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Novel technique of SBAS support in development of GBAS Ionospheric threat model over Equatorial and Low Latitude Region

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ABSTRACT

Introduction

The Ground Based Augmentation System (GBAS) is emerging as a low-cost and efficient alternative to Instrument Landing System (ILS) to provide precision approach and category III level landing guidance to aircrafts. The development of GBAS was necessitated due to the limitation of Satellite Based Augmentation Systems (SBAS) in supporting category III landing capability due to the coarse ionospheric correction (5°x5° lat/long) that hampers the precision of the navigation parameters. The GBAS provides differential cumulative pseudo-range corrections to the aircraft in the vicinity of the airport based on L1 frequency measurements from four reference receivers. All the error sources viz., ephemeris, clock, atmosphere, ionosphere etc., are considered constant in the localized region of ~40 km radius.

Scope of the study

However, the GBAS system also faces challenges over equatorial and low latitude region due to presence of anomalous ionosphere. The Localized sharp spatial gradients in the ionospheric densities may result in safety hazard due to differences in corrections computed by the reference stations and actual ionospheric delay experienced by any aircraft. To safeguard the user and to maintain integrity of service, the existing ionospheric threat models broadcast the bounding term- σ_{vig} (*sigma_ vertical ionospheric gradient*) based on data from mid latitude region (assuming max gradient of 425 mm/km). On the contrary, over the equatorial and low latitude regions, gradients of the order of 500-700 mm/km have been observed during night time due to the formation of plasma bubbles and consequent scintillations. Hence, such threat model is not feasible over equatorial region as it seriously impacts the availability of the system due to enhanced σ_{vig}.

Proposed technique

A ‘dynamic’ threat model which can tune the σ_{vig} to the real ionospheric conditions is proposed, by making use of SBAS. The Grid Ionospheric Vertical Delay (GIVD) and its error bound- Grid

Ionospheric Vertical Error (GIVE) are used to characterize the ionospheric conditions in near real time [2]. Moreover, GIVE is sensitive to scintillations [1] and hence may be used as an external indicator for tuning the σ_{vig} by suitably scaling the same at IGPs surrounding the airport.

Further, an 'innovative' concept is introduced 'for the first time', specifically for the equatorial and low latitude region. The scintillations are caused by irregularities generated by R-T instability over magnetic equator after sunset. The strength of Equatorial Ionization Anomaly (EIA) represented by the ratio of TEC at crest with that at trough latitudes – Crest-to-Trough Ratio (CTR) in the evening/post sun set hours is a potential indicator of scintillation forecast/ now-cast. Since the crest latitude is variable, it is not feasible to estimate the true CTR using limited ground based GPS receivers.

A 'unique' approach based on the ionospheric corrections derived from a single SBAS enabled receiver is proposed to estimate the CTR over the Indian region where GAGAN broadcasts GIVD from 5°S to 45°N, providing a latitudinal profile of TEC over any given Indian longitude.

Results

The SBAS based CTR estimation and its correlation with scintillation occurrence has been validated using scintillation index (S4) at Ahmedabad during February, March 2015 (Figure 1) which depicts the daily occurrence of scintillation intensity with time (UT) and the daily maximum CTR during evening irrespective of the location of the crest. The tentative threshold of CTR>=3 (filled by red color) shows very good one-to-one correlation with scintillation.

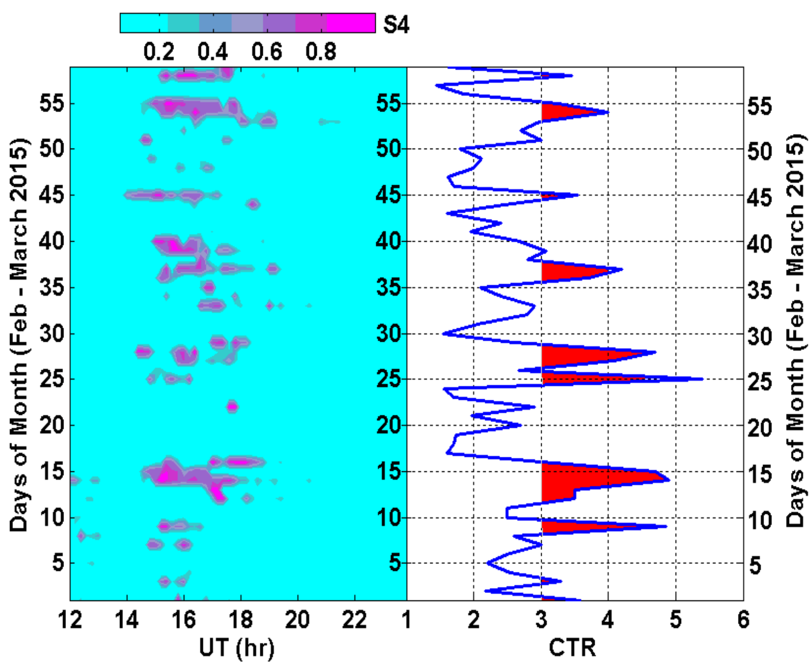

Figure 1: Daily scintillation occurrence pattern with time at Ahmedabad (left panel) along with the daily maximum Crest-to-Trough Ratio (CTR) (right). The y-axis shows the number of days starting from 1st Feb to 31st March 2015.

Conclusion

The hurdles faced in the implementation of GBAS system over equatorial latitudes due to lack of suitable ionospheric threat model is proposed to be overcome by an 'innovative' and 'cost-effective' technique based on SBAS that could dynamically fine-tune the GBAS iono threat model. The Crest-to-Trough Ratio (CTR), derived uniquely from ionospheric corrections broadcast by SBAS, has been shown to be the crucial parameter to be included in the threat model. The proposed technique has been vindicated, preliminary, through actual observations. Further work with more data is needed to establish the threshold of CTR considering the operational scenario of GBAS.

References:

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