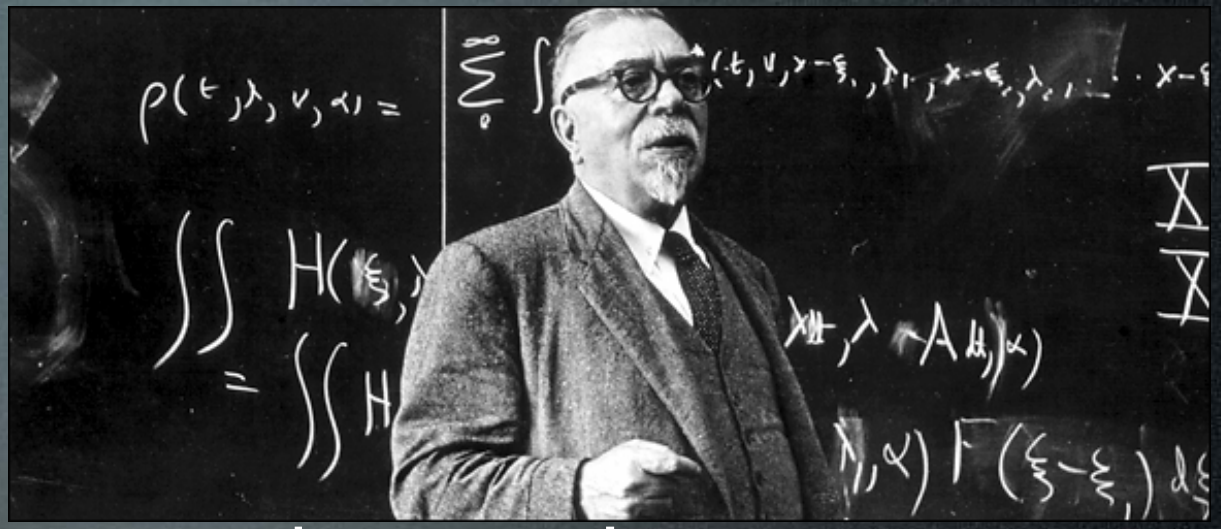
Adaptive Noise Cancellation: A Panacea

M. Evans, R. Adhikari

The Concept

- 5000 Channels
- 1 GW Channel
- Signal = DARM - noise

Wiener Filter



Norbert Wiener, MIT

$$x[n] = \sum_{i=0}^{N} a_i w[n-i]$$

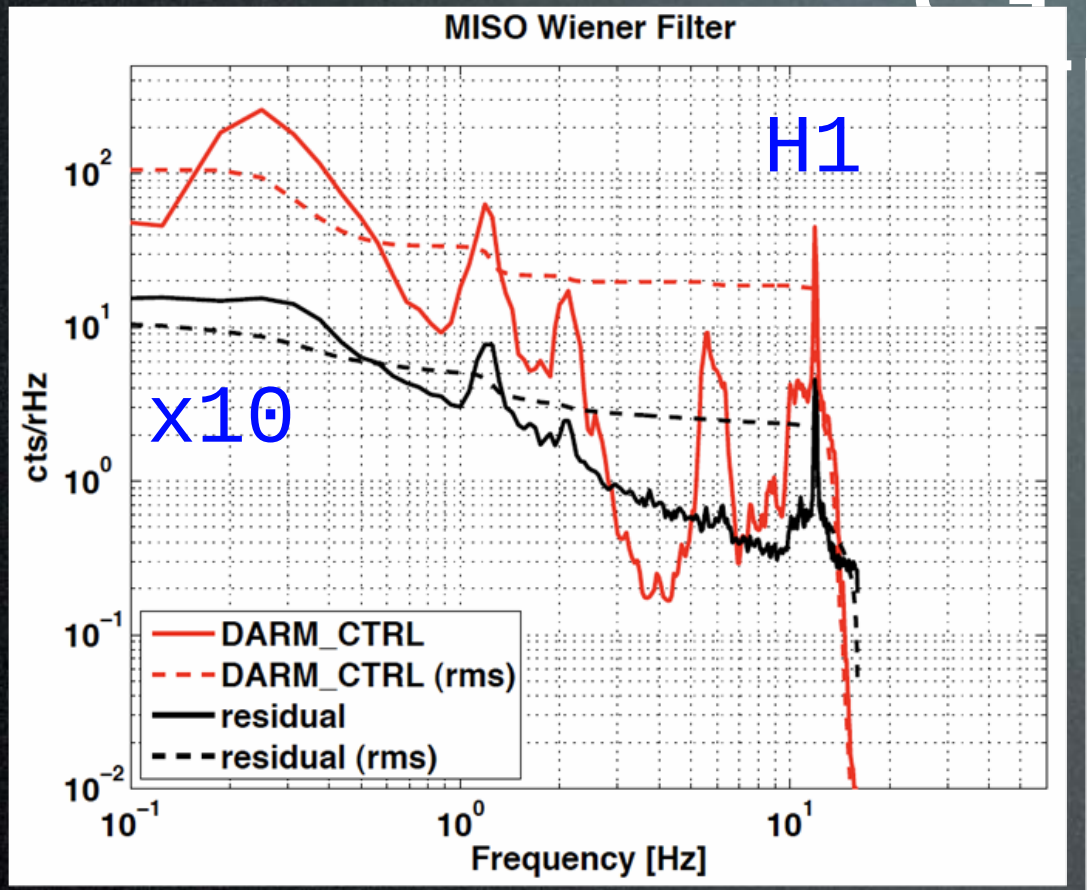
Block Toeplitz

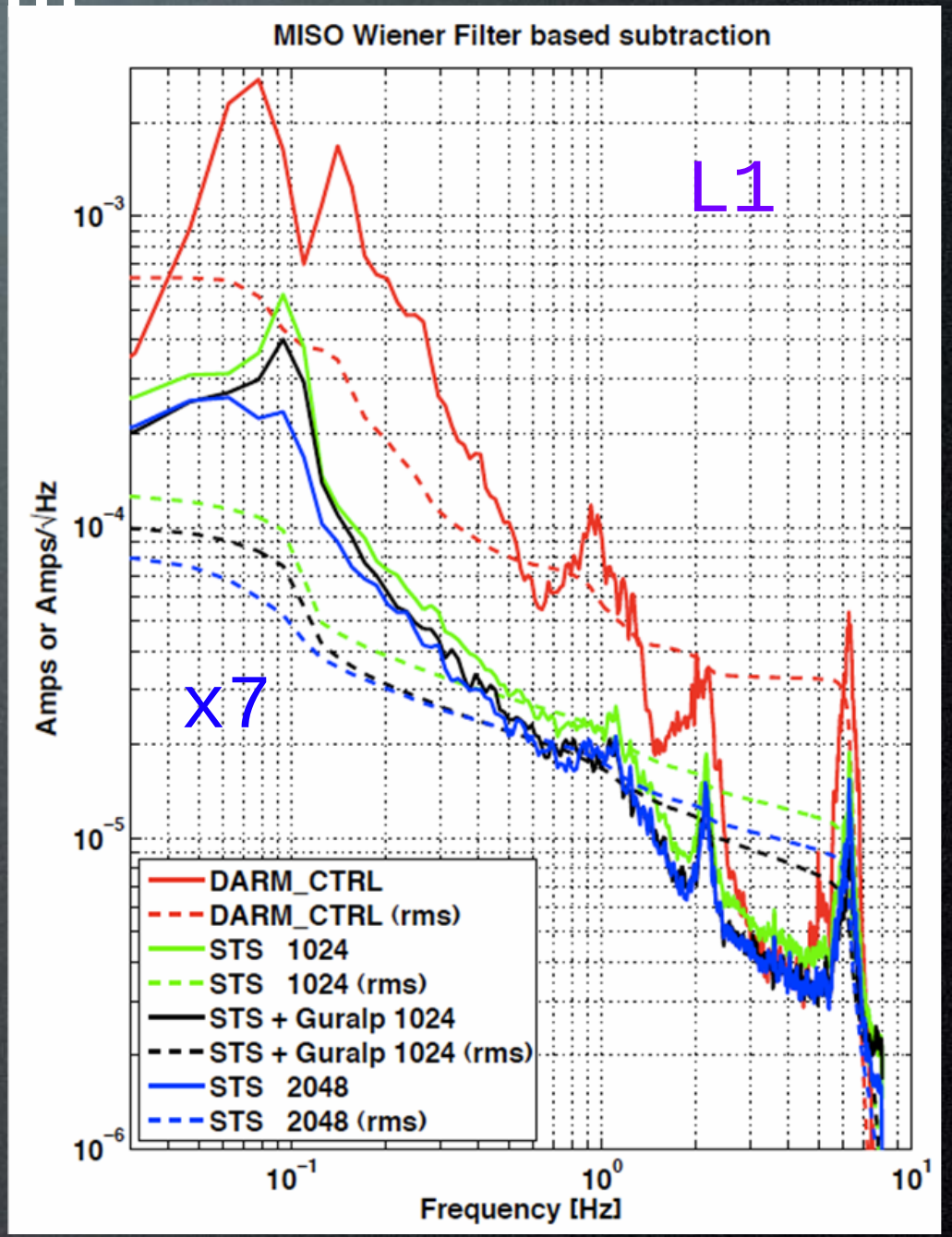
$$\begin{bmatrix} R_w[0] & R_w[1] & \cdots & R_w[N] \\ R_w[1] & R_w[0] & \cdots & R_w[N-1] \\ \vdots & \vdots & \ddots & \vdots \\ R_w[N] & R_w[N-1] & \cdots & R_w[0] \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_N \end{bmatrix} = \begin{bmatrix} R_{sw}[0] \\ R_{sw}[1] \\ \vdots \\ R_{sw}[N] \end{bmatrix}$$

Cross Correlation Matrix

(PEM) Covariance Matrix

Wiener Filter Sim



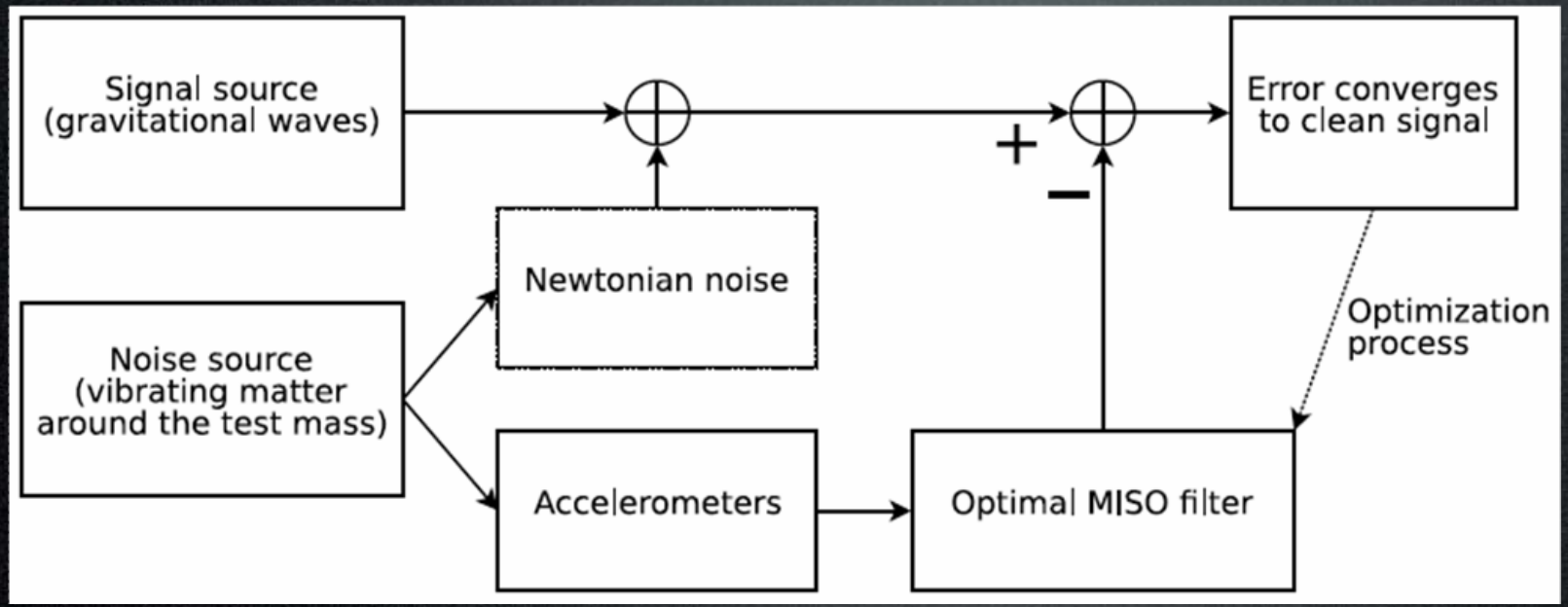


- H1 & L1 DARM (S5)
- All Guralp & STS2
- Vault not used
- Requires ~9 GB RAM
- Levinson-Durbin

