LSC Participation in Initial LIGO Detector Characterization

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Elements of Detector Characterization

- Commissioning
- Online Diagnostics
- Environmental Monitoring (hardware)
- Offline Data Monitoring
  - » Performance Characterization
  - » Transient Analysis (subgroup chair: Fred Raab)
- Data Set Reduction (subgroup chair: Jim Brau)
- Data Set Simulation
  - » Parametrized simulation (subgroup chair: Sam Finn)
  - » End-to-End Model

Goals of Working Group on Detector Characterization

- Quantify “Steady-State” Behavior of IFO’s
  - » Monitor instrumental & environmental noise
  - » Measure channel-to-channel correlations
  - » Quantify IFO sensitivity to standard-candle GW sources
  - » Characterization includes both description & correction

- Identify transients due to instrument or environment
  - » Avoid confusion with astrophysical sources
  - » Identify & correct contamination in data stream
  - » Diagnose and fix recurring disturbances

Examples of Ambient Noise

- Seismic
- Violin modes
- Internal mirror resonances
- Laser frequency noise
- Electrical mains (60 Hz & harmonics)
- Coupling of orientation fluctuations into GW channel
- Electronics noise (RF pickup, amplifiers, ADC/DAC)

Examples of Transients

- Earthquakes, Trains, Airplanes, Wind Gusts
- Army tanks firing (!)
- Machinery vibration
- Magnetic field disturbances
- Wire slippage
- Violin mode ringdown
- Flickering optical modes
- Electronic saturation (analog / digital)
- Servo instability
- Dust in beam

Characterization Methods

- Measured optical, RF, geometrical parameters
- Calibration curve
- Statistical trends & analysis (outliers, likelihood)
- Power spectra
- Time-frequency analysis
  - » Band-limited RMS
  - » Wavelets
- Principal value decomposition
- Non-linear couplings measurement
- Matched filters

Evolution of LSC Detector Characterization Efforts

- Initial work:
  - » Developing infrastructure of online characterization tools:
    - – Data Monitor Tool (DMT -- J. Zweizig)
    - – Diagnostic Test Tool (DTT -- D. Sigg)
  - » Developing software tools & monitors for DMT (broad effort)
- Moving toward 2nd phase - two-pronged approach:
  - » Investigations focussed on engineering runs
    - – 15 teams formed for E2 (Nov 2000)
    - – 13 teams formed for E3 (March 2001)
    - – Prelim reports from all E2 teams given at monthly DetChar telecons
    - – Final presentations & written reports due at March LSC meeting
  - » Participation in four Upper Limits Working Groups for E6
    - – Special session at March LSC meeting to identify where help needed

Software Developed for the Data Monitor Tool (DMT)

DMT Monitors	Scientists	Institutions	Online code available?
Line Noise Monitoring	B. Allen, A. Ottewill S. Klimenko A. Sintes	UWM, Dublin Florida AEI-Potsdam	Yes Yes*
Seismic Noise Monitoring	E. Daw	LSU	Yes*
Inter-Channel Correlations	B. Allen, A. Ottweill	UWM, Dublin	Yes*
Bilinear Cross Couplings	S. Penn	Syracuse	Yes*
Band-limited RMS Monitor	E. Daw	LSU	Yes*
Non-Gaussian noise	L.S. Finn, G. Gonzalez	Penn State	
Power Spectral Transients	S. Mohanty	AEI-Potsdam	
Servo Instability Monitor	D. Chin, K. Riles	Michigan	Yes*
Event Catalog	J. Sylvestre	LIGO-MIT	Yes*
Adaptive Transient Detection	E. Chassande-Mottin	INFN	
Impulse Recognition	M. Ito	Oregon	Yes*
Magnetic Field Transients	R. Frey, R. Rahkola	Oregon	Yes*
Lock transitions	D. Chin, K. Riles	Michigan	Yes*
Power Mains Monitor	D. Sigg	LIGO-LHO	Yes*
GPS Time Ramp Monitor	S. Marka	LIGO-CIT	Yes*
Pre-Stab. Laser Glitches	R. Savage, J. Zweizig	LIGO-LHO/CIT	Yes*
Data Integrity (2 monitors)	J. Zweizig	LIGO-CIT	Yes*

DMT Tools	Scientists	Institutions	Online code Available
Operational State Conditions	D. Chin, K. Riles	Michigan	Yes*
Time-Frequency Plotting	S. Mohanty J. Sylvestre	AEI-Potsdam LIGO-MIT	Yes Yes*
Wavelet Analysis Tools	S. Klimenko	Florida	Yes*

*Used in E2 and/or E3 engineering run & subsequent analysis

Where does LDAS fit in?

