Monitoring Bicoherence

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What are Higher Order Statistics?

- 1D Statistics:
  - » Correlation: $C_{xy}(t) = \int_{-\infty}^{\infty} x(\tau)\, y(t+\tau)\, d\tau \quad \Leftrightarrow \quad X(f)\, Y^{*}(f) = S_{xy}(f)$
  - » Power Spectral Density: $C_{2x}(t) \quad \Leftrightarrow \quad X(f)\, X^{*}(f) = S_{2x}(f)$
  - » Coherence: $C_{xy}(f) = \dfrac{S_{xy}(f)}{\sqrt{S_{2x}(f)\, S_{2y}(f)}}$
    - – Tells us power and phase coherence at a given frequency

Second Order Statistics

- 2D Statistics:
  - Bicumulant:

$$C_{xyz}(t,t') = \int_{-\infty}^{\infty} x(\tau)\, y(t+\tau)\, z(t'+\tau)\, d\tau \quad \Leftrightarrow \quad X(f_1)\, Y(f_2)\, Z^*(f_1+f_2) = S_{xyz}(f_1,f_2)$$

  - Bispectral Density:

$$C_{3x}(t) \quad \Leftrightarrow \quad X(f_1)\, X(f_2)\, X^*(f_1+f_2) = S_{3x}(f_1,f_2)$$

  - Bicoherence:

$$\mathrm{C}_{xyz}(f) = \frac{S_{xyz}(f_1,f_2)}{\sqrt{S_{2x}(f_1)\, S_{2y}(f_2)\, S_{2z}(f_1,f_2)}}$$

    - Tells us power and phase coherence at a coupled frequency

Why Higher Order Statistics?

- For a Gaussian process: $C_{nx}(t) = 0, \text{ for } n > 2$
- For independent processes:

$$z(t) = x(t) + y(t), \quad C_{nz}(t) = C_{nx}(t) + C_{ny}(t) \xrightarrow{n>2} C_{ny}(t)$$

- Allows for separation of Gaussian process for n>2
  - » Visual check of frequency coupling and phase noise
  - » Statistical test for the probability of gaussianity and linearity
  - » Iterative process to reconstruct nongaussian signal from the higher order cumulants

Monitor Versions: Bicoherence MatLab tool

- **MatLab tool:**
  - Flexible tool for quickly examining auto-bicoherence
    Monitors the integrated auto-bicoherence over specified frequency area
  - Allows one to see evidence of bilinear couplings
  - Exists! MEDM version displays trend of data

  - Does not perform background monitoring.
  - Does not allow multiple configurations.
  - Does not calculate cross-bicoherence (limits full diagnosis of noise problem)
  - Vijay, the code author and primary user, has taken another job.

Monitor Versions: BicoMon (Background Monitor)

- Current Version (Exists. Written since August Meeting)
  - » Monitor integrates bicoherence over specified frequency ROI
  - » Calculates bicoherence for multiple channel combinations
  - » Integrates bicoherence over multiple specified ROI for each bicoherence calculation
  - » Can integrate bicoherence over entire unique area (Gaussianity)
  - » Trends Data and sends to DMTviewer.

