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Key points for Precise Navigation under Scintillation Conditions

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ABSTRACT

Scintillation is one of the most challenging problems in GNSS navigation. This phenomenon appears when the signal pass through ionospheric irregularities, which produce rapid changes on refraction index and, depending on the size of such irregularities, also diffractive effects affecting the signal amplitude and can produce cycle slips. In this work we will show that the scintillation effects on the GNSS signal are quite different in low and high latitude.

For low latitude receivers, the main effects, from the point of view of precise navigation, are the growing of the carrier phase noise (sigma-phi) and a fading on the signal intensity (S4) that can produce cycle-slips in the GNSS signal. The detection of these cycle-slips is a challenging problem for precise navigation. Indeed, 1 cycle jump in the L1 carrier represents a jump of 48 cm in the ionosphere-free combination (the combination used in PPP), which, if it is not corrected, would derive in meters of position error.

In high latitude receivers the situation is not the same. In this region the size of the irregularities is typically larger than the Fresnel scale, so the main effects are related with the fast change on the refractive index associated to the fast movement of the irregularities (which can reach up to several km/s). Consequently, as we will show in the presentation, the main effect on the GNSS signal is a fast fluctuation of the carrier phase (large sigma-phi), but with a moderate fading in the intensity (moderate S4). Thus, on one hand, this rapid fluctuation of carrier phases is mostly proportional to the inverse squared frequency of the signals, being the effect quite limited (practically null) on the ionosphere-free combination. On the other hand, these fluctuations do not usually produce cycle-slips. These two characteristics make feasible the use of the ionospheric free combination for high accuracy navigation in high latitudes, also during high ionospheric activity.

As an example, Figure 1, left hand, shows the 3D positioning error, for two different GNSS receives located at a low latitude (SEY1, red color) and at a high latitude (YELL, in blue). The data set was collected on February 27 2014. During this day an ionospheric storm occurred in the evening, affecting the high latitude regions. Meanwhile, the low latitude receiver experienced scintillation after the sunset hours, which is more intense during this season of year (the equinox). These increases of the ionospheric activity can be seen with the AATR index (also shown in the figure) or with the ROTI index for some satellites.

As it can be seen from the AATR index (or from the ROTI), both receivers experience similar ionospheric activity values (for each station), being among the largest of 2014. But, as we will show in the presentation, some of the arcs of the receiver SEY1 suffer cycle slips (mainly in the L2 frequency), which cannot be easily detected because the associated jump involves only one cycle (i.e. ~20 cm).

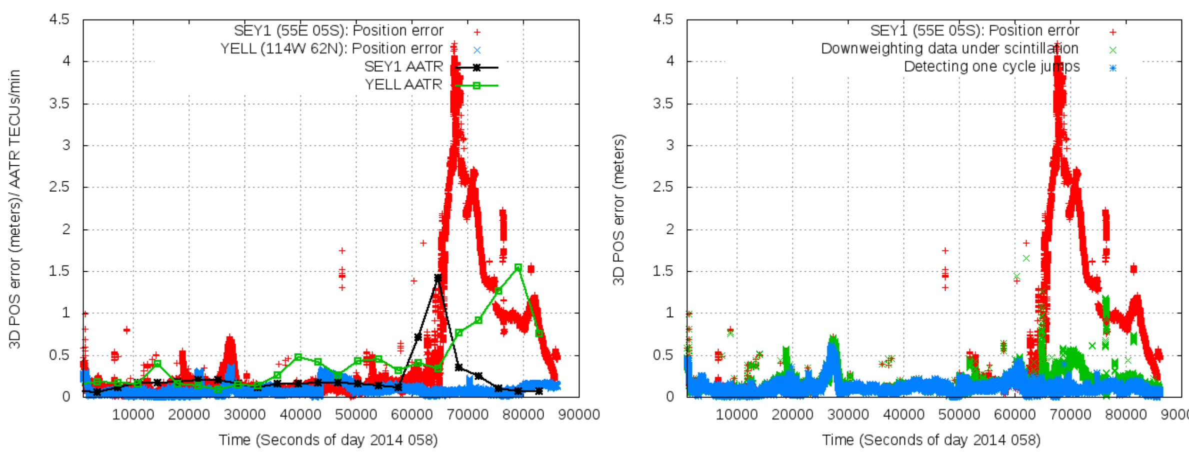

Figure 1**.** Left hand plot shows the 3D error of Precise Point Positioning for two receivers affected by scintillation. Red color is for a receiver located at low latitude (SEY1). Blue color is for a receiver at high latitude YELL). The AATR values are shown in black and green, respectively. The right hand plot shows the 3D positioning error of the low latitude receiver SEY1. The effect, at the user domain, of undetected small cycle-slips due to the scintillation conditions is shown in red. The solution in green has been computed down-weighting in real-time the measurements of satellites affected by scintillation. The navigation error computed using an (off-line) reliable cycle-slip detector able to detect very small jumps (involving just 1 cycle of L1 or L2 carriers) is shown in blue.

Thus, in spite both receivers have a similar ionospheric activity, the navigation for the low latitude receiver experience errors of meters due to above mentioned undetected cycle jumps.

There are several ways to mitigate the impact of such undetected jumps. One approach is to downweight the measurements under scintillation conditions. This can be done in real time by taking into account the SNR of the GNSS measurements. Figure 1, at the right hand, shows in green the positioning error for the low latitude receiver SEY1 applying this down weighting. Nevertheless, the best way would be to have a reliable detection of these jumps, as we have done offline for the results shown in blue Figure 1, at the right hand. In this case the navigation error under scintillation conditions is quite similar to what is expected in non perturbed condition (as in the case of the high latitude receiver in the left hand of Figure 1).

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