Adaptive Filtering / Neural Network

Keenan Pepper

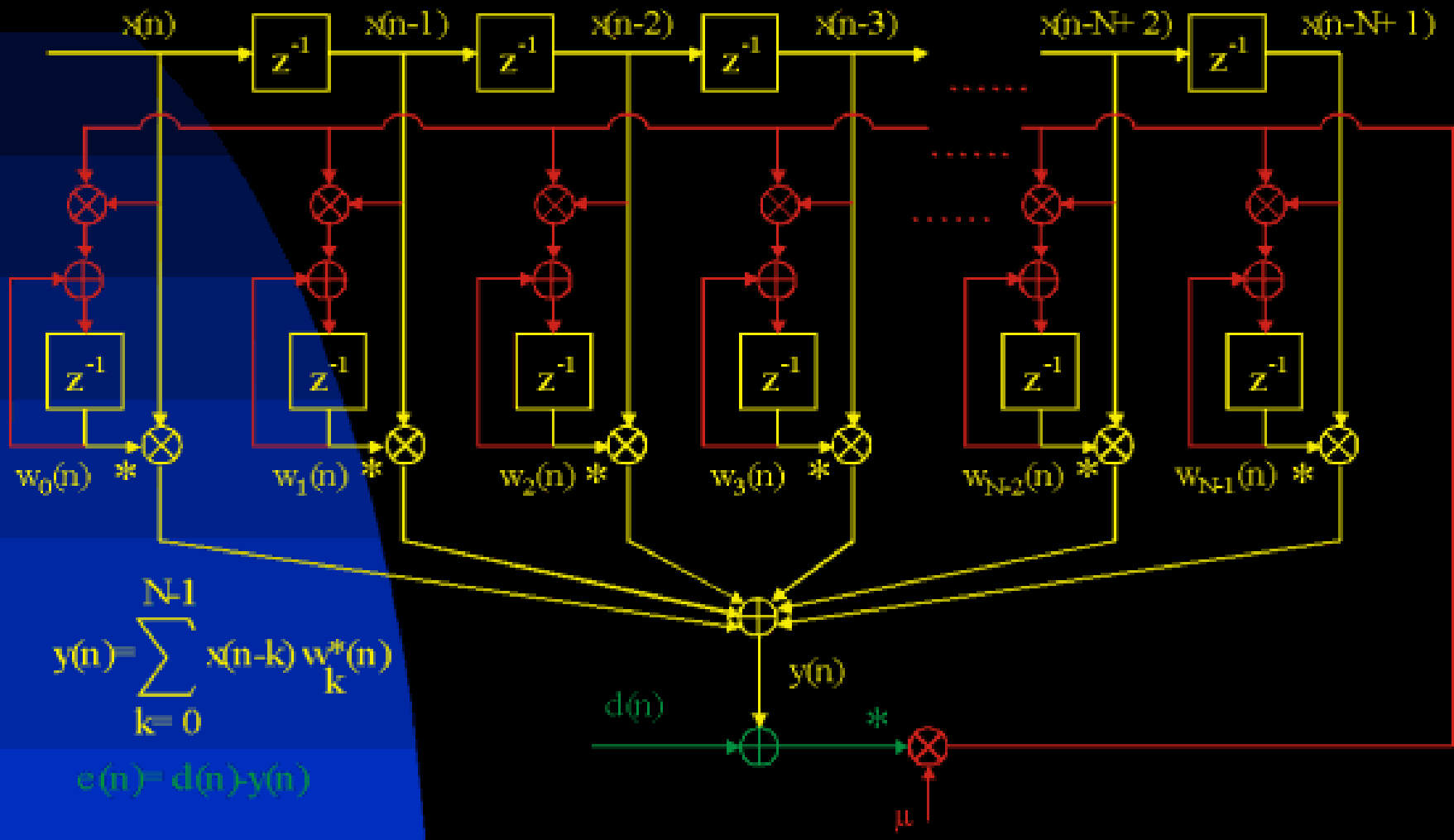
Elena Gasparri



LMS Algorithm

(1st chapter of textbooks)

