8th International Conference and Exhibition on
Satellite & Space Missions
November 21-22, 2022 Toronto, Canada
Rundown of Space Science and Exploration

Space Weather impact on GNSS: current state and perspectives of the problem

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Biography

Vladislav V Demyanov, DrSc in Engineering, has been working as a Senior Research Scientist of the GNSS Remote Sensing Research Group, Institute of Solar and Terrestrial Physics (Siberian Branch of Russian Academy of Science) and as a Full Professor of Irkutsk State Transport University. His research interest include: space weather- geomagnetic storms and solar radio flares and their impact on GNSS and SBAS performance; GNSS\SBAS integrity and positioning availability control under irregular external impacts; GNSS remote sensing of the ionosphere; GNSS application on transportation.

Abstract

To provide GNSS/SBAS reliable performance under Space Weather impacts several solutions are considered. The system of technical-organizing measures that will enable to improve the GNSS performance quality with allowance for current helio-geophysical conditions is proposed. Exact fore- and nowcasting positioning quality under geomagnetic disturbances is out of modern state of technologies. Nevertheless, the forecasting may be proposed as a general measure to alert GNSS\SBAS users for the probable abnormal state of the positioning in advance and in the nearly-real time. Real-time alert of users to a geomagnetic disturbance in the signal propagation medium is considered as enhancement of RAIM solutions. A complex system of differential correction, prediction, and monitoring of the GNSS positioning quality under unfavorable helio-geophysical conditions is proposed. The system is considered as a basis for a perspective service of global monitoring and forecasting of the integrated uniform GNSS current operation quality.

Summary

Considering the GNSS operation under unfavorable helio-geophysical conditions, we recommend a necessary complex of measures aimed at providing GNSS RNPs. The measures involve:

1.Fore- and nowcasts of the positioning quality under geomagnetic disturbance conditions;

2.Real-time alert for users to a geomagnetic disturbance in the GNSS satellite signal propagation medium;

3.Real-time alert to powerful solar radio bursts at the GNSS frequencies, with allowance for the radiation energy distribution spectrum relative to the GNSS operational frequency plan;

4.Use of a complex technical system for differential correction, prediction, and monitoring of the GNSS positioning quality under unfavorable helio-geophysical conditions;

5.Adaptation of PLLs and DLLs to dramatic changes in signal propagation conditions;

6.Measures for DOP artificial improvement.

To perform an alert, one should develop forecast methods and select optimal indices of geomagnetic activity. The issue of selecting the index (a set of indices) optimal for solving the problem by the false-alert minimum criterion has remained open and requires further investigations. Using the Dst- and Kp-indices provides a sufficiently high probability of a false alert. Therefore, there is no possibility to apply those indices to a real-time alert to the current level of RNP availability. However, the above indices may be recommended for forecasts (≥1 h) of the expected positioning availability deterioration.

The up-to-date state of investigations into mechanisms for solar radio burst formation does not allow one to precisely forecast dangerous solar radio bursts in the UHF for GNSS users. The only recommended measure may be continuous radio monitoring of the Sun in the UHF with issuing a real-time alert for GNSS users at the emergence of radio bursts stronger than $>10^3$ sfu. Additionally, we can recommend to comparatively monitor the energy distribution of a radio burst within the radiation spectrum and the GNSS operational frequency plan in order to define a real-time alert to availability of measurements within separate GNSS frequency channels.

Using the S4-index is proposed for a real-time check of radio-navigation parameter measurement integrity by signals from separate satellites under geomagnetic disturbance conditions. At the same time, one should define the measurement accumulation time to compute the current S4-index values. The accumulation time should be optimal to detect ionospheric scintillations that, most likely, may lead to the emergence of abnormal errors in ranging measurements. Open has remained the issue of searching for an alternative index (a set of indices) enabling, with a high probability, to detect an anomalous status of the wave propagation channel and to exclude abnormal ranging measurements within the modified RAIM algorithm.

Using real-time alerts to the status of the wave propagation channel may enable to adapt the hardware to dramatically changing conditions by tuning automatically the DLL and PLL settings. An optimal selection of such tuning parameters (mainly, the smoothing filter noise band) enables to decrease the effect of strong scintillations on the DLL and PLL quality. An efficient measure is also an increase in the power potential of the satellite-receiver line due to augmenting a GNSS satellite transmitter power. One can achieve the same effect by reducing the RF front-end inner thermal noise and improving the spatial-selective directional properties of the receiver antenna.

Nowadays, there are all the necessary elements to deploy a complex system of differential correction, prediction, and monitoring of the GNSS positioning quality under unfavorable helio-geophysical conditions. Ground- and space-based facilities to monitor the status of the Sun and of the near-Earth space have been developing. International and regional networks of constantly operating stationary points to measure radio-navigation parameters have been deployed. There exist analytical centers to process data from measurements of the above networks that determine time–frequency and ephemeris errors, as well as ionospheric and tropospheric ranging errors. These elements enable to generate the structure of such a complex system that will provide the GNSS RNP under unfavorable helio-geophysical conditions. The system may be regarded as a basis for a perspective service of global monitoring and forecasting of the integrated uniform GNSS current operation quality.

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About The Institute

Founded in 1960 on the basis of the Siberia's oldest geomagnetic observatory formed in 1886. Fundamental, exploratory and applied research studies in the following main research areas:

- solar physics;

- near-Earth space physics (magnetosphere, ionosphere and upper atmosphere, the magnetosphere–ionosphere–atmosphere–lithosphere relationships;
- problems of asteroid and comet impact hazards and space ecology;
- analysis and forecast of state of the Earth's climate system: elaboration and enhancement of models of climate change physical mechanisms, solar activity.

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