

Review of Zus et. al. GPS radio occultation with TerraSAR-X and TanDem-X: Sensitivity of lower troposphere sounding to the Open-Loop Doppler model

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The paper presents the refractivity bias obtained from open loop (OL) RO measurements in the lower troposphere between co-located measurements with two identical instruments with slightly different Doppler models.

The addressed topic regarding whether OL measurements can introduce Doppler model dependent biases is interesting and very important. The paper is well written, clear and concise and important questions are raised. The OL measurement with a Doppler model off-set by ± 5 Hz and with subsequent post-processing, at low altitudes shows unambiguously biases with the sign of the off-set following the sign of the Doppler model off-set.

The OL tracking and Doppler model are concluded to the cause of the bias. Rather the bias is understood to be introduced in the ground processing.

No information is lost in OL tracking as long as the sampling frequency covers the Doppler off-set plus signal bandwidth, and also no bias is introduced. Please refer to (Carlström 2013), where simulations from wave optics propagation in the atmosphere and full spectral inversion retrieval are presented.

In eq. (3), the formula for unwrapping the phase (eliminating phase slips) is presented. This phase unwrapping step introduces a bias, in situations where there is noise present and there is an off-set in the Doppler model (as there more or less always will be). The bias will at this point be limited to steps of 2π . This "integer" bias would disappear when the complex amplitude is formed for the subsequent spectral method processing. However, an upsampling of the unwrapped phase will conserve the bias and hence affect the final result. To mitigate this, the interpolation required for the upsampling could be made on the complex samples (I and Q), or, better, the difference between the on-board Doppler/phase model and a more accurate model can be used to improve the upsampling interpolation.

It is hence unfortunate that the paper as a whole, and also in the title, identifies the OL model as the reason for the refractivity bias. The paper is important to illuminate the discussion whether OL is just as accurate as CL, but it should be stated that the observed bias is caused by the ground processing.

With these changes, the paper is recommended for publishing.

Reference:

Carlström, A., et al. "Simulations for the GRAS-2 receiver development", OPAC-IROWG 2013

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