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Strengthening GNSS Navigation with Clocks

Abstract

Clocks are the heart of any global navigation satellite system (GNSS). Stable oscillators, such as e.g., cesium or rubidium clocks, or passive hydrogen masers generate the navigation signals in the satellites. On ground generally low stability TCXO oscillators replicates the signal in the receiver that is correlated with the incoming signal in order determine the signal flight time and subsequently the distance to the satellites. However, GNSS are one-way ranging systems and the transmitter and user clocks are not synchronized. Therefore, only so-called pseudo-ranges and pseudo carrier-phase observations can be measured.

A synchronization is realized by introducing satellite and receiver clock errors w.r.t. GNSS system time. Corrections for the satellite clock errors are made available by the system provider via GNSS navigation message or orbit and clock solutions by the International GNSS Service (IGS). In contrast, due to the limited long-term (>1 s) frequency stability of the receiver internal quartz oscillator and its generally poor accuracy, the receiver clock error has to be estimated in the GNSS analysis epoch-by-epoch together with the coordinates. The consequences are (i) the need of four satellites for positioning, (ii) bad separability of the height component and the clock parameters, and other elevation-dependent effects, like e.g., delays due to tropospheric refraction, (iii) the height component is typically determined three times worse than the horizontal component and most vulnerable to systematic effects. All these effects restricts the interpretation of GNSS results and may mask valuable geophysical or atmospheric signals.

In this presentation, we will first explain how the treatment of clocks in GNSS is linked to the geometry of the navigation problem. Next, we will discuss how the currently used GNSS analysis concepts can be strengthened in order to benefit from modern ultra-stable atomic clocks in kinematic positioning and navigation. This includes terrestrial applications, networks with fiber connection as well as space-based positioning like LEO and MEO. Furthermore, we will question to which extend the physical clock signal is really contained in the attributed parameter “clock error” during GNSS analysis.

References

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