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

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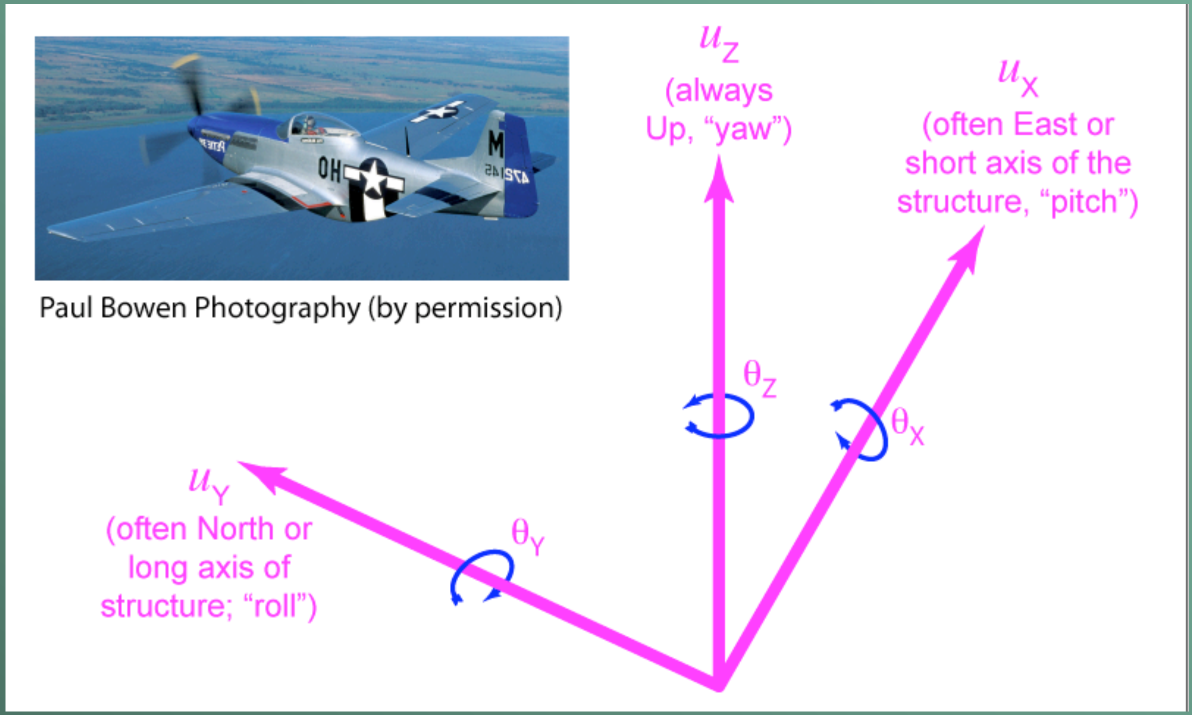
Coordinate System

- 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 …

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Albuquerque Tests — Facilities (2)

