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No Longer Guaranteed ...

Global positioning system alternative necessary

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By Randy Yergert

The U.S. military requires accurate positioning, attitude, velocity, motion compensation, and positioning synchronization data to maintain effective real-time theater coordination of our allies and our highly mobile military forces. Additionally, our military requires an awareness of enemy position and movement. The military's use of the global positioning system (GPS) has created a significant military advantage in accurate navigation and a time reference system. Missile defense and surveillance weapon systems rely on this data through all phases of the system's employment. Additionally, Department of Defense (DoD) embraced GPS for use with many weapon systems to support guidance and navigation of smart, steerable weapons. This heavy reliance upon GPS by the U.S. military, however, makes it a prime target for jamming by hostile forces. Miniature Aircraft Geolocation System (MAGS) is a potentially viable alternative that will allow DoD to continue to embrace GPS and solve the threat of GPS jamming devices.

Currently, an open market exists for commercially available GPS jamming devices. For example, one Russian company is marketing a long-range GPS jamming device that can deny GPS operation over a 200-kilometer diameter area at altitudes up to 50,000 feet. GPS is no longer a guaranteed navigation solution for our forces and weapon systems in times of military conflict. In the absence of the Space segment and GPS satellite access, there are now no sufficiently secure, jam-resistant, precision positioning devices or systems. Accordingly, there is a need for a non-GPS projectile navigation system.

Current inertial navigation systems lack the accuracy, durability, and versatility, in addition to exhibiting poor drift performance and shock sensitivity to fill this need. Over the past several years, two specific technologies have been proposed to overcome these critical weaknesses as well as GPS jamming. One alternative was the use of an inertial navigation system; the other was the use of a MAGS.

To address the issue of overcoming GPS jamming of precision-guided munitions, the Navy first funded a technology development called the extended range guided munitions (ERGM) program. ERGM are rocket-assisted munitions that fly into the target area at extended ranges. Navigation systems are integrated to guide the munitions to the target to achieve greater accuracy and reduce the circular error probability. Initially, GPS was contemplated to provide munitions navigation en route to the target. However, GPS jamming was anticipated so an inertial navigation system was integrated to provide the end of flight navigation function in lieu of GPS.

The second GPS alternative effort was in support of the Office of the Secretary of Defense's smart sensor Web program and included the Office of Naval Research's smart sensor wireless netting program. Part of this effort included development of an ultra wideband (UWB) leveraging non-GPS navigation system. The result of this development was the MAGS concept.

The MAGS consists of multiple subsystems and functions much like the GPS. Unmanned aerial vehicle (UAV) platforms perform identical functions as GPS satellites. Many UAVs fly precise patterns underneath the munitions trajectory path. At regular intervals, the UAVs transmit a series of S-band UWB pulses that signal each UAV's current location and local time. Also similar to GPS, assets requiring location knowledge are equipped with MAGS receivers to process signal differential time of flight and determine resulting locations.

The MAGS UAVs determine their position by using video imagery from a down-looking camera and correlating the images with locations on georegistered maps stored in their on-board map database. UAVs fly

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sufficiently low (approximately 500 feet above ground location) to avoid cloud ceilings and camera image resolution. Also, UAVs use UWB radar altimeters to maintain altitude control and aid in Kalman filtering for their position determination using the map/image correlation. An inertial navigation system supplies the precision location information between map/correlation image navigation updates. Additionally, UAVs carry precision clocks to timestamp the packets transmitted with the UAV geolocation information. Finally, UAVs communicate among themselves to synchronize their system clocks and determine the timing of the packet burst sequences for their geolocation packets.

Those systems requiring location knowledge have MAGS receivers to interface with the inertial navigation systems in the same manner as GPS receivers. The MAGS systems receive UAV location packets and record the relative time of arrival respectively. Based on relative time of arrival between messages with location and transmission time, the receivers calculate position and local time. The relative packet arrival times are measured with a receiver clock capable of surviving system mission stresses and of achieving an accuracy of 1 part per million. UWB waveforms allow the receivers to acquire precise flight time measurements from the UAV transmitters to the MAGS receivers. The receiver architecture is highly sensitive to the leading edge of the first packet pulse for precision time of flight measurement. Additionally, because geolocation transmitters are located in a geometric plane close to the ground, the geometric dilution of precision increases vertically as the MAGS receivers approach the transmitter. To reduce this uncertainty, the MAGS host systems require an UWB radar altimeter.

The use of short pulses, with a broad instantaneous frequency spectrum, provides a unique waveform supportive of a wide variety of applications. In the MAGS architecture, UWB is used for sensing and ranging the ground for altitude and for determining range and location between transmitters and receivers for geolocation and communications. As an added benefit, UWB waveforms offer a low probability of intercept and detection signature, hence a low probability of interference. Finally, because of the nearly all-digital nature of the UWB radar, microminiaturization through the use of custom advanced system integrated circuits (ASICs) and hybrid technology is currently achievable. A further size reduction through ASICs and Radio Frequency Integrated Circuits will allow UWB systems to occupy a very small footprint to fit on nearly all classes of air platforms and munitions.

With improved clock synchronization among MAGS UAVs, it will be possible to provide navigation with the equivalent performance of GPS. Furthermore, the total MAGS system employs technologies that are low cost and, in many instances, currently available via commercial off-the-shelf. UWB technologies are affordable and enable navigation performance with wide distribution. Given these key advantages, the key challenges in the near future facing MAGS development are system integration and ensuring supporting technologies are developed to fit inside the respective receiver packages.

As the proliferation of GPS jamming technology increases, it is imperative that the military develop alternatives to the current satellite-based GPS system. MAGS is one possible solution that will help ensure our military maintains leadership in reliable, precision-guided munitions as well as other technologies dependent upon precise location and timing information.