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Testing Inertial Sensors

In Chapter 2 we described inertial systems error modeling and the generation of specifications for the sensors in an inertial navigator, specifications which could (and should) follow the Institution of Electrical and Electronic Engineers (IEEE) standard formats for inertial sensors. In this chapter we will describe the testing of accelerometers and gyros for conformance to these specifications; we will describe the tests that we would perform for acceptance test procedures (ATPs) on a pendulous accelerometer and on three types of gyro, the single-degree-of-freedom (SDFG), the dynamically tuned gyro (DTG), and the ring laser gyro (RLG). This description is general and takes account of neither specific design issues nor of particular customer needs that would expand the ATP in real life.

When we test accelerometers and gyros with drifts below 50 μg and 10 deg/h, respectively, we need a properly designed and equipped test laboratory, a facility outfitted with precise mechanical positioning equipment and electrical standards.

Inertial Sensor Test Labs

If we wish to verify the performance of a gyro, we need to know the input rotations to the gyro with respect to inertial space, i.e., the earth’s rotation rate component about the gyro’s input axis. For an aircraft navigator gyro, with an accuracy of 0.01 deg/h, we must be sure that the fixture holding the gyro is fixed to the earth to a stability of better than 10⁻⁴ rad (20 arc-sec), because 10⁻⁴ x HER (say 10 deg/h) is 0.001 deg/h, an order better than we are trying to measure. Similarly, for testing an accelerometer for 1 μg stability, the test base must be aligned to the vertical to better than 1 μrad (0.2 arc-sec).

We need to isolate the sensor from ground vibrations, like those from passing trucks or trains, therefore inertial systems manufacturers and prime users have test labs supplied with stable piers, which are massive concrete slabs set on bedrock or in deep sand, isolated from the foundations of the building containing the lab. Some test piers have been supported on air bags, giving the pier a very low natural frequency. The pier at the Air Force Academy Seiler Laboratory in Colorado Springs weighs 450,000 pounds, is floated on pneumatic isolators, and is actively controlled by precise tilt meters; it is stable to better than 10⁻⁸ g and 10⁻³ arc-sec. Probably the best known inertial test lab in the United States is the Central Inertial
Guidance Test Facility (whose acronym is pronounced “CIG-TIF”) at Holloman Air Force Base, New Mexico.

The direction of True North must be precisely known for proper compensation for the earth’s rate, so labs have sight lines from the test pad to the pole star (perhaps through holes in the roof). If this is not feasible, perhaps because the test pad is in a basement on bedrock, star sights are indirectly transferred to designated positions (marked by points in the floor) from outside the building, and retro-reflectors built into the wall are aligned from the star sights. One then aligns the gyro test stands to the retro-reflectors.

**Performance Test Gear**

Sensor test stands can be turned and tilted to position the sensor axes up and down and along the cardinal points of the compass, thereby allowing gravity and/or and the earth’s rate to act along different axes in turn. These tables have arc-sec positioning accuracy and usually have precise spirit levels installed for setting horizontal accurately. They are electrically driven and provide digital outputs of trunnion angles, so they can be programmed to perform tests automatically. This provides repeatability of test conditions and times while reducing personnel costs.

Precise rate tables, controlled so that they can spin up to 1000 deg/s or so about a well-defined axis, are used for measuring the rate gyro’s scale factor. The table will have slip rings to take power to the gyro and signals out to the measuring electronics and will have a precise angle marker, which gives a pulse out per revolution, although some tables provide precise rotation rate (or incremental angle pulses) continuously.

Another type of rate table, the servo table, simulates a single-axis inertial platform (Chapter 1) by having a platen mounted on precise bearings, rotated by a motor. The motor will turn the table platen when commanded by a servo loop signal, the platen speed being proportional to the magnitude of the signal and its direction depending on the signal polarity.

The servo drive signal is obtained from the pickoff of a gyro mounted on the table with its input axis (IA) along the table axis, as shown in Figure 15.1. In order to measure the torquer scale factor of a single-axis floated gyro (SDFG) or a dynamically tuned gyro (DTG), a current is sent in through the table slip rings to the gyro torquer. This causes the gimbal (SDFG) or rotor (DTG) to precess about the output axis (OA) and generates a pickoff signal. This signal passes out through the table slip rings to the external servo, which excites the table motor. The table accelerates until the gyroscopic torque exactly equals the current-induced torque and the gyro pickoff returns to null. Because it needs only a precise current source and a clock to measure table rate, such a table provides a higher accuracy measurement of scale factor than an open-loop rate table, and it is used to determine gyro torquer linearity as described later.