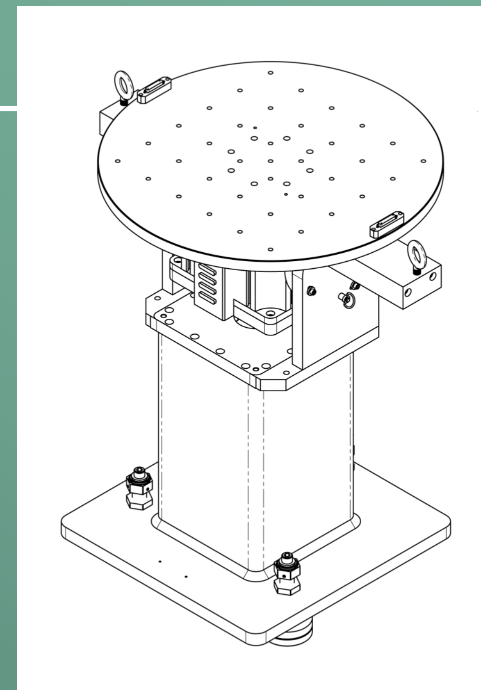
⇐ ASL Rotational Shake Table

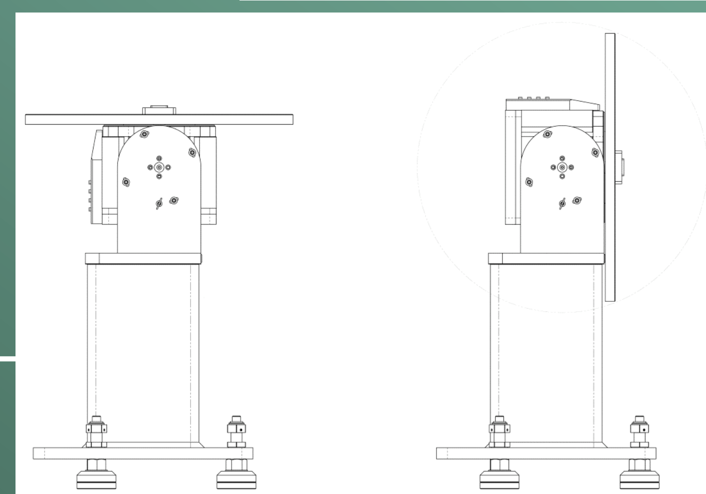
Russian Shake Table ↓

Albuquerque Tests — Facilities (3)

⇐ Litef
μFORS FOG

Aerotech
Centrifuge and
Rate Table ⇒





Albuquerque Tests — Facilities (4)

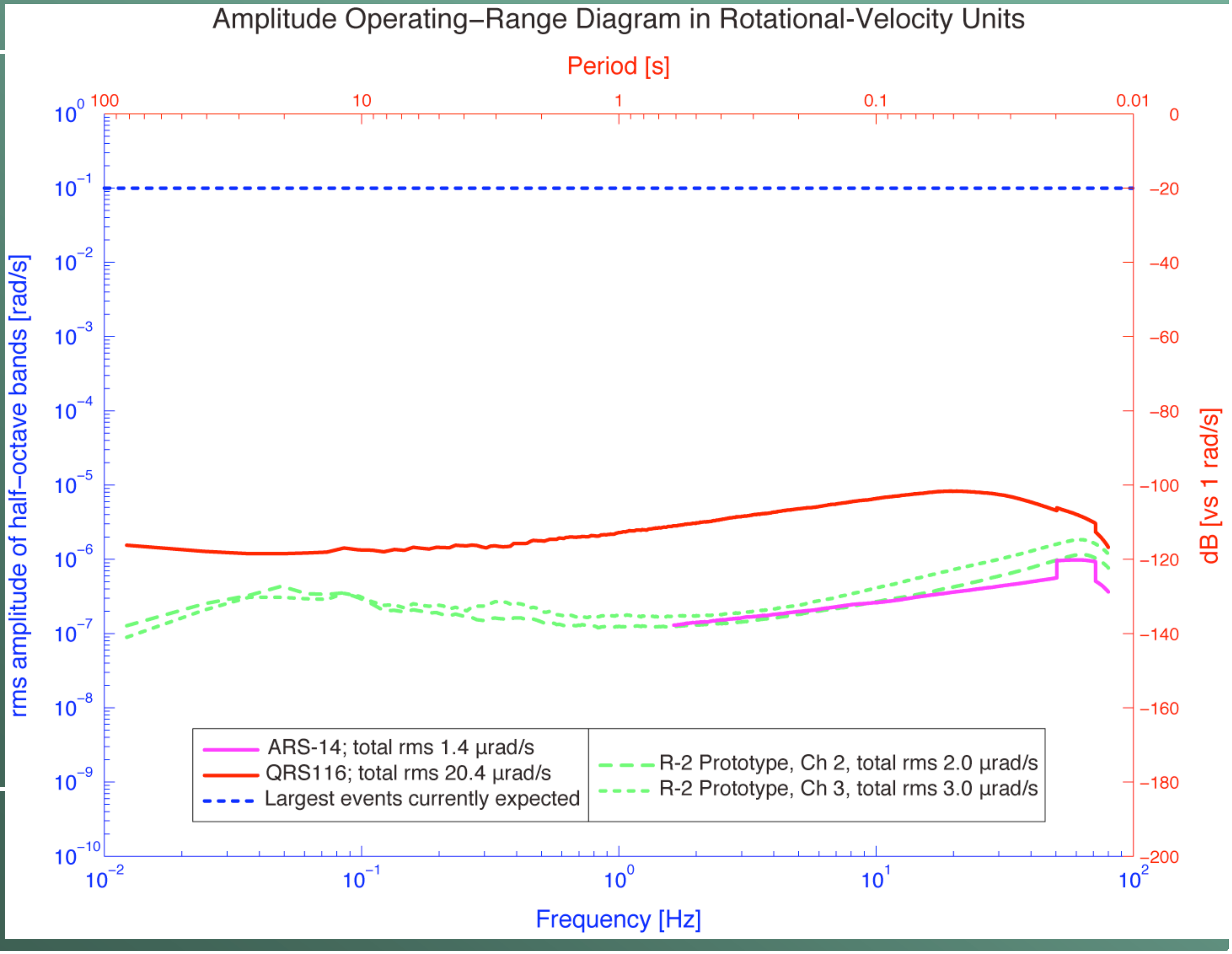
↓ ASL Vaults and Test Chambers ⇒

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)



