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**PROPOSED IEEE CORIOLIS VIBRATORY  
GYRO STANDARD AND OTHER  
INERTIAL SENSOR STANDARDS**

**by**

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# Proposed IEEE Coriolis Vibratory Gyro Standard and Other Inertial Sensor Standards

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## Abstract

A new Coriolis Vibratory Gyro (CVG) Specification Format Guide and Test Procedure is being developed by the IEEE/AESS Gyro and Accelerometer Panel for consideration by the IEEE Standards Association as IEEE Std. 1431. It provides guides for specifying CVG performance and gives test procedures for verifying compliance with requirements. It also describes the various types of CVG, ranging from vibrating shell macro-sized devices to low-cost silicon and quartz chip micro-sized devices. Model equations are given for the various CVG operating and readout modes: whole-angle, open-loop, force-rebalance, and ratiometric. Also discussed in this paper are the IEEE standards that have been published for single- and two-degree-of-freedom spinning wheel gyros, laser gyros, interferometric fiber optic gyros, angular accelerometers, linear accelerometers, accelerometer centrifuge testing, and inertial sensor terminology, and an inertial sensor test equipment and analysis document and an inertial systems terminology document that are under development.

## 1. Introduction

### 1.1 Gyro and Accelerometer Panel Organization

For almost 40 years, the Gyro and Accelerometer Panel of the IEEE Aerospace and Electronics Systems Society has been meeting bimonthly to develop inertial sensor standards that are published by the Standards Association of the Institute of Electrical and Electronic Engineers (see the bibliography at the end of this paper).

Bimonthly Panel meetings usually alternate on the East and West Coasts of the United States, with attendees from Japan and Europe, as well as from the United States, representing many inertial sensor and systems producer and user companies. Since 1998, one meeting a year has been held in Europe.

The public Web site <http://grouper.ieee.org/groups/gap> contains information about the Gyro and Accelerometer

Panel, including the Bylaws, future meeting locations and dates, and current Panel officers with e-mail addresses.

There is a private Web page accessible by password from the public Web page that contains past meeting minutes and drafts of documents under development. The yearly electronic renewal form for either a full member of the Panel or an information-only member is on the private Web page. Full members attend meetings as permitted by business commitments and participate in Panel ballots, with non-IEEE members being allowed to ballot as invited experts upon petition to the IEEE Standards Board. Either class of membership receives the password for accessing the private Web page.

The initial membership application requires a paper form to be filled out and signed. The form can be obtained from a print of the application form on the private Web page provided by a current member, or by requesting the same from the Panel Chair, whose e-mail address is on the public Web page.

### 1.2 Standards Development Process

Any interested party may attend the open meetings where the standards are developed and homework contributions to the standards are discussed and voted upon. The Panel and Committee meetings are conducted using Roberts Rules of Order. Consensus is sought in the standards development.

Before the Gyro and Accelerometer Panel can commence work on a proposed standard, a Project Authorization Request (PAR) describing the scope and purpose of the standard must be approved by the IEEE Standards Board, and a P project number assigned.

Work on standards typically takes place in either the Gyro Committee or in the Accelerometer Committee of the Panel, depending on the type of standard. Some standards development (such as terminology documentation) occurs in the full Panel meeting as a committee of the whole. The Gyro and Accelerometer Panel is becoming involved in inertial systems standards development, and is

considering the possibility of creating a third Inertial Systems Committee for that purpose (see Section 1.5).

After development work is completed and approved by the full Panel, a proposed standard goes out for industry survey to determine possible additional revisions. A Panel ballot is then conducted and requires 75% affirmative votes, with attempted resolution of any negative votes. A balance is required between the producer, user, and general interest ballot categories. Once approved by Panel ballot, the proposed standard is considered by the IEEE Standards Board for becoming a published IEEE standard.

