

Effect of Doppler Collision in Satellite navigation systems

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Abstract

Navigation with Indian Constellation (NavIC or IRNSS) is the Indian regional satellite navigation system. The constellation consists of 7 GSO satellites. Doppler Collision is a specific characteristic experienced by the receiver when the difference between the carrier doppler frequencies of the two satellite signals is within the code tracking loop bandwidth of the receiver [1, 2]. Although this situation is not too frequent in MEO based GNSS, it happens quite frequently in NavIC (especially GEO satellites) and SBAS satellites given their apparent stationary nature [4]. This paper provides the details of experiment simulated to study the effect of Doppler collision in estimated user position using NavIC satellites.

1 Doppler Collision Phenomenon

A necessary condition for Doppler Collision interference is that the relative carrier Doppler between the two interfering signals is less than the receiver code loop bandwidth and the cross-correlation peak/s fall within the auto-correlation peak of the correlators. This condition distorts the correlator function resulting in the tracking error and is known as Doppler Collision [1]. The error due to cross-correlation interference is a function of the signed amplitude of the cross-correlation peak and relative carrier phase, which in turn depend on many parameters like relative range difference, code phase offset, difference in signal power, data-bit polarity and the time period for which relative Doppler is within the code loop bandwidth [3].

In the case of Geostationary Earth Orbit (GEO) satellites, which results in either zero or very low Doppler in receiver, the relative carrier Doppler remains within the code loop bandwidth for quite a long time. This causes higher tracking errors for longer durations. If GEO satellites have 0° inclination, the receiver experiences zero Doppler from such satellites and so the Doppler Collision is likely to be a continuous phenomenon, causing errors in the pseudorange measurements. However, for GEO satellites with a nonzero inclination angle (of about 0.1 degree), the Doppler will not be zero and consequently the relative carrier phase, code phase and range difference will vary continuously. However in these cases, the peak-to-peak measurement errors increase and hence the standard deviation of the pseudorange measurements increases. Thus the effect of the Doppler collision is similar to that of the multipath signal.

2 Simulations carried out to estimate error in user position

2.1 Experimental setup

A NavIC simulator is used to simulate NavIC constellation. The inclination of IRNSS-1C satellite was chosen as 5° and 0° respectively to introduce Doppler collisions in the measurements. The ionospheric, tropospheric and multipath errors were modelled to be zero.

A high precision ground reference receiver was used for making the pseudorange measurements. The frequency inputs for both the systems (simulator and receiver) were coherent. The delay lock loop bandwidth was kept 0.2Hz. Both the systems were prior calibrated.

The true or geometric or simulated ranges, recorded by simulator, were compared with pseudoranges made by the high precision reference receiver.

2.1 Observations

Figure-1 and 2 shows the difference in range measurement as experienced by IRNSS-1B (PRN2) and IRNSS-1C (PRN3) before and after the introduction of the Doppler Collision.

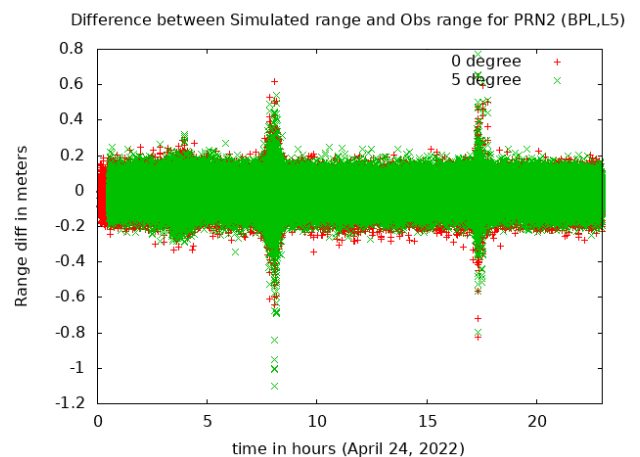


Figure 1: Range difference as experienced in the measurements of PRN2 (L5) when PRN 3's inclination was changed from 5° to 0°

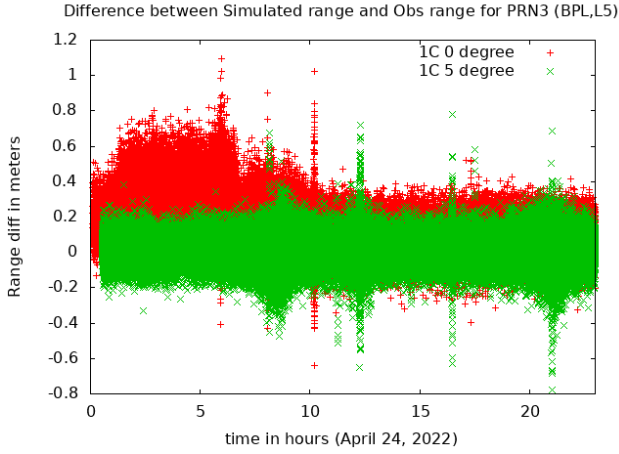


Figure 2: Range difference as experienced in the measurements of PRN3 (L5) when its inclination was changed from 5° to 0°

From above two plots, it is clear that the static reference receiver experiences doppler collision for relatively stationary satellite (GEO) when other (GSO) satellite is crossing the equator. Figure-5 shows the impact of doppler collision in user receiver, where code tracking loop has more bandwidth compared to reference receiver.

