A Method of Measuring Low-Noise Acoustical Impulse Responses at High Sampling Rates

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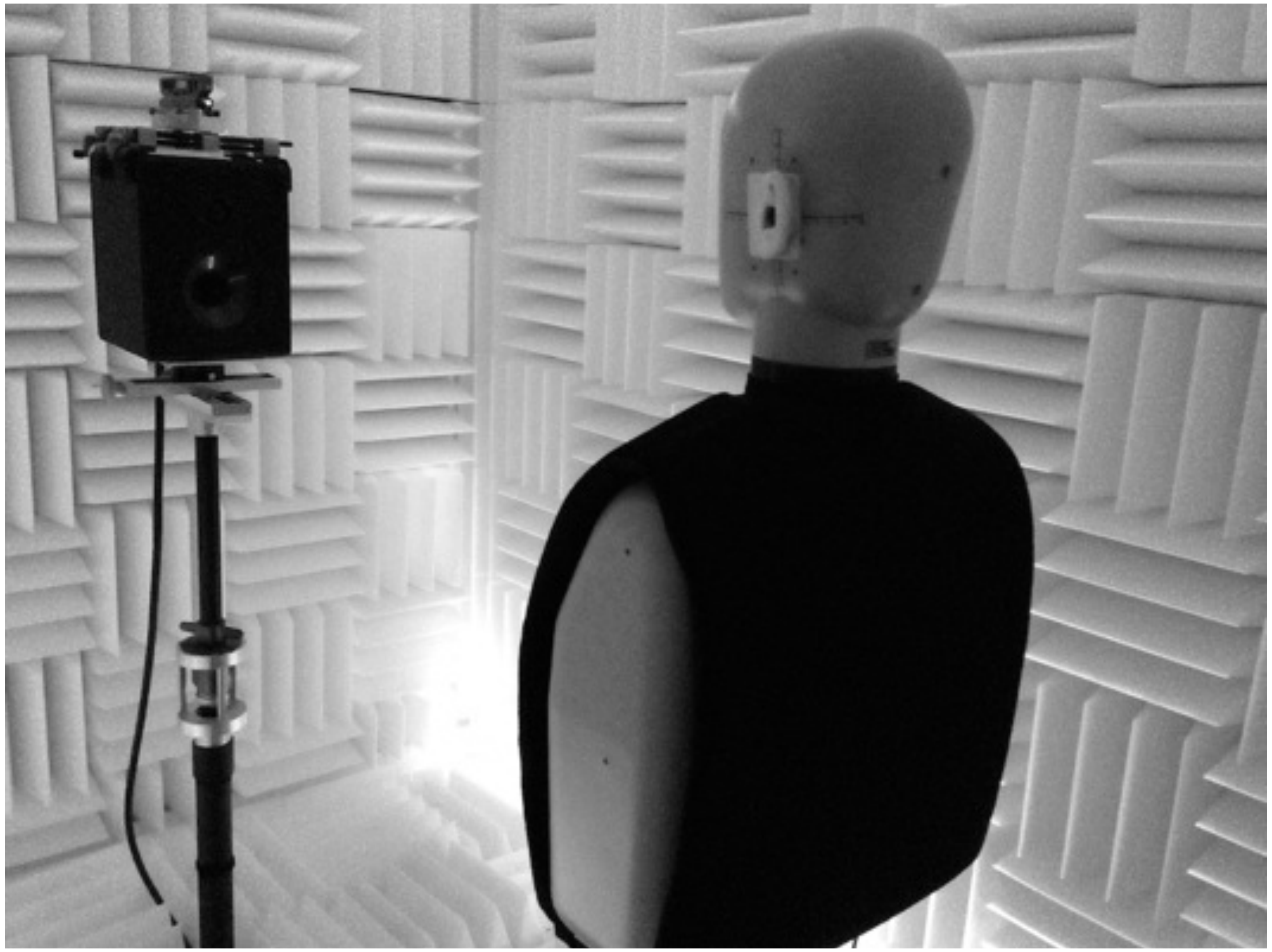
Applications