### 1.3 Proposed CVG Standard

The Gyro and Accelerometer Panel will soon be sending out for industry survey the newly developed Coriolis Vibratory Gyro Specification Format Guide and Test Procedure, document P1431. This document has been under development for the past six years, and is proposed to be IEEE Std. 1431 [10]. When approved by Panel Ballot and by the IEEE Standards Board, it will join the collection of IEEE inertial sensor standards that have been developed by the Gyro and Accelerometer Panel over the years [1-9].

Gyroscopes measure angular motion with respect to inertial space without external reference. They traditionally have used the angular momentum stored in a spinning wheel or the Sagnac effect in counterpropagating light beams in a ring laser cavity or fiber optic coil to accomplish this feat.

Recently, gyroscopes are being sold for which the measure of rotation is provided by the Coriolis effect on a vibrating mass rather than from the inertial reference direction provided by a spinning mass or rotating photons. The IEEE Gyro and Accelerometer Panel has coined the term "Coriolis Vibratory Gyros (CVGs)" to describe such devices. They range from high-accuracy, macro-sized vibrating shell devices to lower-accuracy and very low-cost silicon and quartz chip micro-sized devices. The chip-sized devices are being produced in the millions per year for many non-traditional applications, such as in consumer products and the automotive industry.

As described in the body of this paper, the P1431 specification format guide provides a template for specifying CVG performance requirements. Model equations are given for the various CVG operating and readout modes: whole-angle, open-loop, force-rebalance, and ratiometric. The test procedure gives instructions for carrying out CVG acceptance, calibration, and other tests. There are informative annexes on the various types of CVG devices and on their principles of operation.

### 1.4 Published Inertial Sensor Standards

Appendix A of this paper describes the standards that have been published for single- and two-degree-of-freedom spinning wheel gyros, laser gyros, interferometric fiber optic gyros, angular accelerometers, linear accelerometers, accelerometer centrifuge testing, and inertial sensor terminology.

### 1.5 Other Standards Under Development

Appendix B describes an inertial sensor test equipment and analysis document and an inertial systems terminology document that are currently under development.

Standards that industry might want to develop for radio navigation aided inertial navigation systems (e.g. GPS/INS) could profitably make use of the IEEE standards development and publishing facilities that are available to the Gyro and Accelerometer Panel. The Panel is considering creating an Inertial Systems Committee to join the Gyro Committee and the Accelerometer Committee in order to carry out systems standards development in addition to the systems terminology document that is currently being written by the full Panel.