- Detector characterization used online for diagnosis / warnings and offline for interpreting data
- Characterization conveyed downstream to LDAS via meta-database and frame-contained constants
- Meta-database entries (examples)
  - » Calibration constants and power spectra
  - » Environmental noise measures
  - » Cross-coupling coefficients (for regression)
  - » Line noise strength and phase
  - » Triggers (for veto or “handle with care”):
    - – Environmental disturbances
    - – Excess noise or unstable conditions

Other Detector Characterization Software Tools from LSC

- Data Set Reduction:
  - » Wavelet methods (lossless & lossy) -- Sergey Klimenko (Florida)
  - » Data set summary -- Benoit Mours (Annecy/CIT) et al
  - » Data channel selection -- David Strom (Oregon)
- Data Set Simulation - Parametrized
  - » SimData package -- Sam Finn (Penn State)
    - – Time domain simulation tool (shot noise, radiation pressure, thermal substrates, suspensions, seismic)
    - – Integrated into End-to-End Model

Engineering Run Investigations (E2 - November 2000)

Investigation	Scientists
Lock losses	Michigan: D. Chin, R. Gustafson, K. Riles* Oregon: M. Ito Rochester: W. Butler
Seismic noise	CIT: D. Ugolini LSU: E. Daw* Oregon: R. Schofield
Cross-correlations with GW channel	Carleton: N. Christensen* Dublin: A. Ottewill
Stationarity	LSU: E. Daw Oregon: R. Schofield* Syracuse: P. Saulson
Calibration stability	Annecy/CIT: B. Mours CIT: L. Matone, P. Shawhan LHO: M. Landry*
Non-Gaussianity	ANU: S. Scott CIT: V. Sannibale Syracuse: S. Penn*
Angular fluctuations	CIT: B. Bhawal LHO: D. Ottaway Penn State: G. Gonzalez*, T. Summerscales

*Investigation leader

Engineering Run Investigations (E2 - November 2000)

Impulses	LHO: R. Savage* Oregon: R. Frey, R. Rahkola
Bursts & chirps	MIT: J. Sylvestre* Oregon: M. Ito, R. Rahkola
Tidal model	CIT: M. Barton LHO: F. Raab, H. Radkins Oregon: D. Strom*
Timing precision	CIT: S. Marka LHO: D. Sigg* Tokyo: A. Takamori
Data integrity	CIT: J. Zweizig*
Line noise	AEI-Potsdam: A. Sintes Annecy: R. Flaminio ANU: S. Scott Florida: B. Whiting, S. Klimenko*, B. Whiting
Data compression	Annecy/CIT: B. Mours* Florida: S. Klimenko
Frequency noise	CIT: H. Yamamoto MIT: R. Adhikari*, P. Fritschel, D. Shoemaker, J. Sylvestre, M. Zucker

*Investigation leader

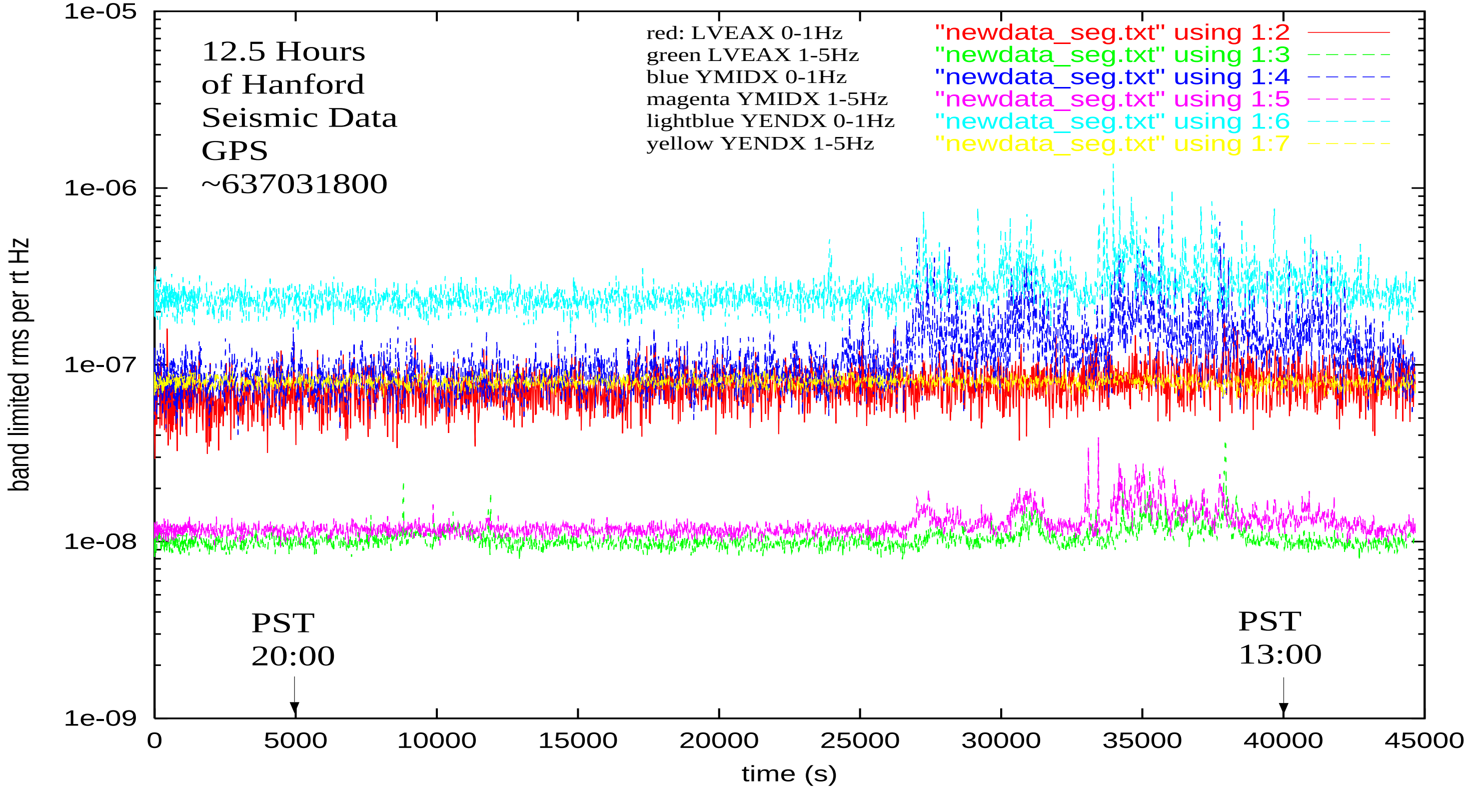
Engineering Run Investigations (E3 - March 2001)