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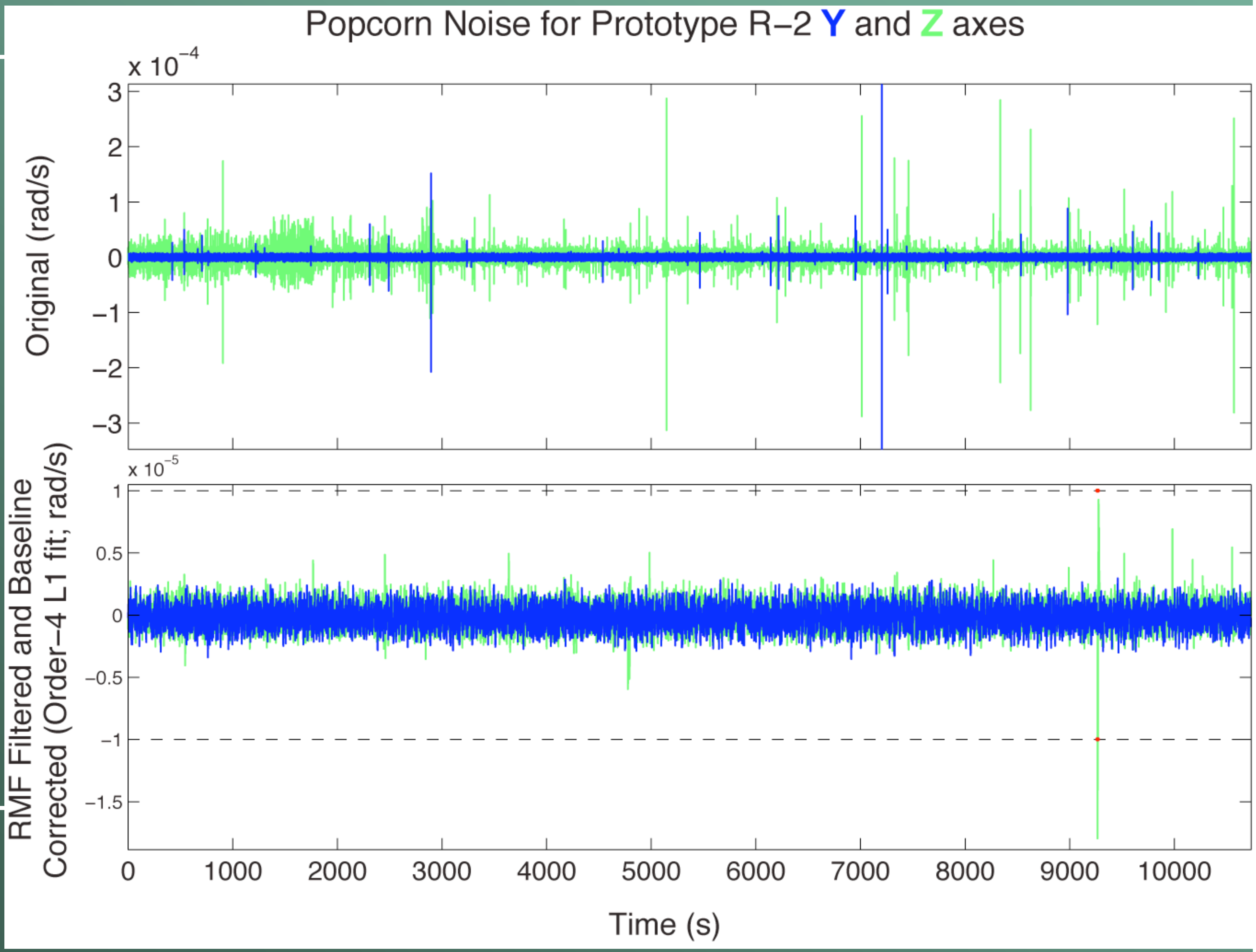
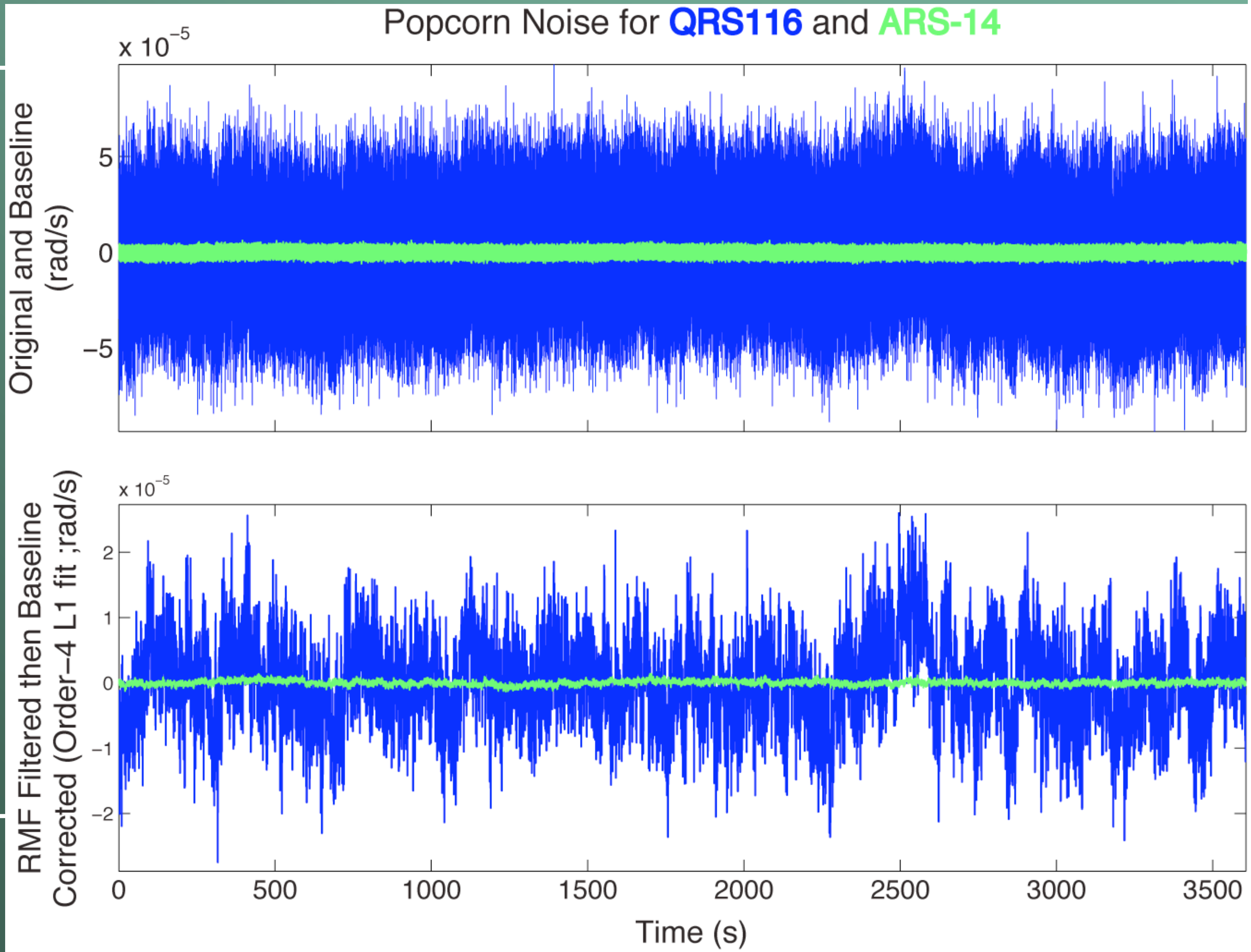
Results (3): "Popcorn" Noise, Prototype R-2



