



Signatures of Doppler Collision in NavIC

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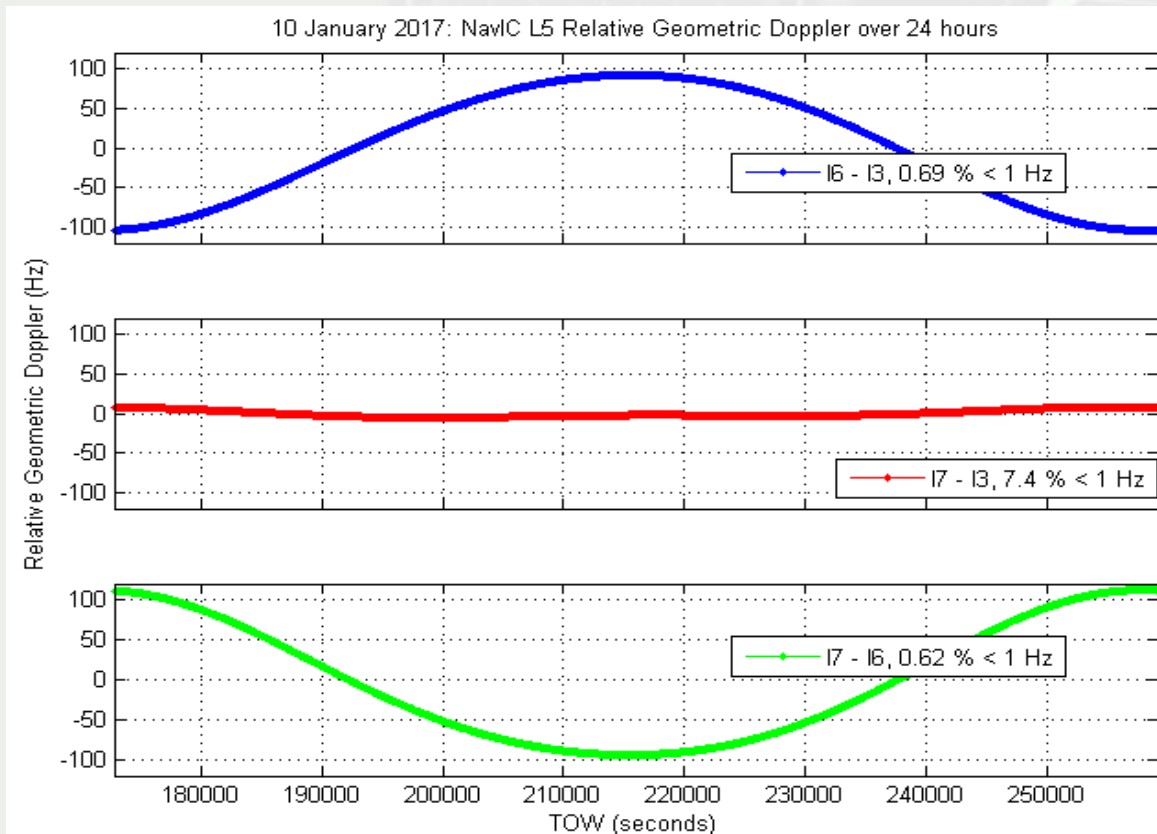
Ahmedabad, India

- Briefly discuss Doppler collision
- Relative Doppler analysis
- Setup to observe Doppler collision
- Relative Doppler and delta code analysis at test location
- Doppler collision event