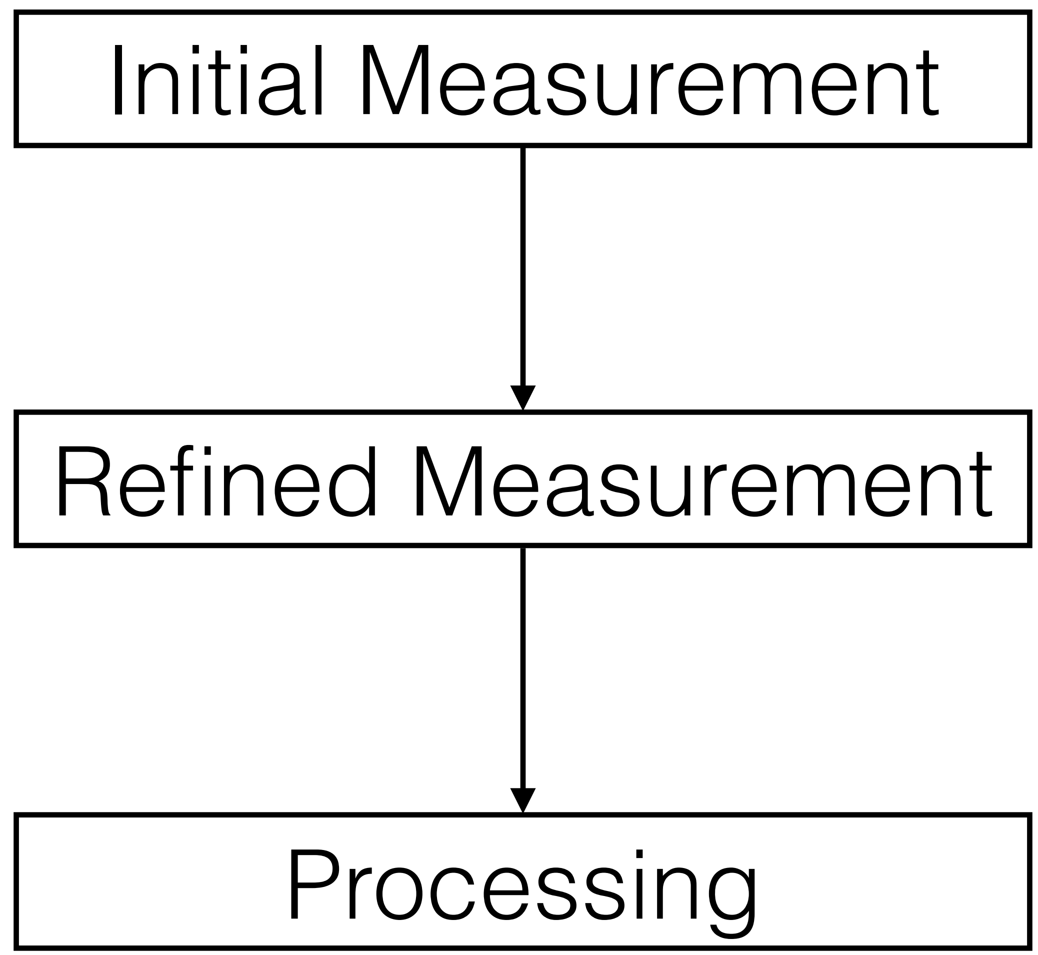


HRTF Measurements
3D3A Lab, Princeton University

Objectives

- Measurements at high sampling rates (>48 kHz)
- Efficient, low-noise, and artifact-free measurements

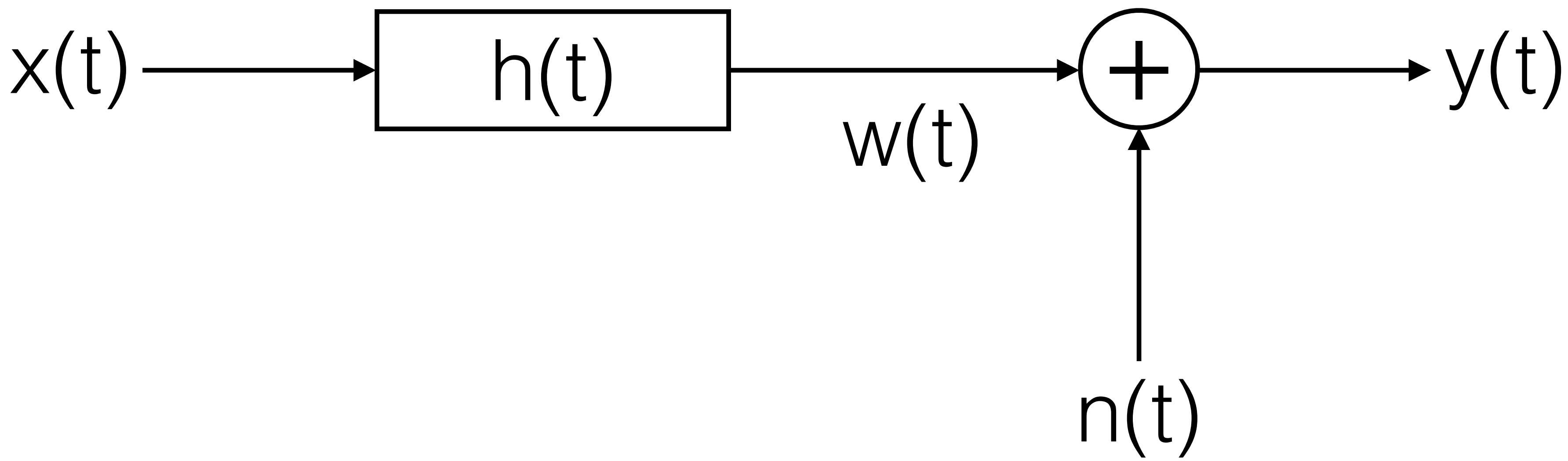
Approach



Outline

- Review: impulse response (IR) measurements
- Measurements at high sampling rates
- Proposed measurement procedure
- Experimental results