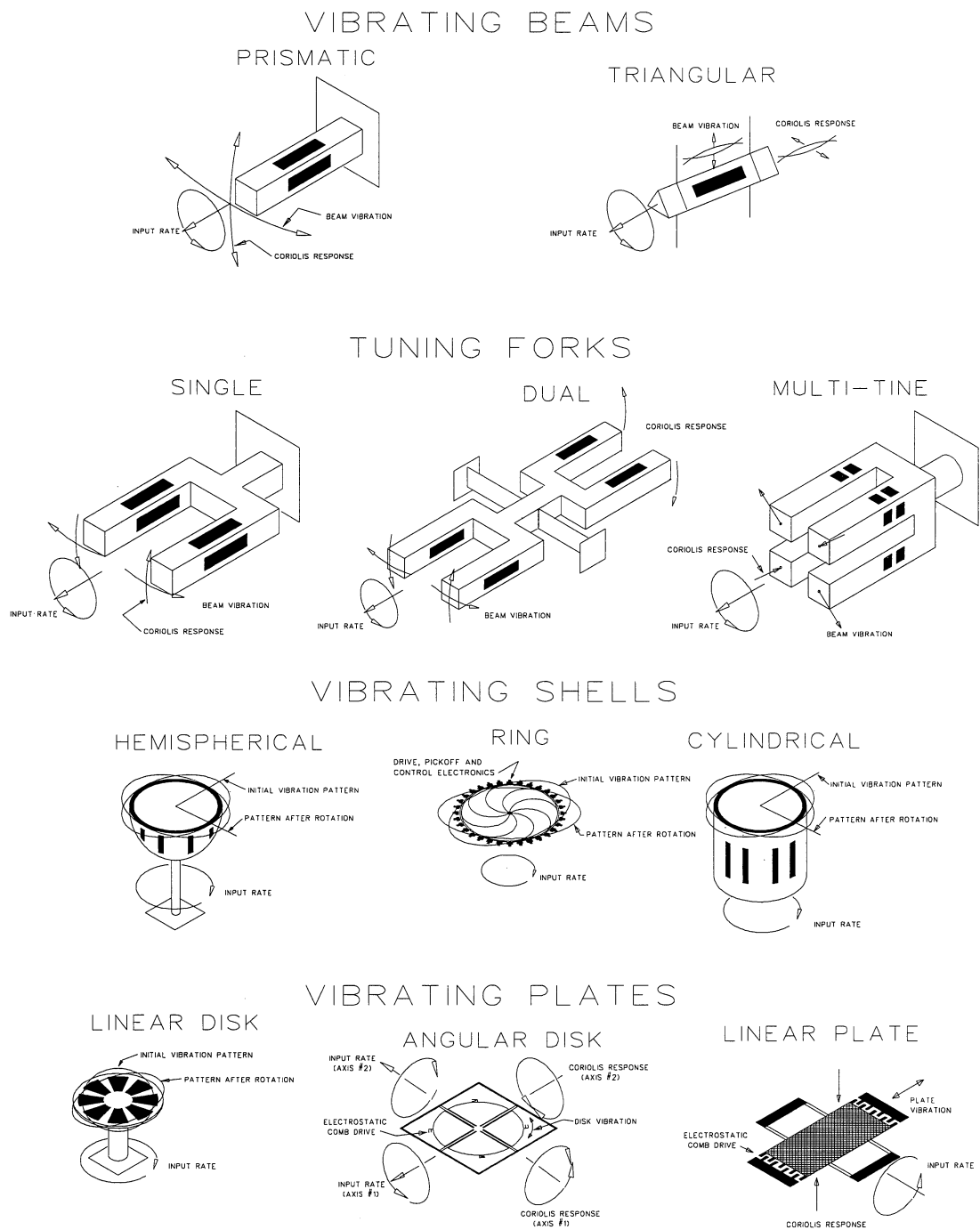
### 1.6 Bibliography of Inertial Sensor Standards

A bibliography of IEEE inertial sensor standards is given at the end of this paper, with publication dates ranging from 1969 to the present. Every 5 years, each of these IEEE standards is reaffirmed by vote of the Gyro and Accelerometer Panel, updated, or withdrawn as a standard.

## **2. Types of Coriolis Vibratory Gyros**

A Coriolis vibratory gyro (CVG) is a gyroscope based on the coupling of a structural, driven, vibrating mode into at least one other structural mode (pickoff) via Coriolis acceleration, where the Coriolis force arises from the motion of the vibrating structure relative to the CVG case-fixed frame that is rotating relative to inertial space. Figure 1 depicts the various types of CVG that have been commercially constructed.

A non-commercial example of a CVG is the Foucault pendulum (1851), where the back and forth pattern of the pendulum rotates a certain fraction of the earth rotation angle (depending on the latitude) as the earth rotates. Because of imperfections in the mounting, some of the pendulum energy goes into quadrature motion of the pendulum perpendicular to the back and forth motion, so



**Figure 1. Types of Coriolis Vibratory Gyros**

that the back and forth motion becomes elliptical and eventually circular, destroying the angle measuring capability of the pendulum.

This unwanted quadrature motion is also present in some commercial CVG designs, and requires a quadrature-suppression control loop in the CVG electronics. The CVG electronics also require an amplitude-maintaining control loop, a pickoff scheme, a force-rebalance control loop for CVGs in this operating mode, possibly a temperature control loop, and other control loops, signal processing, and compensation.