Results (4): "Popcorn" Noise, Prototype ARS-14 and QRS116



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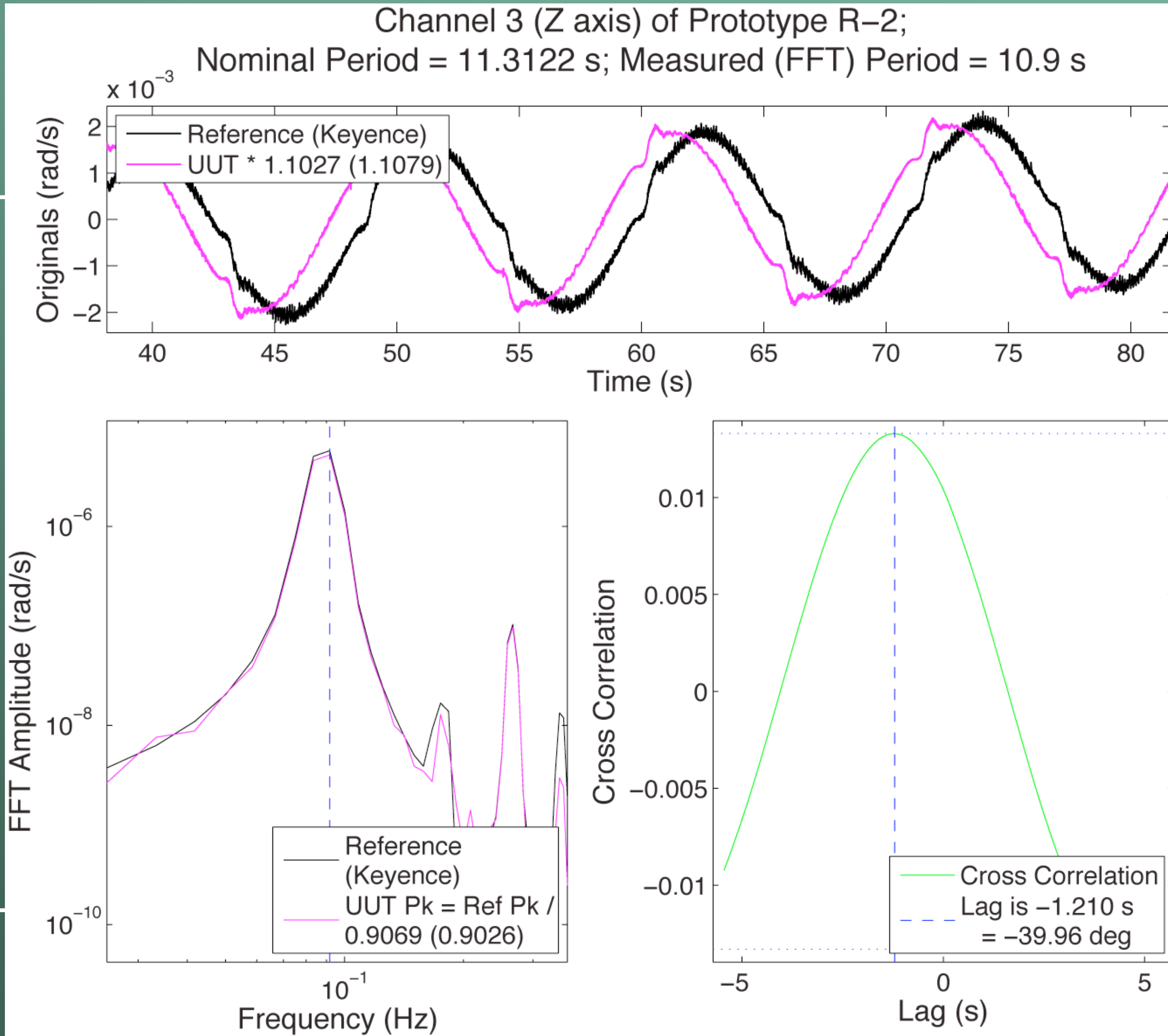
Results (5): Transfer Function Estimation, Method