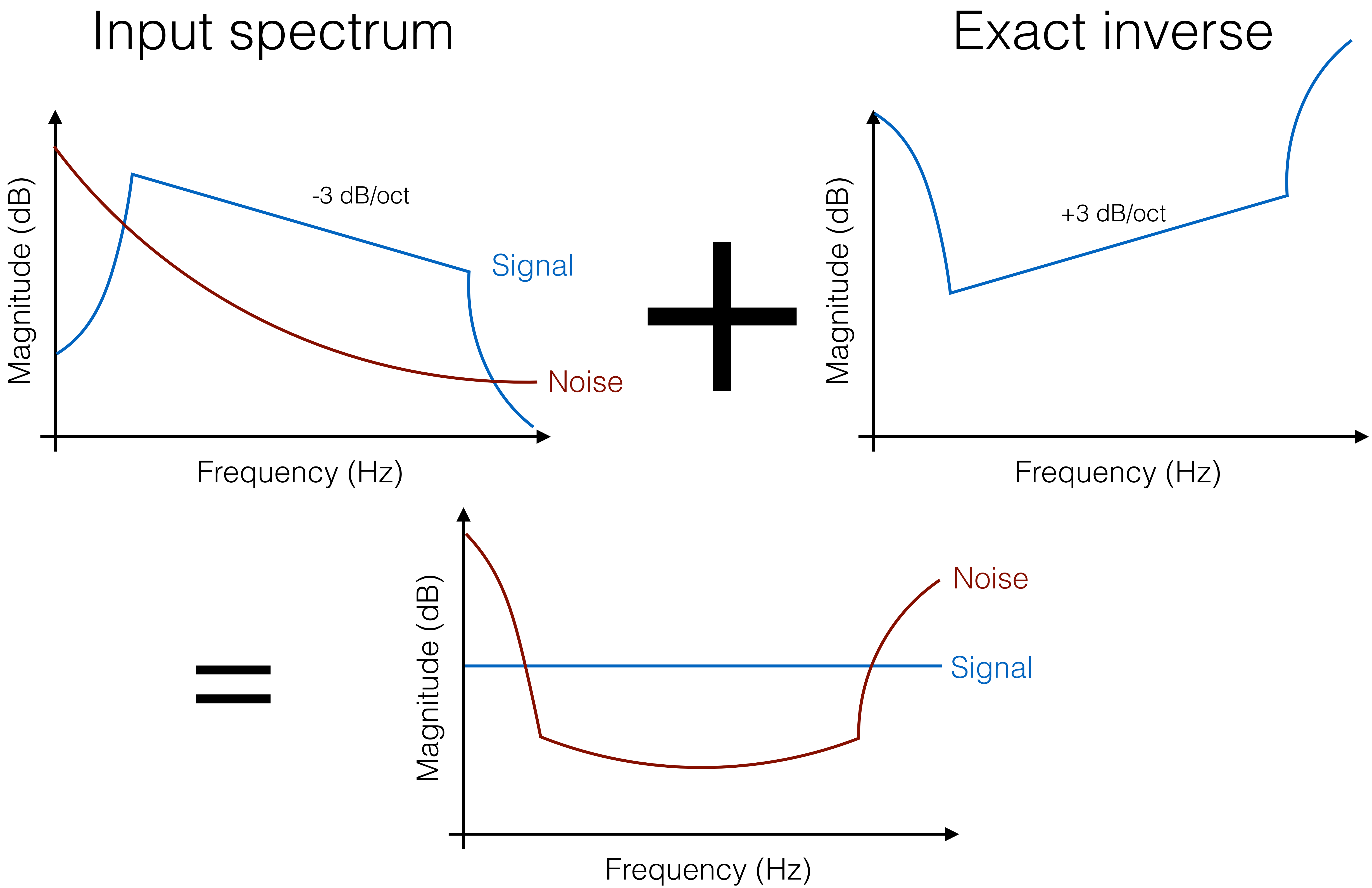
IR Measurements



- Exponential sine sweep (ESS) [1, 2]
- Deconvolution

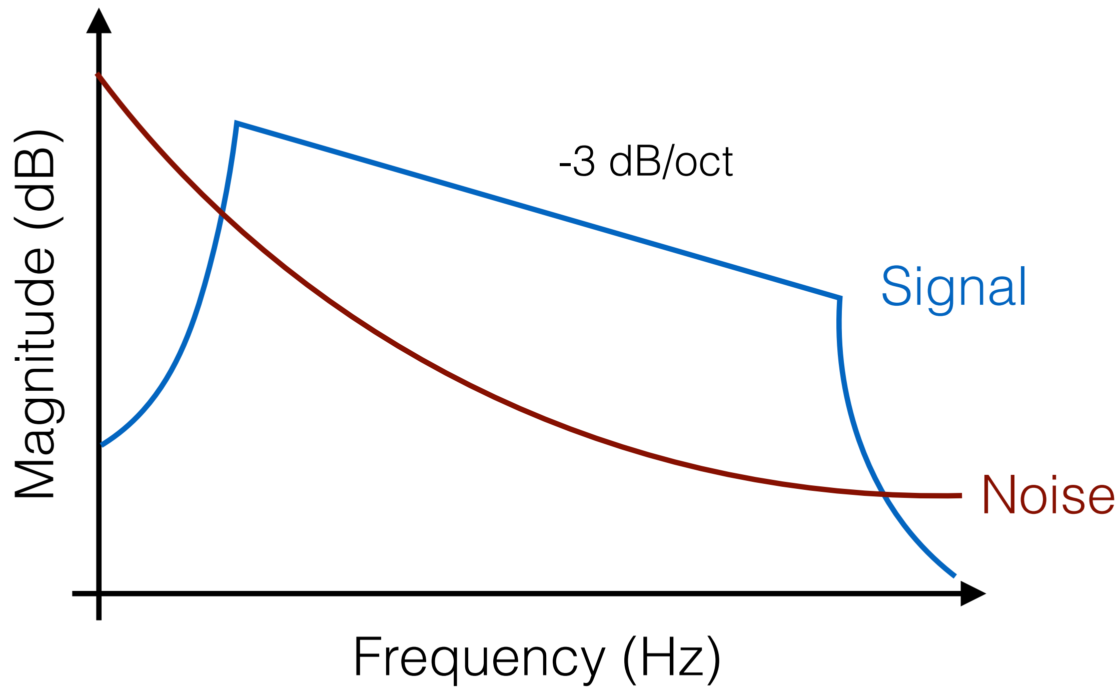
[1] A. Farina (2007) Advancements in Impulse Response Measurements by Sine Sweeps
[2] S. Müller and P. Massarani (2001) Transfer-Function Measurements with Sweeps

