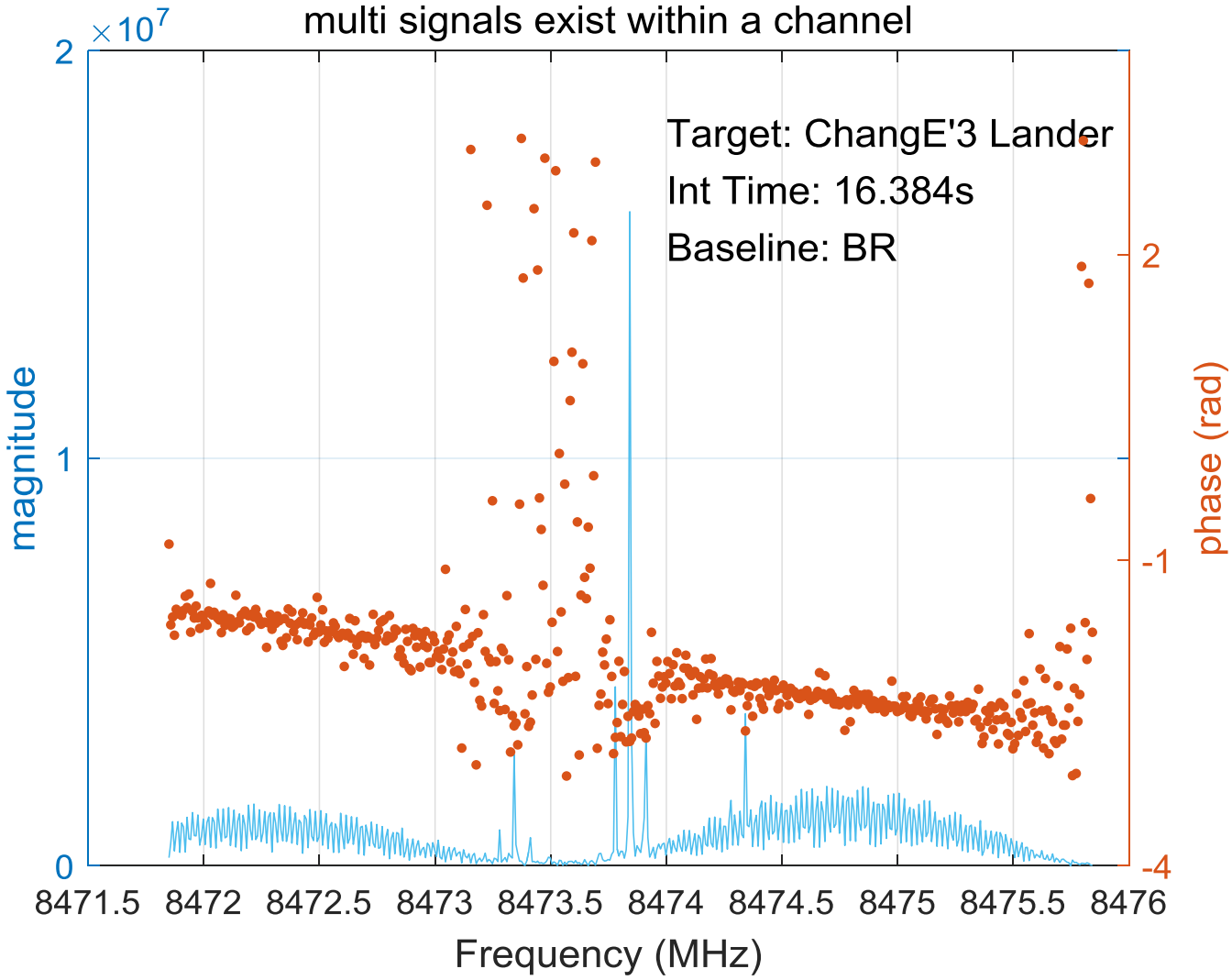

Summary

	HOPS/fourfit	Our Algorithm
Domain	fringe rate -- delay	fringe rate -- frequency
Observables	Multiband delay Delay rate Singleband delay	Multiband delay Delay rate
Accuracy		
Efficiency		
Interference suppression		
DOR Tones Spectrum	**Our algorithm is recommended!**	

Thank you for your attention!

Questions are welcomed!

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