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Improvement of IRNSS Position Accuracy using SNR and Doppler

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Abstract— ***The Indian Regional Navigation Satellite System (IRNSS) is Indian satellite-based navigation system developed by Indian Space Research Organization (ISRO) which uses L5 and S1 band frequencies. The operational name of the IRNSS is Navigation with Indian Constellation (NavIC). Military and civilian users are provided with positional accuracy of 10 meters and 0.1 meters, respectively. Many sources of error affect the positional accuracy of IRNSS systems, including ionosphere delays, troposphere delays, multipath errors, and receiver errors. There are various methods for compensating for GPS system, including RTK-GPS (Real Time Kinematic GPS), D-GPS (Differential GPS), and A-GPS (Assisted GPS). In this paper SNR and Doppler Effect of receiving signal are taken under consideration and therefore the weak signals are exempted from the calculation of position accuracy. In literature this method is employed to calculate the position accuracy of Global Positioning System (GPS). Experimental testing was conducted in a dense environment under static conditions rather than dynamic conditions in order to verify the performance of the proposed method. Using the proposed method, the position accuracy of IRNSS system is reduced up to 10 m.***

Index Terms— ***IRNSS, GPS, SNR, Doppler, RTK.***

I. INTRODUCTION

In and around India, the IRNSS system provides navigation, timing, and positioning services. Working of the IRNSS is extremely almost like GPS implemented by US. With the help of this system, users in India and those out-spreading up to 1500 km from the Indian border will be able to obtain precise positioning data [1]. In the primary service area of the system, which is India, the system has an edge accuracy of about 20 meters. GPS is not guaranteed to work in hostile environments, so a satellite navigation system is required. The IRNSS is independent of using any delay causing frequency models to detect frequency error thanks to its use of Dual-Band (S and L band) frequencies. This makes it better than GPS but its area coverage is restricted only to India and its neighboring countries which may be a limitation. Within the Indian landmass and within the Indian Ocean, the system will provide absolute positioning accuracy better than 10 metres.

Position accuracy is suffering from many errors like ionospheric delay, tropospheric delay, multipath, clock error and receiver error. During this paper the position accuracy is calculated by eliminating weak signals. During this method SNR and Doppler Effect are considered to exempt the weak signals. SNR of a receiver depends on satellite elevation angle. SNR becomes weaker, when it receives reflected signal. Hence, the data is acquired from the receiver's antenna mounted on the roof top of the building of AGRL, Department of ECE, UCE, OU. Multipath error is less at this place.

II. DATA ANALYSIS AND METHODOLOGY

In this paper 24 hours data on 7th Nov, 2019 is acquired from IGS (IRNSS-GPS-SBAS) receiver located in Advanced GNSS laboratory (AGRL), Department of ECE, University College of Engineering (UCE), Osmania University (OU), Hyderabad. Each satellite data is obtained within the sort of .csv file. During this proposed method, the SNR value is fixed as greater than or adequate to 45 dB-Hz. The signals which are having less than 45 dB-Hz are eliminated within the calculation of position accuracy. Figure 1 shows the principle of satellite positioning.

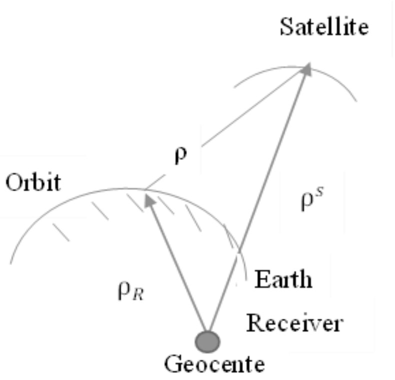

Fig.1. Principle of satellite positioning

$$SNR_{dB} = P_{signal}/P_{noise} \quad (1)$$

where SNR_{dB} is signal to noise ratio in dB, P_{signal} is that the signal power and P_{noise} is that the noise power. As shown in equation 1, satellites are often separated from receivers by a distance [2].

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$\rho = \|\rho_s - \rho^R\|$ (2)

where ρ and ρ_s are the distance between a satellite to the IRNSS receiver and the coordinates of the satellite respectively. ρ^R is the position vector of the IRNSS receiver in terms of ECEF (Earth Centred Earth Fixed) frame [2].

The pseudo distance between a satellite and the receiver is given by [2]

$$R = \rho + \Delta\rho = \rho + c\Delta\delta \quad (3)$$

where *R* represents the pseudo distance between a satellite to the receiver, ρ represents the important distance between a satellite and the receiver, $\Delta\rho$ is the space error by the clock, which may be determined by the speed of light, c and the error of clock, $\Delta\delta$. Generally Doppler Effect is often defined as

$$\Delta f = f_r - f_e = -\frac{1}{c}(v_p f_e) \quad (4)$$

where f_r and f_e are the frequencies of the received and transmitting signals respectively, c is the speed of light, v_p is the speed of the satellite. When v_p becomes maximum and its value is 0.9 km/s, Δf becomes 4*5*103 Hz for the given transmitting frequency, f_e = 1.5 GHz.