Exact Deconvolution

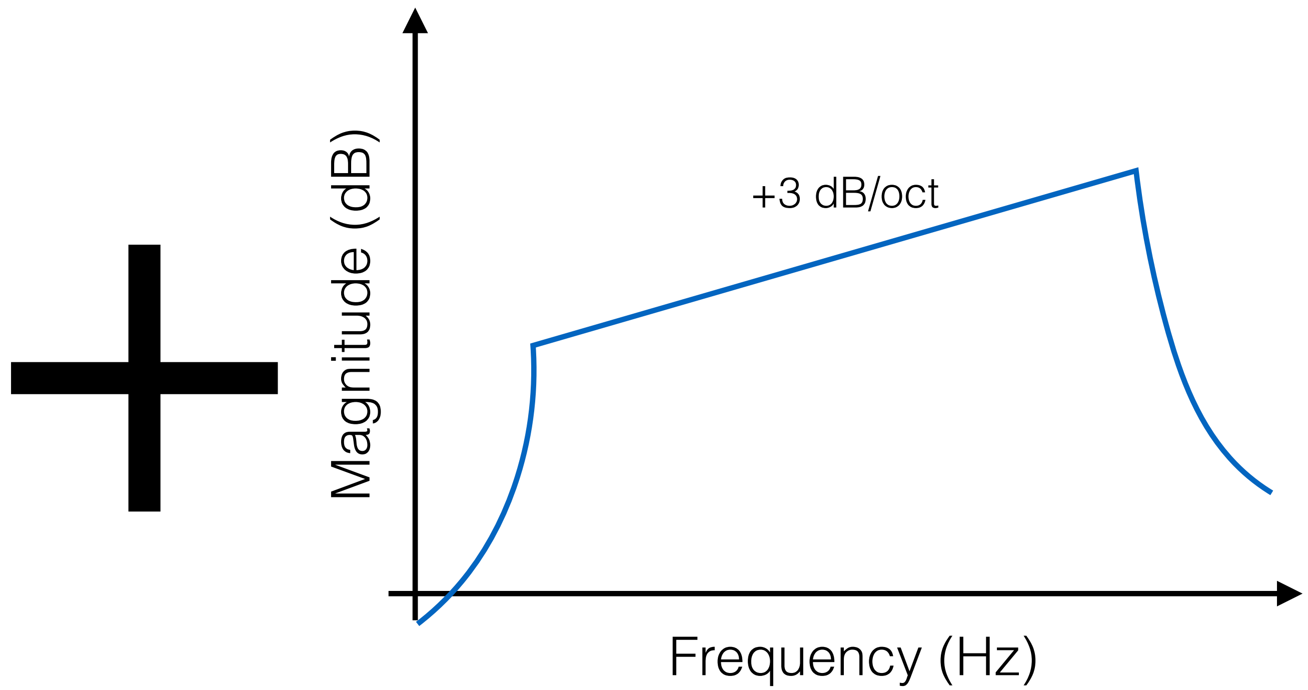


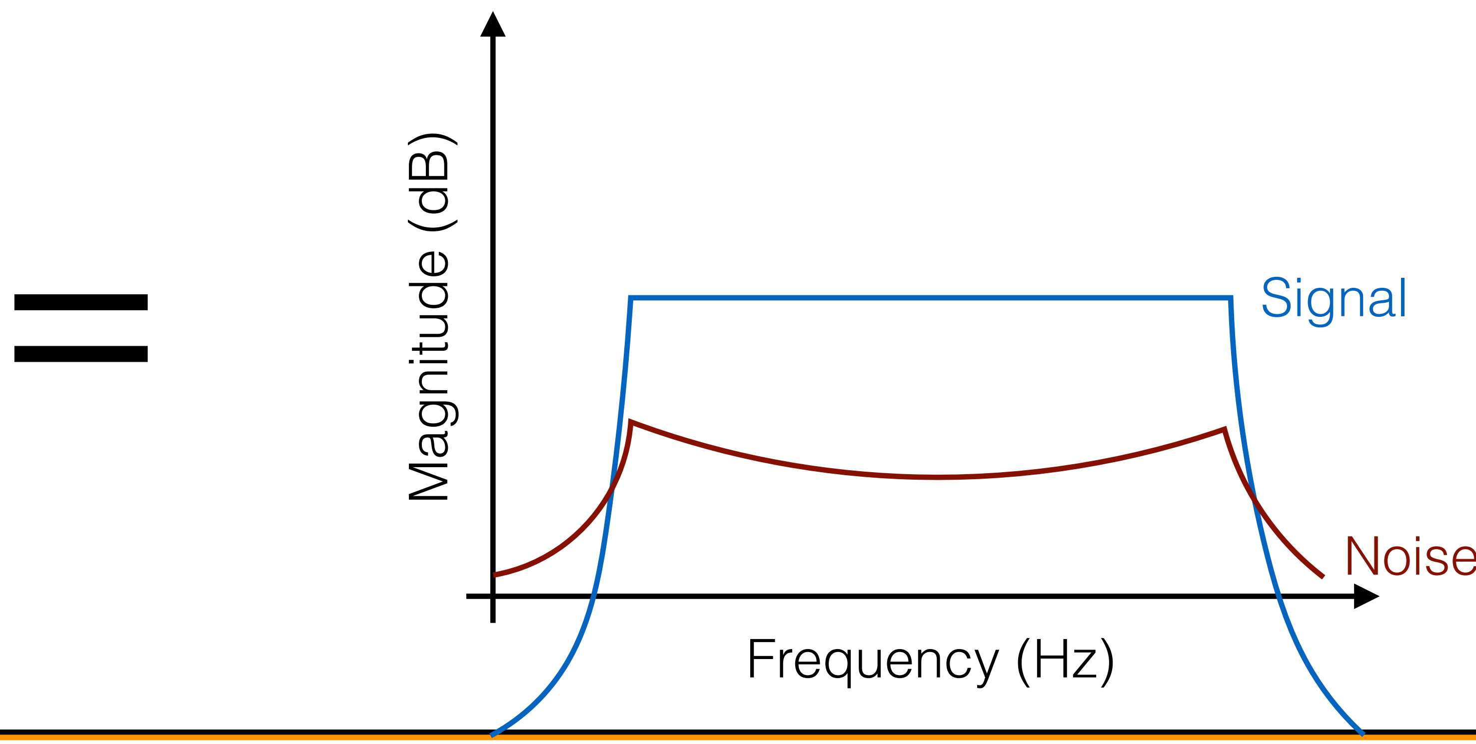
Time-Reversed Deconvolution

Input spectrum

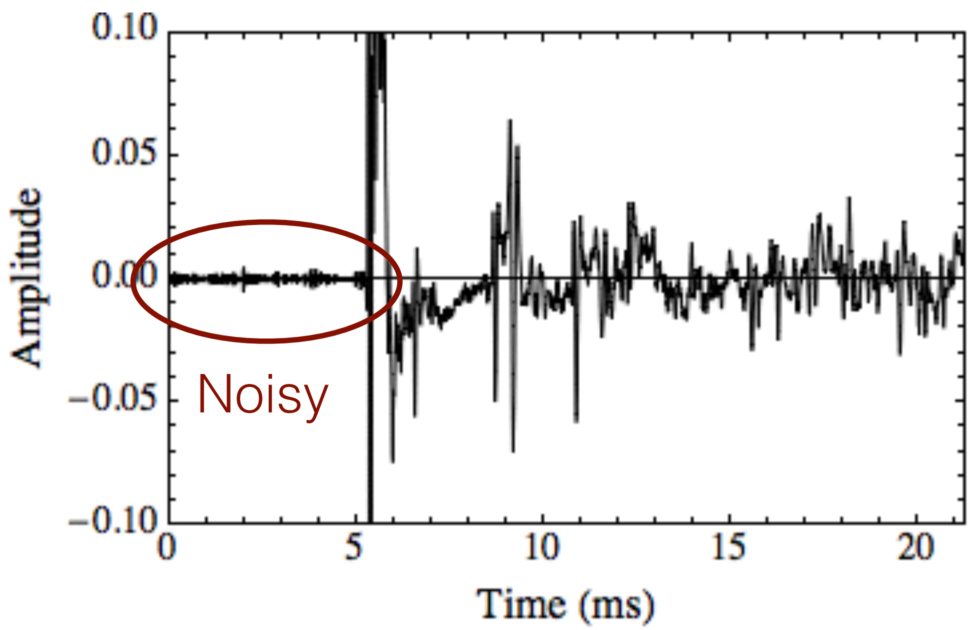


Time-reversed inverse [1]



