Review of paper "Open-loop GPS signal tracking at low elevation angles from a ground-based observation site" by Georg Beyerle and Florian Zus

General Remarks

The paper describes ground based observations of GPS signals tracked in the open-loop mode by the multi-channel OpenGPS hardware developed and built at GFZ. The experimental allows for tracking signals at high sampling rates and saving all the raw data for the further analysis. The tracking was performed by two channels using NCO models separated by 10 Hz.

The paper present an extremely interesting experimental study, and it definitely deserves publishing.

On the negative side, the paper is overloaded with technical details. For example, for a reader it may be difficult and hardly necessary to understand DUMP and TIC events. The authors should more concentrate on the issues important for radio occultations. On the other hand, the paper discusses multipath propagation, but it suffers from the lack of discussion of difference between the conditions of multipath propagation for space-born and ground-based receiver observations. Therefore, the paper should be stripped off the technical details and complemented with a physical discussion of multipath propagation in ground-based observations.

Specific Remarks

1. Introduction

While the authors are discussing ground-based experiment, it is expedient to discuss not only radio occultations, but also ground-based observation used for integrated water vapor retrieval.

36–37. *The resulting optical path length differences lead to constructive and destructive interferences*

Terms "constructive interference" and "destructive interference" are understood as in-phase or counter-phase interference resulting in amplification of attenuation of resulting amplitude. Such a detailed description is unnecessary here. It is enough to say that interference results in signal scintillations.

92–93. *...from the signal tracking perspective we may still regard "GLESER" recordings as radio occultation events in slow motion.*

This statement needs more elaboration. Ground-based observations have a different geometry and, therefore, different conditions for multipath propagation. These factors have to be analyzed.

163–165. *This 10 Hz shift can clearly be identified in fig. 3 (insert); here, O/L tracking mode starts at an elevation angle of −0.08° and reaches the nominal 10 Hz shift after a short settling phase at −0.13° elevation.*

However, here we observe some asymmetric between red and green curve. How can this be accounted for?

170–180. For a reader, it may be difficult to understand what DUMP and TIC events are. Is it necessary to go into these technical details?

Figure 9. Success rate of internal navigation bit retrieval…

I would not term the value of E a success rate. This value is zero for the ideal demodulation, and it is unity for randomly chosen navigation bits. Therefore, it should rather be termed a failure rate.

393. *with respect azimuth angle*
with respect to azimuth angle

Figure 13. Add the explanation of dark and light blue curves in the caption.

515–525, Figure 16.
All this part needs a significant improvement. The authors state that multipath presupposes vertical refractivity gradient, which is simply wrong. Take a simple exponential atmospheric model. This model acts as a defocusing lens, and, regardless of the vertical refractivity gradient, never creates multipath (effects like planetary flash are put aside). Multipath propagation is caused rather by non-monotonic profile of refraction angle, i.e. it should be linked to the second derivative of the refractivity. However, even this would not suffice, because this effect requires some observation distance. The authors state that they average the vertical gradient over the height interval from 0 to 2 km, but it remains unclear, what horizontal locations were chosen. If they took just the observation region, then this does not make sense. Figure 16 is not convincing either. In my view, none of the plots indicates any correlation between the average refractivity gradient and C/N0 fluctuations. I cannot see anything special for PRN 22, 7, and 13. Moreover, this is not surprising in the light of my previous remark.
The authors should present a physical analysis of the multipath propagation condition, instead of the speculative model. Consequently, Figure 16 should be replaced by the correlation with a more characteristic quantity derived from ECMWF fields. The best way is just to perform forward simulation. To my knowledge, at least one of the authors (Georg Beyerle) has enough experience for that.