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Low Latitude Ionosphere Error Correction Algorithms for Global Navigation Satellite System

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Abstract: *The ionospheric errors occur due to loss of data in ionospheric region. Low latitudinal regions are the most affected regions due to ionospheric errors and also causes loss of signal or data for space based augmentation system(SBAS) such as aircraft. So to reduce these ionospheric errors in low latitude regions of Global Navigation Satellite System(GNSS) Klobuchar algorithm is used which mitigates the errors occurring in low latitude regions and is used as a standard algorithm in US Global Positioning System(GPS) till now; however, this model can reduce the ionospheric error by approximately 50-60% Root Mean Square(RMS) error in low-latitudes. So in order to increase the percentage deviation of errors In low-latitude regions, Enhanced Klobuchar algorithm is proposed which enhances the correction of low-latitude ionospheric errors approximately up to 80% RMS for a single frequency GPS user. In this paper error correction algorithms are performed over International GPS Service(IGS) data was collected using Hyderabad station receiver, Telangana (latitude- 17.41728°, longitude-78.55088°) in southern part of India during year 2016.*

Keywords: *Ionospheric errors, IGS, IRNSS, GAGAN, GPS, GNSS, SBAS, low latitude ionospheric error corrections.*

I. INTRODUCTION

Ionosphere is the region where large number of electrically charged atoms and molecules collectively form a region in earth's atmosphere. The earth's upper atmosphere from 60km to 1000km is known as ionosphere region[1]. There are many errors to be concerned in the ionosphere region which lead to data loss, delay etc. The radio signals are effected which ranges from few meters to tens of meters due to ionosphere depending on several factors like amplitude and phase scintillation. This is one of the main source of concern in satellite based augmentation system(SBAS). Most of these effects depend on The ionospheric total electron content (TEC) is the major factor by which most of these effects are occurred is the no. of electrons in a vertical column of 1 m^2 cross sectional area. The values for TEC ranges between 10^{16} e/m^2 and 10^{19} e/m^2 which depends on local time, position, season, solar, geomagnetic activities, etc.[2].

Especially these errors occur in low-latitudinal regions. The regions of ionosphere in India of low latitudeswere categorized by variations like spatial and temporal which were invented fromlow latitude electrodynamicsand equatorialwhichexhibits a phenomena during daytime as equatorial ionization anomaly (EIA)and during night-time have large scale plasma depletions known as equatorial plasma bubbles (EPB). Electron density perturbations of equatorial and in low latitude ionospheric regionsin F-region were produced by EPBs[3].

Global Positioning System(GPS), Global Navigation Satellite System(GLONASS), and Galileo are the satellite navigation systems which are been currently used. The Global Navigation Satellite System (GNSS) conducts its development in various areas such as signal generation, precise positioning, high-precision geodesy and survey in relation to individual satellite navigation systems, has drawn more attention in recent years[4]. Ionospheric effects are complex and inhomogeneous nature of the medium on GNSS signals which are difficult to mitigate. GPS Aided Geo Augmented Navigation (GAGAN) is the navigation systemserving the aircraft navigation over Indian subcontinent used in India's regional SBAS which has been fully operative since 2014. It is mostly concerned for its low-latitude ionospheric errors such as Equatorial Electro Jet (EEJ), EPB, Scintillation effects etc.[5]. In order to mitigate these errors in low-latitude ionospheric regions, error detection and correction algorithms are used.

The low-latitude ionospheric errors are corrected over a particular station's data using error correction algorithms. Here Klobuchar algorithm is used for error correction of low-latitude ionospheric errors over single frequency receivers. The Klobuchar algorithm mitigates the errors in low-latitude ionosphere and is used as a standard algorithm in US GPS till now and it is the most widely used algorithm for ionospheric correction because it is simple in structure and easy to calculate[6][7]. The drawback of the Klobuchar algorithm is that it reduces the errors only 50-60% Root Mean Square(RMS) error in low-latitudinal regions.

So in order to enhance the ionospheric error correction proportion percentage enhanced version of Klobuchar algorithm is proposed known as EnhancedKlobuchar algorithm. The Enhanced Klobuchar algorithm improves about 80% on average of the ionospheric errors, which are useful to single frequency GPS users[8]. The Enhanced Klobuchar algorithm corrects the low-latitude ionospheric errors of 30% RMS more than Klobuchar algorithm by calculating the difference between TEC of both the algorithms[9]. The equation(1) is used to evaluate the performance of the models by computing percentage of deviation (PD) from observed data [10].

$$PD = \frac{\text{Experimental} - \text{Model}}{\text{Experimental}} * 100 \qquad (1)$$

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