Investigation	Scientists
Seismic noise	CIT: P. Charlton* Louisiana Tech: D. Greenwood, N. Simicevic
Cross-correlations with GW channel	Carleton: N. Christensen* Dublin: A. Ottewill Syracuse: S. Penn
Inter-site environmental correlations	AEI-Potsdam: S. Mohanty LHO: M.Landry* Oregon: R. Rahkola, R. Schofield*
Catalog environmental disturbances	AEI-Potsdam: S. Mohanty MIT: J. Sylvestre Oregon: M. Ito, R. Rahkola, R. Schofield* Syracuse: S. Penn, P. Saulson
Calibration stability	Annecy/CIT: B. Mours CIT: S. Marka, L. Matone LHO: M. Landry* LSU: W. Johnson

Engineering Run Investigations (E3 - March 2001)

Angular fluctuations	Penn State: G. Gonzalez*, T. Summerscales
Tidal model	LHO: F. Raab* Oregon: D. Strom
Lock losses	Michigan: D. Chin, R. Gustafson, K. Riles* Oregon: M. Ito Rochester: W. Butler
Timing precision	CIT: S. Marka LHO: D. Sigg*
Data integrity	CIT: P. Shawhan, J. Zweizig*
Data merging	CIT: P. Shawhan*
Line noise	Florida: R. Coldwell, S. Klimenko*, B. Whiting
Frequency noise	CIT: A. Vicere MIT: R. Adhikari Wisconsin: D. Brown

DMT Example: Seismic Noise Monitoring



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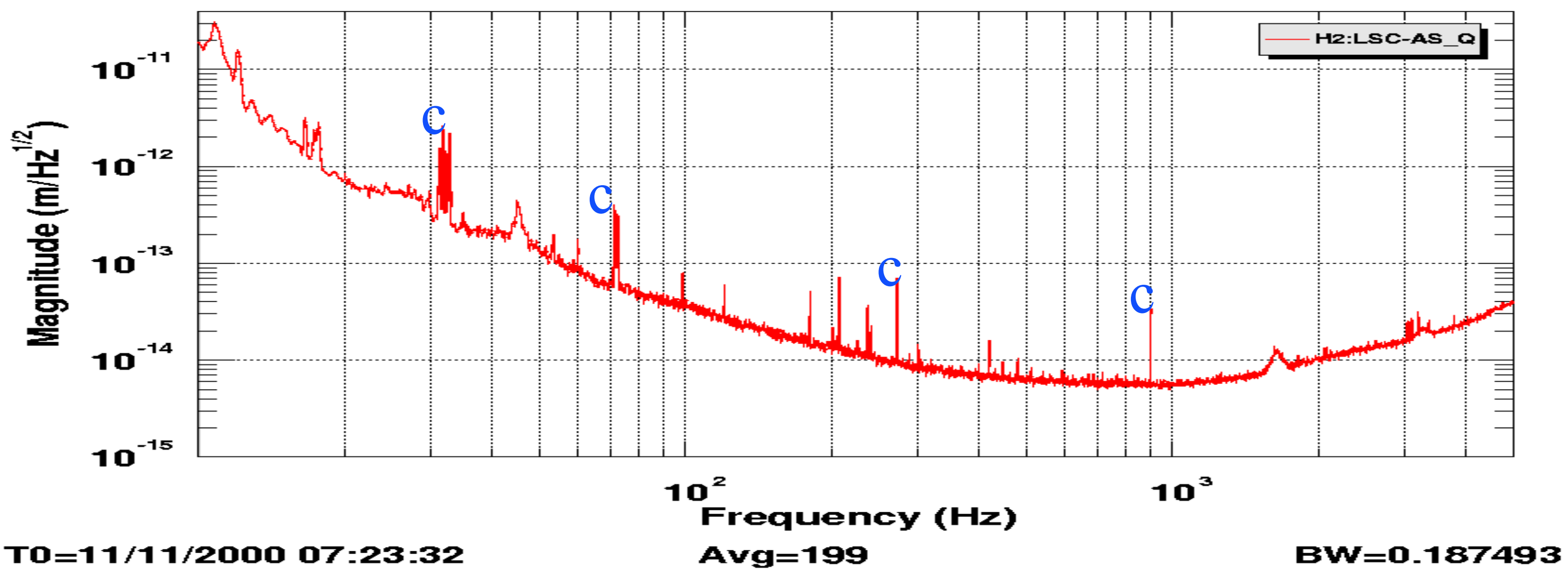
Engineering Run Results (Calibration studies)



