

# DOE/OE Transmission Reliability Program

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## Spectral Analysis of Power Grid PMU Data

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CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

# Project Team

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- PNNL Team
  - Ning Zhou
  - Da Meng
- BPA Collaboration Team
  - Dmitry Kosterev
  - Anthony (Tony) Faris
  - Greg Stult
- Advisors
  - Dan Trudnowski (MT)
  - Dmitry Kosterev (BPA)
  - Jeff Dagle (PNNL)
  - Joe Eto (LBNL)
  - John Pierre (UW)
  - Zhenyu Huang (PNNL)



Project Objective:

# Detect and Analyze Dynamic Events

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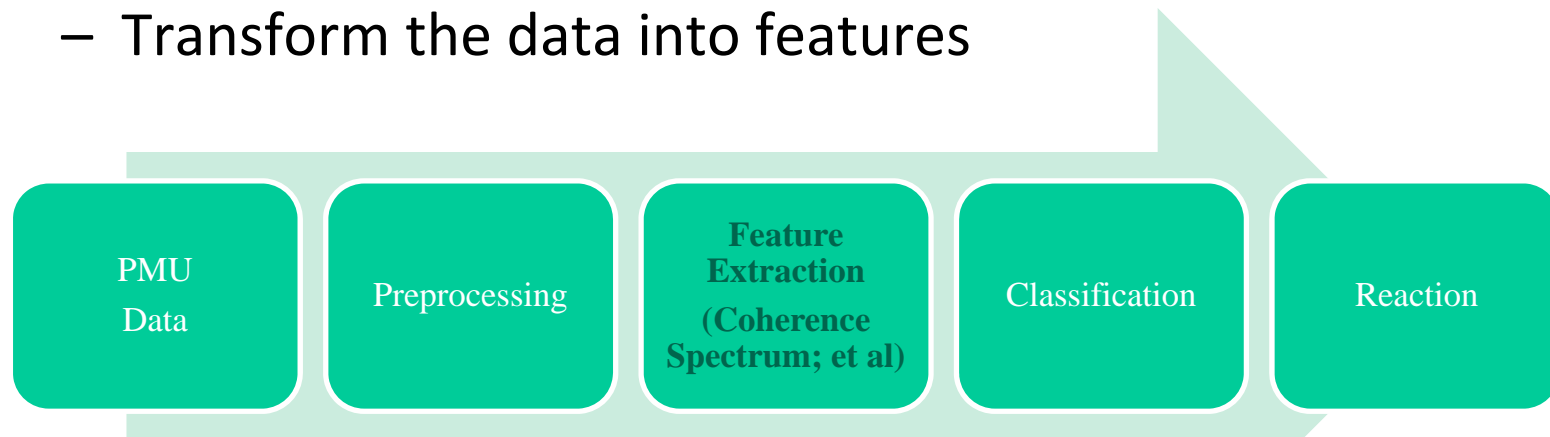
- Problem formulation:
  - Some dynamic events (e.g. mistuned PSS, malfunction of generator controllers) may push the system into alert and emergency states.
  
- Objective:
  - Enable operators to detect and analyze unusual dynamic events over a wide frequency band.



# Challenges & Approaches

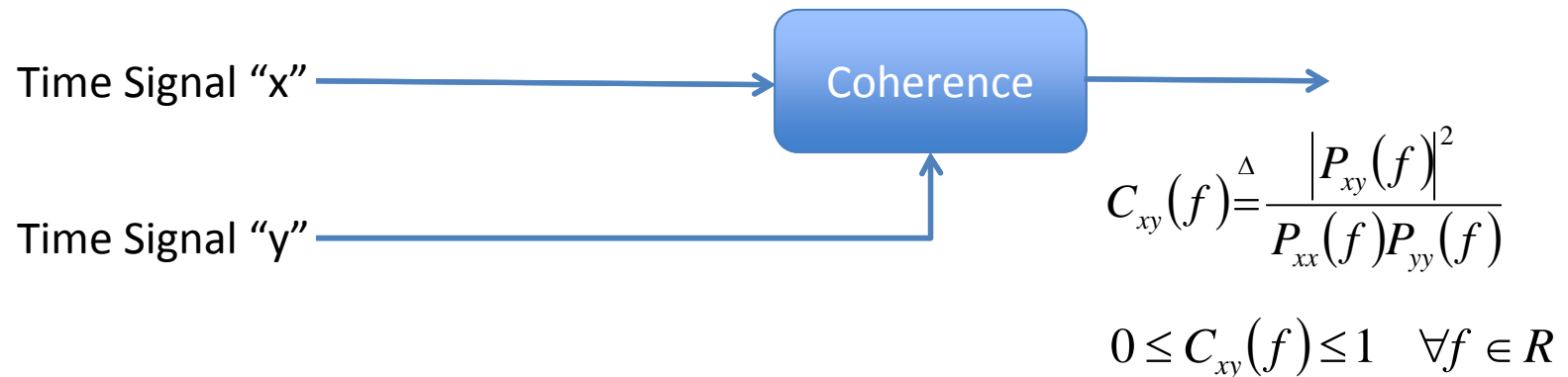
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- Challenges:
  - The time domain PMU data often do NOT reveal dynamic features in a straightforward manner
- Approaches:
  - Transform the data into features