Configuration File

Calculation Parameters

Measurement Parameters

```
3  30

C 2   H1:LSC-AS_Q                          16384
      H1:SUS-ITMX_OPLEV_PERROR  2048
      256     1.0           0.5           64

M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_ALL          0  0 0
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_60_2_2      60  2 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_60_10_2     60 10 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_60_38_2     60 38 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_60_50_2     60 50 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_120_2_2    120  2 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_120_10_2   120 10 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_120_38_2   120 38 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_120_50_2   120 50 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_180_2_2    180  2 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_180_10_2   180 10 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_180_38_2   180 38 2
M  Bico:H1:AS_Q-ITMX_OPLEV_PERROR_180_50_2   180 50 2

C 2   H1:LSC-AS_Q                          16384
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M  Bico:H1:AS_Q-ITMY_OPLEV_PERROR_180_38_2   180 38 2
M  Bico:H1:AS_Q-ITMY_OPLEV_PERROR_180_50_2   180 50 2

C 1   H1:LSC-AS_Q                          16384
      256     1.0           0.5           64

M  Bico:H1:AS_Q_ALL            0   0 0
M  Bico:H1:AS_Q_120_2_2      120   2 2
M  Bico:H1:AS_Q_120_10_2     120  10 2
M  Bico:H1:AS_Q_120_38_2     120  38 2
```
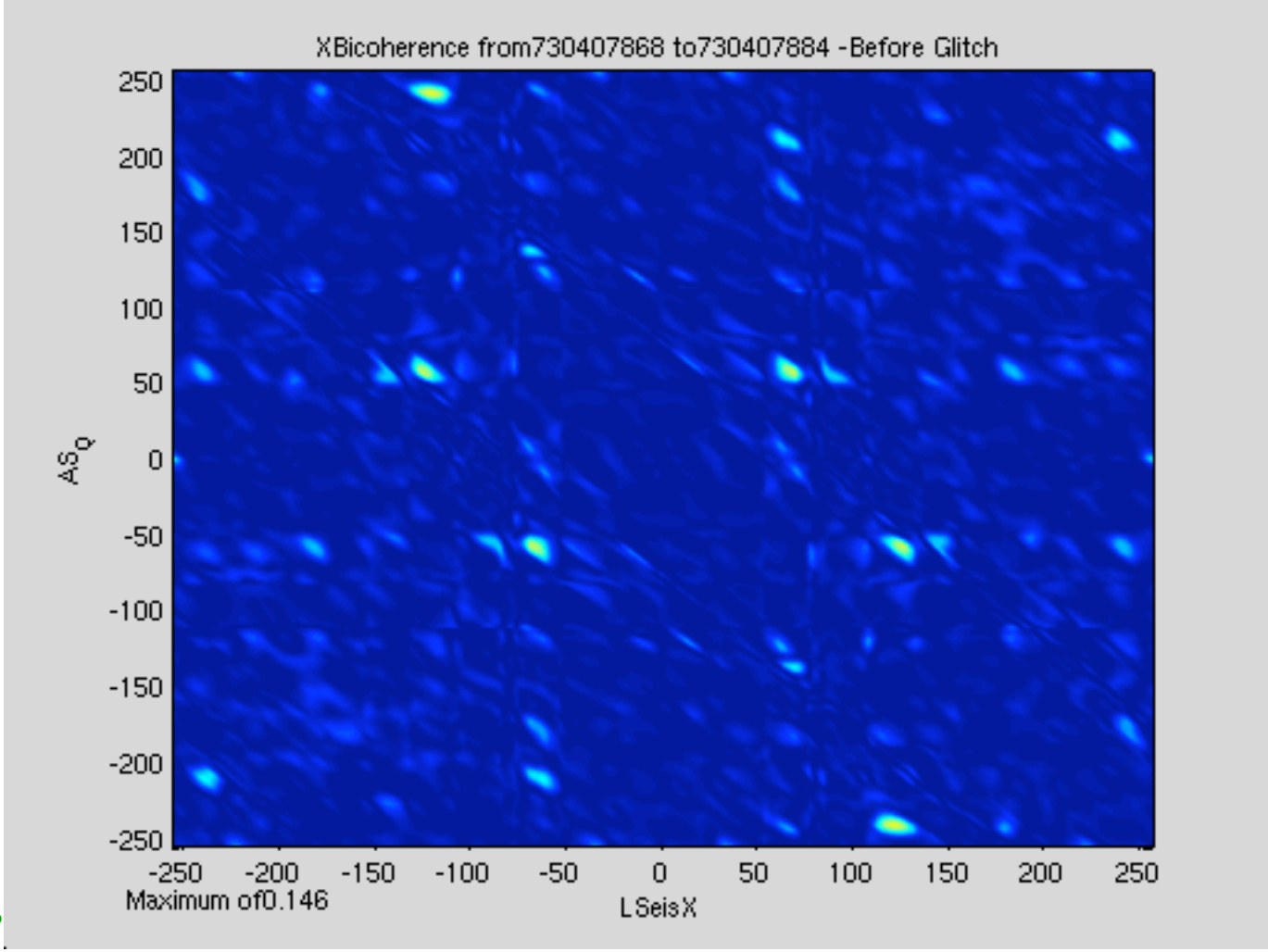

Monitor Plan: BicoViewer (Foreground Monitor)

- Plots (cross-)bicoherence, (cross-)bispectrum, & PSD's
- Automatic decimation
- Optimized windowing
- User specified:
  - » f_{max} & Δf (Limited to factor 2^n)
  - » accuracy/averaging
  - » Calculation method
- Outputs GIF files of the plots
- Vectorized FFT routines for speed
- Heterodyning
- Monitoring bicoherence of certain ROI and changes in bicoherence
- Output calculation parameters as configuration for BicoMon

Monitor Plan: Bicocoherence Movies



Conclusions

- Bicoherence monitors could be a useful tool for analyzing data for glitches, gaussianity, upconversion, and chirps.
- We are now at sensitivity where up-converted data can be seen
- Background Monitor exists.
- Viewer still needs work.
- We need people!

  We lost Vijay to the BioTech industry

  Nelson and I are both at undergraduate colleges with large teaching loads