The vibrating shell approach (see Figure 1) for a CVG was discovered for a wineglass by Bryan in 1891. Due to Coriolis forces, a vibration standing wave pattern on a hemispherical, cylindrical, or other shaped resonator moves relative to the gyro case a certain fraction of the inertial rotation angle that the CVG is subjected to about its axis of symmetry. This fractional scale factor is a function of the resonator geometry, and for a hemisphere is 0.3. In commercial implementations, the vibration standing wave amplitude of the amorphous quartz or other material resonator is maintained with electrostatic or capacitive forcing. Quadrature motion 90° out of phase with the main vibration motion arises because of resonator nonuniform mass distribution and must be suppressed.

A whole-angle-mode vibrating shell gyroscope uses the position of the vibration standing wave relative to the case as the measure of inertial angular rotation. A closed-loop vibrating shell gyroscope uses the amount of capacitive voltage force required to keep the standing wave stationary relative to the gyro case as the measure of inertial angular rate.

Another type of CVG uses the vibration of a beam, tuning fork, ring, or plate (see Figure 1) to detect angular rotation rate perpendicular to the plane of vibration by the out-of-plane motion generated by the Coriolis effect on the moving mass.

A crystalline quartz resonator is kept vibrating with a piezoelectric oscillator loop, whereas a silicon resonator uses an electrostatic oscillator loop. Out-of-plane oscillatory motion is detected with a capacitive pickoff for silicon devices, or by the piezoelectric strain in a crystalline quartz tuning fork that causes variation in its frequency output. The silicon device's out-of-plane capacitive pickoff voltage is amplified and demodulated to generate a voltage that is proportional to input inertial angular rate. This mode of operation is called open-loop, because the pickoff signal is just observed, without any attempt to null it out.

The CVGs described so far are single-degree-of-freedom devices. There is a commercial two-degree-of-freedom

CVG in which the shape of a vibrating disk is observed with a laser profilometer to detect the Coriolis effects due to rotations about two orthogonal axes (see Figure 1).

Vibrating shell CVGs are higher accuracy macro-sized devices, some with better than 0.01°/h temperature controlled performance. Vibrating beam, tuning fork, ring, and plate CVGs are micro-sized devices manufactured from silicon or quartz chips using the photolithographic, acid etch, and other techniques of the integrated circuit industry, and hence are low cost. Devices range from several degrees-per-second performance to tens of degrees-per-hour performance with temperature compensation over a wide temperature range. Since the CVG scale factor is proportional to the resonator mass, performance can be improved by making the chip devices larger and thicker, as long as they can still be etched without problems such as curling.

There are no rotating wheels in nature for detecting angular motion, although the flagella of certain bacteria can rotate continuously for locomotion. However, some insects use vibrating stubs or antennae attached to nerve endings to detect angular motion using Coriolis forces. (See Appendix A.4 for the angle acceleration measuring device used in the human and vertebrate inner ear.)

### 3. CVG Model Equation

Annex B of document P1431 [10] gives the dynamic equations of motion of the vibrating mass in a CVG. The end result is the input-output model equation used in inertial navigation and other applications given in Clause 8 of P1431 for the various operating modes.

#### 3.1 Force-Rebalance -Mode and Open-Loop-Analog-Output-Mode Model Equation

$$S_0 V_o = [\Omega + D] [1 + 10^{-6} \epsilon_K]^{-1}$$

where

$S_0$	=	Nominal scale factor ((°/h)/V)
$V_o$	=	Analog output voltage (demodulated pickoff voltage for open-loop mode or force-rebalance voltage for closed-loop mode)
$\Omega$	=	Input inertial angular rate about IA (°/h)
$\epsilon_K$	=	Scale factor error (ppm)
$D$	=	Drift rate (°/h)
	=	$D_F + D_R + E$
$D_F$	=	Bias (°/h)

- $D_R$  = Random drift (angle random walk, flicker bias instability, rate random walk, quantization, Markov noise, ramp) ( $^{\circ}/h$ )
- $E$  = Environmentally sensitive drift (bias temperature sensitivity, acceleration sensitivities, etc.) ( $^{\circ}/h$ )

Scale factor can also have environmental sensitivities and nonlinearities.