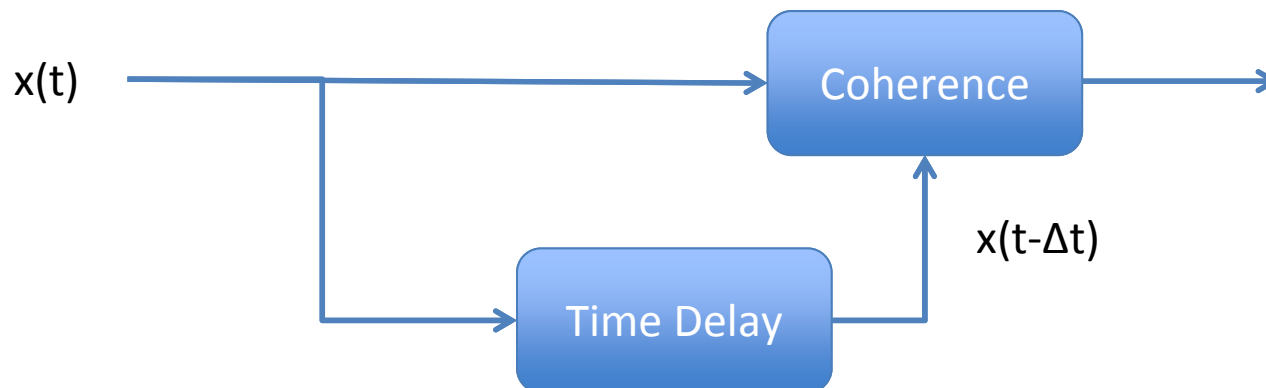


# The Coherence ANalysis ('CAN')

- The Cross-coherence spectra

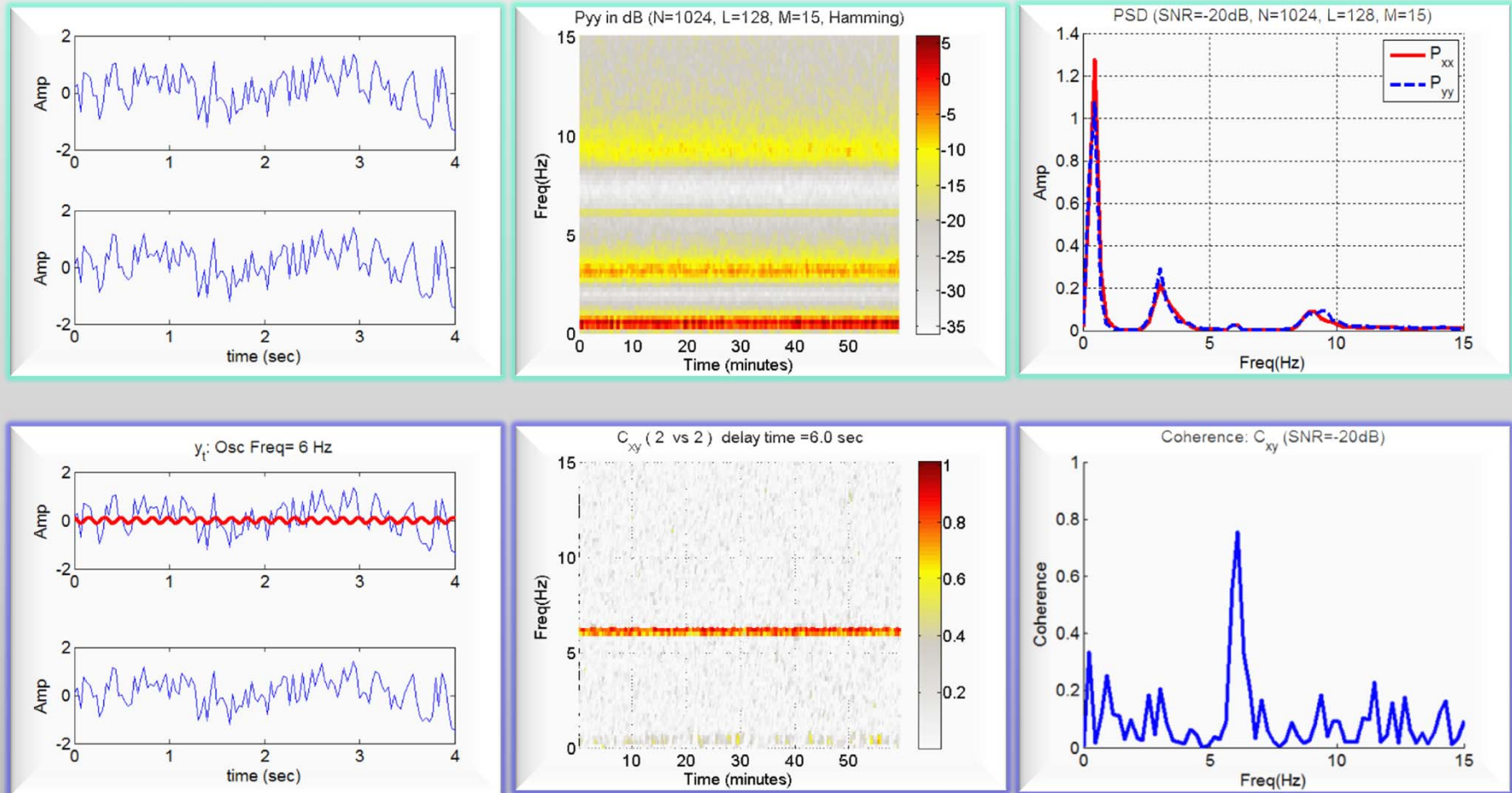