- Scale set by absolute calibration
- Visible calibration lines ("c")
- 30% calibration accuracy

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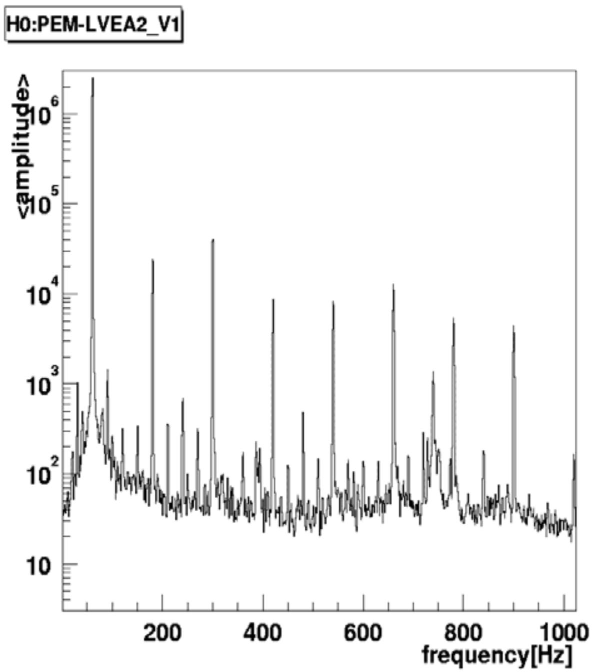
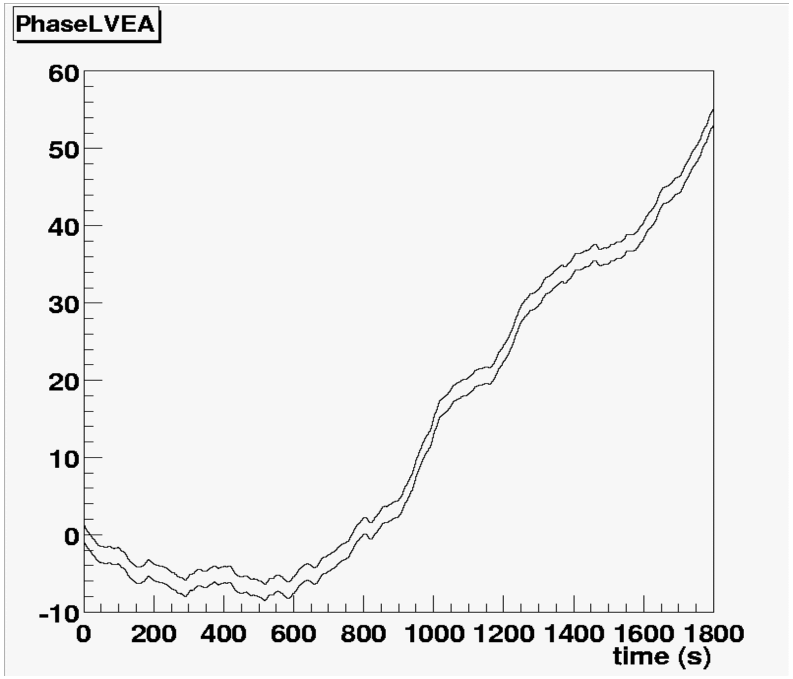
Engineering Run Results (Line noise monitoring)

AC Power line monitor:



Phase of 60 Hz:



