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WORKSHOP ON IONOSPHERIC DATA COLLECTION, ANALYSIS AND SHARING (IDCAS) TO SUPPORT GNSS IMPLEMENTATION

5 – 6 May 2011, Bangkok, Thailand

IONOSPHERIC EFFECTS ON SBAS PERFORMANCE

(Presented by India)

EXECUTIVE SUMMARY

GPS Aided Geo Augmentation Navigation (GAGAN) – the Indian Satellite Based Navigation System (SBAS) is progressing as per the milestones set out for providing the ground infrastructure development plans and the launch of the GEOs – GSAT8 and GSAT-10.

GAGAN Technology Demonstration Systems phase was successfully completed by demonstrating the accuracy requirements within the SBAS specification. Currently it is in the Final Operational Phase (GAGAN-FOP).

The GAGAN service volume is more susceptible to the ionospheric variations as it lies in Equatorial Ionization Anomaly region. The temporal and spatial variations of total electron content are very high and GPS as well as GEO signals are affected by depletion and scintillation in this region.

To meet the set objective of achieving APV1.0 over the Indian land mass, for GAGAN-FOP, an unique IGM-MLDF model is undergoing threat model analysis.

1. Introduction

1.1 India has taken major steps towards the development of Indian regional Satellite Based Augmentation System (SBAS) - GAGAN. GAGAN footprints will provide opportunity for most of the states in the Asia Pacific Region to move towards GNSS Augmented SBAS services in line with Global GNSS implementation plan.

1.2 India has adopted GAGAN Architecture similar to WAAS of US, MSAS of Japan. However due to Ionospheric depletions & scintillations GAGAN had to adopt a regional specific model different from the planer fit model used by the other SBAS systems. This makes GAGAN programme unique.

1.3 The ionosphere introduces the range error due to group delay of signal traveling through it from the satellite to the receiver. It is quite calm and stable over mid latitudes where as it is highly variable and anomalous over low latitude and equatorial regions.

1.4 India lies in the Equatorial Ionization Anomaly (EIA) region where crest of EIA lies in middle of Indian landmass (15^0-20^0 N) and trough is at southern point of India. L band scintillation and plasma bubbles are prominent features of EIA which affects the GPS and GEO signals. Apart from degrading the position accuracy, high scintillation can fade the signal strength below the Phase Locked Loop (PLL) threshold, leading to loss of lock of satellite signal which can affect the service availability.

1.5 To study and develop a best fit model for EIA, a GPS-TEC network consisting of 18 stations was established in 2004 and later increased to 26 to study the ionospheric response over the Indian equatorial region.. A GSV4004A/B receiver is deployed at these stations to collect the ionospheric and scintillation data.

2. Temporal and Spatial Study of TEC

2.1 The variations of Total Electron Content (TEC) have been analyzed since 2004 at all the stations. The stations are almost evenly separated on latitudes and longitudes to study the spatial variations of TEC. Large day-to-day variations in TEC/range delay have been observed mainly over crest stations of EIA during the peak ionization time of 1200 to 1600 Hrs (IST). The peak ionization density is positively correlated with the solar activity (Sun spot number) since 2004 to 2010.

2.2 The development of equatorial ionization anomaly (EIA) is influenced by various factors- Solar flux, Equatorial Electro Jet (EEJ), solar cycle variations, geomagnetic storms etc. It is observed that the crest of EIA passes through 20^0-25^0 N in 2004-2006 (Medium solar activity) and 15-20^0 N in 2007-2009 (Solar Minima). The development of EIA is maximum in equinoctial months of March, April, September and October, followed by winter months and then summer.

3. Scintillation Studies

3.1 Scintillation of $S_4 \geq 0.4$ have been detected and statistics are generated with respect to dependent variables i.e. solar cycle (year), season, location (latitude), local time and elevation angle of satellite using the continuous data of 2004 to 2009. It has been helpful in developing the scintillation model based on measurements over equatorial region.