- The Self-coherence spectra

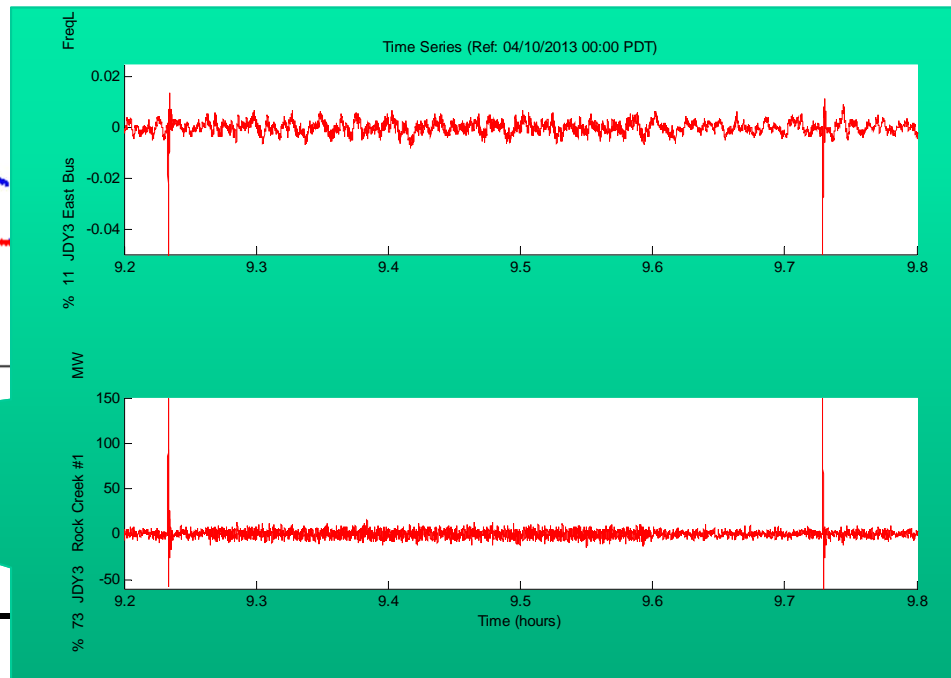
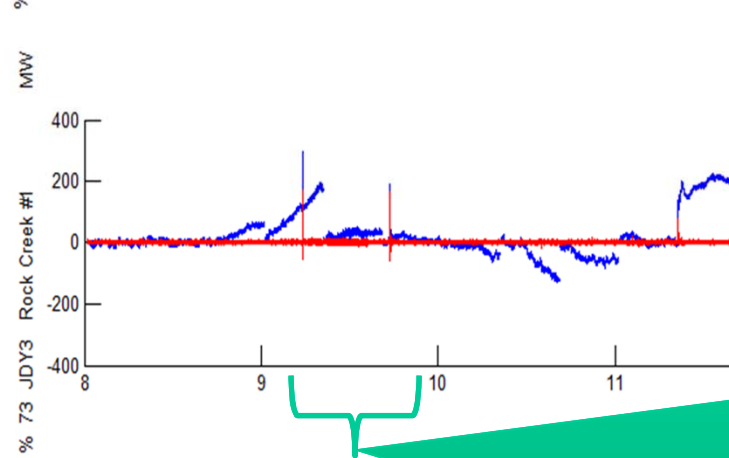
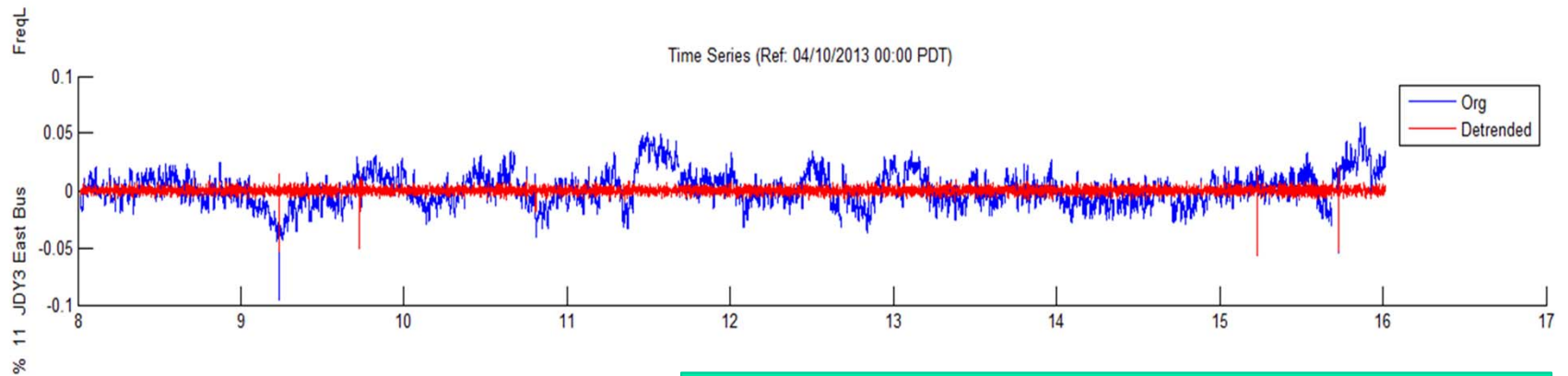