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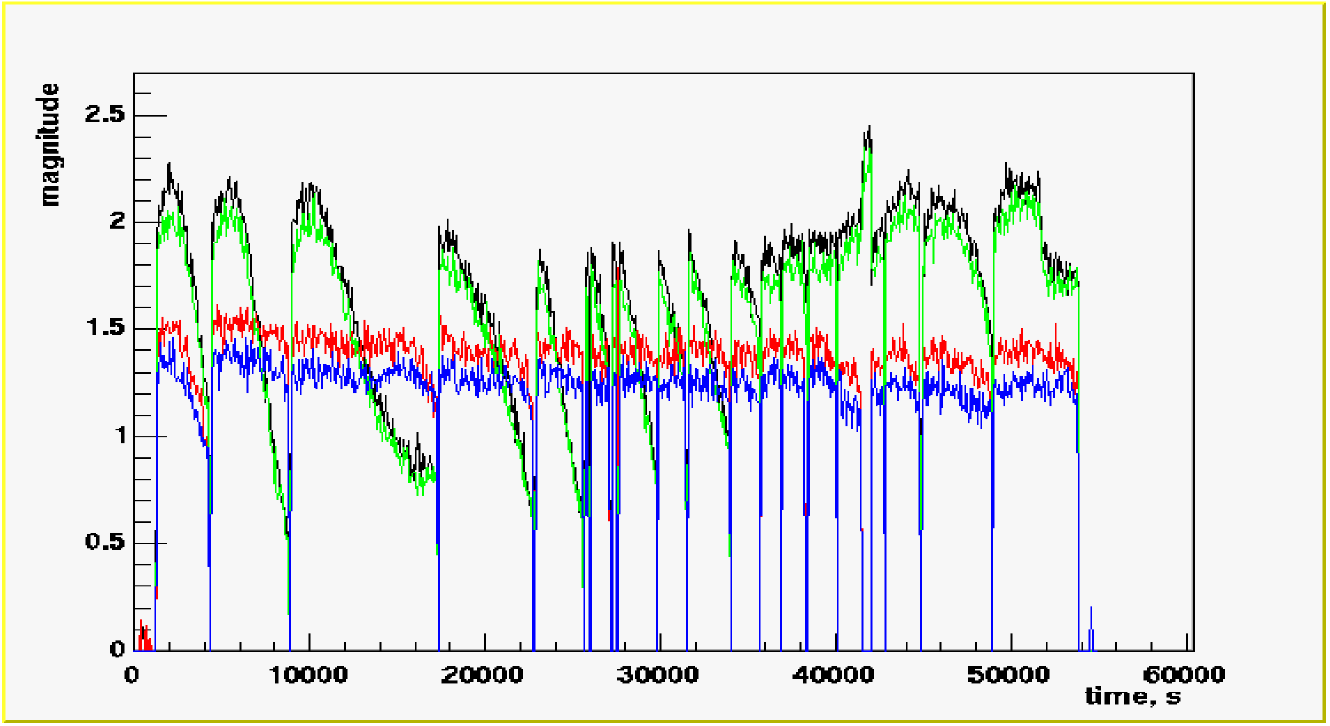
Engineering Run Results
(Line noise monitoring)

Tracking strength of injected calibration lines:

(One arm stable; the other degrading with time in lock)