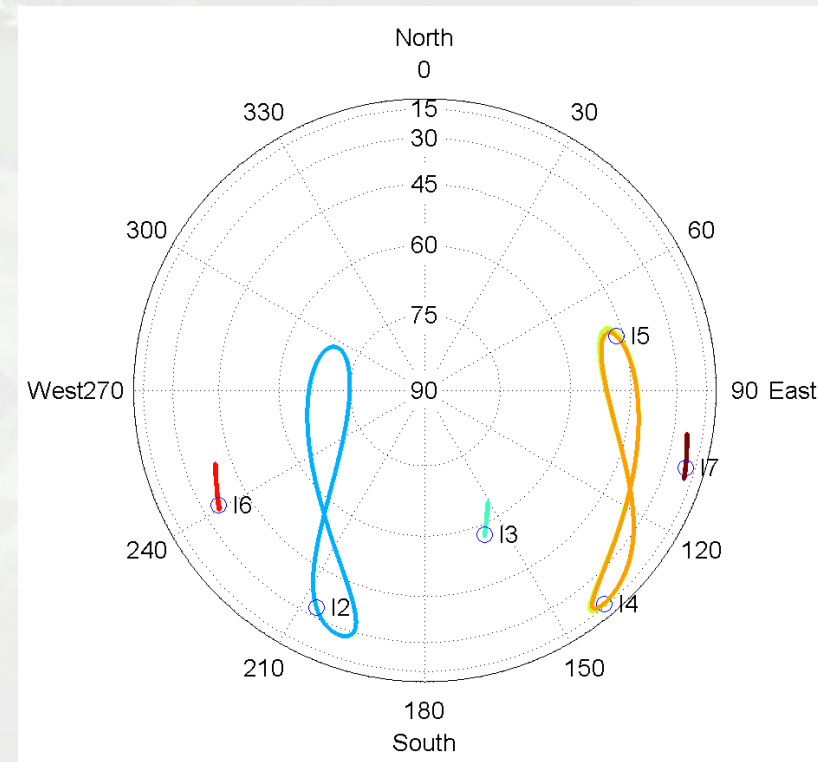
What is Doppler Collision?

- A multipath like phenomenon where cross-correlation peaks of other GNSS satellites interact with primary peak of desired satellite signal
- Conditions for Doppler collision
 - Relative Doppler within DLL bandwidth
 - Presence of cross-correlation peak
 - Relative code delay
 - Relative power
 - Sign of message data
 - Relative carrier phase
- In NavIC constellation, satellites 1C, 1F, and 1G are quasi-geostationary (5° inclination angle)
- NavIC L1 has C/A codes where probability of secondary peaks is 25%

Relative Doppler Analysis -Location Ahmedabad, India



Relative Doppler over 24 hours and percentage of time where relative Doppler is below DLL BW



- Doppler of NavIC 1C (PRN 3) and 1G (PRN 7) in synch
- Relative Doppler below DLL BW (1 Hz) for 7.4 % of 24 hours (~1.8 hours)