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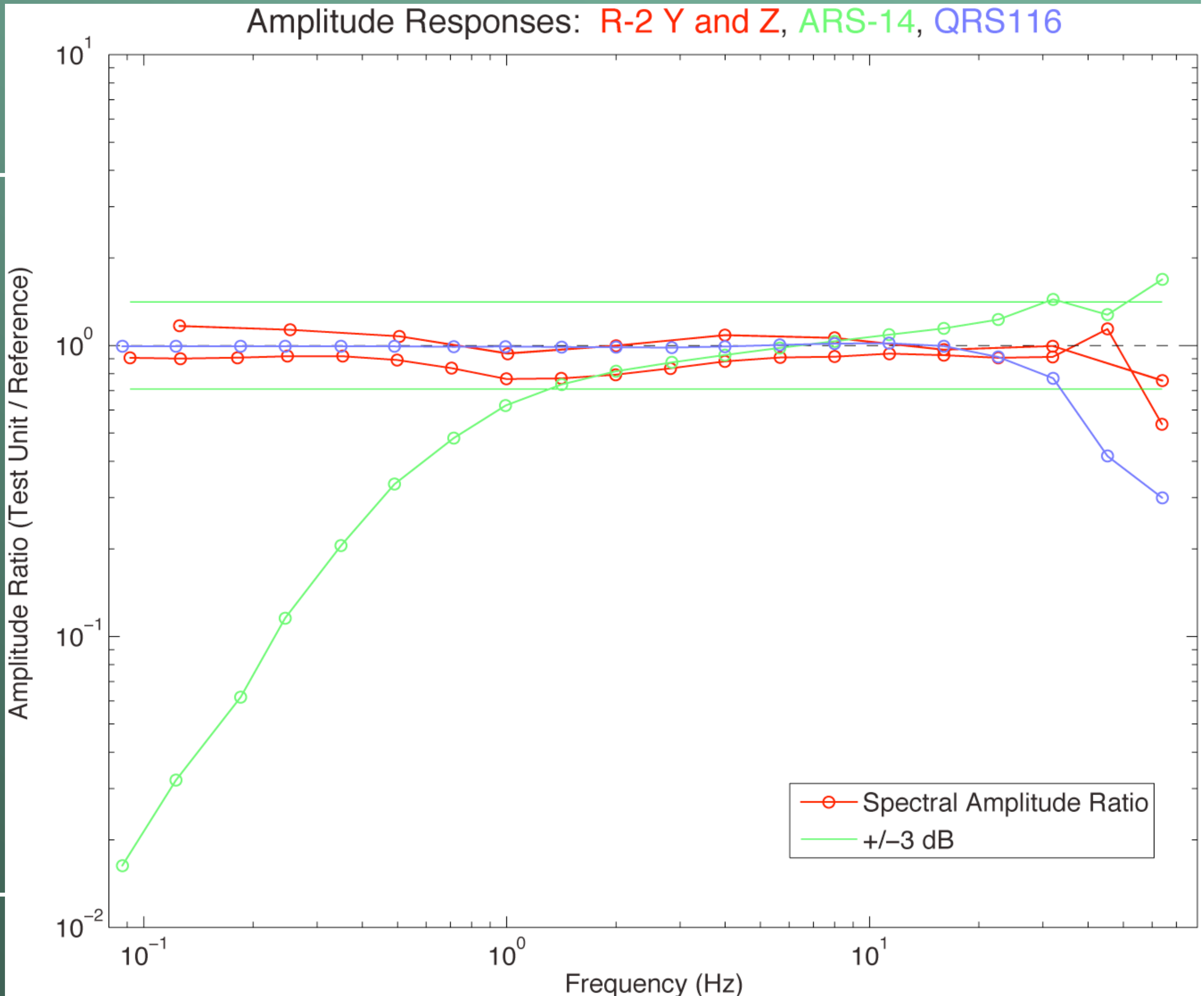