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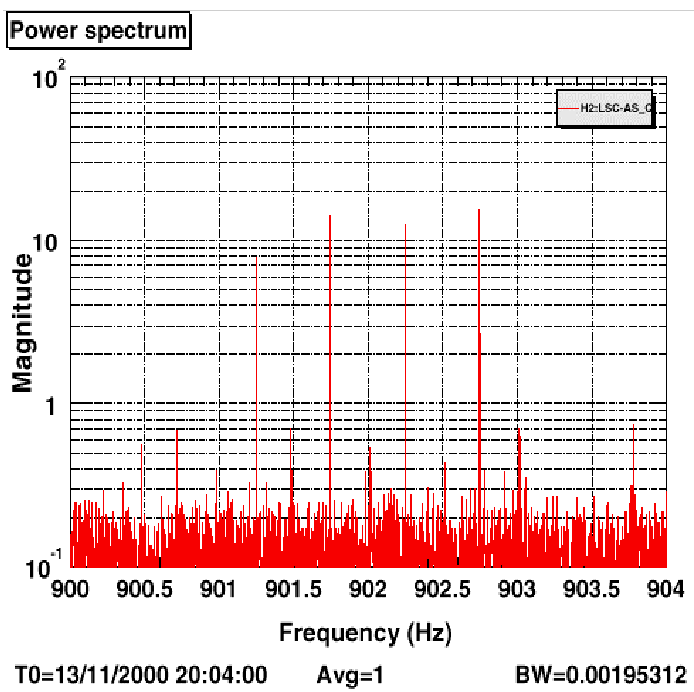
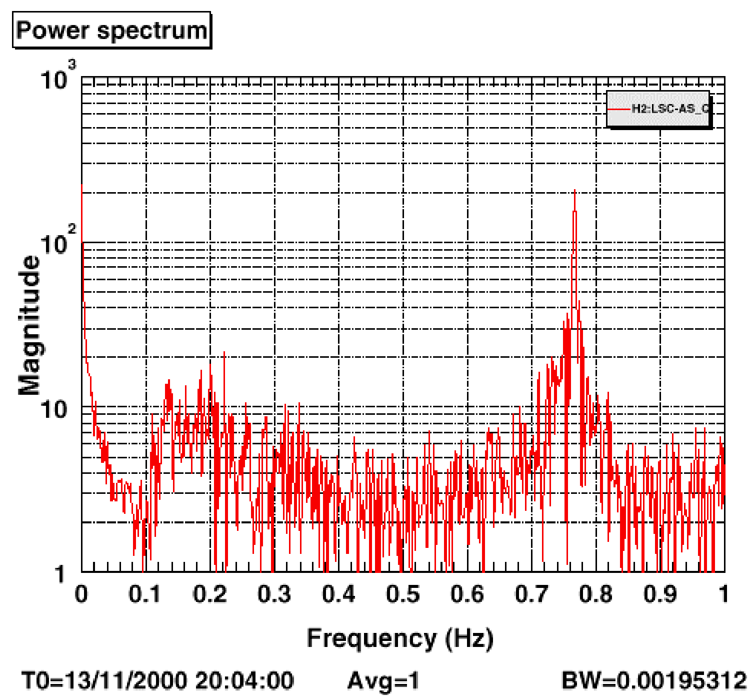
Engineering Run Results (Line noise monitoring)

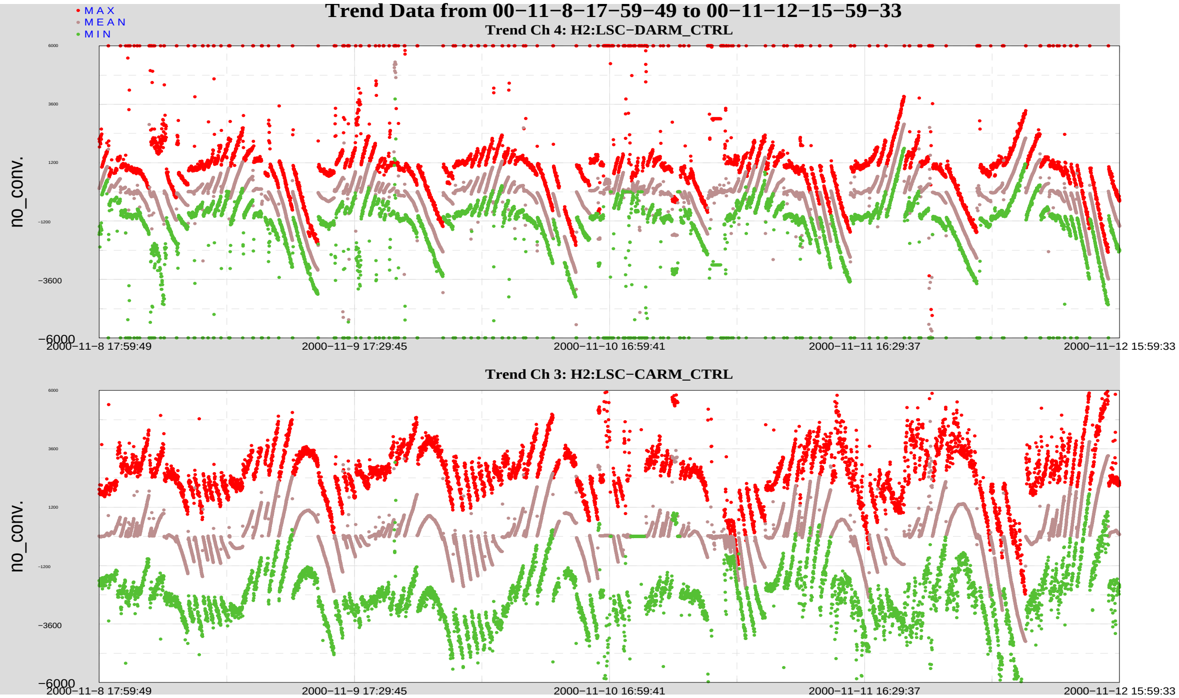
Non-linearity signature - sidebands on calibration lines:





Engineering Run Results (Lock losses)