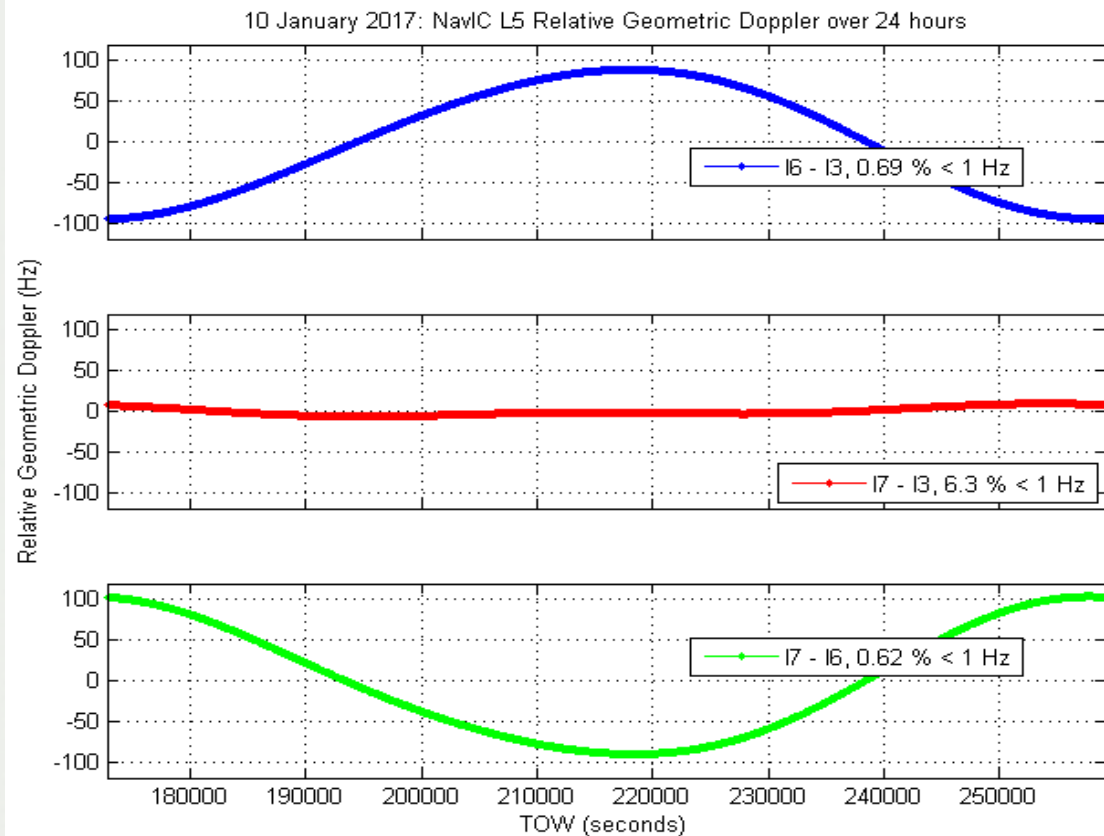
- Similar relative Doppler analysis is conducted at multiple locations over edge of service area

Location	Percentage of Time Duration over 24 hours where relative Doppler is less than 1 Hz					
	Day1 10 January 2017			Day2 10 July 2017		
	Between 1F & 1C	Between 1G & 1C	Between 1G & 1F	Between 1F & 1C	Between 1G & 1C	Between 1G & 1F
Colombo, Sri Lanka	1.10	3.50	1.40	1.10	4.00	1.50
Hanoi, Vietnam	0.69	6.30	0.62	0.69	6.60	0.76
Dubai, UAE	0.62	7.10	0.56	0.69	9.60	0.56
Ahmedabad, India	0.69	7.40	0.62	0.69	8.90	0.69
Srinagar, India	0.56	3.30	0.49	0.56	3.70	0.42

