Simulated Data Sets

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Goal:

Generate "noise" with spectral character of LIGO I

Use:

Monte Carlo testing of, e.g., data analysis pipelines, artifact removal

Requirements:

- Deliver in Frames
- Instrument artifacts — Power lines, Violin modes, transients, ...
- Signals
- (non) Gaussian background

} Better than "Real-time" Performance

Expression of interest:

Ed Daw, Bernard Whiting, Susan Scott

Relationship to E2E:

"Macro" vs. "Micro" model – eventually integrated into E2E

General Design:

Quasi-Stationary Background

Seismic noise: *ground measurements + Hytec xfer function*

Thermal, shot, rad pressure: *linear filters + white noise*

Power lines
Transients
Signals
} *Add-ons*

Implementation:

Prototype: Matlab

Final: E2E (DMT?)

Schedule:

First Matlab Prototype 1 November 1999

- Fundamental noise (includes violin modes)
- Seismic noise
- No frames

Second Matlab Prototype 15 December 1999

- Writes frames
- Simple transients
- Non-Gaussian noise (mixture Gaussian)

Simulating Thermal Noise from Structurally-damped Systems

Examples:

Violin suspension modes, test masses

Idea:

Linear filter + white noise

$$y = H x \qquad S_x(f) = S_0$$

$$S_y(f) \propto |\tilde{H}(f)|^2 S_x(f)$$

Problem:

$$f_0 \approx 400 \text{ Hz}, \quad Q \gtrsim 10^6, \quad f_s = 16384 \text{ Hz}$$

$$\Delta f_{FWHM} \lesssim \frac{f_0}{Q} \simeq 4 \cdot 10^{-4} \text{ Hz}$$

$$N_{FIR} \gg f_s/\Delta f \simeq 4.1 \cdot 10^{7} \text{ !}$$

Problem:

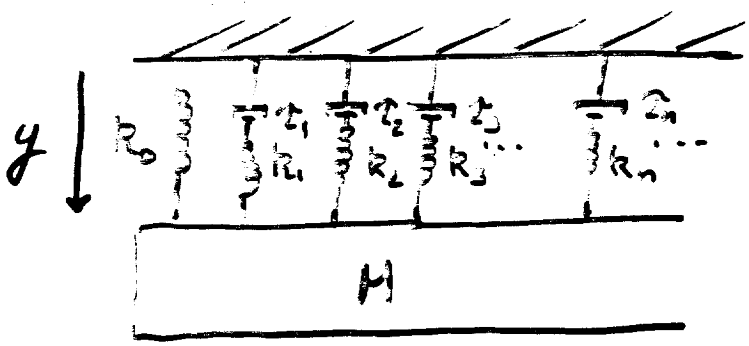
1) $H(t<0) = 0$ — Causality
2) $H(s)$ has poles in left-half-plane — Stability
3) $|\tilde{H}(f)|^2 \propto \frac{\phi}{f} \frac{1}{(f^2-f_0^2)^2 + (f_0^2 \phi)^2}$ — Spectrum

Note: ϕ constant in-band, but can't be constant everywhere

Note :

① Causality ($H(t<0)=0$) $\longrightarrow$ $\mathcal{H}(2\pi i f) = \tilde{H}(f)$

② Adopt physical system model to get "physical" $\phi(f)$



$$\Phi \simeq \sum_n^N \frac{R_n}{R_0} \frac{2\pi f \tau_n}{1+(2\pi f \tau_n)^2}$$

