Efficiency of ionospheric scintillation indices and new index based on the GNSS high-rate data: analysis based on case study.

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GNSS data with high-rate sampling becomes more and more available worldwide. This provides new opportunities in the field of ionospheric scintillation research. The ionospheric indices *S4*, $\sigma\varphi$, *ROTI* and *DROTI* are the most popular and widely used for the ionospheric scintillations studies. All the mentioned indices are reliable and informative tools. At the same time, the efficiency and reliability of the mentioned scintillation indices strictly depend on the integration time, sampling rate, de-trending procedures, GNSS hardware features and pre-adjustments. Uncertainties in the ionospheric indices computations can cause in turn the uncertainties in the results interpretation. In case of high-rate GNSS data it is very important to find an ionospheric scintillation index which will be easy-derived and whose dependence on GNSS hardware features will be clearly known for the particular type/model of GNSS receiver. We consider the carrier phase observable to be the most promising means to detect the ionospheric scintillation events. Further, we suggest the second-order derivative of the GPS signal carrier phase based on high-rate carrier phase time series as a new tool for the ionospheric scintillation research. The suggested new index is an easy means to detect the ionospheric scintillations events directly from the high-rate L1 or L2 phase data with no additional complex processing. As ionospheric scintillations manifest themselves differently at different GNSS frequencies, we used the single-frequency data for data interpretation and the analysis. The new index was tested for the case of the intense geomagnetic storm occurred on June 21-24, 2015 (Dstmin = -204 nT). Modeling and experimental results proved that that the second-order derivative allows us to detect the small-scale ionospheric irregularities of Fresnel size order. In addition, it was shown that for the purposes of ionosphere diagnostics, the sampling rate of 50 Hz is the sufficient time resolution to reveal the small-scale irregularities responsible for ionospheric scintillations. To use the new index additional conditions should be considered. First, PLL thermal noise should be kept small enough by means of PLL correct adaptive adjustments and short-term Allan variance should be 10^{-11} or better. Second, our comparison showed crucial dependence of sensitivity of the scintillation indices on the sampling rate of data used. The increase of the sampling rate resulted in (a) the better pronounced peaks of index values (better detection of scintillation presence); (b) the lower noise background; and (c) the low frequency trend absence. Third, we compared the results of scintillation detection based on the second-order derivative of the phase and with the results

based on other scintillation indices, in particular TEC, ROTI, DROTI, *S4* and $\sigma\varphi$. The mentioned parameters have very different “sensitivity” for the scintillation detection. Different ionospheric turbulences can be detected with use of different scintillation indices depending on the data pre-processing procedures (de-trending and filtering). Forth, it should be noted that sometimes, the bursts of the values of the second-order derivative of the signal phase can be caused not by scintillation events (associated with the small-scale ionospheric disturbances) but with the multipath effect and with the blocked signal effect.