LMS Algorithm

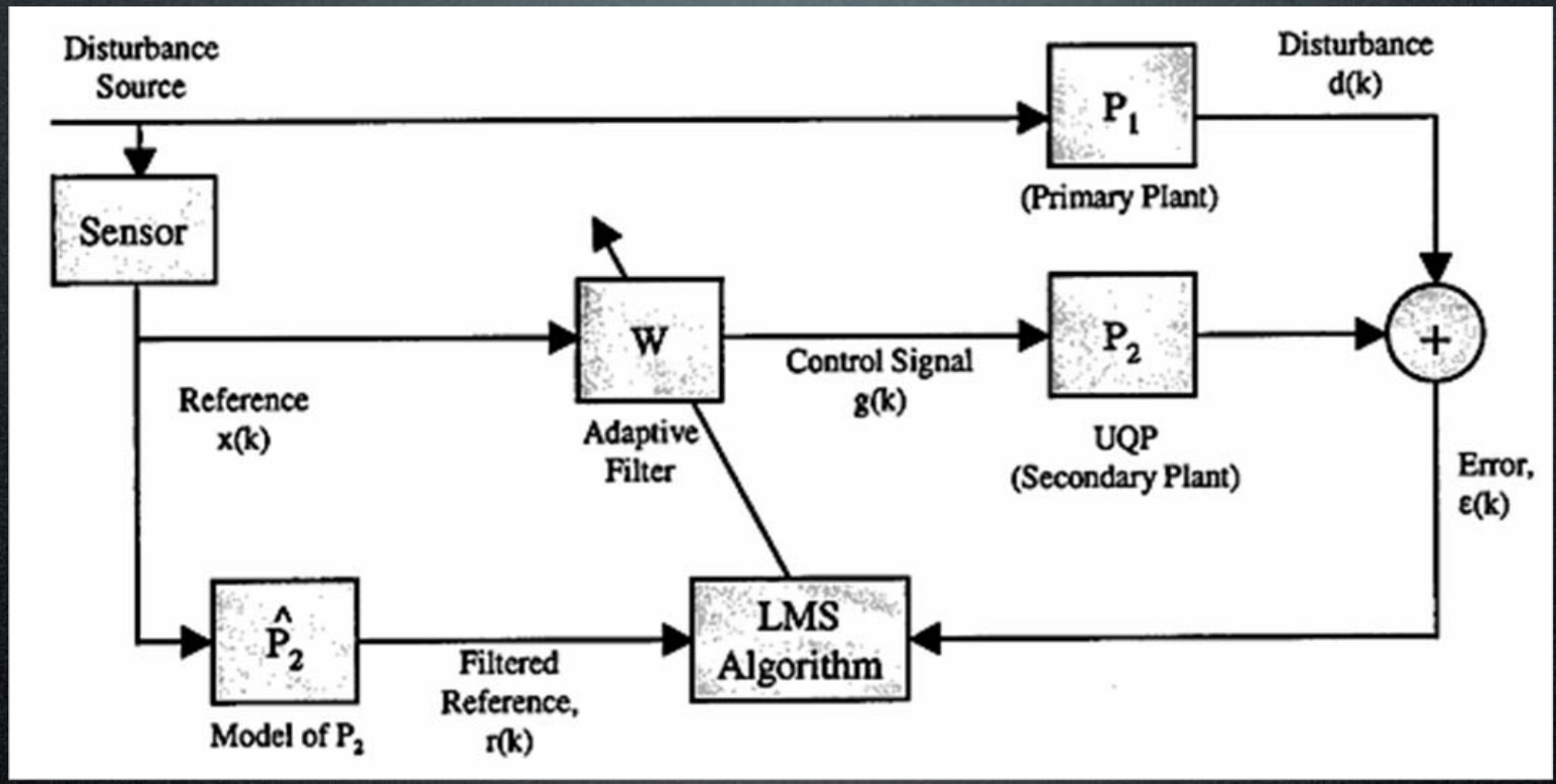


$$y(n)=\sum_{k=0}^{N-1} x(n-k)\, w_k^*(n)$$

$$e(n)= d(n)-y(n)$$

$$w_k(n+1)= w_k(n)+ \mu\, e^*(n)\, x(n-k)$$

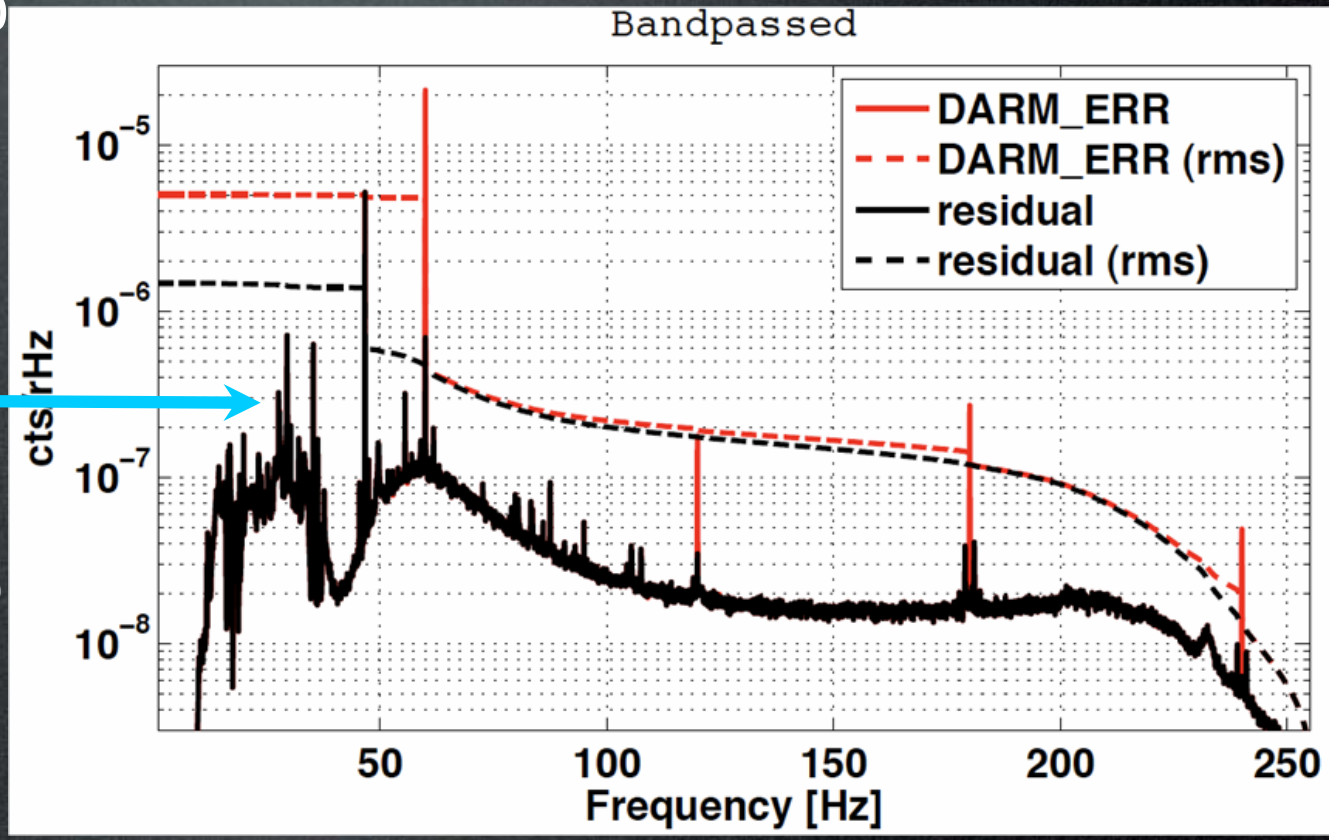
Filtered-X LMS



Edwards, Thesis
(declassified)