choose $\frac{R_n}{R_0} = \varepsilon$

τ_k / τ_{k+1} constant

③ "Factor" $|\mathcal{H}(s)|^2 = |\tilde{H}(-is/2\pi)|^2 = S_y(-is/2\pi)$

N+2 poles , N zeros

poles, zeros in left half-plane for stability, invertibility

N = 2 · # decades gives ϕ constant to better than ε%

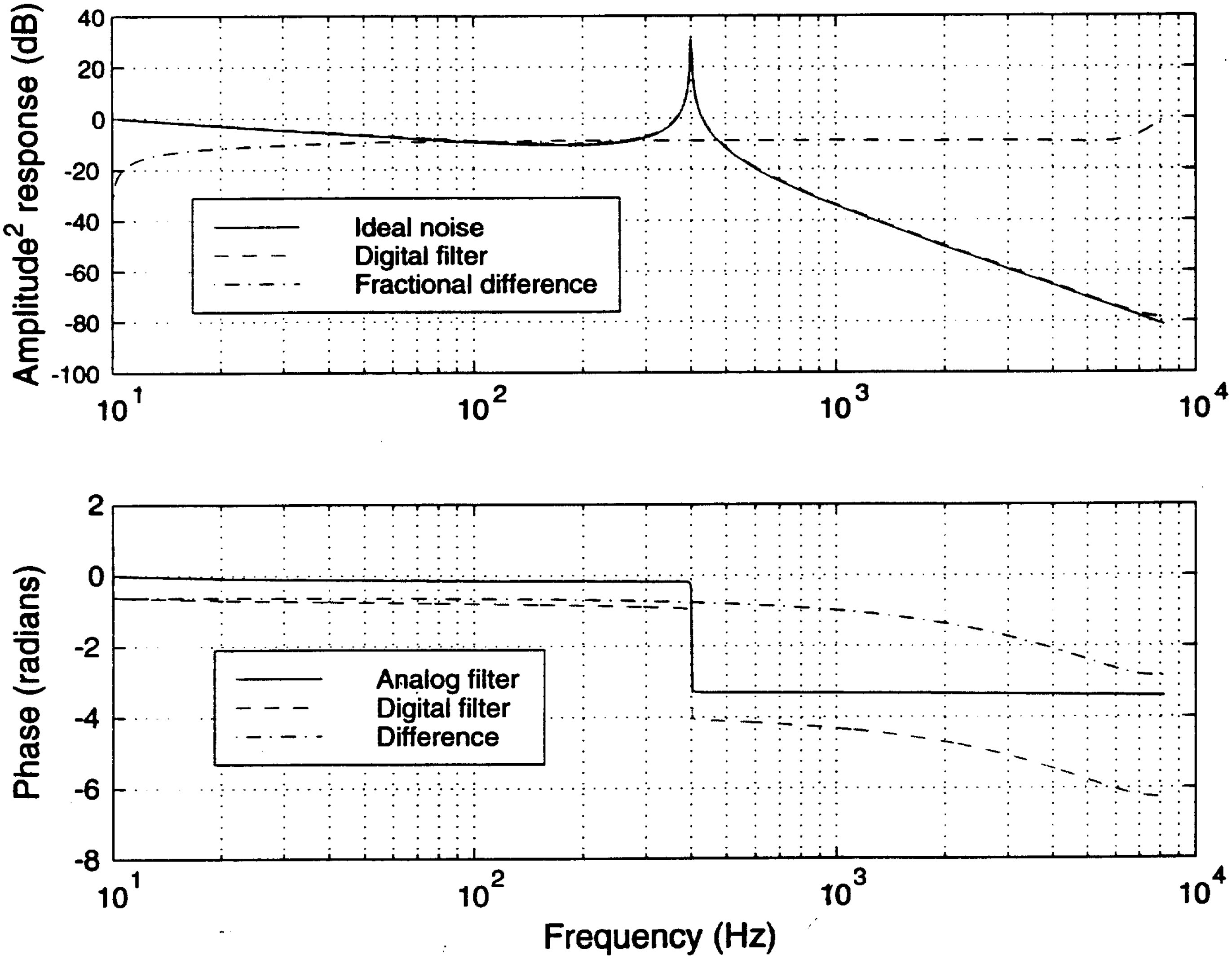
④ Continuum to discrete time (analog to digital) transformation

State Space :

