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ORIGINAL ARTICLE

Characterization of between-receiver GPS-Galileo inter-system biases and their effect on mixed ambiguity resolution

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Abstract The Global Positioning System (GPS) and Galileo will transmit signals on similar frequencies, that is, the L1–E1 and L5–E5a frequencies. This will be beneficial for mixed GPS and Galileo applications in which the integer carrier phase ambiguities need to be resolved, in order to estimate the positioning unknowns with centimeter accuracy or better. In this contribution, we derive the mixed GPS + Galileo model that is based on "inter-system" double differencing, that is, differencing the Galileo phase and code observations relative to those corresponding to the reference or pivot satellite of GPS. As a consequence of this, additional between-receiver inter-system bias (ISB) parameters need to be solved as well for both phase and code data. We investigate the size and variability of these between-receiver ISBs, estimated from L1 and L5 observations of GPS, as well as E1 and E5a observations of the two experimental Galileo In-Orbit Validation Element (GIOVE) satellites. The data were collected using high-grade multi-GNSS receivers of different manufacturers for several zero- and short-baseline setups in Australia and the USA. From this analysis, it follows that differential ISBs are only significant for receivers of different types and manufacturers; for baselines formed by identical receiver types, no differential ISBs have shown up; thus, implying that the GPS and GIOVE data are then fully interoperable. Fortunately, in case of different receiver types, our analysis also indicates that the phase and code ISBs may be calibrated, since their estimates, based on several datasets separated in time, are shown to be very stable. When the single-frequency (E1) GIOVE phase and code data of different receiver types are a priori corrected for the differential ISBs, the short-baseline instantaneous ambiguity success rate increases significantly and becomes comparable to the success rate of mixed GPS + GIOVE ambiguity resolution based on identical receiver types.

Keywords GPS-Galileo interoperability · Between-receiver inter-system bias · Integer ambiguity resolution · GIOVE

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Introduction

The two experimental Galileo satellites, GIOVE (Galileo In-Orbit Validation Element) A and B, have been in orbit since 2005 and 2008, respectively. One of the objectives of the GIOVE mission is to characterize the novel features of the Galileo signal design (see http://www.esa.int). In addition, two new satellites were launched on October 21, 2011, and an additional two on October 10, 2012, as part of the In-Orbit Validation (IOV) stage of Europe's Galileo project. Both the GIOVE and IOV satellites broadcast signals at the proposed Galileo frequencies, which are the E1, E5a, E5b, E5 (E5a + E5b), and E6 frequencies. It is remarked that the E6 frequency will only be received as part of Galileo's Commercial Service, while all other frequencies will be used in the (free) Open Service. From this set of Galileo frequencies, the E1 (1,575.42 MHz) and E5a (1,176.45 MHz) are overlapping the L1 and L5 frequencies of the US Global Positioning System (GPS). At present (2012), L5 signals are only transmitted by the GPS Block IIF satellites, that is, G25 (SVN62), which was launched in