Naval Research Postgraduate School

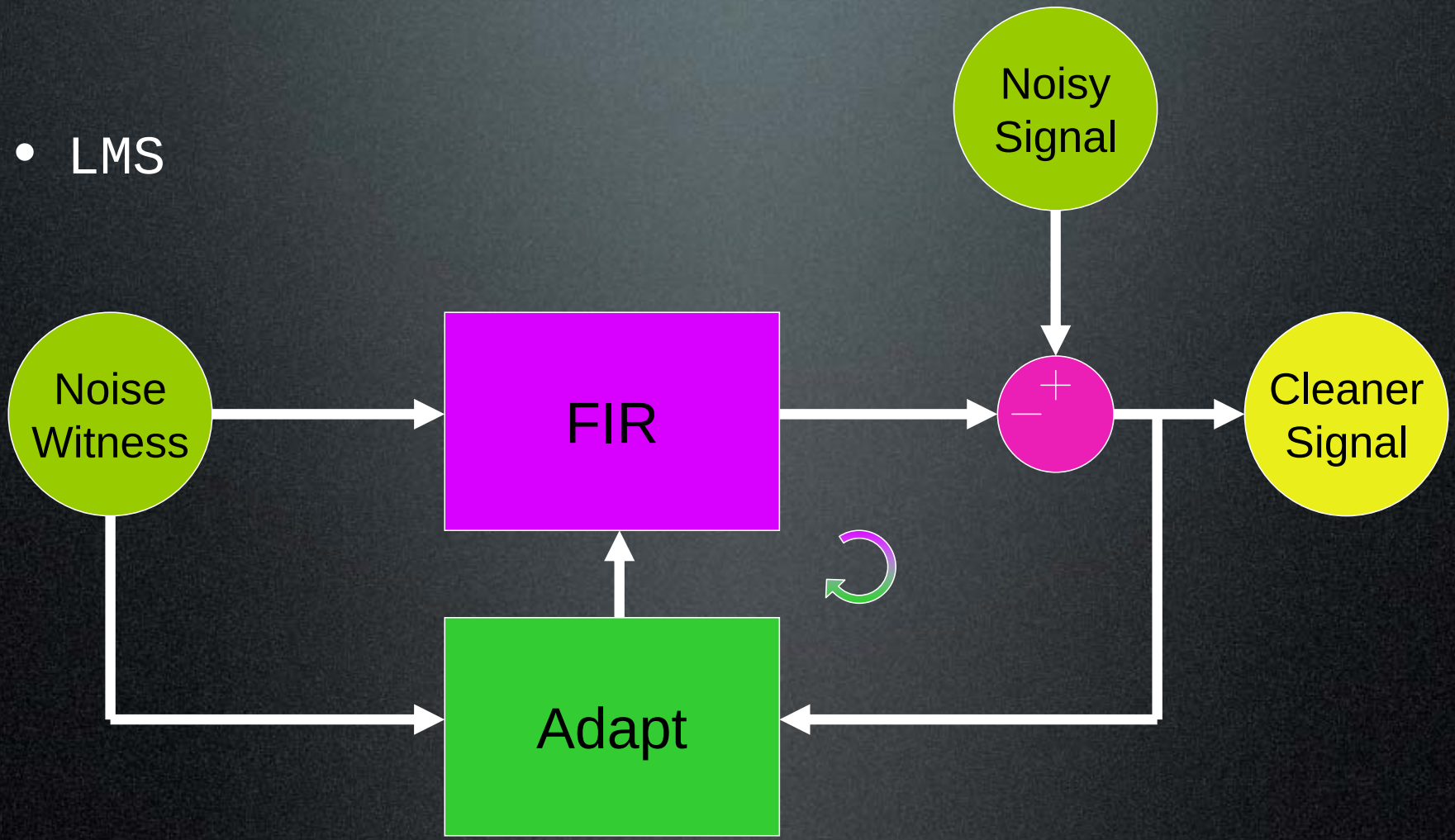
Applications

- Seismic Noise (0 - 40 Hz)
  - Upconversion
  - Lock Acquisition
  - Bilinear (Crab shoulder)
- Acoustic Noise (50-900 Hz)
- Magnetic (power lines)
- H1/H2 correlatio
- MICH/PRC/SRC