### 3.2 Frequency-Output-Mode Model Equation

$$S_0 F = [\Omega + D][1 + 10^{-6}\epsilon_K]^{-1}$$

where the notation is the same as in Section 3.1 except

- $S_0$  = Nominal scale factor ( $(^{\circ}/h)/Hz$ )
- $F$  = Output frequency (Hz)

### 3.3 Ratiometric-Output-Mode Model Equation

$$S_0(V_{ref}/V_p)V_o = [\Omega + D][1 + 10^{-6}\epsilon_K]^{-1}[1 + K_r(V_{ref}/V_p)]$$

where the notation is the same as in Section 3.1 except

- $V_{ref}$  = Voltage at which nominal scale factor is measured
- $V_p$  = Power supply voltage
- $K_r$  = Ratiometric error coefficient

### 3.4 Whole-Angle-Output-Mode Model Equation

$$S_0(\Delta\theta_{pickoff}/\Delta t) = [\Omega + D][1 + 10^{-6}\epsilon_K]^{-1}$$

where the notation is the same as in Section 3.1 except

- $S_0$  = Nominal scale factor of whole angle pickoff ( $^{\circ}/LSB$ )
- $\Delta\theta_{pickoff}$  = Angle rotated in time interval  $\Delta t$
- $\Delta t$  = Time between output data words (s)

The pickoff angle  $\theta_{pickoff}$  and the  $D_F$  bias component of  $D$  have harmonic errors as functions of pickoff angle, which must be calibrated for accurate applications of whole angle output mode.

## 4. CVG Specification Format Guide

The first part of P1431 [10] is a specification format guide. Requirements are given with blanks to be filled in by the user.

Requirements are listed for scale factor, bias, and input axis (IA) misalignments:

- Nominal value  $\pm$  a range
- Repeatability across environmental changes (temperature, vibration, shock, turn-off and turn-on, etc.)
- Stability over time
- Sensitivities (to temperature, magnetic fields, acceleration, etc.)

Requirements are given for scale factor nonlinearity and asymmetry, noise characteristics, turn-on and warm-up times, angle storage across power interrupt (if any), mechanical and electrical characteristics, built-in test capability, and temperature sensors for temperature compensation and control.

The operating environment is specified, including normal and over-range linear and angular acceleration, angular velocity, vibration, shock, temperature, magnetic fields, radiation, etc.

Many applications of CVGs require temperature-compensated operation over a wide temperature range, such as  $-65^{\circ}C$  to  $+85^{\circ}C$  or more.

A whole-angle output mode CVG can measure very high input angular rates. In closed-loop mode, the input angular rate is limited by the force-rebalance capability of the CVG, and in open-loop mode, it is limited by the gap between the out-of-vibration-plane motion used by the pickoff and the stops. For many CVGs, this upper limit can be rather high.

Gas leakage requirements are given. For a CVG that operates vacuum encapsulated, the gas leakage can be measured by the time taken for the vibration to run down when drive power is removed, or by the degradation of other operating characteristics.

## 5. CVG Test Procedure

The second part of P1431 [10] is a test procedure for examination of product, acceptance tests, calibration tests, qualification tests, environmental tests, and reliability tests.

Test conditions and equipment and test and analysis software are specified. Every specification requirement has a test procedure for verifying that the requirement is met.

