A TIDGET/Inertial Missile Sensor Fusion System[1]

Josef Coetsee, Armando Montalvo and Alison Brown
NAVSYS Corporation

ABSTRACT:

Many guided munitions systems could benefit from the use of GPS position information to augment existing inertial navigation systems. These applications however, are characterized by no pre-launch visibility of GPS satellites, short duration, and high launch dynamics, which preclude the use of conventional GPS receivers. This paper describes and innovative approach to GPS/INS data fusion for these demanding applications that optimally combines GPS and INS data from both the launch platform and smart munitions. The advantages of this system include no initialization of GPS sensor pre-launch, rapid signal acquisition even in high dynamic environments (Time To First Fix < 1 sec), improved Anti-Jamming performance when compared to even an ideal conventional receiver, and inherent differential operation.

1. INTRODUCTION

1.1 GPS FOR PRECISION WEAPON DELIVERY

Attack aircraft currently carry a suite of precision sensors such as Global Positioning System (GPS), Inertial Navigation System (INS), Forward Looking Infrared (FLIR) systems, and Synthetic Aperture Radar (SAR) that can be used to provide precision air-to-ground or air-to-air targeting. Smart weapons also carry a sensor suite including inexpensive IMUs and sometimes GPS equipment for precision weapon delivery. However, the size, weight, and cost of the missile electronics limit the functions that can be performed on-board. The ability to fuse data from on-board sensors and off-board assets can significantly improve the accuracy of the weapon delivery while reducing the cost of the weapon system.

NAVSYS has designed an innovative tracking system that optimally combines data from the aircraft and missile sensors, including GPS and INS data from both sources. This architecture has the following key advantages over previous GPS/INS missile guidance systems.

- Low cost GPS sensor used in place of a full receiver on the missile.
- No initialization needed of GPS sensor pre-launch.
- Rapid initial signal acquisition even in high dynamic maneuvers (TTFF <1 sec).
- Sensor fusion of aircraft and missile GPS/INS data performs rapid in-flight alignment of missile INS, reducing time needed for pre-launch initialization and alignment.
- Enhanced signal processing of GPS data on aircraft increases signal margin and anti-jamming (A/J) performance of missile GPS data.
- "Differential" missile-to-aircraft operation provides improved GPS precision for targeting using aircraft sensors.

The TIDGET/INS Missile (TIM) system concept, is

[1] This research was supported by an SBIR award, Topic: AF94-122.

illustrated in Figure 1.

The missile carries on-board an inexpensive, miniaturized GPS sensor, the TIDGET™. The TIDGET is used to periodically collect "snapshots" of the GPS data. This data is formatted into a message that also includes the missile INS position, velocity, and attitude data, which is transmitted back to the aircraft. The aircraft receives the data from the missile and passes it to the TIM tracking system for processing. The TIM tracking system combines the data from the aircraft GPS/INS systems with the TIDGET/INS data received from the missile, and processes this to compute an integrated GPS/INS solution for the relative location and velocity of the missile to the aircraft. This can be combined with FLIR and SAR data to accurately target the weapon system.

1.2 APPLICATIONS

Several applications can benefit from the use of a TIM tracking system to improve the guidance accuracy. This paper focuses on the use of the technology in an extended range air-to-air missile that operates as follows:

A target is acquired by the launch aircraft. The missile is then launched and uses its on-board INS to fly towards an aim point (expected future location of the target) supplied by the launch aircraft. Based on the target motion, the launch aircraft transmits updates of the aim point to the missile during flight. Once the missile reaches the aim point and the target can be acquired by the missile seeker, the mid-course guidance phase ends and the missile starts using its seeker for terminal guidance to the target. Note that if the missile INS provides inaccurate navigation information, the capability of the missile to reach the aim point will be severely degraded.

Although this paper considers an air-to-air application, the TIM system can be used in any guided missile or bomb that relies on an on-board INS for navigation/guidance.

1.3 TECHNICAL ISSUES

A block diagram of the NAVSYS TIM tracking system is shown in Figure 2. The key technical issues in the design of the TIM system are:

TIDGET/INS Data Fusion

A system that relies on an INS navigation information for guidance is subject to guidance errors due to the fact that the INS (if uncorrected) exhibits errors that grow with time. The magnitude of the INS errors depends on the size of initialization errors, as well as the instrument, i.e. accelerometer and gyro errors. In airborne applications where missiles are launched from wing mounts, a large source of INS error occurs due to incorrect attitude initialization (i.e. incorrect alignment), which results from wing twist etc [1]. Furthermore, if low cost Inertial Measurement Units (IMU's) are used, the accelerometers and gyros will exhibit large errors.

By fusing GPS and INS data, improvements in system accuracy are obtained because of:

- Improved INS initialization: by using the appropriate data fusion process, it is possible to significantly reduce the effects of incorrect INS initialization after processing only a few GPS measurements. This means that for example in a hostile jamming environment, only a small number of GPS measurements are required, whereupon autonomous operation using only the INS is possible.
- Improved Navigation information: if the GPS data is used to correct the INS at regular intervals throughout the missile flight, one obtains a system that exhibits the best characteristics of both GPS and inertial navigation systems, viz. the accuracy and stability of GPS, as well as the high bandwidth of an INS.