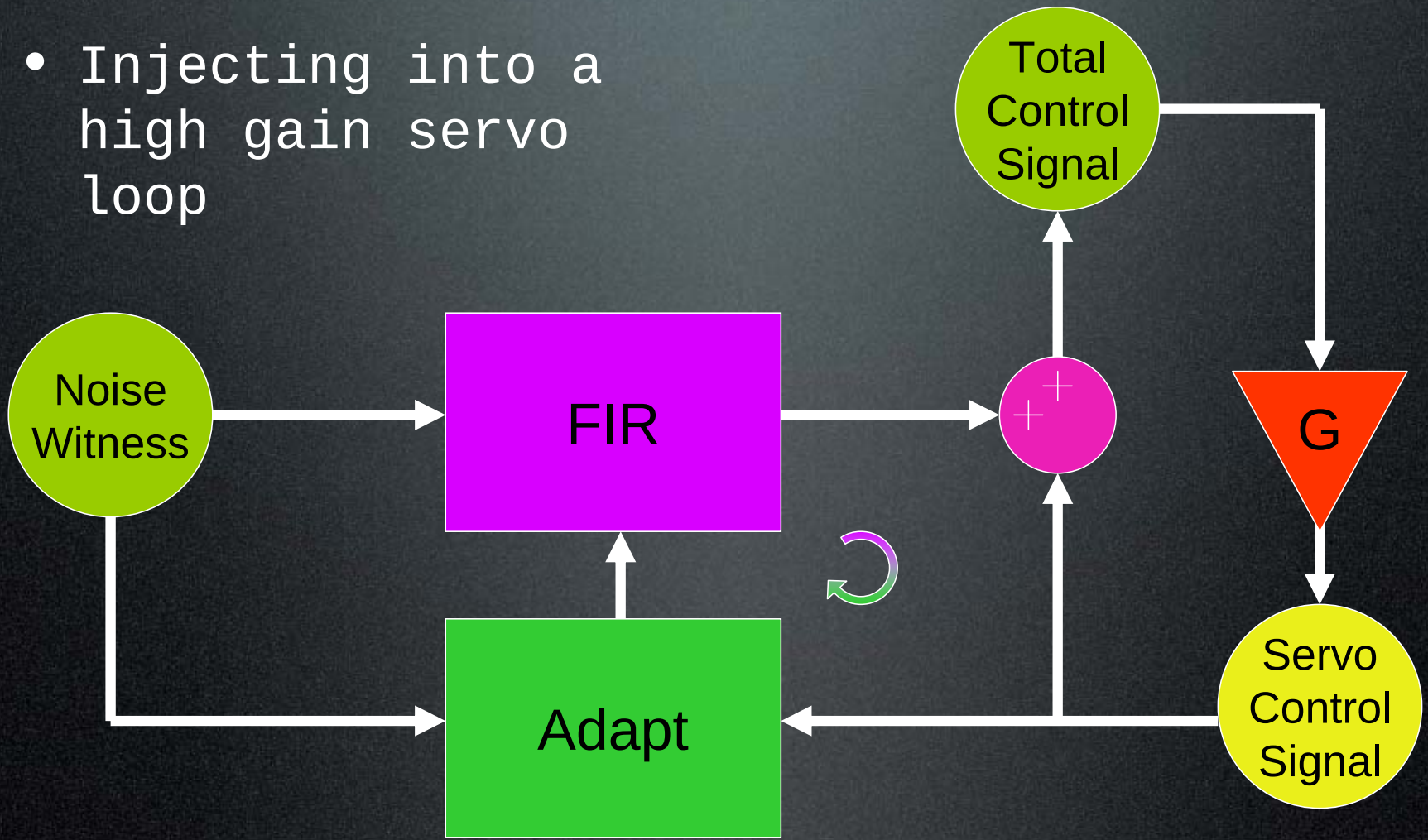
From LMS to Filtered-X

- LMS



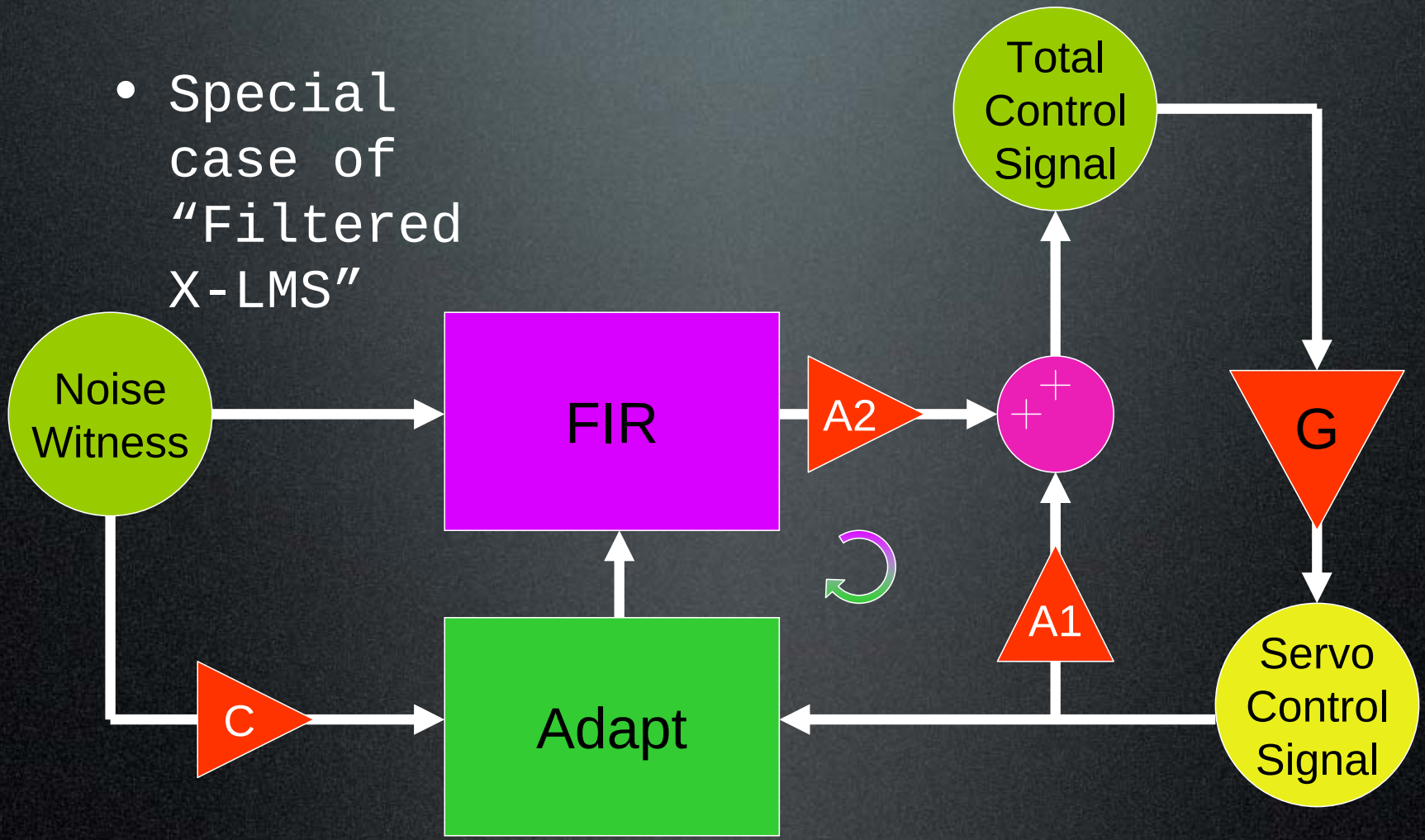
From LMS to Filtered-X

- Injecting into a high gain servo loop



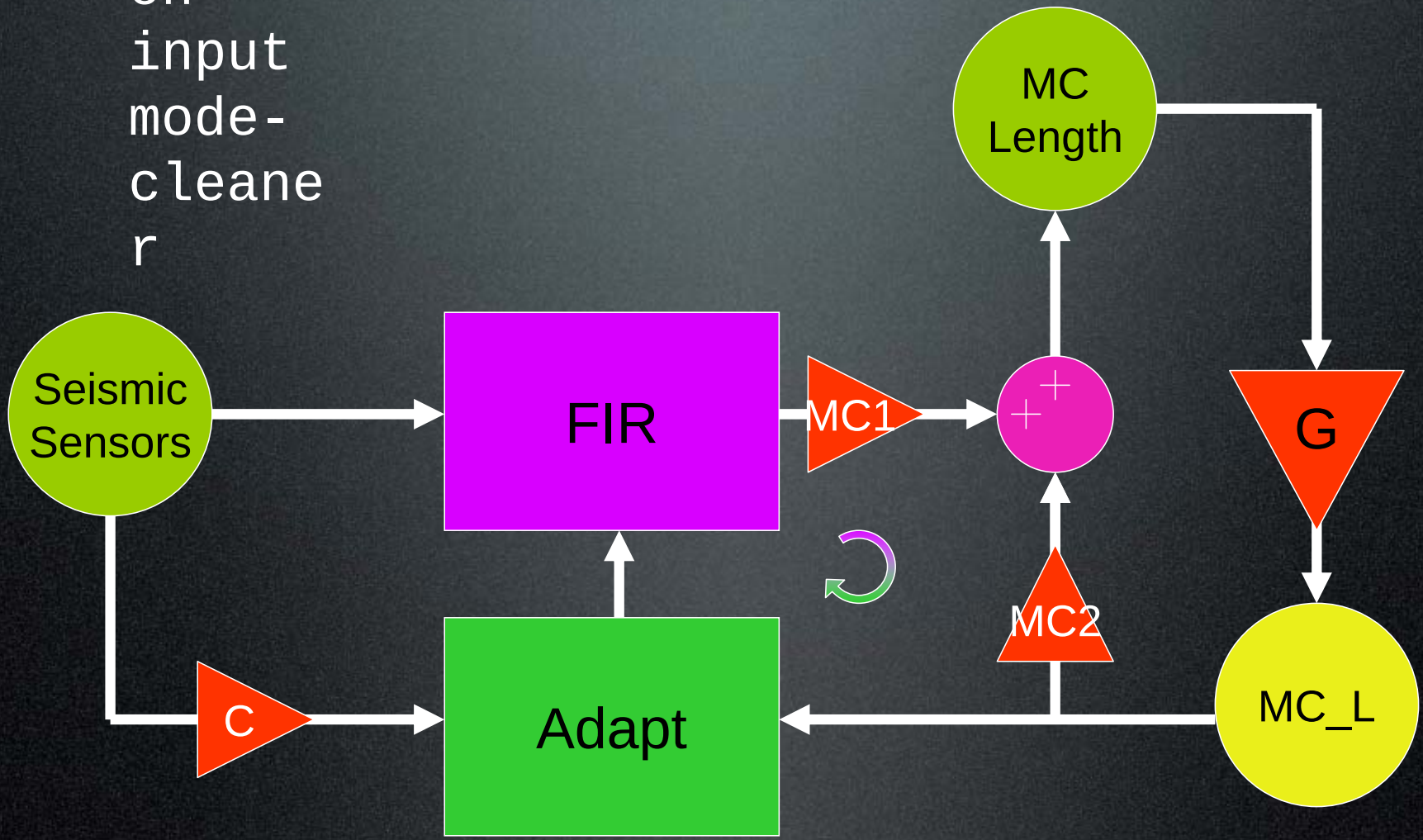
From LMS to Filtered-X

- Separated Actuators
  - Special case of “Filtered X-LMS”

