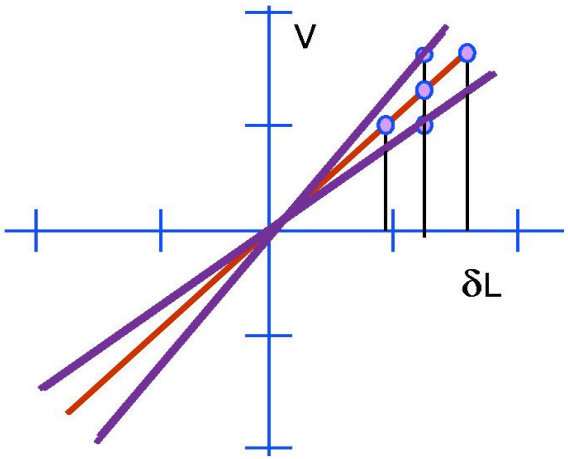
Bilinear noise mechanisms

e2e 15may02 dhs

- Attempt to list the kinds of bilinear effects that could lead to noise
- Needs discussion on prioritization and ease of implementation
- Should lead to description of data needed (Detector) and models needed (e2e), ideally with people's names

Stan's Hobbyhorse: Bilinear Noise Sources

- Simplest Example:
  - » Sensing of arm length difference is proportional to input laser intensity



$$"\Delta L"(t) \approx I(t)\delta L(t)$$

$$"\Delta \tilde{L}"(\omega) \approx \tilde{I}(\omega_1)\delta \tilde{L}(\omega \pm \omega_1)$$

- Noise term linear in two variables ("bilinear") creates output noise at sum and difference frequency

Importance of Bilinear noise mechanisms (Stan)

- Our interferometer configuration is insensitive to (most) first order noise sources
- “Traditional” noise investigation techniques (transfer functions, coherence) don’t pin-point bilinear sources
  - » Requires alternative techniques (e.g., addition of band-limited white noise)
- Understanding full nature of noise source gives experimenter two chances to reduce the output noise
- Bilinear noise sources are fairly common
- Most importantly, e2e is a good tool for investigating bilinear noise sources

Candidates for interactions

- In general:
  mechanical or optical offset, RMS usually (could also be DC…)
  - » Static system are susceptible to simpler solutions
  - » sensing system noise at baseband or at modulation frequency

- A product of some two things below

  optic axial position << Easy (…says Hiro)
  optic angles << Easy
  optic reflectivities/losses << Easy
  optic ROC << Possible (reliability under investigation)
  optic beam positions (wrt sweet spot) << Easy
  scattered light amplitude
- spectra at the input and the output of the Mode Cleaner
- optic angle (dynamic) << Easy RNA FRED laser intensity fluctuations << Easy (data needed) RICK
- laser frequency noise << Easy (data needed) RANA and RICK
- laser pointing noise << Easy (data needed) DAVE O
- modulation frequency noise << Easy (data needed)
  modulation intensity noise << Easy (data needed)

- In the main optical system (cavities or michelson), or the mode cleaner

Some examples

- Scattered light
  - » amplitude of scatterer x relative velocity of components
  - » Hiro: Possible (we discussed about a simple implementation of this noise)
- TM angular motion
  - » offset from 'sweet spot' x angular noise of optics
  - » Hiro: Qualitative answer is yes, quantitativeness is not clear (reliability of time domain modal model with finite modes)

More examples

- Feedthrough of laser intensity fluctuations
  - » offset from servo null, any length servo (static or RMS dynamic) x laser intensity fluctuations at baseband
  - » Hiro: Not ready : Common mode servo and more refined PSL (and IOO) needed
- Feedthrough of laser frequency fluctuations
  - » imbalance of reflectivity of arms x laser frequency noise
  - » Hiro: Not ready : Common mode servo and more refined PSL (and IOO) needed
- Feedthrough of sideband imperfections
  - » Sideband imbalance x LO oscillator intensity noise
  - » Hiro: Not ready : Common mode servo and more refined PSL (and IOO) needed
  - » --- passage through the Mode Cleaner

More examples

- Rai: cross product of mode cleaner motion with other fluctuations - this one worries me more now as I see how the amplitude of the sidebands are modulated by the mode cleaner
  - » Hiro: Not ready : Need to make a refined mode cleaner model
- Rai: need to establish what causes the quadrature term in a given error signal to fluctuate, this is becoming a bothersome problem especially as we try to increase the gain eithet optically or electronically
  - » Not itself a bilinear process, but a good thing to pursue!
  - » Hiro: Possible, now that Matt has made a good LSC model

Discussion

- Most important use of e2e:
  - » May have already dreamt up 80% of the important bilinear sources
  - » The things we have _not_ thought about are the most useful outputs from the e2e model; should not lose that focus
- Make sure that the inputs are there
- MC input data: mirror angles (HF and LF motion)
- Remote control room – 10% of someone's time
- Bi-spectrum monitor from Steve Penn
  - » http://www.ligo.caltech.edu/docs/G/G010331-00.pdf