# Detect Sustained Oscillations

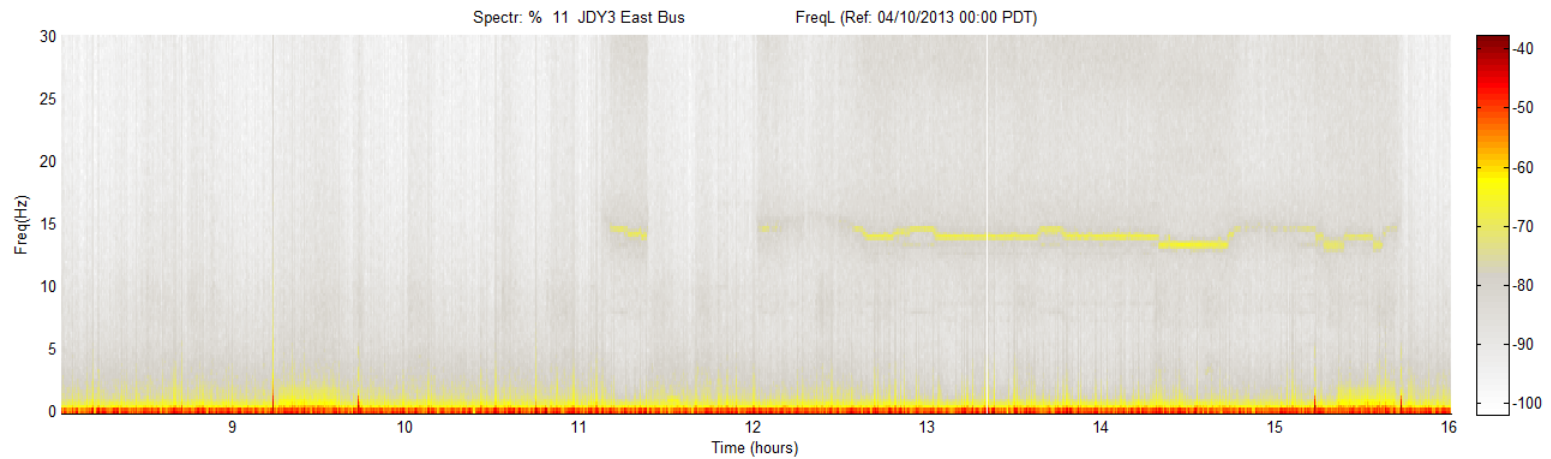
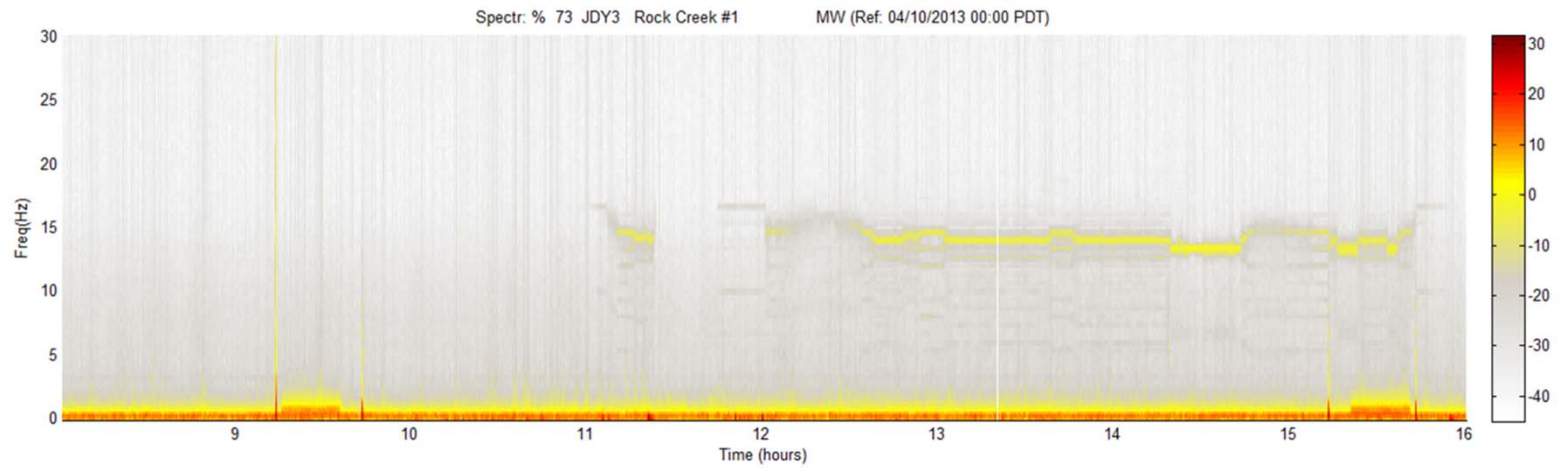
To detect sustained oscillations (low SNR) from PMU data.



# 9 Hours of Data on 04/10

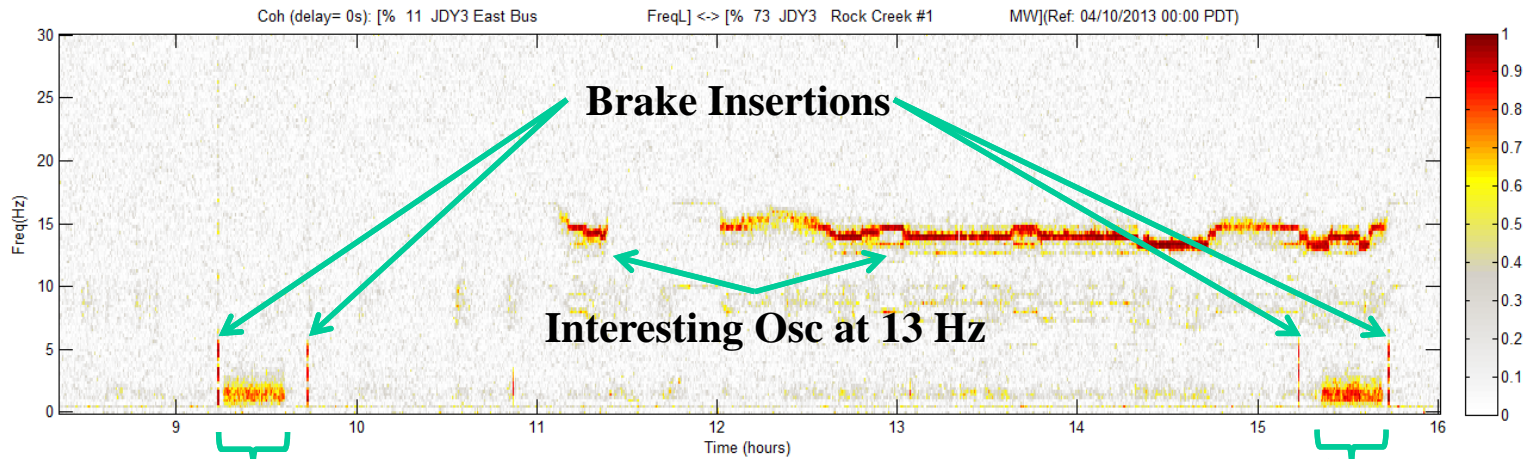
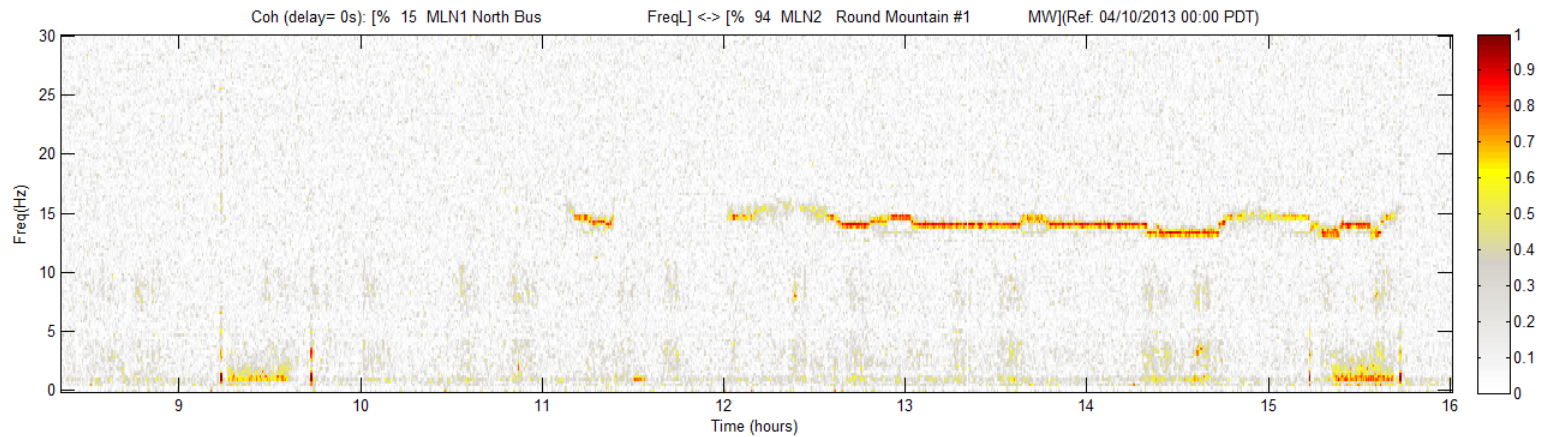