Tidal correction disabled - periodic saturation of coils



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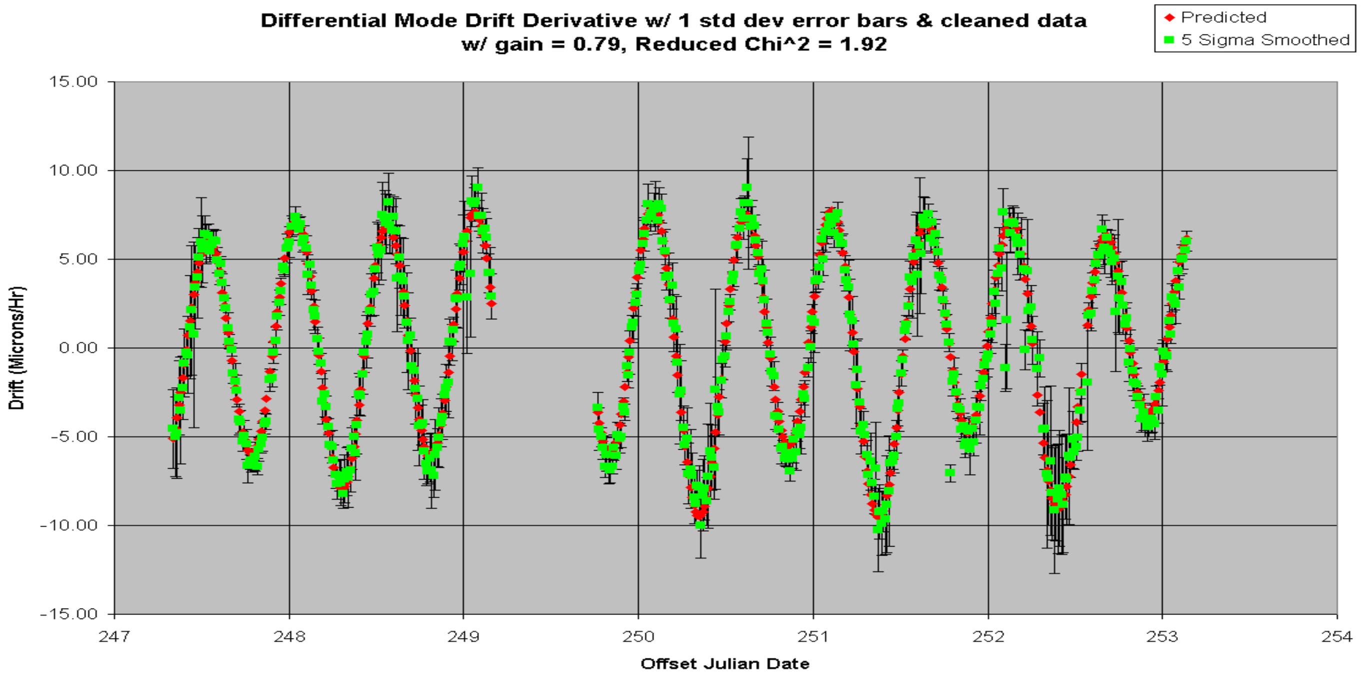
Engineering Run Results (Tidal modelling)

Comparison of tidal *derivative* prediction with data (one free parameter): Differential Mode



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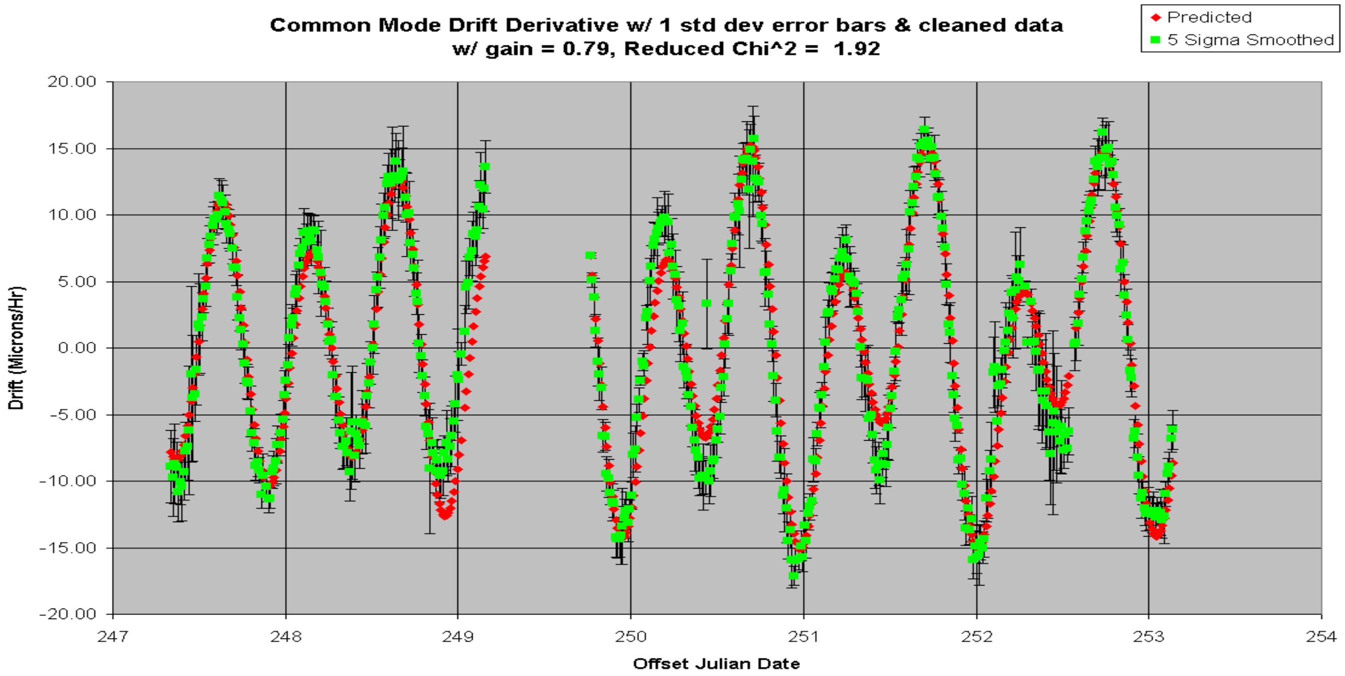
Engineering Run Results (Tidal modelling)