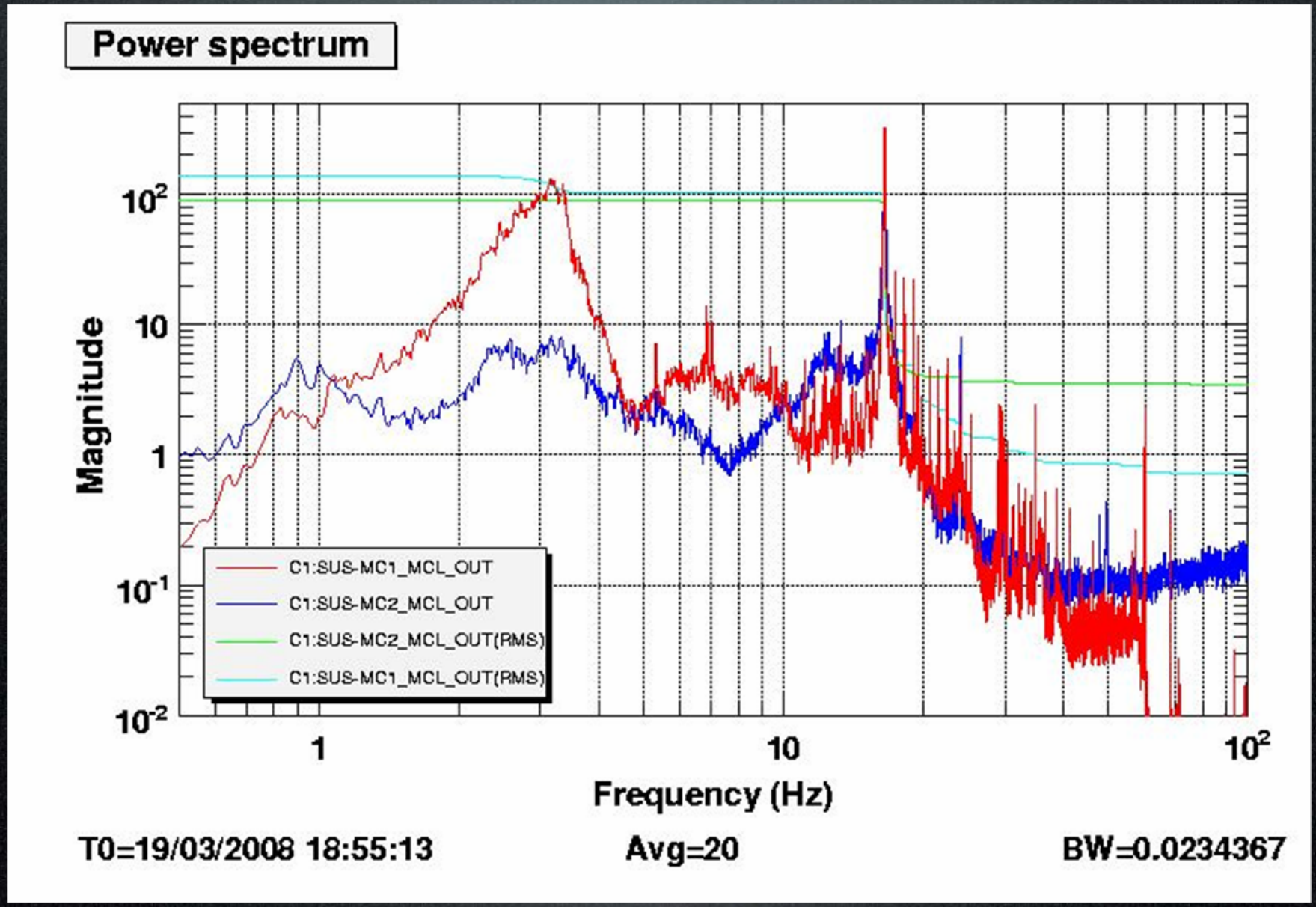


At the 40m

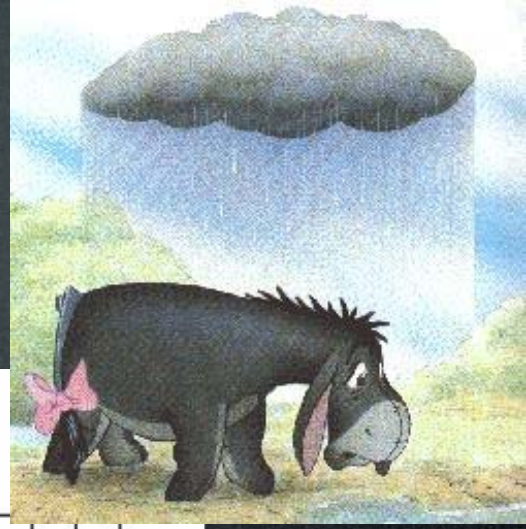
- Test on input mode-cleaner

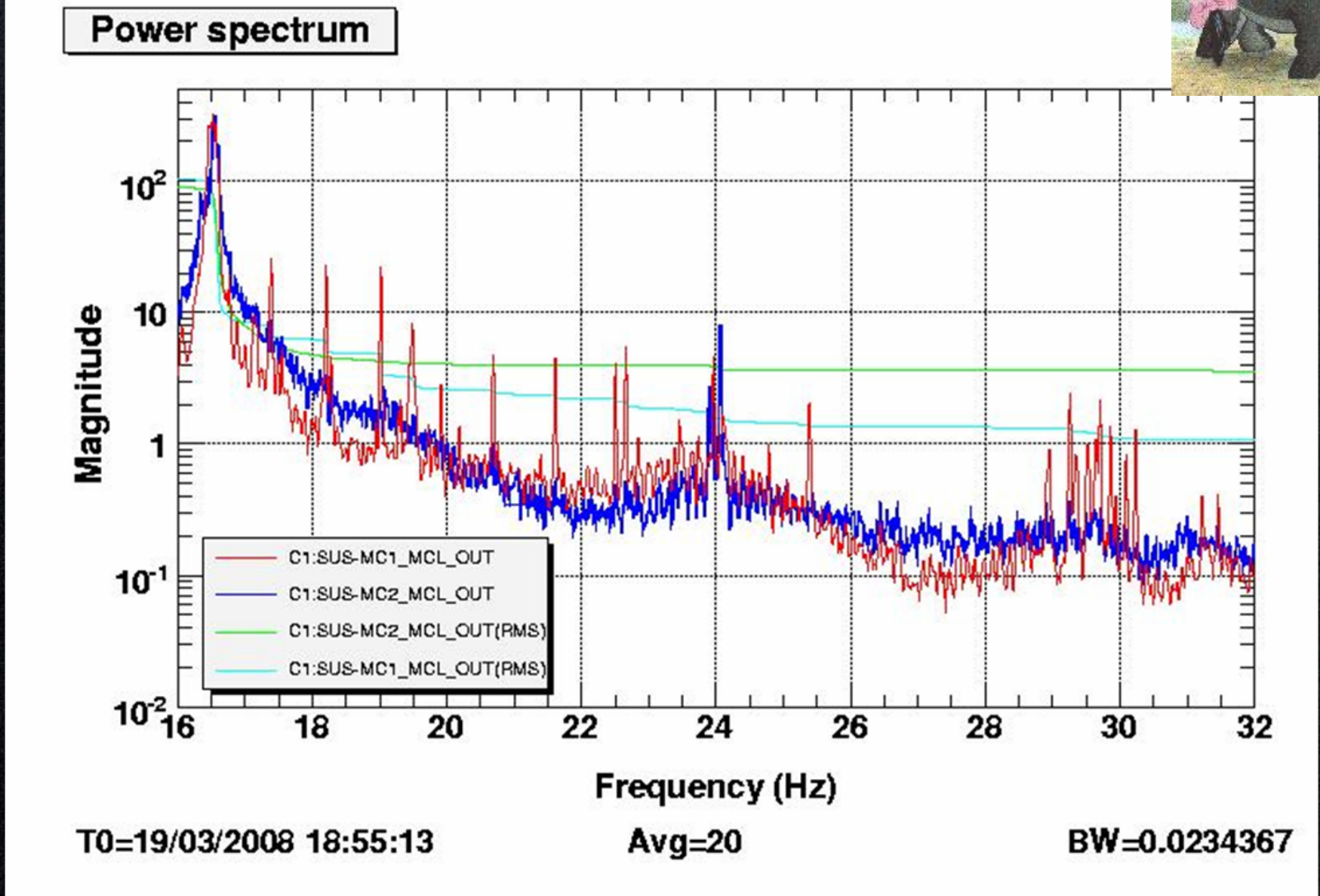


At the 40m

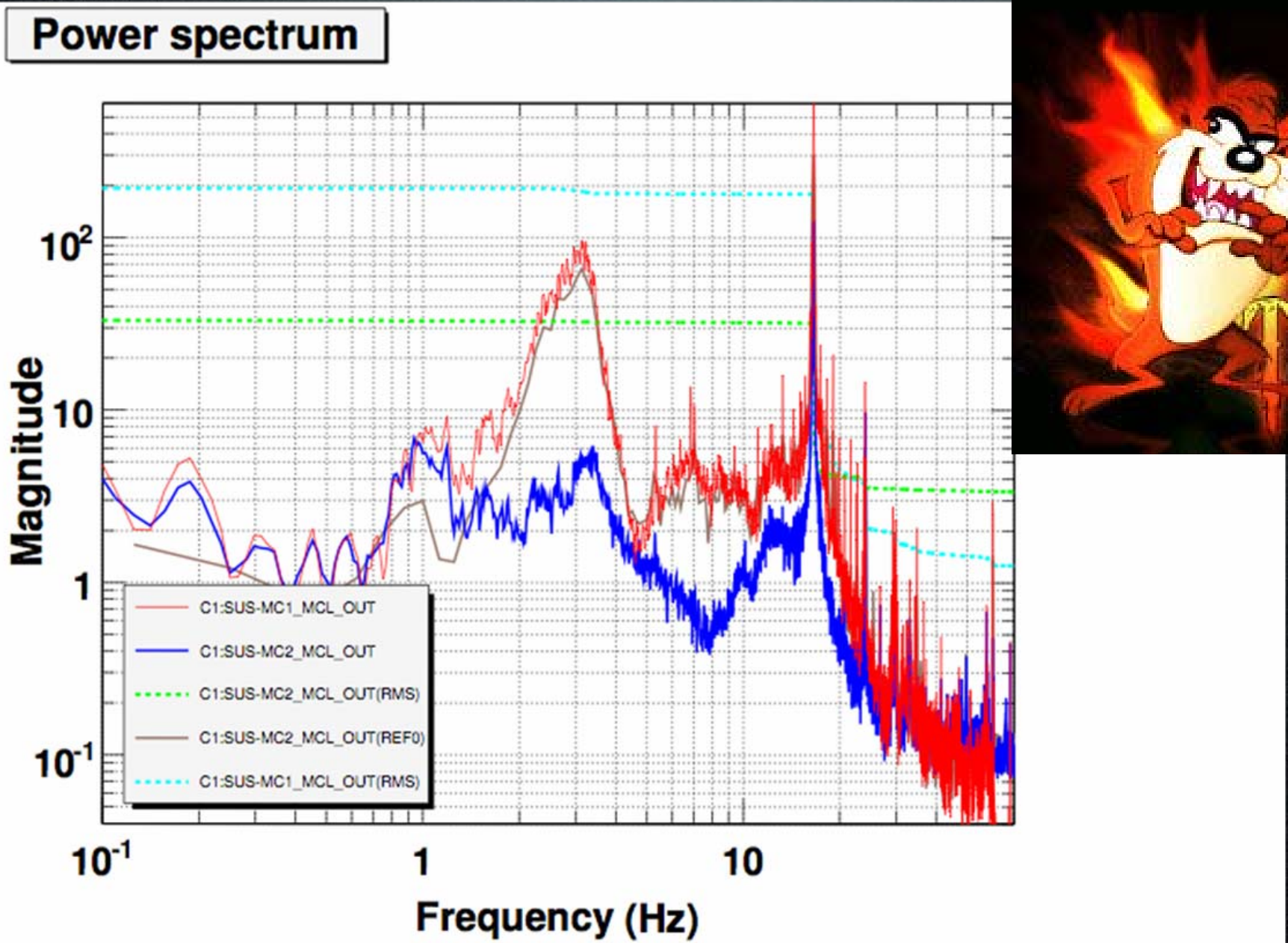

Power spectrum
Magnitude
10^2
10
1
10^{-1}
10^{-2}
1
10
10^2
Frequency (Hz)
C1:SUS-MC1_MCL_OUT
C1:SUS-MC2_MCL_OUT
C1:SUS-MC2_MCL_OUT(RMS)
C1:SUS-MC1_MCL_OUT(RMS)
T0=19/03/2008 18:55:13
Avg=20
BW=0.0234367

At the 40m




Power spectrum
Magnitude
10^2
10
1
10^{-1}
10^{-2}
16
18
20
22
24
26
28
30
32
Frequency (Hz)
C1:SUS-MC1_MCL_OUT
C1:SUS-MC2_MCL_OUT
C1:SUS-MC2_MCL_OUT(RMS)
C1:SUS-MC1_MCL_OUT(RMS)
T0=19/03/2008 18:55:13
Avg=20
BW=0.0234367

And more !


Power spectrum
Magnitude
10^2
10
1
10^{-1}
C1:SUS-MC1_MCL_OUT
C1:SUS-MC2_MCL_OUT
C1:SUS-MC2_MCL_OUT(RMS)
C1:SUS-MC2_MCL_OUT(REF0)
C1:SUS-MC1_MCL_OUT(RMS)
10^{-1}
1
10
Frequency (Hz)
*T0=19/03/2008 22:24:32 Avg=20
*BW=0.0234367

TAZ