Technologies for High-Frequency Rotational Measurements, Part 2

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Background

- Rotational seismology is a new field of significant current interest (six of the 50 most-downloaded BSSA papers in the last six months)
- Weak-motion broadband rotational seismometry is dominated by large RLGs — beyond my scope today
- Strong-motion rotational seismometry is currently dominated by electrochemical-torus sensors but the field is evolving rapidly — the subject of this talk
- Field applications few so far; Taiwan clearly in the lead; we have enough data for preliminary evaluations
Seismologists and earthquake engineers are unfamiliar with rotation, so ...

... an annoying detail—rotation coordinates
Albuquerque Tests — Facilities (1)

- ASL greatly extending its testing abilities in support of ANSS, particularly in strong-motion translational and rotational seismometry (already had broadband)
- For rotation, we have a rotational shake table for estimating transfer functions, and cross-axis sensitivity (*five terms*), and noise test capabilities; have a new rotation-rate table and FOG rotational reference sensors
- These are works in progress, with questions of bearing wobble and sine purity, for example
- Facilities photos …
Albuquerque Tests — Facilities (2)

↔ ASL Rotational Shake Table

Russian Shake Table ↓
Albuquerque Tests — Facilities (3)

← Litef
µFORS FOG

Aerotech
Centrifuge and
Rate Table →
Albuquerque Tests — Facilities (4)

ASL Vaults and Test Chambers

GST2 Rogue’s Gallery
Albuquerque Tests — Results (1)

- May 2009 tests of
  - Prototype eentec R-2 (electrochemical)
  - Prototype Systron Donner QRS116 (Coriolis)
  - Production ATA Sensors ARS-14 (magnetohydrodynamic)
- Also have R-1 tests (not shown here)
- They all have strengths and weaknesses for seismology and earthquake engineering uses
- Working with Bob Dunn on large RLG for ASL
- Working with Ulli Schreiber on rotational noise model
- Several other efforts afoot to move the technologies
Results (2): Serviceable “Operating Ranges” for Selected Rotational Seismometers (cf. Dynamic Range)
Results (3): “Popcorn” Noise, Prototype R-2
Results (4): “Popcorn” Noise, Prototype ARS-14 and QRS116
Results (5): Transfer Function Estimation, Method
Results (6):
Transfer Function Estimation, Amplitude
Results (7):
Transfer Function Estimation, Phase

Phase Responses: R-2 Y and Z, ARS-14, QRS116

Phase Difference (Test Unit - Reference; degrees)

Frequency (Hz)
Outlook

· Sensor technologies appropriate for seismology and earthquake engineering are new (to us)
· Growing pains for both sensors and test facilities
· No present option is ideal in all respects (cost, noise, linearity, bandwidth, …)
· Clearer demonstration of need is required (by funding) sources (horizontal-accelerometer corrections, new applications of new data)
  · Preliminary evaluation follows …
· Now have method for correcting horizontal translational sensors for such errors (from inertial navigation practice; Lin et al., BSSA, in press)
Crude Evaluation of Need (1) — Taiwan M6 at ~40 km

Crude Test of Rotation Significance — Accelerations

- North (cm/s/s)
  - Directly Measured Acceleration
  - Acceleration Error from Tilt
  - Error / Observed Acceleration = 1.7%

- East (cm/s/s)
  - Error / Observed Acceleration = 0.4%
Crude Evaluation of Need (2) — Taiwan M6 at ~40 km

Crude Test of Rotation Significance — Displacements

- Displacement from Acceleration
- Displacement Error from Rotation

Error / Observed Displacement Error = 1.3%

Error / Observed Displacement Error = 2.9%