4. Empirical Models

4.1 There are various empirical models of ionosphere developed for scientific purposes. They can be used for generating the ‘Supertruth’ data for verification and validation of grid based model implemented in SBAS. The International Reference Ionosphere (IRI), which is developed and updated by a joint working group of URSI and COSPAR, is the most popular and widely used iono model. Raytheon proposed to use IRI model for generating ‘supertruth’ data. The analysis and comparison of IRI with measured TEC was carried out by ISRO/AAI. It has been observed that, in general, IRI overestimates TEC over many of the locations in India and is more close to the observations at mid latitude than over low latitude stations of India.

4.2 A measurement driven empirical model named as ISRO-TEC model was developed by ISRO. It uses the measured TEC data over a longitude chain of 77^0 E which is considered as reference longitude. The first principle model (PIM model) is initialized using the interpolated latitude profile which is generated using the best polynomial fit from the measured data. It can generate TEC at any latitude and longitude with 1 deg resolution. ISRO-TEC model provides a reasonable accurate estimate of TEC at Indian latitudes and was selected for generating the ‘Supertruth’ data.

5. Grid Based Models

5.1 The Grid based models have been suggested as per the RTCA MOPS for implementation in the SBAS. They are used for generating the GIVE and GIVD to be transmitted to GEO for error correction at User end (Aircraft). Various models like US-WAAS, Planar, Kriging, Dual-shell, and MLDF have been compared and validated to select the best model for Indian SBAS (GAGAN). Some of these models needed a change in the MOPS to re-quantize the GIVE index. But it was decided against them as changing the MOPS is a difficult process involving several agencies and it can create the compatibility issues for SBAS receivers.

5.2 Simulated 'Supertruth' data were generated using the ISRO-TEC model for validation and verification of grid based models. 10 nominal days and 5 storm days were selected for algorithm evaluation. Depletion features were included in the data for both user and INRES.

5.3 ISRO GIVE MODEL-Multi Layer Data Fusion (IGM-MLDF) model was proposed by ISRO. The same was down selected for implementation in the GAGAN. This model has been selected to cater to "No MOPS change" approach adopted for GAGAN, resulting in ease of GAGAN message usage by all the users, including the legacy users. IGM-MLDF employs an innovative approach for computing the ionosphere corrections and confidences at pre-defined grid points at 350 Km shell height. Ionosphere delays are computed at 250 and 450 km shell heights in order to capture the vertical movement and large scale irregularity of the Indian ionosphere and then employing data fusion for fusing the delays and confidences at 350 km shell height. Ionosphere storm detection algorithm utilizes goodness of fit test to protect the user from irregular behaviour of ionosphere. Moreover, IGM-MLDF models the associated uncertainties to protect a GAGAN user from ionosphere abnormalities.

5.4 An Algorithm Working Group (AWG) for GAGAN is developing a single frequency user-based method for characterizing ionospheric delays that provide mitigation to the depletion problem. The format and resolution of the data have been determined by the AWG and Algorithm Review Team (ART).

6. Conclusion

6.1 GAGAN has a capability to provide the augmentation service within its footprint, which covers a large portion of the Asia-Pacific region.

6.2 A wide network of GPS-TEC receivers helped in analyzing the spatial and temporal variations of TEC over the Indian landmass.

6.3 Scintillation and depletion are the prominent features over India. IGM-MLDF model for GAGAN has been down selected and is undergoing threat model analysis.

6.4 GAGAN is being developed to meet the ICAO GNSS SARPs and it will be interoperable with WAAS, MSAS and EGNOS.

7. Action taken by the meeting

7.1 The meeting is invited to note:

- The continuing commitment of India to implement SBAS over Indian airspace and to provide seamless air navigation service across regional boundaries; and

- Invite neighbouring states to plan the use of GAGAN Signal in Space for providing SBAS service volumes in their flight information regions.

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