## Appendix A. Other Inertial Sensor Standards

### A.1 Spinning Wheel Gyros

Older IEEE Stds. 292-1969 [1] and 517-1974 [2] cover single degree of freedom rate and rate-integrating spinning-wheel gyros. One of the natural degrees of freedom of a spinning wheel is suppressed, and there is a pickoff for sensing the other degree of freedom. The pickoff output or the torque required to keep that pickoff at null is the measure of input angular rate, or there could be servo control of guidance system gimbals to keep the pickoffs at null for three orthogonal single-degree-of-freedom gyros.

Std. 813-1988 [6] discusses two-degree-of-freedom dynamically-tuned gyros (DTG). The spinning wheel is on a shaft with a special hinge. At a certain tuned rotation rate, the spinning wheel becomes as if it has no attachment to the case. There is a certain amount of angular movement that is possible, e.g., about  $0.5^\circ$ , before the spinning wheel hits the gyro stops. Hence the pickoff of the angular displacement of the wheel relative to the case in two orthogonal directions X and Y perpendicular to the wheel spin direction can be used to servo-control guidance system gimbals, to keep the pickoffs at null and the platform on which the DTG is located fixed in inertial space along these axes.

Another method of operation is to use electromagnetic torquing about the X and Y axes to keep the pickoffs at null, with the amount of torque being the measure of the input angular rates about the X and Y directions. For a gimballed guidance system with two DTGs, one pickoff axis on one of the DTGs is caged (i. e., torqued to null) and the other DTG pickoff axes are kept at null with appropriate servo control of the guidance system gimbals.

The DTG model equations about two axes have scale factors, bias drift errors, acceleration and acceleration-squared sensitive drift errors, and anisoinertia and cross-coupling drift errors. Specifications and tests are given for calibration, stability, repeatability, and temperature and other sensitivities of these parameters and misalignments. A multiposition tumble test is described for calibrating acceleration sensitivities. Noise tests and tests for determining special characteristics of a DTG (such as torquer and tuning speed characteristics) are described.

## A.2 Laser Gyros

Clockwise (CW) and counter-clockwise (CCW) propagation of laser light in a polygonal closed gas cavity (three, four, or more sides with mirrors at the vertices) leads to a standing wave(s). Under rotation of the gyro case, the standing wave(s) fixed in inertial space moves relative to a photodetector at one of the mirrors (Sagnac effect), which thereby provides a measure of the rotation as the wave crests move past the photodetector. The scale factor sensitivity (arcsec per laser wave crest pulse) is

inversely proportional to the enclosed area of the closed laser path, so the larger the diameter or path length of the laser resonator cavity, the more sensitive is the laser gyro.

The laser gain medium is helium-neon gas with a high voltage discharge to excite atomic transitions. Piezo-optical or other path length control has to be provided. If operated near zero input angular rates, a technique for preventing lock between the CW and CCW laser beams is required; this can either be mechanical dither of the mounting post, or a magneto-optical means of shifting frequencies and creating multiple laser resonant frequencies.

The laser gyro model equation includes scale factor, bias, and random noise in bias. Specifications and tests are given in IEEE Std. 647-1995 [4] for calibration, stability, repeatability, and temperature, temperature gradient, magnetic, and warm-up sensitivities of these parameters and misalignments. The Allan variance technique is described for determining the random error components:

- Angle random walk
- Bias instability (flicker noise)
- Rate random walk
- Rate ramp
- Combined effect of angle quantization and anti-lock residual

Tests for scale factor asymmetry and nonlinearity are described, along with tests to measure special laser gyro characteristics such as electromagnetic interference, magnetic leakage, electrical characteristics, and gas leakage.

## A.3 Interferometric Fiber Optic Gyros

A Fiber Optic Gyro multiplies the Sagnac effect scale factor by having many repeated turns of an optical fiber around a spindle, so that the longer the fiber length for a given enclosed area, the greater the sensitivity to detecting rotation. An Interferometric Fiber Optic Gyro (IFOG) sends clockwise (CW) and counterclockwise (CCW) broad band laser light through the fiber. The interference pattern between the counterpropagating light waves after traversing the fiber is the measure of angular rotation for an open-loop IFOG. A closed-loop IFOG increases the dynamic range of the IFOG with an electro-optic ramping phase bias to keep the interference pattern biased  $\pi/2$  radians in phase off null, with the ramp having to be reset every  $2\pi$  radians of phase.