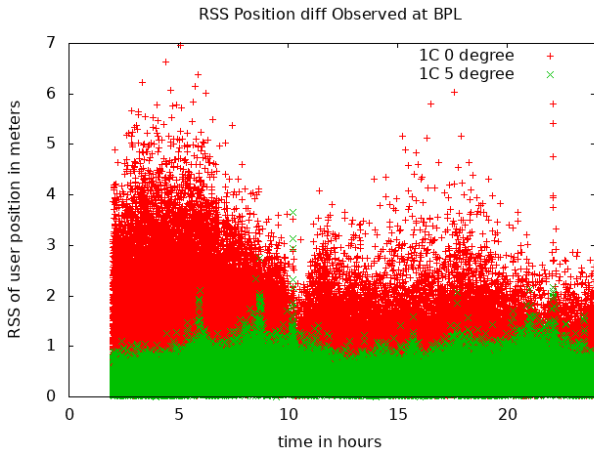


Figure 3: Effect on user position accuracy in Bhopal when PRN3 was inclined at 0deg and 5deg respectively

3 Simulations carried out with varying code loop bandwidth

Since Doppler collision depends on code loop bandwidth, the above exercise was reworked using different loop filter bandwidths in the reference receiver.

The reference receiver was configured for 0.01Hz, 0.2Hz and 0.5Hz delay lock loop bandwidth (DLL BW). Other parameters were kept same in the simulation.

Difference between simulated range and observed range for PRN1 (GSO in L5 band) and PRN3 are shown in Figure-4 and 5 respectively.

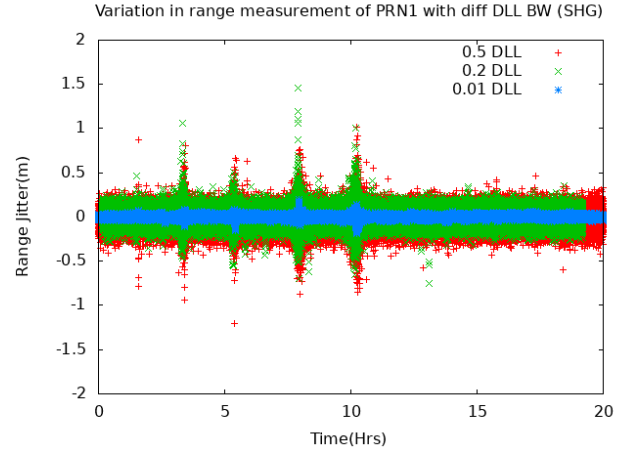


Figure 4: Impact of Variation in DLL BW (L5 band) for PRN1 when PRN3 was at 0° inclination.

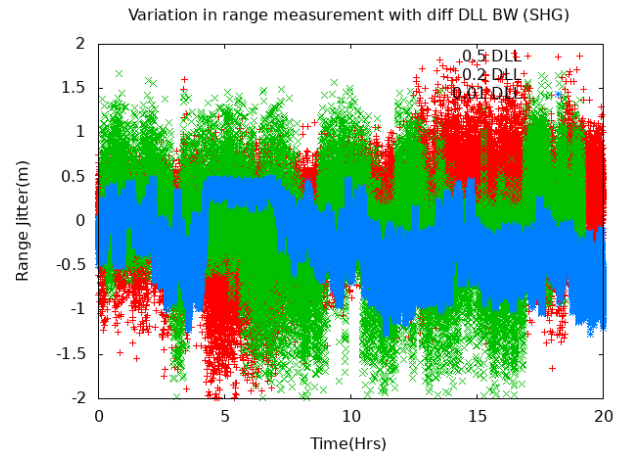


Figure 5: Impact of Variation in DLL BW (L5 band) for PRN3 when it is at 0° inclination.

4 Conclusion

Following are the conclusions from the conducted experiments

- The longer the duration for which two satellites are apparently stationary to the reference receiver, the range measurements are degraded in terms of jitter experienced due to Doppler collision.
- Impact on the user positioning is enhanced due to effect of DOP in user position calculation.
- Although decrease in DLL bandwidth limits the jitter experienced, yet it can affect the tracking of non GEO satellites.

5 References

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