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Degradation of signals and operation failures of radio engineering satellite systems during geospace disturbances accompanied by abrupt changes in the geomagnetic field

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Abstract

With the development of progress, our civilization is becoming increasingly dependent on technological navigation and radar systems whose performance is to a certain extent governed by geospace conditions. Degradation of transionospheric radio signals and operation failures during geospace disturbances constitute a crucial factor of space weather influence on radio engineering satellite systems performance (along with other factors such as spacecraft surface charging, etc.). The objective of this report is to demonstrate how ionospheric disturbances during magnetic storms contribute to the degradation of signals and failures of the GPS system. We used automated software complex GLOBDET for global GPS detection and monitoring of ionospheric disturbances has been developed at the ISTP SB RAS. GLOBDET makes it possible to automate the acquisition, filtering and pretreatment process of the GPS data received via the Internet. The study is based on using Internet-available selected data from the global GPS network, with the simultaneously handled number of receiving stations ranging from 100 to 300. The analysis used 35 days from the period 1998–2002, with the values of the geomagnetic field disturbance index Dst from 0 to -300 nT. We found that ionospheric disturbances during magnetic storms contribute to signal degradation and GPS system malfunctions not only at the equator and in the polar zone but also even at mid-latitudes. During strong magnetic storms, the errors of determination of the range, frequency Doppler shift and angles of arrival of transionospheric radio signals exceeds the one for magnetically quiet days by one order of magnitude as a minimum. This can be the cause of performance degradation of current satellite radio engineering navigation, communication and radar systems as well as of superlong-baseline radio interferometry systems. The relative density of phase slips at mid-latitudes exceeds its mean value for magnetically quiet days at least by the order of 1 or 2, that makes a few percent of the total density of GPS observations. Furthermore, the level of phase slips for the GPS satellites located at the sunward side of the Earth was 5-10 times larger compared to the opposite side of the Earth.