SECTION 16.1—INERTIAL NAVIGATION SYSTEMS AND RELATED COMPONENTS

Highlights

- Inertial navigation technologies provide an autonomous, covert, and nonjammable 3–D position and velocity reference for land, sea, and space platforms, which will enhance the ability of the military to achieve mission goals.
- Major reduction in manufacturing complexity, size, and cost of INS will be realized by use of MEMS sensors, electronics, and radio-frequency (RF) interfaces. This will allow expanded applications, thereby providing a larger market for more nontraditional manufacturers of inertial navigation technology.
- Through better noise compensation techniques, RLG and FOG will continue to improve free inertial performance (1.0–0.1 nm/hr).
- Future developments in nanotechnology, particularly NEMS accelerometers, may eliminate the need for gyroscopes if quantum noise measurement techniques are resolved.
- Military application of INS with embedded GPS, LORAN, and data-based referenced navigation systems (DBRNS) will increase. These hybrid systems bound the time-dependent errors of the inertial gyroscopes.
- Built-in redundancy through low cost, small size, lightweight, and highly reliable components will allow an affordable, throwaway logistics concept. This will enable a rapid affordable technology insertion of INS technology.

OVERVIEW

An INS is a self-contained, covert system that provides continuous estimates of some or all components of a vehicle state, such as position, velocity, acceleration, attitude, angular rate, and often guidance or steering inputs. The current major obstacle of more universal INS use is its loss of accuracy over time and high cost. Figures 16.1-1 and 16.1-2 address the key gyroscope and accelerometer performance requirements for military applications, as well the key commercial automotive uses. INS technology has been enormously affected by advances in computer technology (memory and throughput), sensors, power quality, and electronics. Most current INS use optical gyroscopes: RLG or FOGs. RLG and FOG INS technology will continue to improve free inertial sensor performance from 1.0 nmph to less than 0.1 nmph, while decreasing costs.

Future key critical technologies are the emergence of low-cost, microminiaturized INS using MEMS (MEMS could revolutionize navigation). The commercial automotive markets are driving the MEMS technology development. Current MEMS gyroscopes are less than 5 × 1 cm, with an accuracy of 100 deg/hr at a cost of under $50. Industry expectations are to achieve 10 deg/hr by the end of 2000. Depending on military investments in that market, over the next 5–10 years MEMS-type gyroscopes could achieve tactical accuracy of 1.0–0.1 deg/hr.

Future miniaturization using NEMS sensors may be possible. The advantage would be the elimination of the gyroscope, using only accelerometers for sensing linear and rotational acceleration in a 360-deg cluster per axis. The issue is the sensitivity of the accelerometer to detect Earth's gravity because of the sensor's small mass and ability to detect quantum noise levels. Currently, the NEMS market driver is focused on medical commercial applications. Figure 16.1-3 shows the INS technology trends and costs projections over the next 10–20 years across multiple INS users. Figure 16.1-3 also shows that more sensor hybridization will occur over the next 5–10 years as GPS and other telecommunication functions are tightly coupled and integrated with INS. This massive production base, as well as the low cost of MEMS and NEMS sensors, could significantly reduce the cost of many military INS to less than $500. As the cost of INS decreases, their use in commercial applications will increase dramatically, cameras (analogous to weapon sight stabilization) and automotive ride and stability control (analogous to turret stabilization).