# Power Spectra

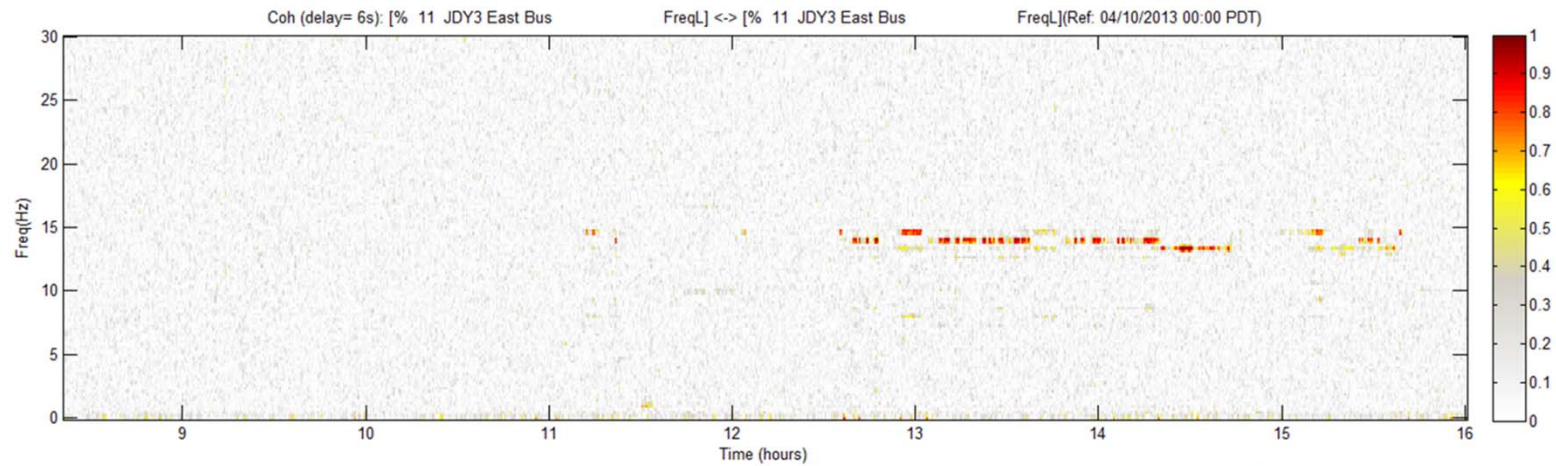
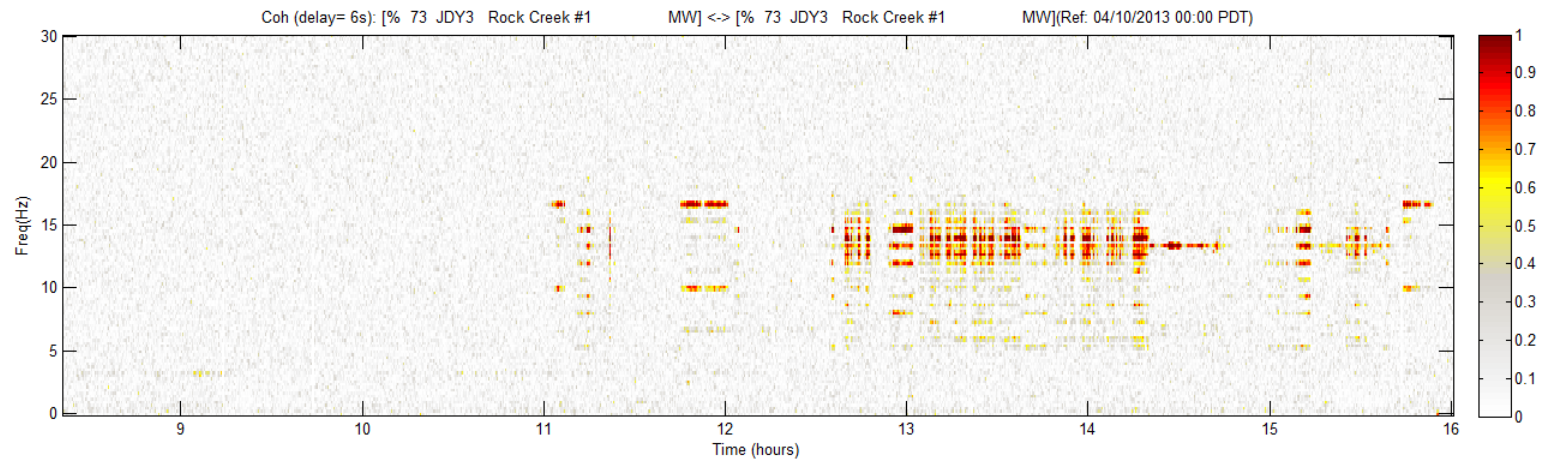