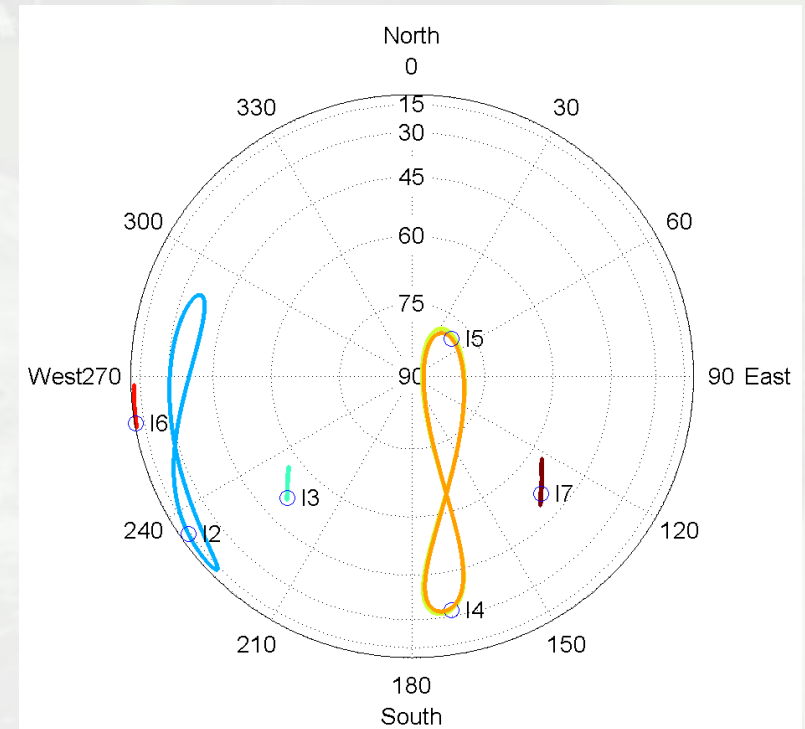
Setup for Doppler Collision Event

- Based on relative Doppler Analysis of NavIC 1C and 1G, an attempt is made to observe Doppler collision in potential windows
- A live scenario is simulated in NavIC simulator for day: 10 January 2017
- Data collection is done during windows where relative Doppler is small
- Location - Hanoi, Vietnam, relative carrier Doppler is less than 1 Hz for ~7% of day time
- Code and carrier phase observations are collected using NavIC receiver with following settings
 - Chip spacing (E-L) – 1 chip, standard correlator
 - DLL bandwidth – 1 Hz

Relative Doppler Analysis - Location Hanoi, Vietnam

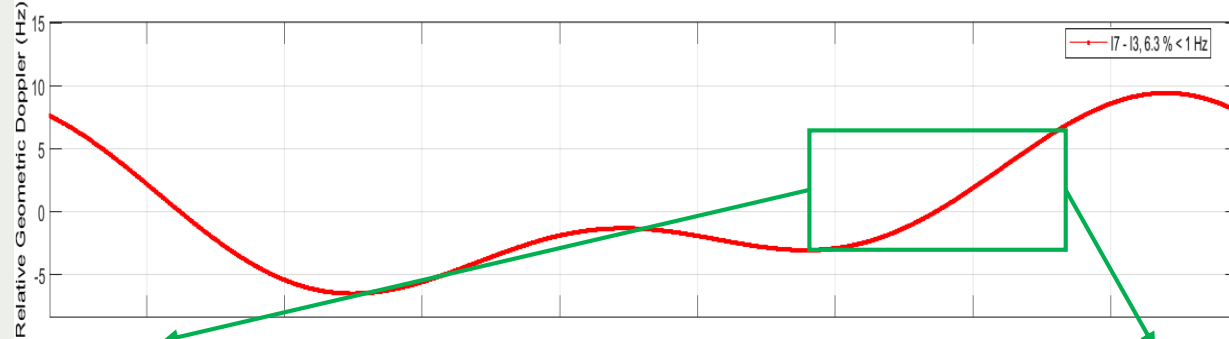


Relative Doppler over 24 hours and percentage of time where relative Doppler is below DLL BW

