Satellite Clock Modelling and Multi-GNSS Solutions

In the clock determination run, a single inter-system bias parameter per station and per day has been setup. A zero-mean condition over all those parameters per day for all stations has been applied.

The different noise levels between the IOV satellites and the Block IIF (E11, E12, G11, G12) and that of previous generations of GPS satellites (G24 and G15) is already obvious from Fig. 3. The modified Allan deviation plot presented in Fig. 4 clearly confirms the much improved stability of the newest satellites. At 30 s, they perform one order of magnitude better than the Rubidium clocks of previous generations of Galileo satellites. Galileo IOV satellite clock overall outperform those of GPS Block II satellites. In particular, they show a much less pronounced once-per-revolution variation.

The reason for the observed variations may thus be the temperature sensitivity of the oscillator or elements along the signal chain, or other errors caused by deficiencies in the radiation pressure model. Fig. 7 shows the same clock corrections based on two radiation pressure models (CODE-5 parameter and box-wing), indicates that the second reason seems more realistic. For the box-wing model, for high beta angles the amplitude remains rather constant while for low beta angles the clock corrections are very large. This may indicate that the satellite does not use the standard satellite yaw model.

If the once-per-revolution variations observed in the clock corrections are not caused by thermal effects but by systematic radial orbit errors, modelling the clocks should have the potential to improve the orbit. In the following, clock corrections were modelled by a daily independent linear function (offset and drift) as well as an epoch-wise clock offset with a variable constraint to the linear model. Solved-for parameters are: orbit initial conditions, radiation pressure parameters (CODE model and box-wing), clock parameters (offset, drift, and epoch-wise offsets), and ambiguity parameters. Validation of the orbits computed with different orbit models and clock parameter constraints was performed by investigating the short-term orbit prediction. Fig. 8 shows that a minimum orbit prediction error is obtained if the constraints applied to the epoch-wise clock estimates are between 3 and 10 ps, i.e., around the phase measurement noise level.

With optimal clock constraining, the standard deviation of the radial orbit difference between the predicted and the observed orbit decreases when increasing the weight of the relative constraint imposed on the clock. Very strong weights, e.g., a relative constraint on the clock of 0.1 mm, may cause slight degradation (see e.g., the black line).

4. Conclusions

The improved stability of the clocks onboard the Galileo IOV or GPS Block II satellites achieved such a quality, allowing the modelling of the clocks. This way, clocks, themselves can be used as a tool for monitoring the quality of the orbit modelling. Clock modelling also improves predicted orbits and their consistency with (predicted) orbit differences.

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Contact address

Ettore Orliac
Astronomical Institute, University of Bern
Lobeliensgasse 5
3012 Bern (Switzerland)
eettore.orliac@aiub.unibe.ch