# Cross-Coherence Spectrum



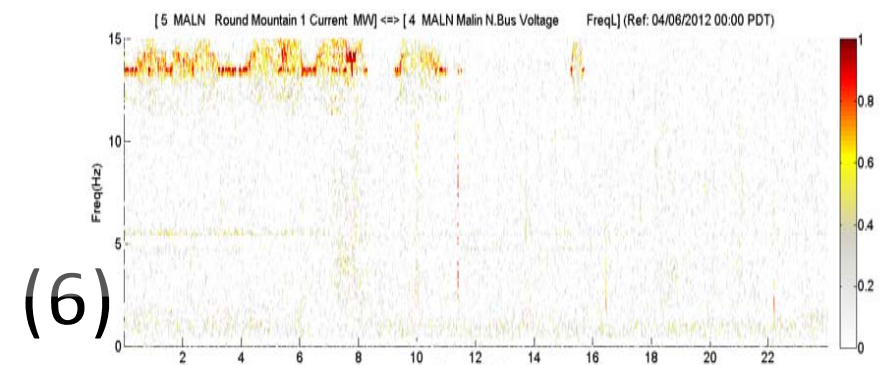
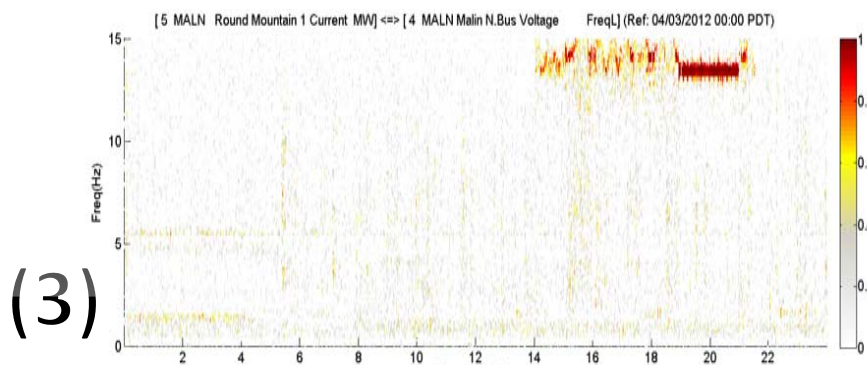
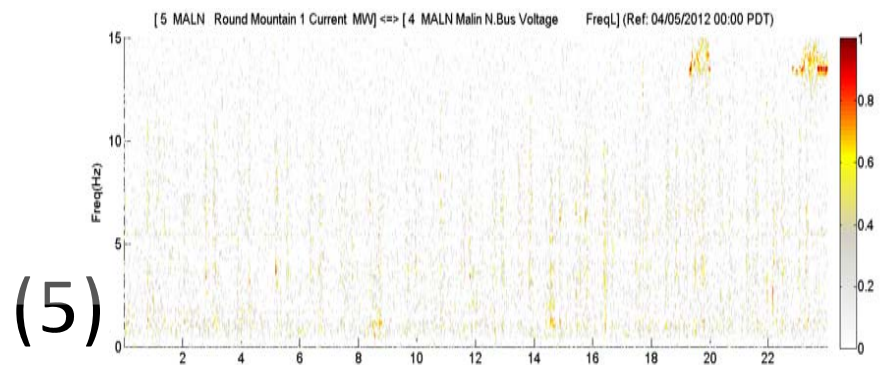
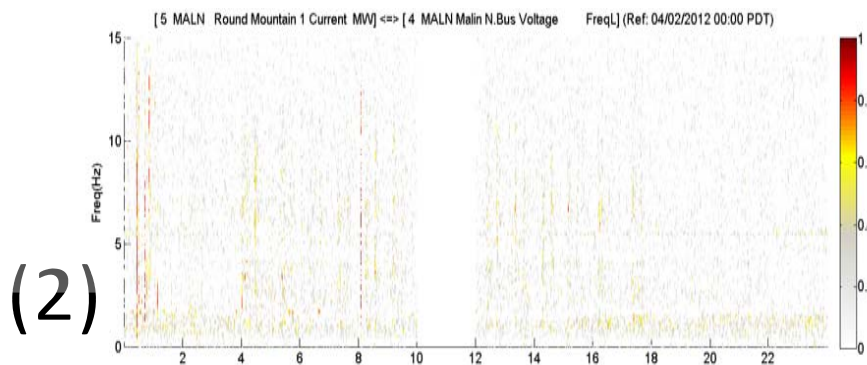
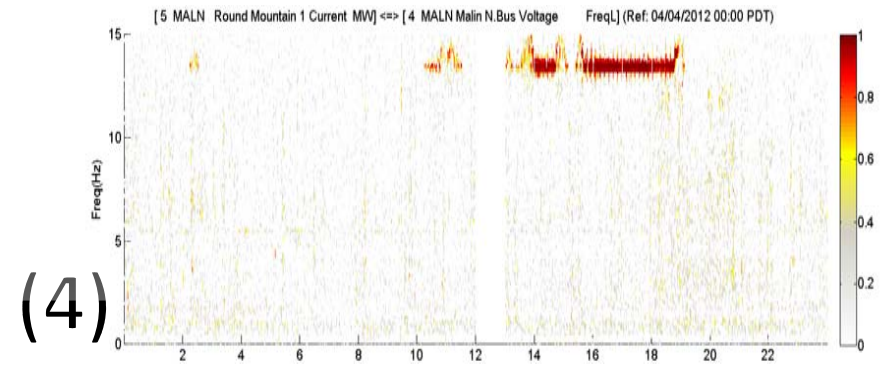
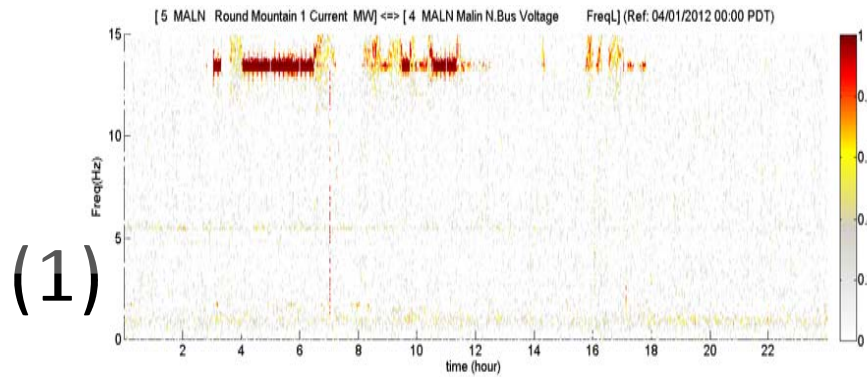
# Self-Coherence Spectrum