Comparison of tidal *derivative* prediction with data (one free parameter): Common Mode



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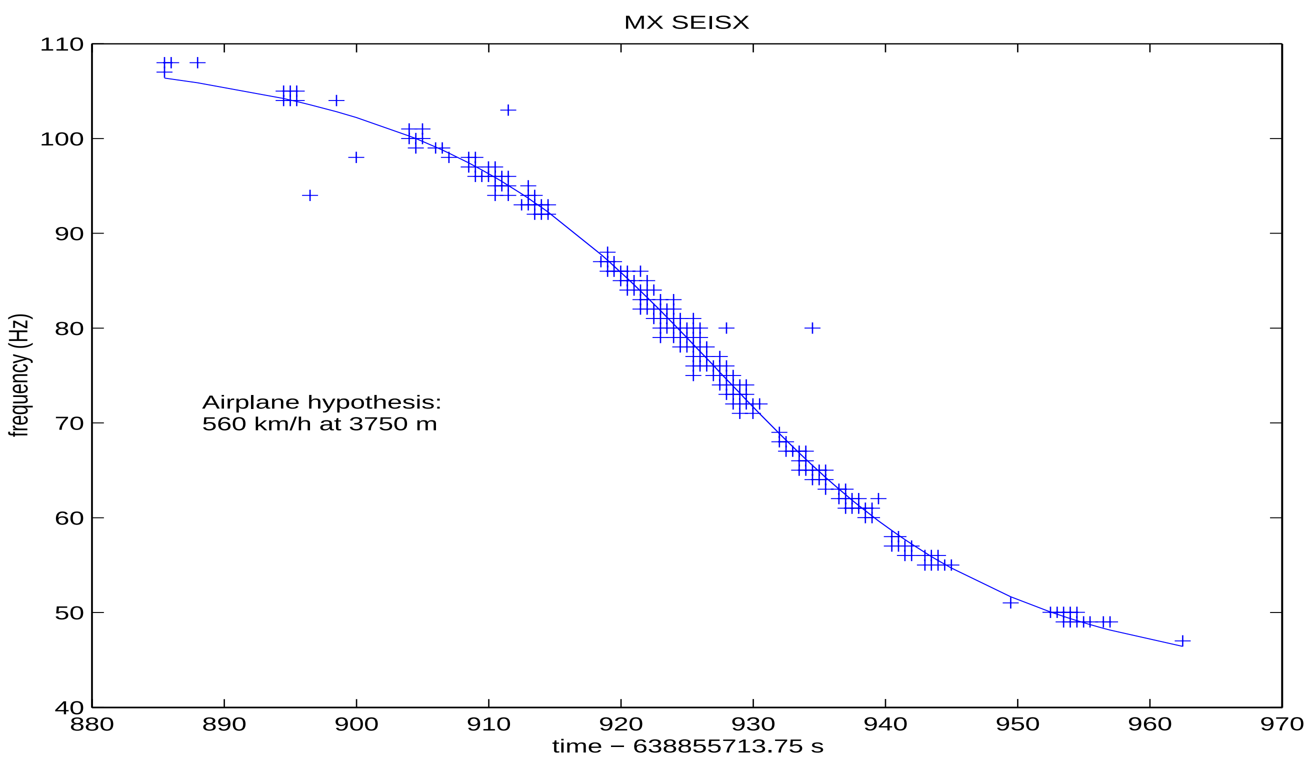
Engineering Run Results (Transients)

Airplane seen in E1 run: (seismometer time/freq plot)



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