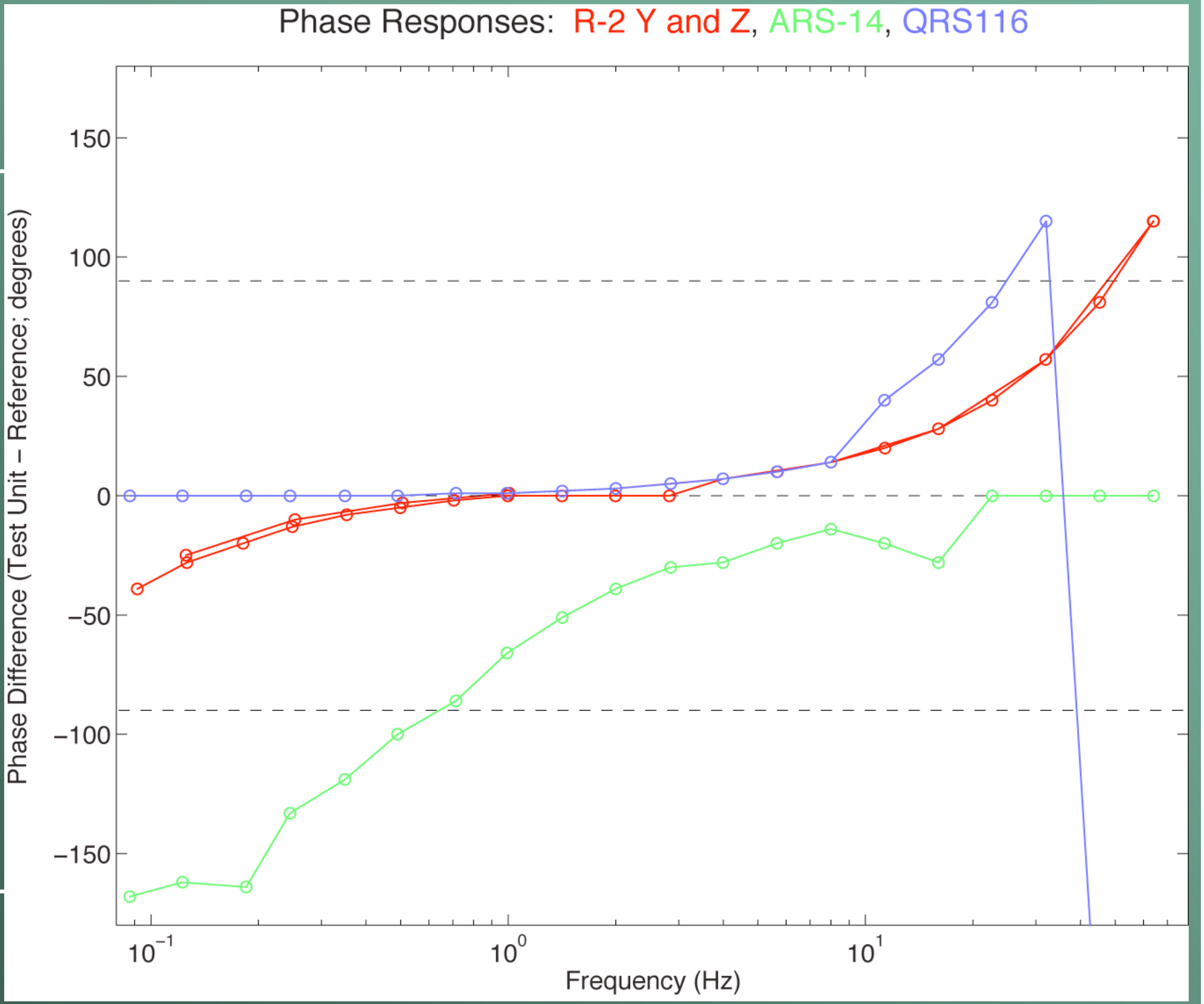
Results (6): Transfer Function Estimation, Amplitude