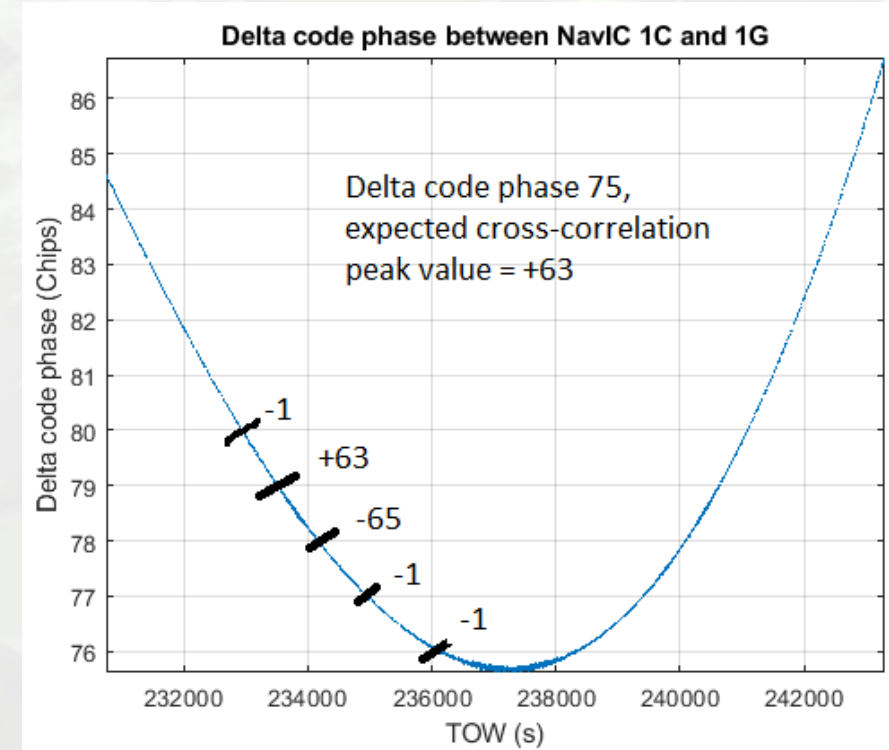
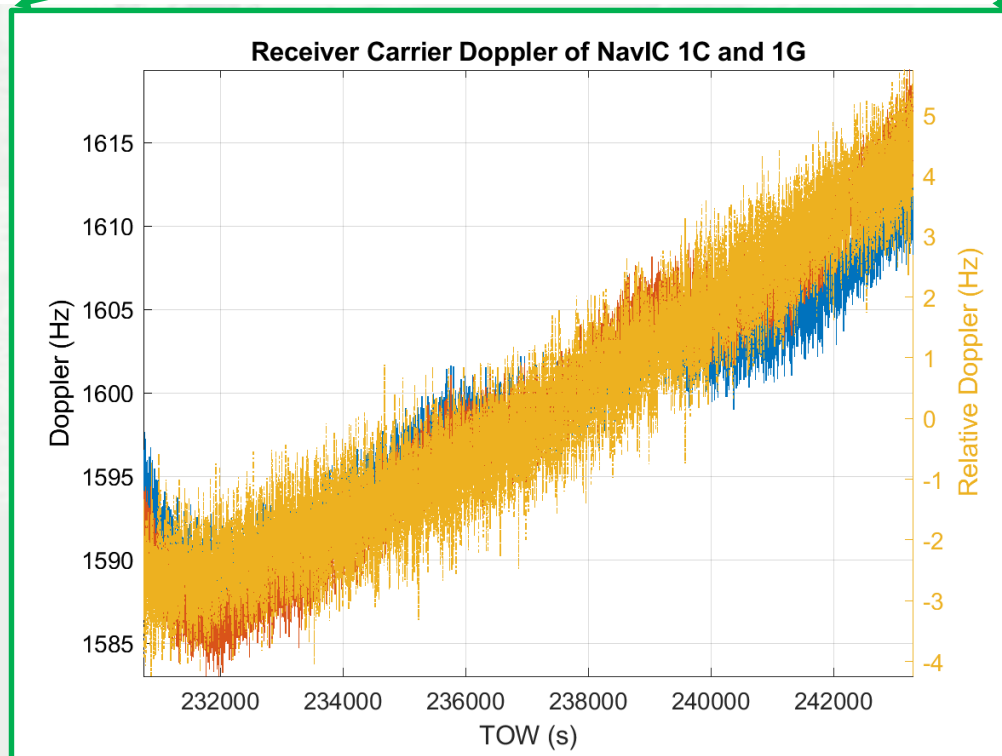


- Doppler of NavIC 1C (PRN 3) and 1G (PRN 7) in synch
- Relative Doppler below DLL BW (1 Hz) for 6.4 % of 24 hours (~1.5 hours)

