



International Civil Aviation Organization

THE SIXTH MEETING OF IONOSPHERIC STUDIES TASK FORCE (ISTF/6)

Bangkok, Thailand, 19 – 21 January 2016

Agenda Item 3: Review of status of States' activities and ISTF webconferences

**DEVELOPMENT OF A GROUND-BASED AUGMENTATION SYSTEM (GBAS)
IONOSPHERIC THREAT MODEL (GITM) FOR SINGAPORE**

(Presented by Singapore)

SUMMARY

This paper provides a short summary of an upcoming Joint Research Project between Civil Aviation Authority of Singapore and The MITRE Corporation.

1. INTRODUCTION AND OBJECTIVES

1.1 In 2012, the Civil Aviation Authority of Singapore (CAAS) had initialized a Research and Development Project to study Ionospheric impact in Singapore Changi Airport. However, due to health condition of the project scientist, CAAS has decided to engage the MITRE Corporation (MITRE) to continue collecting and analysing more data. The objective of the upcoming work is to develop a Ground-Based Augmentation System (GBAS) Ionospheric Threat Model (GITM) for Singapore using actual ionospheric delay data collected. The data will be collected using the existing four GPS receivers (NovAtel FLEX6-G5S-BOG-TTN). The data will be recorded with an appropriate data rate and include, at a minimum, GPS L1, and L2 pseudorange and carrier phase measurements, GPS navigation data, and other data.

1.2 The GITM will characterize anomalous ionospheric delay gradients. Such gradients can be the result of increased variability in the distribution of free electrons in the upper atmosphere during periods of increased geomagnetic activity (e.g., between local sunset and early morning in Singapore, because it is located in the Equatorial region). They can also be caused by ionospheric depletions. In general, a GITM is region dependent because the behavior of the ionosphere varies from one region to another and over one solar cycle (i.e. 11 years). It depends principally on the geomagnetic latitude of the location where a GBAS installation is being considered. However, it also depends to some extent on the specific location of the GBAS, since differences in the intensity of certain ionospheric perturbations have been observed between regions with similar geomagnetic latitudes. Ionospheric depletions, sometimes called plasma bubbles, are a phenomenon that occurs principally and frequently in low geomagnetic latitude regions. They can result in large and steep gradients at the edges and the middle of these bubbles. Bubbles are narrow in the East-West direction, elongated in the North-South direction, and typically move from West to East. The GITM characterizes the sizes and speeds of such gradients when observed from the location of interest. The worst ionospheric events will be recorded in a series of charts. The x-axis of a typical chart represents

the maximum slope (spatial gradient) in mm/km for the slant ionospheric delay, and the y-axis represents the elevation angle of the satellite being observed. Gradients can also be plotted with respect to estimated ionospheric front speed (in m/s) relative to the ground and estimated front width (in km) from peak to trough of ionospheric delay, or vice versa.

1.3 The development of a GITM for a specific location relies on analysis of ionospheric delay data collected at that location using data collection equipment (receivers, antennas, and data recording computer) arranged in a pattern allowing the observation of gradients in the East-West and North-South directions, approximately. A fairly large set of dual-frequency (L1 and L2 or L5) data (for at least one year) is necessary in order to capture a reasonably full set of gradients and adequately characterize the type of behavior that GBAS could possibly see while in operations. These data should ideally be collected at multiple nearby locations and during a period of time near the peak of the solar cycle. The last peak of the solar cycle occurred over a relatively long period starting toward the end of 2012 and extending to the beginning of 2015.

1.4 The results obtained from the data processing that will be done during this project will be used to generate a dedicated GITM for Singapore. However, a recommended practice is to compare this GITM with other validated threat models from other locations that are comparable from an ionospheric behavior point of view. The lack of significant differences between models can provide additional confidence that the model adequately captures the full range of ionospheric behaviors that could affect the GBAS service. The presence of significant differences between models could indicate that the data set processed may not have been sufficient to capture the full range of ionospheric behaviors.

2. Proposed Scope of Work

2.1 CAAS and MITRE will:

- Coordinate with relevant stakeholders to examine the installation of the receivers and the setup of the data recording and transfer process and equipment.
- Collect data from the existing receivers and antennae as well as add on additional necessary equipment.
- Develop a GITM using expertise gained by MITRE, the Federal Aviation Administration (FAA), and other organizations involved in GBAS development. This will comprise:
 - Developing a software tool using available software functions that have been developed for other research and development efforts (whenever feasible)
 - Modifying the above software functions as necessary
 - Integrating the above software functions for the GITM analysis
 - Validating and testing the software tool
- Verify, using a first batch of data (corresponding to approximately 1 month of data), that:
 - The data are useable (i.e. the necessary parameters were recorded, the multipath errors affecting range measurements remain within an acceptable range, the frequency of cycle slips and other data corruptions remains within an acceptable range, and the frequency of data gaps remains within an acceptable range)

- The software processes the data without a problem and that the output of the processing is correct. Software changes will be made to correct any problem that is traced to the software.

In addition, it is important to note that data processing should continue indefinitely to ensure that any significant phenomena are observed and considered in the GITM model for Singapore and the region.

3. ACTION REQUIRED BY THE MEETING

3.1 The meeting is invited to do the following:

- a) note the information presented in this paper;
- b) provide advice to the proposed work scope; and
- c) discuss any relevant matters as appropriate