The IFOG model equation includes scale factor, bias, and random noise in bias. Specifications and tests are given in IEEE Std. 952-1997 [8] for calibration, stability, repeatability, and temperature, temperature gradient, magnetic, and warm-up sensitivities of these parameters and misalignments. A revision is given to the description

in IEEE Std. 647-1995 of the Allan variance technique for determining noise characteristics.

Tests for scale factor asymmetry and nonlinearity are described, along with tests to measure special IFOG characteristics such as electromagnetic interference, electrical characteristics, and dead band.

#### A.4 Angular Accelerometers

Std. 671-1985 [5] discusses nongyroscopic angular accelerometers and other angular motion sensors. An example of such a device is a fluid filled torus or donut. When the toroidal case is rotated, the fluid tends to stand still. Paddles inserted in the fluid then detect that the fluid is moving relative to the case.

A biological example of such an angular accelerometer is provided by the three orthogonal semicircular canals in the vestibular system in the human inner ear, where hairs projecting into the fluid are attached to nerve endings. Also in the human inner ear are two IA orthogonal linear accelerometers (nearly horizontal when a person is standing) mechanized by calcium carbonate proof masses imbedded in a gelatinous material. Under acceleration or head tilt, displacement of the proof masses excite nerve endings.

#### A.5 Linear Accelerometers

IEEE Std. 1293-1998 [9] provides a guide for specifying linear single-axis accelerometer performance and descriptions of tests for verifying this performance, both for general accelerometer characteristics and for specific types of accelerometers. Informative annexes describe specific types of accelerometers, namely pendulous force-rebalance accelerometers, Vibrating Beam Accelerometers (VBA), and micromechanical accelerometers.

An accelerometer measures the difference between total acceleration and gravitational acceleration along its input axis(es) by the movement of a proof mass relative to the accelerometer case. Piezoelectric accelerometers, used to measure ac accelerations by the strain on a piezoelectric sensor attached to a proof mass, such as during vibration tests, are not discussed, nor are gyroscopic accelerometers or gravimeters (input-axis-vertical limited-range accelerometers) that have a narrow range of applications.

The generic linear accelerometer model equation involves scale factor, bias, input axis misalignments, acceleration nonlinearities, and angular velocity and acceleration sensitivities arising from the proof mass pendulum moments of inertia.

The pickoff for proof mass movement in a macro-sized force-rebalance accelerometer could be electromagnetic, capacitive, or optical. The forcer or torquer to restore the proof mass to the null position is usually electromagnetic. However, the restoring force for a three-axis low-g accelerometer for space applications is capacitive.

A VBA has piezoelectrically-driven quartz resonators or electrostatically-driven silicon resonators attached to separate proof masses or to a common proof mass, where the measure of acceleration is the difference frequency of the IA-antiparallel resonators for common mode rejection of many error effects.

Micromechanical accelerometers are made from silicon or quartz chips using photolithographic and chemical etching techniques from the integrated circuit industry with pendulous or translational proof masses, and are thus low cost. They are often open loop devices, where the deflection of the proof mass against an elastic restraint measured capacitively, piezoresistively, or otherwise is the measure of acceleration. A micro-sized accelerometer could be a force-rebalance design using a capacitive torquer or forcer.

IEEE Std. 1293-1998 contains extensive discussions of 1-g tumble tests and vibration and shock tests for calibrating accelerometer model coefficients and for determining performance through and across environments. Power Spectral Density (PSD) noise analysis and digital filtering are discussed.