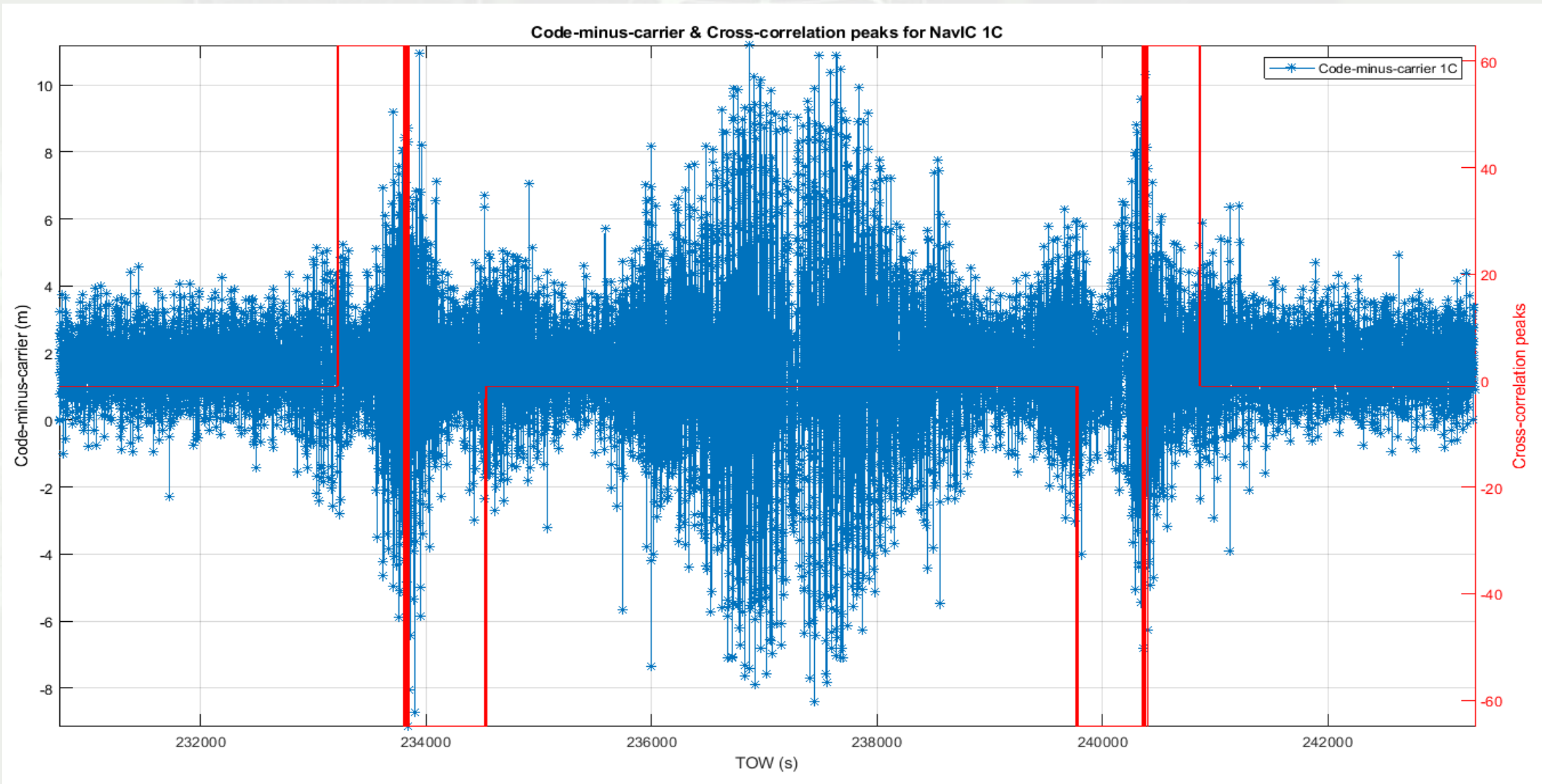
Relative Doppler & Delta Code Phase – 1C and 1G, Hanoi