Satellites pass overhead, changing their range, which causes the signal phase to change steadily and smoothly as it gets into the receiver. Doppler shift is used by the IRNSS as an observable. Signal processing can use it to process a variety of signals. This variable is useful in kinematic surveying, detecting cycle slips, and determining integer ambiguities, as well as separating signals from various IRNSS satellites. With the help of Doppler data, it is possible to determine the range rate of a receiver and satellite. A satellite's range and receiver's range rate are shown in fig. 2, and the range rate indicates how fast this distance changes over time.

In this paper, a method is proposed for checking the SNR of each satellite visible at the receiver as shown in Fig. 3. We considered the threshold value of SNR is 45 dB-Hz. Because the signal strength of IRNSS is greater than 45 dB-Hz most of the time. There is a difference between the number of satellites observed at the receiver and the number used to estimate position using satellites., but in the experiment, only satellites with SNR values of 45 dB-Hz or more are used to estimate position. The next step is to check for Doppler Shift for satellite signals with SNRs of 45 dB-Hz or more. As soon as the instantaneous change amount is greater than the previous time step, Doppler Shift eliminates the satellite signal. In a case where the Doppler Shift change is different than the previous value, the distance error between a satellite is more and the satellite has more error than the estimated position. A position data output is displayed if there are four or more satellites visible. Otherwise, the position data corresponding to its previous time point is outputted.

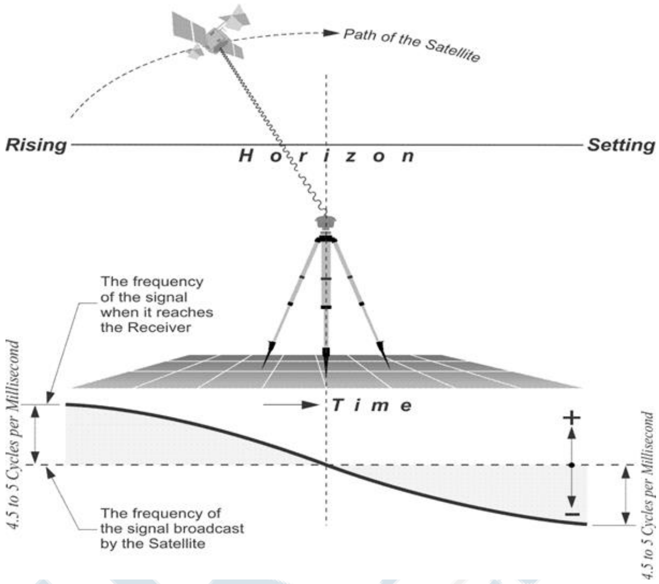

Fig.2. Typical Doppler shift (Source: GPS for land surveyors)

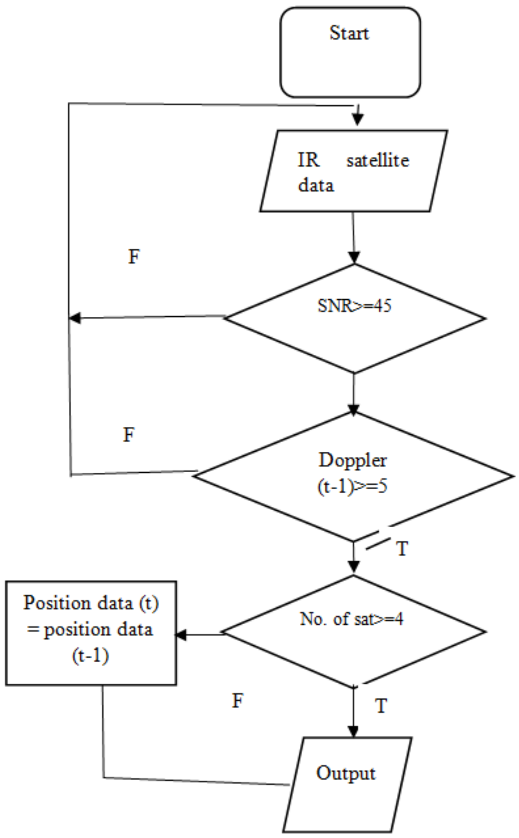

Fig.3. Overall flowchart of proposed method

III. RESULTS AND DISCUSSION

The Doppler shift and SNR before correction is shown in fig. (4-5). From the figures it is observed that the range rate between the satellites is less. The value of SNR is lies between 41 and 53 dB-Hz. Fig. (6-7) show the SNR and

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Doppler shift after correction respectively. The SNR value is fixed as 45 dB-Hz. The signals which are having less than 45 dB-Hz SNR, those signals are not considered in calculation of position accuracy using this method.