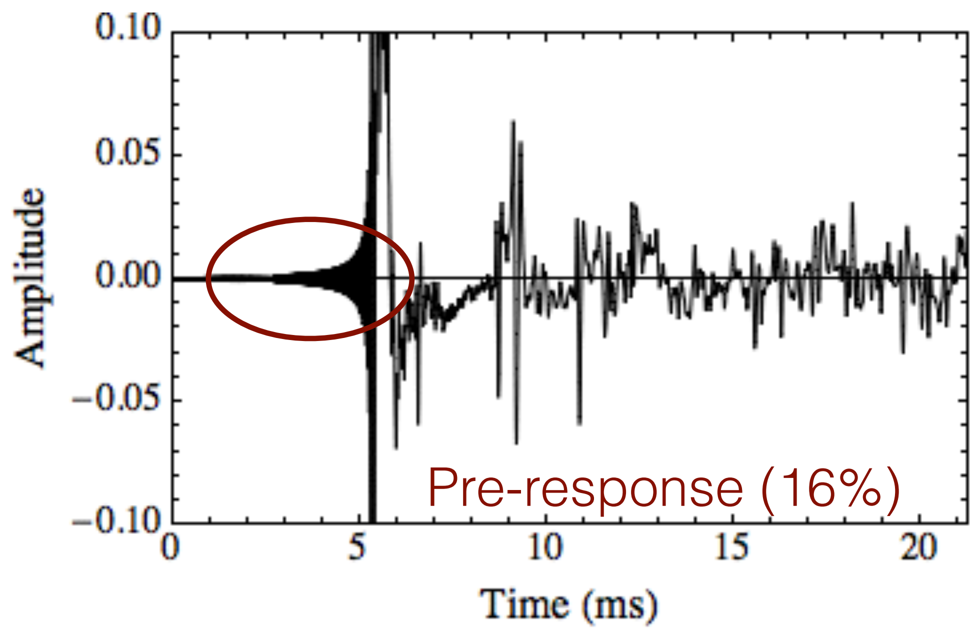


Exact deconvolution



SNR = 25 dB

Time-reversed deconvolution



SNR = 32 dB

An improvement of 7 dB due to BPF

Settings: 96 kHz sampling rate, 5 second sweep from 20 Hz to 24 kHz

Why high sampling rates?