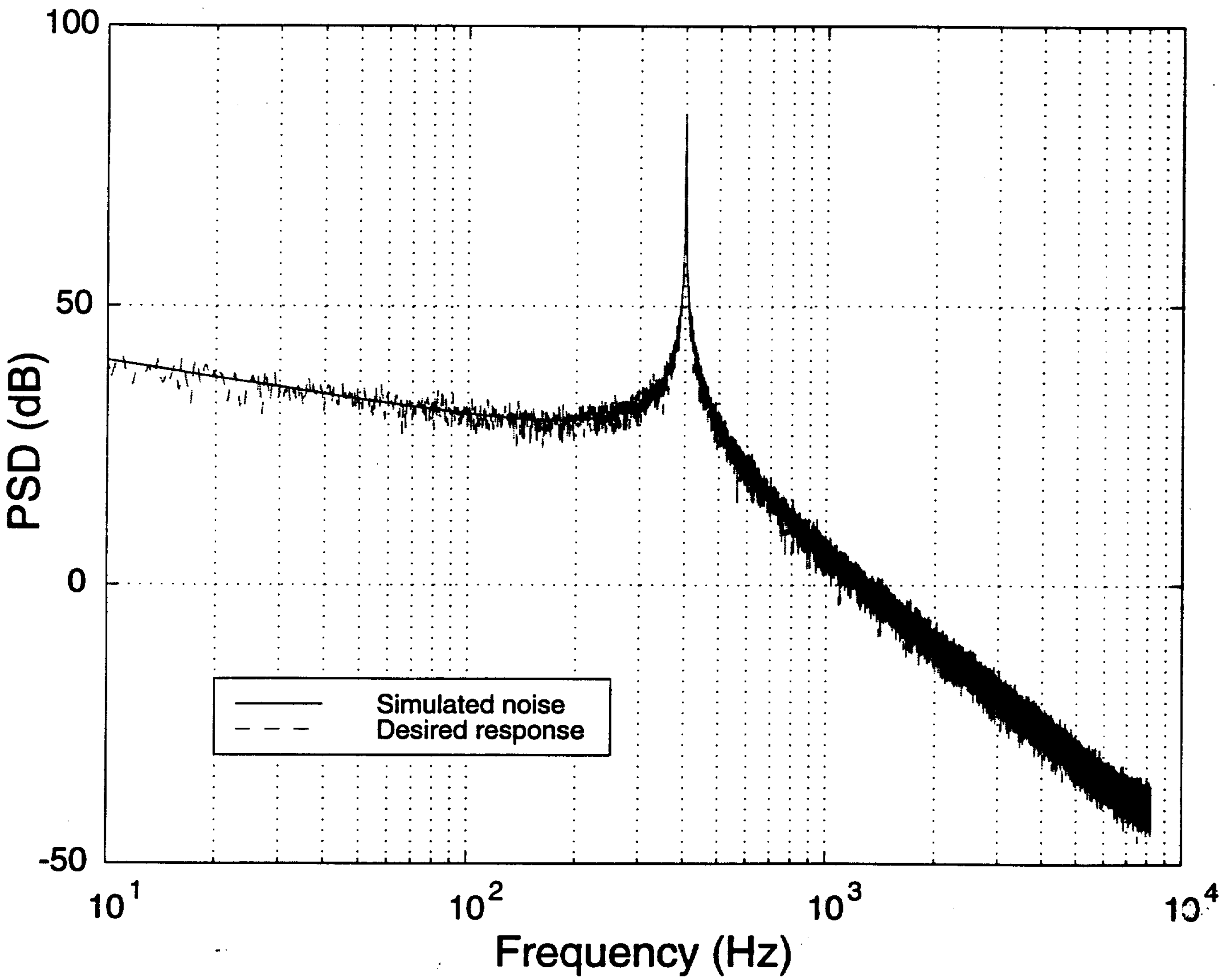
~~state~~ $\longrightarrow$ $\dot{x} = A \cdot x + Bu$ (input) $\longrightarrow$ $x[k] = e^{A/f_s} \cdot x[k-1] + Bu[k]$

$y = C \cdot x + 0$ $\qquad$ $y[k] = C \cdot x[k]$

No direct input!



Amplitude² response (dB)
40
20
0
-20
-40
-60
-80
-100
Ideal noise
Digital filter
Fractional difference
10^1
10^2
10^3
10^4
Phase (radians)
2
0
-2
-4
-6
-8
Analog filter
Digital filter
Difference
10^1
10^2
10^3
10^4
Frequency (Hz)


100
50
0
-50
PSD (dB)
Simulated noise
Desired response
10^1
10^2
10^3
10^4
Frequency (Hz)

Note 1, Linda Turner, 08/17/99 09:12:34 PM
LIGO-G990079-40-M