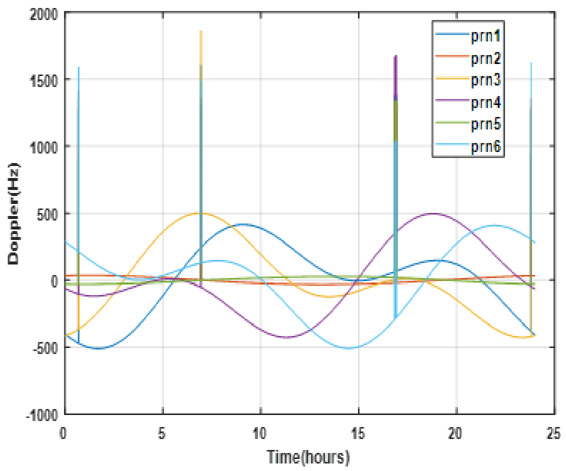


Fig. 4. Doppler shift before correction

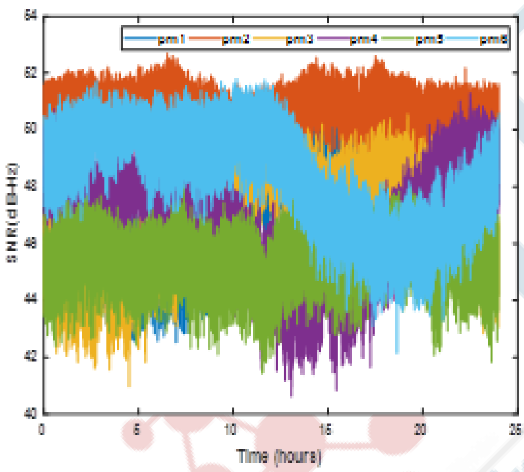


Fig.5. SNR before correction

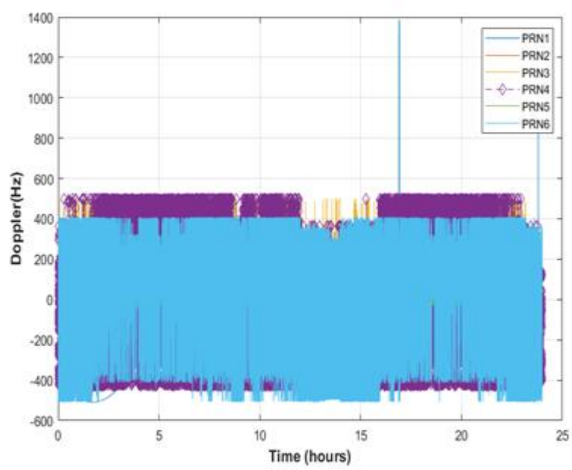


Fig.6. Doppler shit after correction

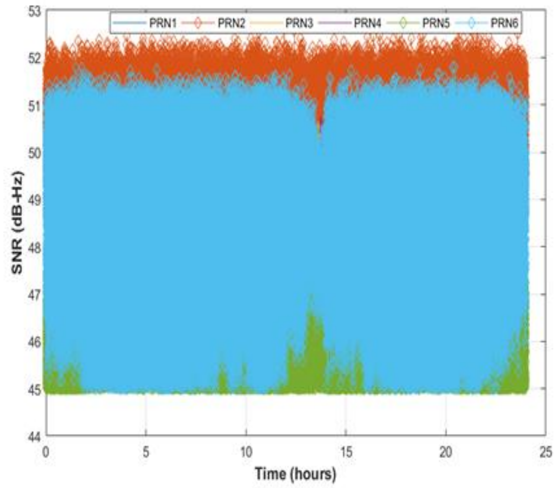
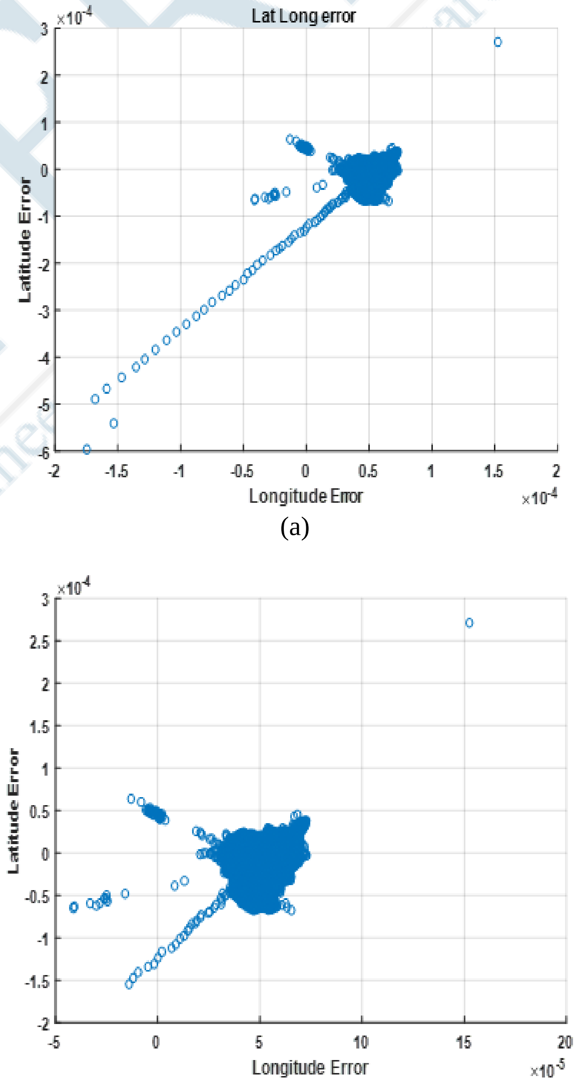