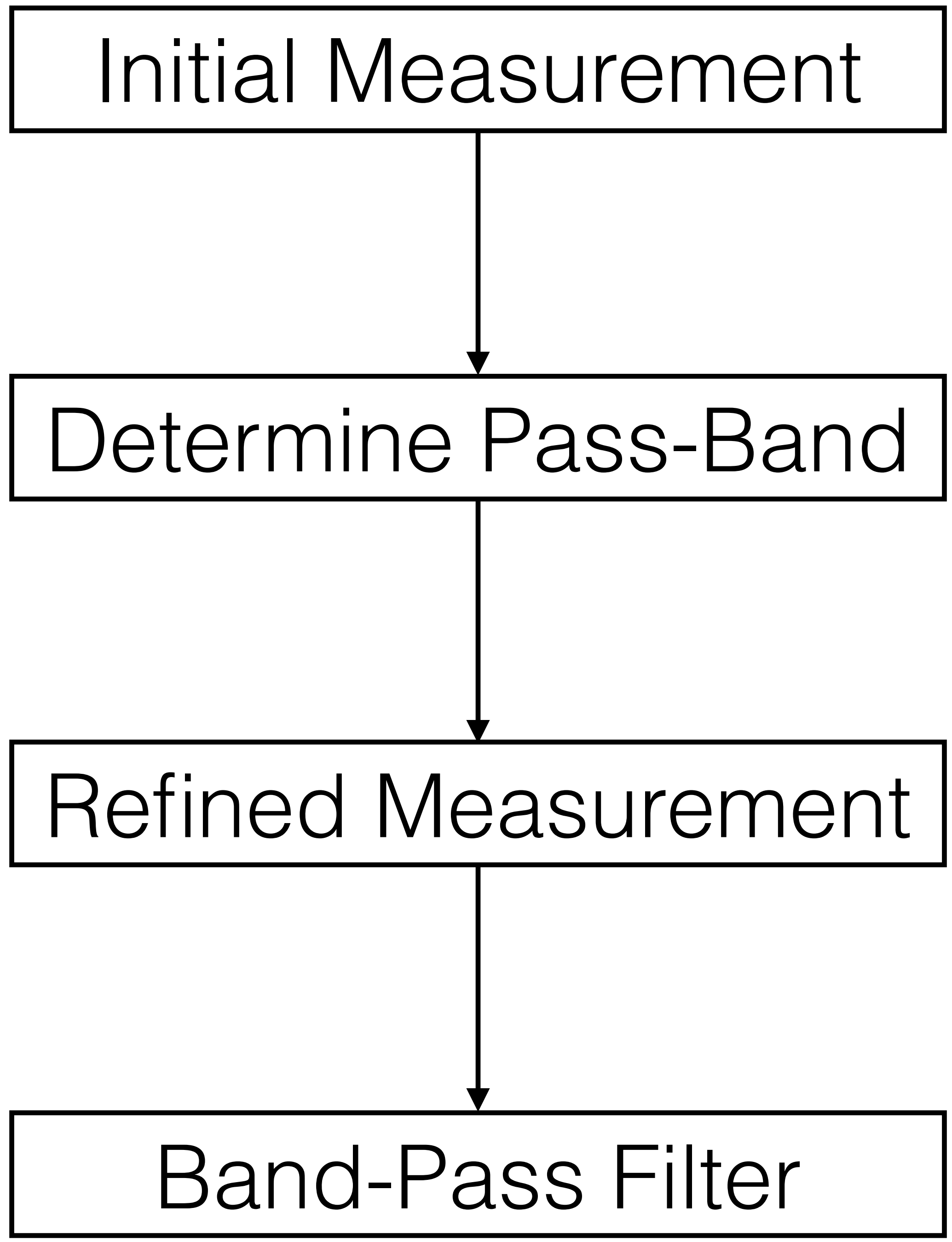
- Ultrasonic transducers
- "Time-smear" [3]
- Minimum interaural time difference ~ 10 μs [4]
- Facilitate subjective tests

[3] P. G. Craven (2004) Antialias Filters and System Transient Response at High Sample Rates
[4] A. W. Mills (1958) On the Minimum Audible Angle