Results (7): Transfer Function Estimation, Phase



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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)

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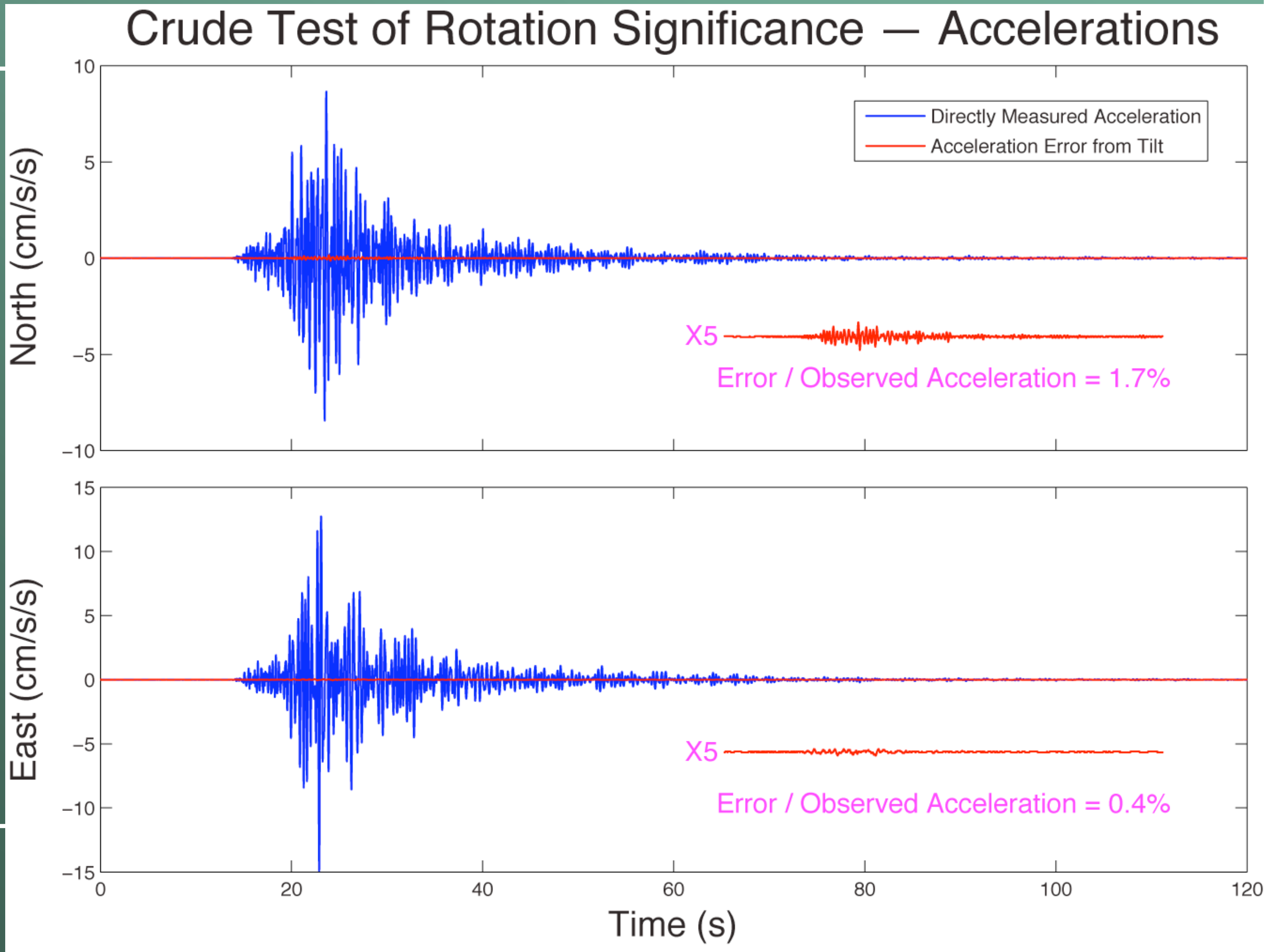