Figure 7: SNR after correction



(a)

(b)

Fig.8. Longitude and latitude errors (a) before correction (b) after correction

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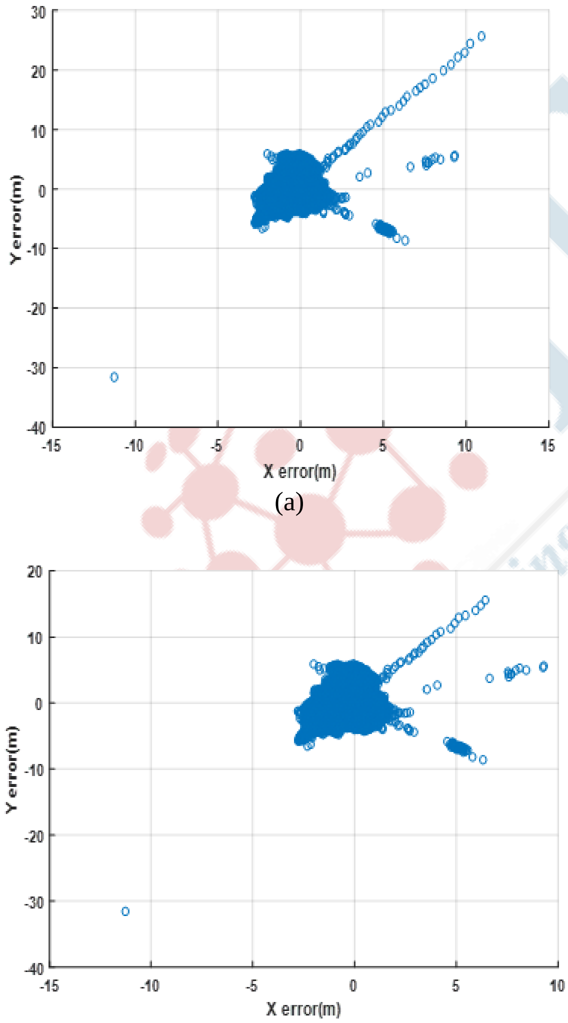
Statistics of SNR values of all IRNSS satellites are depicted in table I.

Table I. Maximum and minimum SNR (dB-Hz)

SNR	PRN2	PRN3	PRN4	PRN5	PRN6	PRN9
Min	42.53	42.27	40.98	40.63	41.43	42.14
Max	51.42	52.68	50.98	51.29	48.05	51.79

From the table, the minimum SNR values are noted before correction i.e., before applying the proposed method. After correction the minimum SNR value 45 dB-Hz for all the PRNs.

Fig.8. (a & b) shows the latitude and longitude errors of IRNSS receiver before and after correction. The errors in latitude and longitude are reduces reasonably. Figure (9-10) show the X-error and Y-error before correction and after correction respectively. The error value before correction is 27 m and after correction, the error is reduced to 17 m.



(a)

(b)

Fig.9. X-error and Y-error in meters (a) before correction (b) X-error and Y-error after correction

IV. CONCLUSION

In this paper the position accuracy determined using a proposed algorithm. Here SNR value is fixed at 45 dB-Hz. As the overhead pass continues, the Doppler shift changes continuously. During the rising or setting of the satellite, when the satellite is at its maximum range, the signal would have its maximum Doppler shift, 4 ½ to 5 cycles per millisecond. Less than this value all the signals are excluded from the calculation of position accuracy. Using this method, the error is reduced up to 10 m.

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