ANALYSIS OF IONOSPHERE SCINTILLATION IN LOW LATITUDE REGIONS USING IRNSS/GPS SIGNALS AND MITIGATION

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Introduction

GPS/IRNSS signals when traversing through the regions of ionosphere having irregular density of ionized electrons may experience ionosphere scintillation. Ionosphere scintillation is characterized by rapid amplitude and phase fluctuations of a satellite signal. Severe amplitude fading and phase scintillation affects the reliability, integrity and continuity of GPS/IRNSS navigational system.

In order to confirm the drop or variations in carrier to noise ratio and variations in phase are due to ionosphere scintillation, the other non scintillation noise sources such as satellite receiver motion, oscillator noise and interference should be removed which is achieved via detrending filters at cutoff frequency called Fresnel frequency. The strength and the severity of ionosphere scintillation can be measured via two scintillation indices amplitude scintillation index S4 , $S_4 = \frac{\sqrt{\langle I^2 \rangle - \langle I \rangle^2}}{\langle I \rangle}$ and phase scintillation index σ_ϕ

Phase scintillation, given by σφ is defined as the standard deviation of a signal's phase over a given time interval. As with the signal intensity measurements, the signal carrier phase measurements are detrended to remove the effects of integrated Doppler due to satellite-receiver motion, satellite/user clocks, and multipath. As an example Figure 1 illustrates the scintillation effect with an example of intense fading of IRNSS 1B signals during midnight

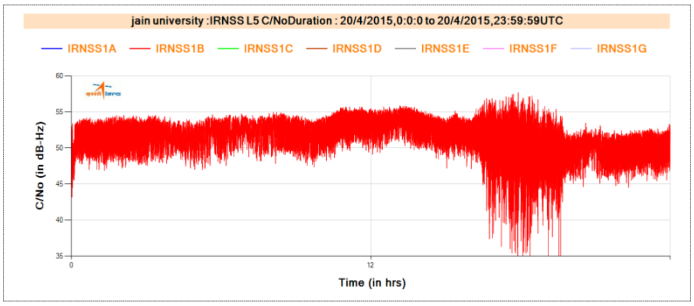

Figure.1. Fading of the L5 Signals from 1B IRNSS satellite recorded on 20 April 2015

Mitigation

To work under adverse signal conditions, the carrier tracking loop is designed to have variable bandwidth. Variable bandwidth filtering in carrier tracking loop can be accomplished by replacing loop filter with Kalman filter (KF). KF is tuned according to measurement and noise covariance matrix R and Q respectively. The loss of phase lock could occur in the carrier tracking loop due to increase in the phase error or due to inadequate bandwidth to track scintillated signal. The former can be addressed by extending linearity region of the phase detector by using four quadrant arctangent discriminator. The latter can be addressed by analyzing the tracking range bandwidth of KF loop. The upper limit on tracking range bandwidth is set by level of C/N0 that needs to be tracked while the lower limit is set by the dynamics of the signal. If the operating bandwidth is within the tracking range bandwidth it ensures successful tracking without loss of lock. The block diagram of the KF based carrier tracking loop is shown in the figure.

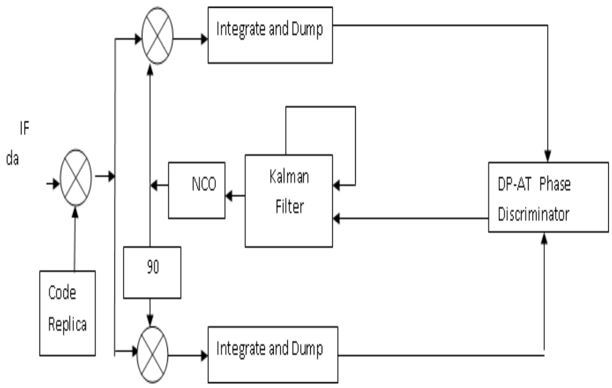

Figure.2 The block diagram of the KF based carrier tracking loop

In normal signal conditions operating bandwidth is within the tracking range bandwidth and hence successful tracking takes place but under scintillation conditions, the condition stated above is violated leading to loss of phase lock. Algorithm for KF based carrier tracking loop to avoid loss of phase lock

- Q is initialized to accommodate the moderate level of scintillation in terms of T.
- Initially the bandwidth for KF loops is set equal to the dynamic limit by tuning the KF according to Q for moderate level of scintillations. This is to ensure to have the bandwidth wide enough to respond fast at the beginning of the filter operation.
- Then onwards KF is tuned as a function of C/N0 by varying R and fixed Q
- As C/N0 decreases the bandwidth also decreases but when it reaches lower limit on the bandwidth it is maintained constant by fixed value of R as phase error measurements are less reliable at low C/N0.
- Due to maintaining bandwidth constant with decreasing C/N0, phase error builds up which is compensated by reducing phase error updating to the next iteration. Where r is weighing factor varying from 0 to1 $\left(\frac{C/N0_{K+1}}{C/N0_{th1} - C/N0_{th0}}\right) r$

Methodology

The intermediate frequency (IF) data collected from IRNSSUR receiver at L5 and S band is processed using software receiver. The software receiver acquires, tracks incoming signals and generates In phase and Quadrature phase correlator outputs. Correlator outputs are detrended using filters to obtain amplitude scintillation and phase scintillation indices. Scintillation parameters T and p are extracted from the phase scintillation spectrum and is used to update the Q matrix to account for scintillation noise. And KF is operated according to the proposed Algorithm; the objective is to avoid loss of phase lock occurring due to inadequate bandwidth.

Conclusion

This study helps in determining the robustness of KF in tracking the signal under ionosphere scintillation and the areas or factors to which the tracking fails and mitigating methods. Future scope also includes examining the suitability of KF in addressing interference phenomena