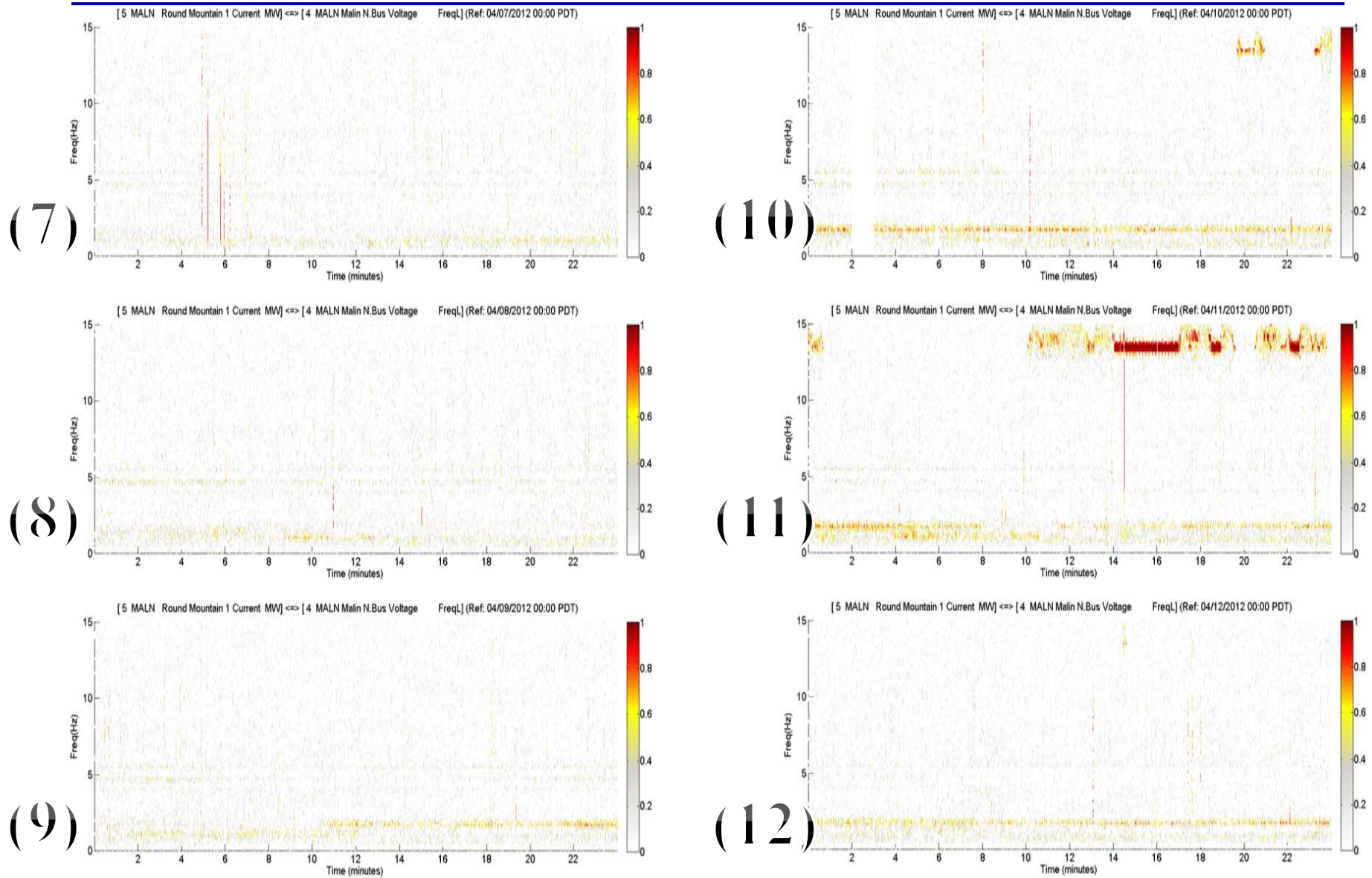
# 12 Days of Data Analysis

(04/1-04/06/12)



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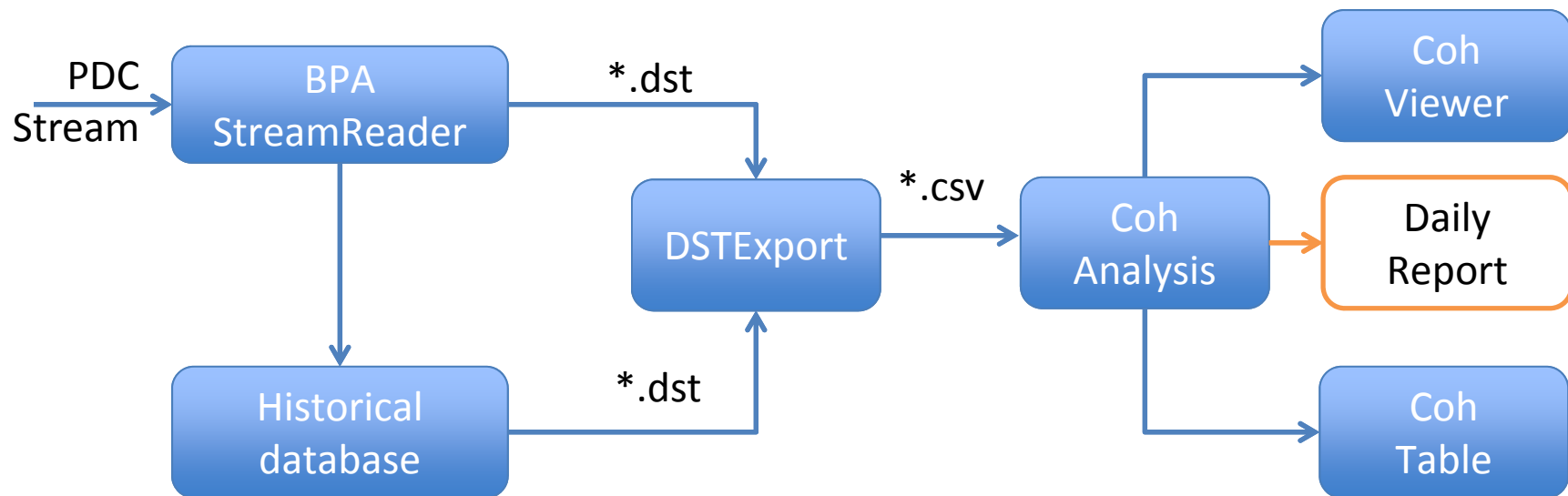
(04/7-04/12/12)



