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QUALITY OF GPS PERFORMANCE DURING IONOSPHERIC STORMS AND SOLAR FLARES

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Abstract: The Earth's ionosphere changes the phase and amplitude of propagating radio signals, effecting on performance of satellite and navigation systems. The Global GPS Network is a set of precise GPS receivers, nowadays widely used for a variety of scientific and real-time applications, including a very high accuracy positioning service that can provide a user position within 10-20 cm accuracy, on land, in the air or in the Earth's orbit. GPS measures the group and phase delays of signals, which are proportional to the ionosphere total electron content (TEC) along the path between a satellite and a receiver. The GPS frequency is high enough (more than 1 GHz) for signals not to be affected by the medium, so the system is considered as highly reliable and practically invulnerable. However, recent studies showed that significant errors and failures in the performance of GPS system occur during geomagnetic storms and during large solar flares.

The main purpose of this study is to analyze the operation quality of GPS under geomagnetically disturbed conditions. For our analysis we have selected events that occurred in during the last solar cycle and with a drop of IMF Bz below −12–15 nT that lasted more than 3 hours and consequently led to a decreases of Dst index to −120–150 nT. We have also estimated the quality of the GPS functioning from the following parameters: 1) counts omissions in the GPS RINEX files, 2) GPS phase slips estimated from L1 and L2 phase measurements, when TEC derivation exceeds 5 TECU/min.

According to our preliminary comparative analysis, the maximum number of counts omissions and phase slips corresponds to events that can be classified as ionospheric storms, i.e. with prominent changes in the ionosphere such as ionosphere dayside uplift and super-fountain effect.

Apart from the ionosphere effects by geomagnetic storms, the performance of satellite systems can be affected by massive explosion on the Sun’s surface (solar flares) and by clouds of solar matter (coronal mass ejections). A good example of serious impact on the GPS and other communication technologies using radio waves, is the event of 5-6 December 2006, when a solar flare of class X6.5 was recorded from 18:29 to 19:00 UT. Despite this flare was far from the strongest ones in the X-ray and UV ranges, it attracted attention of not only astronomers and radioastronomers, but also of a wide range of scientists and engineers. It turned out that the broadband solar radioemission (in the 1.4 GHz band), which followed the flare from 19:25 to 19:40 UT, was at least two to three orders of magnitude stronger than all previously known flares. The consequences of such radiobursts were failures of GPS and other navigational systems, since the radio noise of “solar” origin disrupted connections between satellites and receivers. Besides, X-ray radiation released by the flare caused major disruption to short-wave (HF) radio communication. As a result, long range HF communications such as those used by Defense Forces, emergency services and airlines were completely blocked out for about two hours following the flare.

It should be noted, that such disruptive events can occur not only during the maximum of solar activity cycle, when many solar flares occur often, but also under low solar activity, as it happened in December 2006. Therefore, it is important to consider the potential impact of future, more powerful, solar radio bursts of high solar activity.