INS (Inertial Navigation System) and GPS (Global Positioning System) have complementary characteristics. GPS pseudorange measurements are available at all times in all weather conditions at a relatively low sample rate. The GPS system provides position and velocity estimates with bounded estimation error. A GPS user may, however, experience short-term loss of the GPS signals because of signal blockage, interference, or jamming. The high output rate of the INS is limited primarily by the choice of computational approach and equipment. The INS state estimates are calculated based on the outputs of inertial sensors that are not dependent on the external fields and are therefore essentially immune to external interference. High-frequency noise on the inertial instrument outputs is attenuated by the low-pass nature of the INS; however, low-frequency noise and especially sensor bias are amplified. The unaided-INS position and velocity errors may be unbounded. This complementary nature of inertial and GPS-based navigation systems makes INS/GPS integrated navigation system have been being researched and used widely.

Among various integration techniques, loosely-coupled and tightly-coupled integration techniques have been widely used. The loosely-coupled and tightly-coupled systems are classified according to GPS measurements used for integration filter. The loosely-coupled system uses the estimated GPS position and velocity as measurements and therefore it has a disadvantage that at least 4 in-view satellites are required for integrated navigation. The tightly-coupled technique was proposed to make up for this weakness and it uses GPS pseudoranges and pseudorange rates and it can provide integrated navigation solutions even if at most one satellite is visible.

In recent years, researches for smartization of conventional weapons such as gun-launched munitions have been being actively carried out. Navigation systems for such weapons may experience extremely harsh environmental conditions such as high shock, high rotation and so on. Therefore, robust algorithms and equipment, which resist such environment, are required. As an alternative, MEMS-based IMUs are developed and applied for INS/GPS integrated navigation systems. However, MEMS-based gyroscopes provide poorer performance than the existing gyroscopes such as RLG (Ring Laser Gyro) and FOG (Fiber Optic Gyro) and thus the MEMS-based navigation systems necessarily require external aiding such as GPS. However, GPS can not provide immunity against external interference and robustness against user’s high dynamics. For this reason, another new integration technique known as deeply-coupled integration was proposed and has been widely researched.

The deeply-coupled integration combines GPS signal tracking loops and GPS/INS integration into a single estimation filter. The estimation filter operates on the GPS receiver’s tracking loop I and Q samples and the IMU measurements to estimate navigation information. The deeply-coupled integration gives optimal performance compared with other integration techniques. In particular, it has robustness against user’s high dynamics and anti-jamming capability against external interference [1, 2].

In this thesis, a design of deeply-coupled GPS/INS integrated navigation system is proposed. The proposed deeply-coupled GPS/INS integrated navigation system uses the outputs of GPS receiver’s carrier and code tracking loop discriminators as measurements for the integrated Kalman filter. The inputs of the error discriminators are GPS receiver’s I and Q samples, and their outputs are carrier phase/frequency error and code delay. For the purpose of simulation studies, GPS IF signals are modeled and baseband processing parts are implemented using commercial software, MATLAB®. The navigation performance and GPS signal tracking performance of the proposed deeply-coupled GPS/INS integrated system are compared with other existing integration techniques using the implemented simulation environment.

As expected, the proposed deeply-coupled GPS/INS integrated system makes up for the weak point of the loosely-coupled INS/GPS integrated navigation system that minimum 4 in-view satellites are required for the integrated navigation. The proposed deeply-coupled GPS/INS integrated system provides the similar navigation performance with the tightly-coupled INS/GPS integrated system unless the GPS signal tracking performance is taken into account.
The deeply-coupled GPS/INS integrated system shows better tracking performance than tightly-coupled INS/GPS integrated system under the vehicle’s initial high dynamics; however, the navigation performance, which converges to GPS’s navigation accuracy, is qualitatively similar with the tightly-coupled INS/GPS integrated navigation system.

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