Challenges

- Signal-to-noise ratio (SNR)
- Deconvolution issues
- Transducer heating/damage

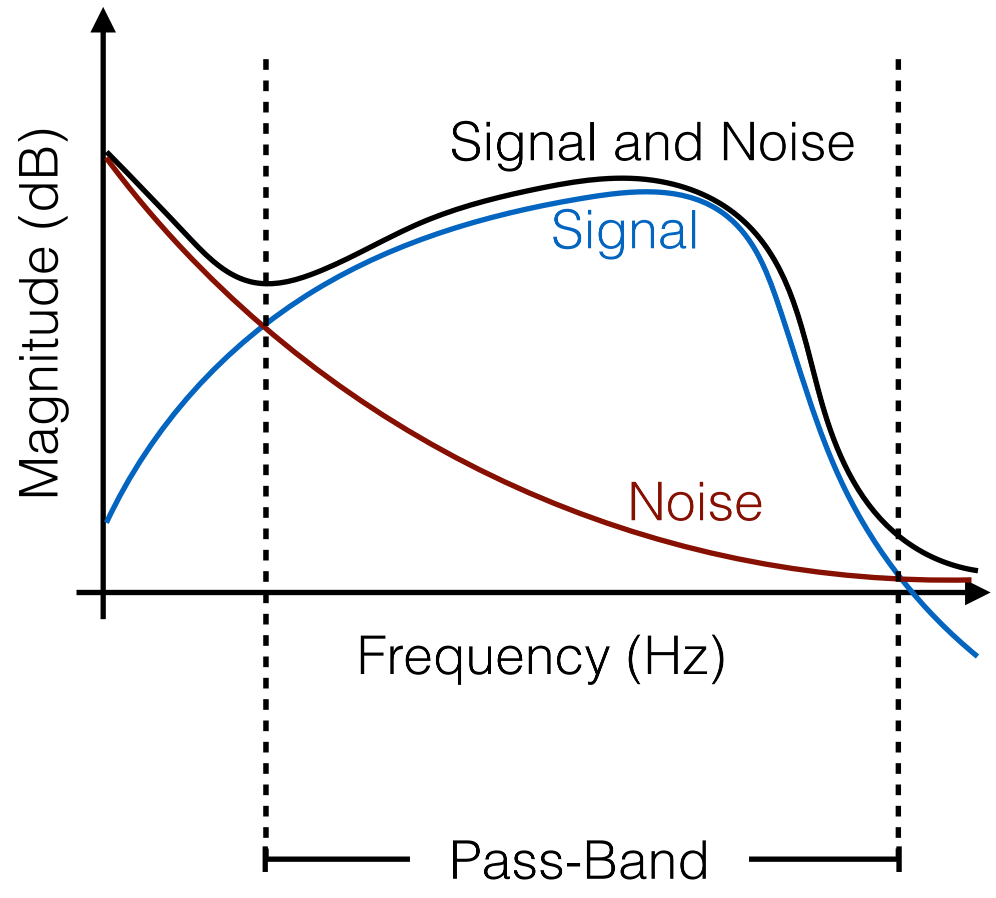
Measurement Procedure



Defining the Pass-Band