# Major Technical Accomplishments

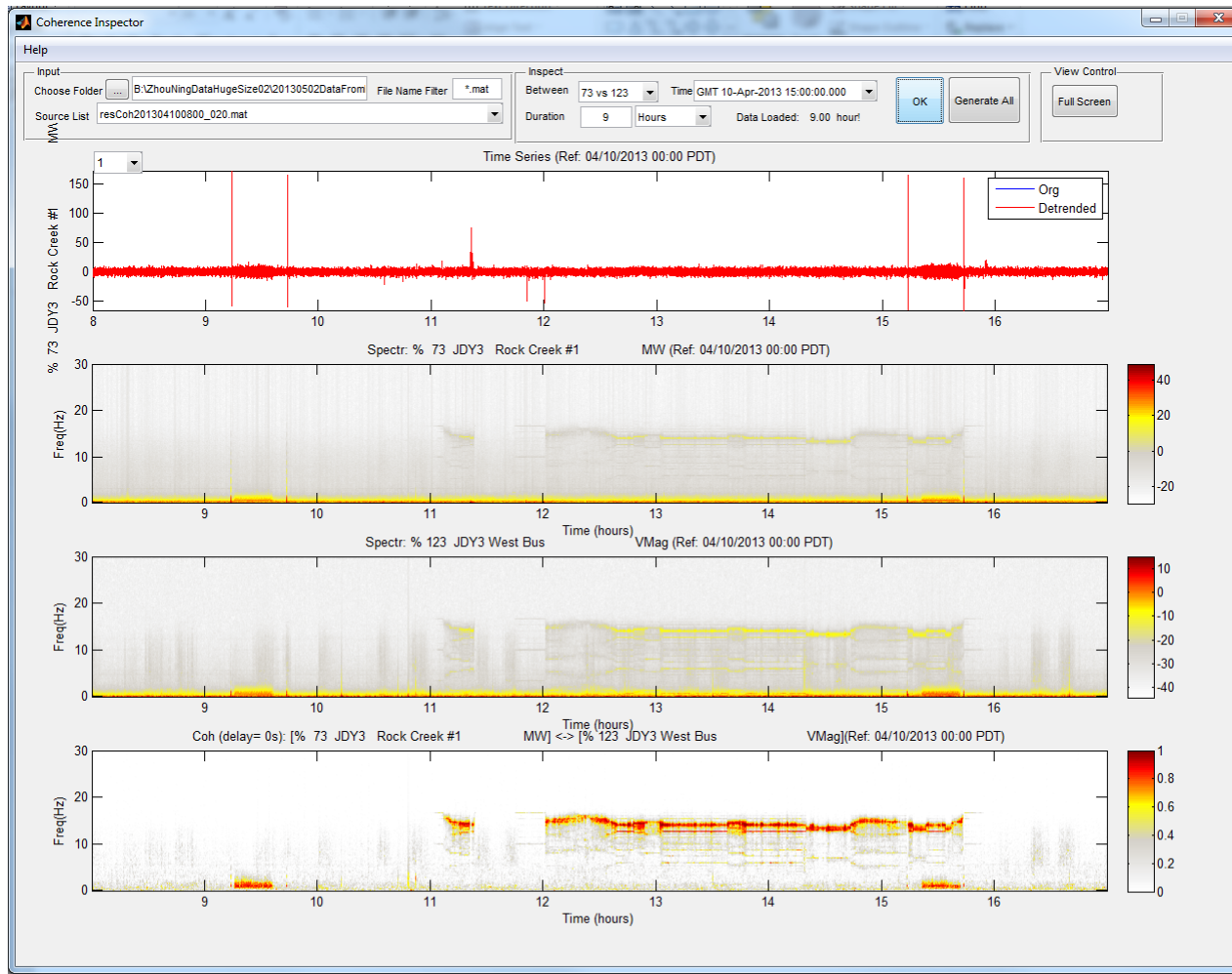
- Developed a prototype tool for **Coherence Analysis ('CAN')**
- Installed the '**CAN**' tool in BPA lab running in ps (06/06/2013)
- Assisted BPA engineers using the '**CAN**' for analyzing historical data

**RD&D CYCLE:**  
 3. Prototype  
 4. Field Demo (BPA)





# The 'CAN' Demo



# Deliverables and Schedule

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- Develop and implement post processing algorithms for Coherence **AN**alysis baselining. (07/30/2013, Done)
- Develop a prototype tool for evaluating the performance of the algorithms using field measurement data. (01/30/2014, 50%)
  - Installed the CAN prototype tool (ver 1.0) in BPA lab on 06/06/2013
- Report the study results, and plan for future study. (03/31/2014, 40%)
  - 1 conference paper accepted by IEEE PES GM 2013
  - 1 paper is drafted
  - Presentation in "Oscillation Detection and Analysis meeting" in BPA, Portland, 03/19/2013
  - WECC JSIS meeting, in WECC, Salt Lake City, 06/11-06/13/2013



# Risk Factors

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- For completing planned activities
  - May finish the study earlier than originally planned
- For moving through RD&D cycle
  - Goal: move up to the “Pre-commercial”
  - Risk factors:
    - The methods are easy to implement
    - The papers & presentations will likely enable vendors to develop their own ‘CAN’ tools





# Early Thoughts for FY 14

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- Intensive studies on field measurement data to build an application example
- Methods for locating the disturbance sources
- Methods for identifying the type of disturbance sources



# Summary

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- Cross Coherence
  - Periodic oscillations
  - Forced responses
    - Ringdown
    - Probing
- Self Coherence
  - Periodic oscillations
- Developed the 'CAN', a prototype **C**oherence **A**nalysis tool.
  - Running in BPA lab in pseudo real time on PMU measurements
  - Used by BPA engineers for studying historical PMU measurements



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# Questions or Comments?

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