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ORIGINAL ARTICLE

A scheme for weak GPS signal acquisition aided by SINS information

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Abstract In order to enhance the acquisition performance of global positioning system (GPS) receivers in weak signal conditions, a high-sensitivity acquisition scheme aided by strapdown inertial navigation system (SINS) information is proposed. The carrier Doppler shift and Doppler rate are pre-estimated with SINS aiding and GPS ephemeris, so that the frequency search space is reduced, and the dynamic effect on the acquisition sensitivity is mitigated effectively. Meanwhile, to eliminate the signal-to-noise ratio gain attenuation caused by data bit transitions, an optimal estimation of the unknown data bits is implemented with the Viterbi algorithm. A differential correction method is then utilized to improve the acquisition accuracy of Doppler shift and therefore to meet the requirement of carrier-tracking loop initialization. Finally, the reacquisition experiments of weak GPS signals are implemented in short signal blockage situations. The simulation results show that the proposed scheme can significantly improve the acquisition accuracy and sensitivity and shorten the reacquisition time.

Keywords GPS · High sensitivity · Signal acquisition · SINS aiding · Data bits estimation

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Introduction

The design of high-sensitivity receivers in harsh environment such as urban canyon, dense foliage canopies, and tunnels has become an important issue in current research (Ziedan 2006; O'Drisoll 2007; Jin 2012). The sensitivity of global positioning system (GPS) receiver mainly depends on the performance of the front-end and the acquisition scheme. In general, the extension of coherent integration time is a typical strategy for improving the acquisition sensitivity. Such extension, however, is limited by several factors including data bit transitions, increased power loss due to frequency errors (O'Drisoll 2007; Jin 2012), and a sharp increase in signal acquisition time.

In order to eliminate the negative effect of data bit transitions, the noncoherent combination (NC) method and the differential combination (DC) method are introduced to the acquisition of weak GPS signals (Zarrabizadeh and Sousa 1997; Choi et al. 2002). New algorithms, such as half-bit alternation and block addition can be treated as variations of the NC or DC methods (Tsui 2004; Ma et al. 2009; Chuang and Feng 2006). In noncoherent processing, the bit transitions are eliminated through the squaring operation. However, the noise is also squared and averaged toward a nonzero value. This value is referred as the squaring loss which attenuates the signal-to-noise ratio (SNR) processing gain of NC method significantly (Strässle 2007). Unlike NC method, the DC method, in which the present coherent integration result multiplies with the delay conjugate of the last result, can utilize the noise independence property at different sampling times to eliminate squaring loss. The differential approach in DC method can also lessen the bit transition effect and provide an overall sensitivity improvement with respect to that of the NC method (Borio et al. 2009;

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