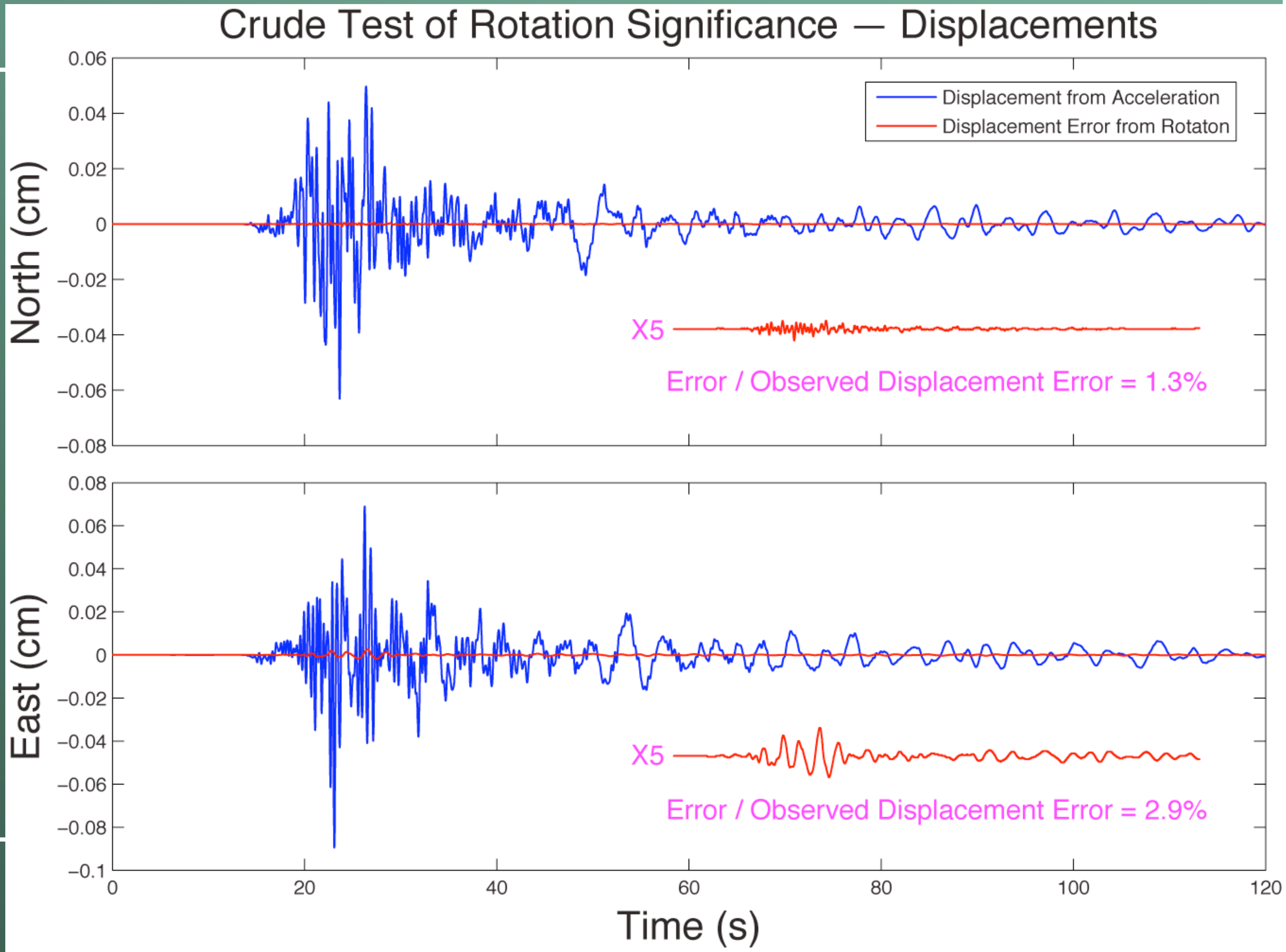
Crude Evaluation of Need (1) — Taiwan M6 at ~40 km



Crude Evaluation of Need (2) — Taiwan M6 at ~40 km



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