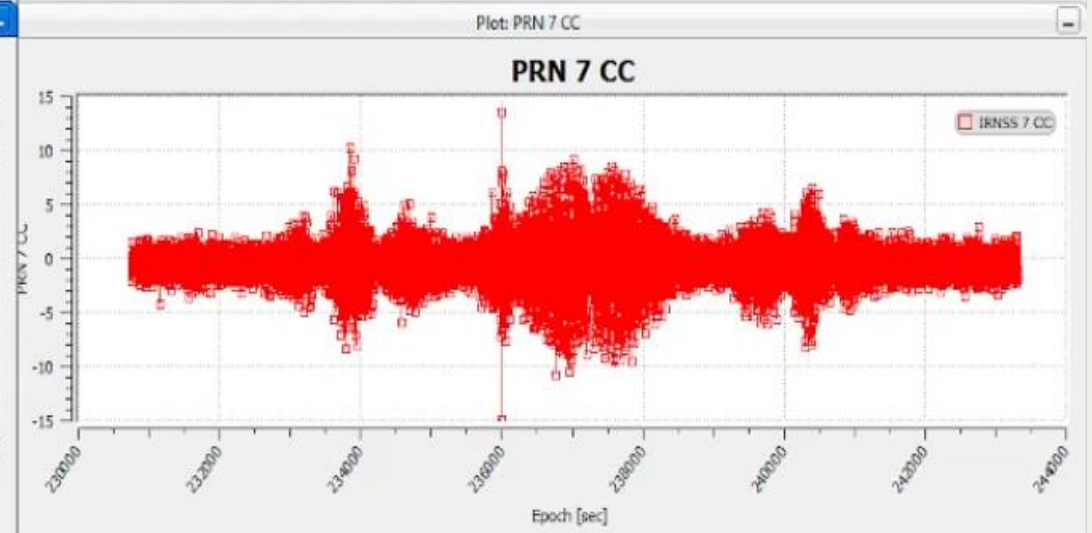
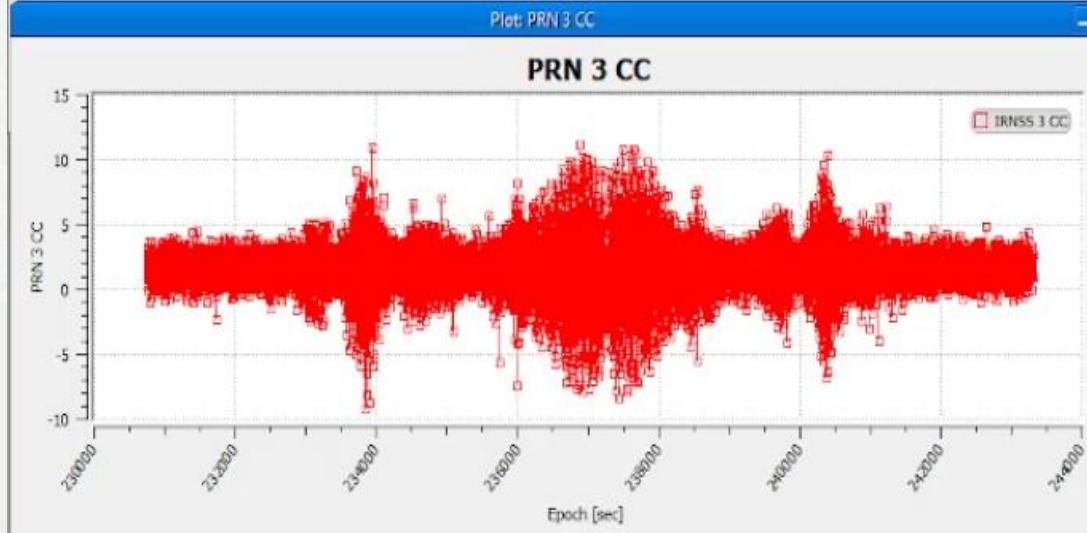
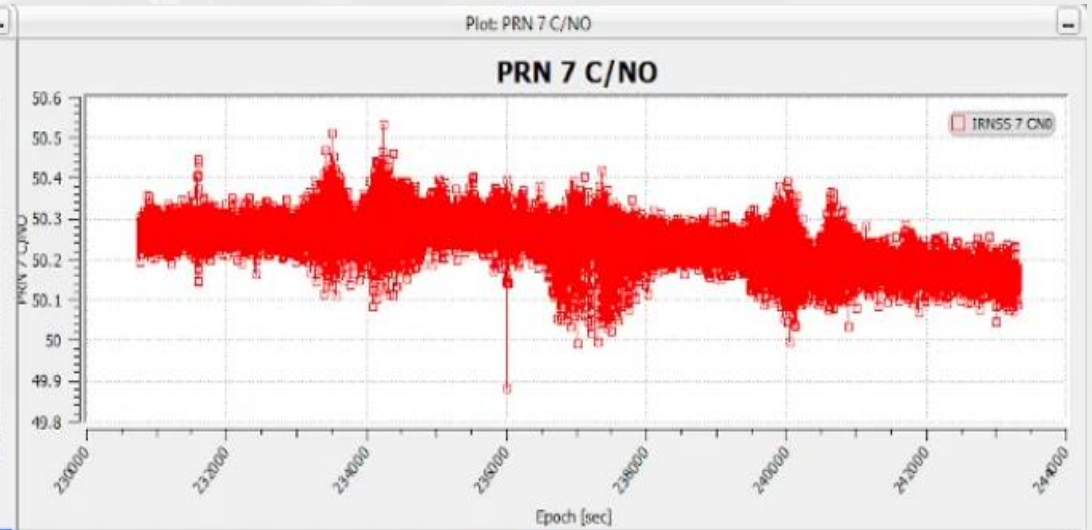
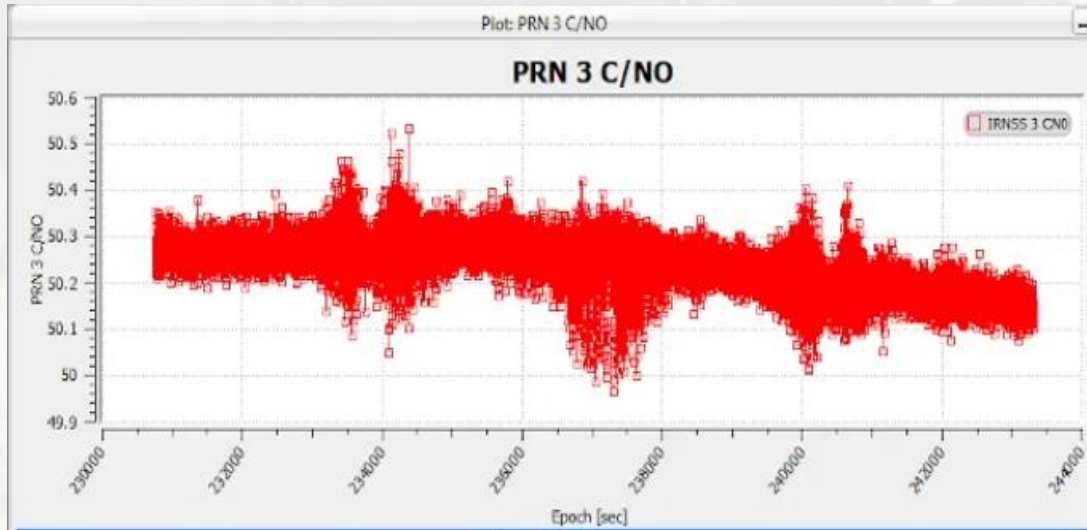


- Observed window – relative Doppler is small
- Delta code phase changes sign in sync with relative Doppler



NavIC 1C Code-minus-carrier and Theoretical Correlation Peaks, Hanoi





Summary and conclusions

- Thorough analysis carried out for relative Doppler and cross-correlation between NavIC 1C and 1G
- Simulation tool is developed to identify time window and location of Doppler collision for NavIC satellites
- Test bench is developed to observe Doppler collision events
- It is observed that Doppler of NavIC 1C and 1G are in synch
 - The relative phasing among 1C and 1G can be optimized to reduce Doppler collision window
- More analysis is required to identify Doppler collision scenarios between existing/future GEO satellites in GNSS



Thank you