#### A.6 Accelerometer Centrifuge Tests

IEEE Std. 836-2001 [7] describes calibration of accelerometer higher order acceleration-sensitive model terms using a precision centrifuge. Overload capacity and other such tests can employ a lesser accuracy centrifuge.

A precision centrifuge could have an arm length of several meters, so that variations in arm length have a smaller percentage effect on the acceleration applied to a test article at the end of the centrifuge arm. In addition, variations in arm length and droop during a test are monitored and compensated using capacitive, laser interferometer, or other such techniques, and the centrifuge rotation rate is precisely controlled.

The accelerometer model coefficients are estimated from data collected at several centrifuge rotation rates with various accelerometer orientations, including input axis pointing towards and away from the center of rotation.

#### A.7 Inertial Sensor Terminology

IEEE Std. 528-2001 [3] gives definitions of 289 terms related to inertial sensor technology. It is a revision to



IEEE Std. 528-1994, which listed 246 terms, of which 9 were deleted and 98 revised in the new Std. 528-2001. Hence Std. 528-2001 has 52 new terms, a number of which are related to CVG technology.

## **Appendix B. Other Documents Under Development**

### **B. Test Equipment and Analysis**

Document P1554 [11] is a recommended practice for carrying out gyroscope and accelerometer tests. Inertial sensor test equipment and instrumentation is described, including test tables and fixtures, centrifuges and vibrators, environmental chambers, and general and sensor specific electronics, such as continuous counters, phase-locked loops, voltage-to-frequency converters, voltmeters and A/D converters, etc.

Data acquisition computers and software are described, including real-time digital filtering and automatic test equipment. Data analysis techniques are discussed, such as fitting models to data and performing Power Spectral Density (PSD) and Allan variance noise analyses.

### **B.2 Inertial Systems Terminology**

A new project for the Gyro and Accelerometer Panel is P1559 on inertial systems terminology [12]. It could be the start of a new initiative in radio navigation and inertial systems standards development making use of the IEEE standards developing and publishing facilities (see Section 1.5).

## **Acknowledgement**

The members of the Gyro and Accelerometer Panel contributing to the proposed Coriolis Vibratory Gyro standard are too numerous to acknowledge individually. Special mention is made of Bart Morrow, who provided Figure 1 in this paper, also included in Annex A of the proposed CVG standard, and of David Lynch, who wrote Annex B in the proposed CVG standard giving the principles of operation of these devices.

## **Bibliography of IEEE Inertial Sensor Standards**

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- [2] Std. 517-1974, *IEEE Standard Specification Format Guide and Test Procedure for Single-Degree-of-Freedom Rate Integrating Gyro*
- [3] Std. 528-2001, *IEEE Standard for Inertial Sensor Terminology*
- [4] Std. 647-1995, *IEEE Standard Specification Format Guide and Test Procedure for Single-Axis Laser Gyros*
- [5] Std. 671-1985, *IEEE Standard Specification Format Guide and Test Procedure for Nongyroscopic Inertial Angular Sensors: Jerk, Acceleration, Velocity, and Displacement*
- [6] Std. 813-1988, *IEEE Specification Format Guide and Test Procedure for Two-Degree-of-Freedom Dynamically Tuned Gyros*
- [7] Std. 836-2001, *IEEE Recommended Practice for Precision Centrifuge Testing of Linear Accelerometers*
- [8] Std. 952-1997, *IEEE Standard Specification Format Guide and Test Procedure for Single-Axis Interferometric Fiber Optic Gyros*
- [9] IEEE Std. 1293-1998, *IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Nongyroscopic Accelerometers*
- [10] In preparation, P1431, *Standard Specification Format Guide and Test Procedure for Coriolis Vibratory Gyros*
- [11] In preparation, P1554, *Recommended Practice for Inertial Sensor Test Equipment, Instrumentation, Data Acquisition, and Analysis*
- [12] In preparation, P1559, *Standard for Inertial Systems Terminology*