Simulation of the Effects of the Low Latitude Ionosphere on the Performance of a Satellite-Based Augmentation System

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ABSTRACT

Ionospheric effects exhibit extreme variability in space and time, significantly degrading the performance of Space-Based Augmentation Systems (SBASs). This is particularly true at equatorial anomaly latitudes, where intense gradients in the vertical TEC (total electron content) and field-aligned plasma bubbles can be observed, depending on the existing geophysical conditions. Brazil is one of the countries in the world that are affected by both peaks of the equatorial anomaly. Therefore, designing a SBAS to serve its large area will be a challenging task and planners would benefit from the availability of simulation tools.

This contribution will present results from a simulation model of the combined effects of the equatorial anomaly and of plasma bubbles on the performance of a SBAS in the Brazilian sector. This model uses the Parameterized Ionospheric Model (PIM 1.7) [1],[2], driven by realistic input values, to represent the "quiet" ionosphere. The vertical TEC values provided by the model will be compared with those in the Global Ionospheric Maps produced by the Center for Orbit Determination in Europe (CODE) [3] to assess the suitability of PIM 1.7 to the present application. A statistical submodel of the effects of plasma bubbles on TEC will also be described. This submodel has been developed from the processing of data recorded by the Rede Brasileira de Monitoramento Contínuo of the Instituto Brasileiro de Geografia e Estatística (RBMC/IBGE), a Brazilian network of GPS stations for geodetic applications [4], as well as from other experimental results. PIM 1.7 is coupled to the statistical submodel of the effects of plasma bubbles on TEC to provide a more realistic representation of the ionosphere in the Brazilian sector. The simulation model also implements the basic procedures described in the RTCA MOPS Document [5]. That is, TEC values along slant paths between GPS satellites and Reference Stations are determined and used to estimate the vertical TEC at the corresponding 350-km pierce points. These results are next used to generate vertical TEC values at the vertices of a 5^o x 5^o reference grid. The model is able to employ a number of pre-selected linear or nonlinear interpolation schemes to do this. The vertical TEC values at the vertices of the reference grid are collected by the Master Station and broadcast through geostationary satellites. Finally, each user employs this information to correct the pseudorange to each visible GPS satellite. This is done by bilinear interpolation based on the vertical TEC values at appropriate vertices of the reference grid, followed by estimation of TEC along the path between the user and the corresponding GPS satellite [5].

The above model relies on a piecewise-planar representation of the variations of vertical TEC, which performs quite well in mid-latitude regions. However, its performance in the low latitude region may not be as satisfactory in the presence of the equatorial anomaly and of plasma bubbles. On the other hand, it should be noted that the performance of any model for the variations of vertical TEC with position, among many factors, also depends on the number of Reference Stations, as well as on their locations. This is a fundamental issue in the design of a Brazilian SBAS. It will be analyzed on the basis of the effects of two uniformly-deployed networks of Reference Stations on the cumulative distribution functions: (1) of the difference between vertical TEC values at the reference grid points either directly calculated by the representation of the perturbed ionosphere in the Brazilian sector or estimated by interpolation using TEC values at the pierce points; and (2) of the errors in the horizontal and vertical positions of the users.

[1] Computational Physics, Inc., PIM 1.7 User Guide, Computational Physics, Inc., Norwood, MA, EUA, 1998.

[2] Daniell Jr., R. E., L. D. Brown, D. N. Anderson, M. W. Fox, P. H. Doherty, D. T. Decker, J. J. Sojka, and R. W. Schunk, Parameterized Ionospheric Model: A Global Ionospheric Parameterization Based on First Principles Models, **Radio Science**, **30**(5), 1499-1510, September/October, 1995.

[3] http://www.aiub.unibe.ch/ionosphere.html

[4] http://www.ibge.gov.br/

[5] RTCA, Inc., Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment, Document no. RTCA/DO-229A, Washington, DC, EUA, 1998.