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# Time-space difference based GPS / SINS Ultra-tight integrated navigation method

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**Abstract:** Presently there are several shortcomings in Global Positioning System/Strapdown Inertial Navigation System (GPS/SINS) ultra-tight integrated navigation system, for example, presences of modelling errors, heavy computation load and residual time errors, etc. To address these problems, this paper proposes a time-space difference based ultra-tight integrated navigation method. This system carries out difference in time and space which eliminates the troposphere delay, ionosphere delay, satellite and receiver clock error, reduces the system complexity and decreases the adverse impact (frequently changing weather and the low accuracy clocks of receiver and satellites) on the system,. In this way the system improves the estimation accuracy and anti-jamming ability. Finally, theoretical analysis and simulation results substantiate that the proposed system has the practicability and superiority over the contemporary ultra-tight integration schemes.

**Keywords:** GPS/SINS ultra-tight integrated system; Vector tracking loop; Difference;

## 1 Introduction

Owing to complementary characteristics, the GPS/SINS integrated navigation has emerged as an important research field in navigation systems. According to different ways of integration, the GPS/SINS can be divided into three modes: the loose mode, the tight mode and the ultra-tightly mode [1]. Compared with that in the loose mode and tight mode, the information output by GPS and SINS can be further integrated in ultra-tight mode, and the result can not only correct inertial device and restrain error accumulation, but also amend receiver parameter to improve its tracking ability of satellite signal.

At present, vector-tracking based GPS/SINS ultra-tightly integrated navigation model is wildly used (named VTGPS/SINS here) [2, 3]. This model is based upon the structure of vector tracking loop which puts together the satellite signal tracking with the integration of GPS/SINS information: the In-phase/Quadrature (I/Q) signals are employed as input to the navigation filter, the outputs of filter render corrections to the parameters of SINS and GPS, and then generate the corrective signals to the numerically controlled oscillators to achieve the goal of tracking the satellite signals. Compared with the former model, this one has the stronger and better signal tracking and anti-jamming ability.

However, VTGPS/SINS system functions are established by using the relationship between I/Q signal (or expectations of I/Q) and navigation errors, which leads to three limitations [7-8]:

(1) Model error: As the expectations of I/Q are employed to establish system mode, the system functions reflect the relationships between expectations of I/Q and navigation errors, rather than the relationships between I/Q themselves and the navigation errors. Therefore, the system models cannot describe the relationships between the receiver and the SINS accurately.

(2) Heavy computational load: I/Q are cosine/sine functions. Hence they lead to a strong non-linear system model. Therefore, this model has the shortcomings of high demand for filter algorithm and huge computation which make the system lose its real time.

(3) Residual time errors: Although existing VTGPS/SINS compensates these errors (ionosphere delay, troposphere delay, satellite clock error and receiver clock error) by establishing the corresponding error models, the effects are unsatisfactory because the residuals errors still exist which results in decreasing of positioning accuracy. Meanwhile, these residual time errors cannot be modeled and estimated as they are susceptible to frequency drift of clocks, sunspot activity and continual climatic change, which increases the uncertainty of system.

Taking the above problems into account, this paper proposes a novel GPS/SINS ultra-tightly integrated method named time-space difference based GPS/SINS ultra-tightly integrated system (TSDGPS/SINS). It directly employs the angular velocity error and the initial phase error as measurements, which are obtained from I/Q. Specifically, the time-space difference method is used to eliminate the tropospheric delay, ionosphere delay, satellite clock error, and receiver clock error completely, at the same time, this method also wipes out residual errors. On the basis of above steps, linear system equations are derived to further reduce the computation load and system complexity. Finally, the performance of the new system is evaluated by

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