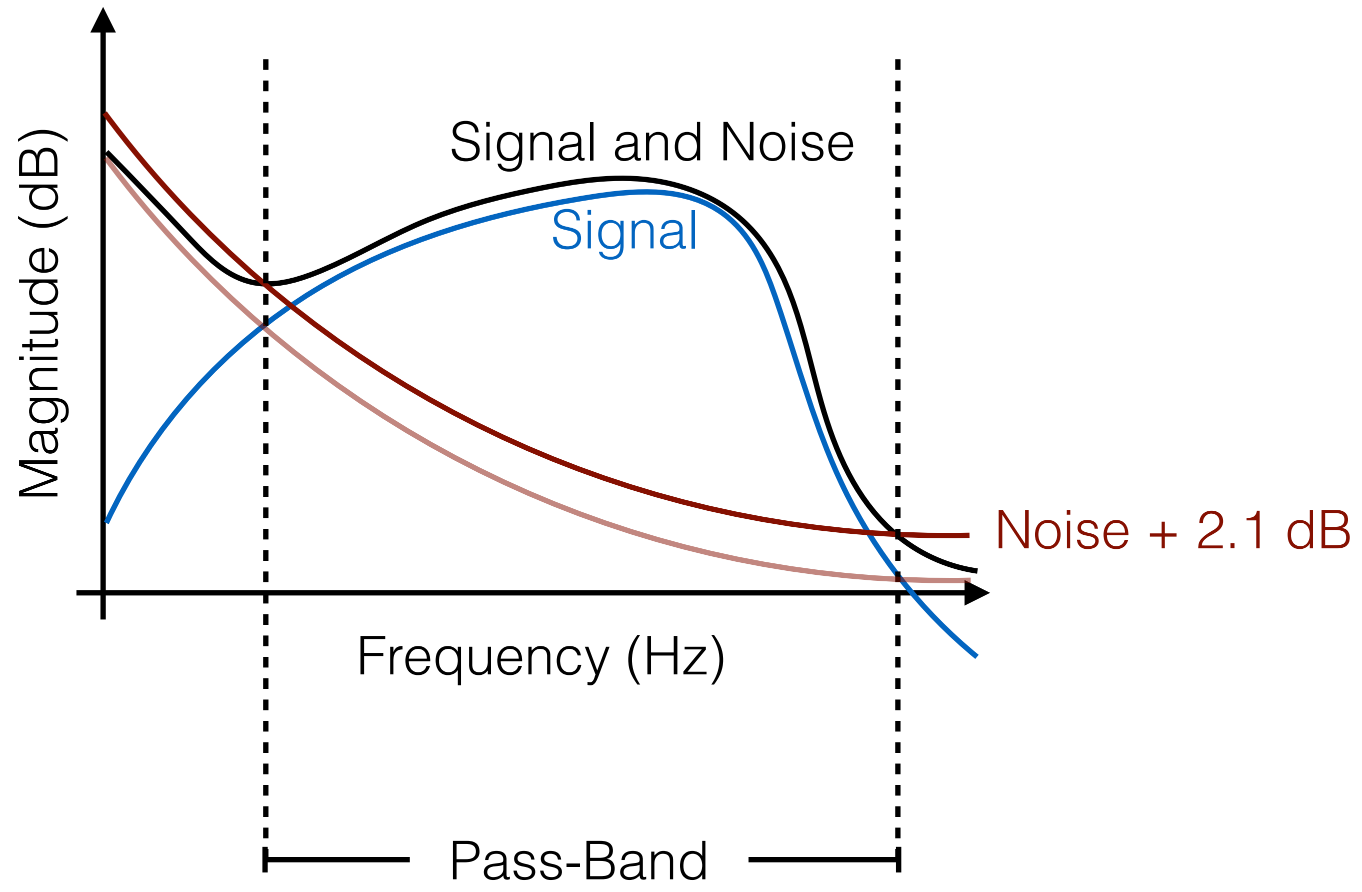
- Improved signal-to-noise ratio
- Minimal filtering artifacts (PDA)
- User preferences
- Cost function?

Optimal SNR



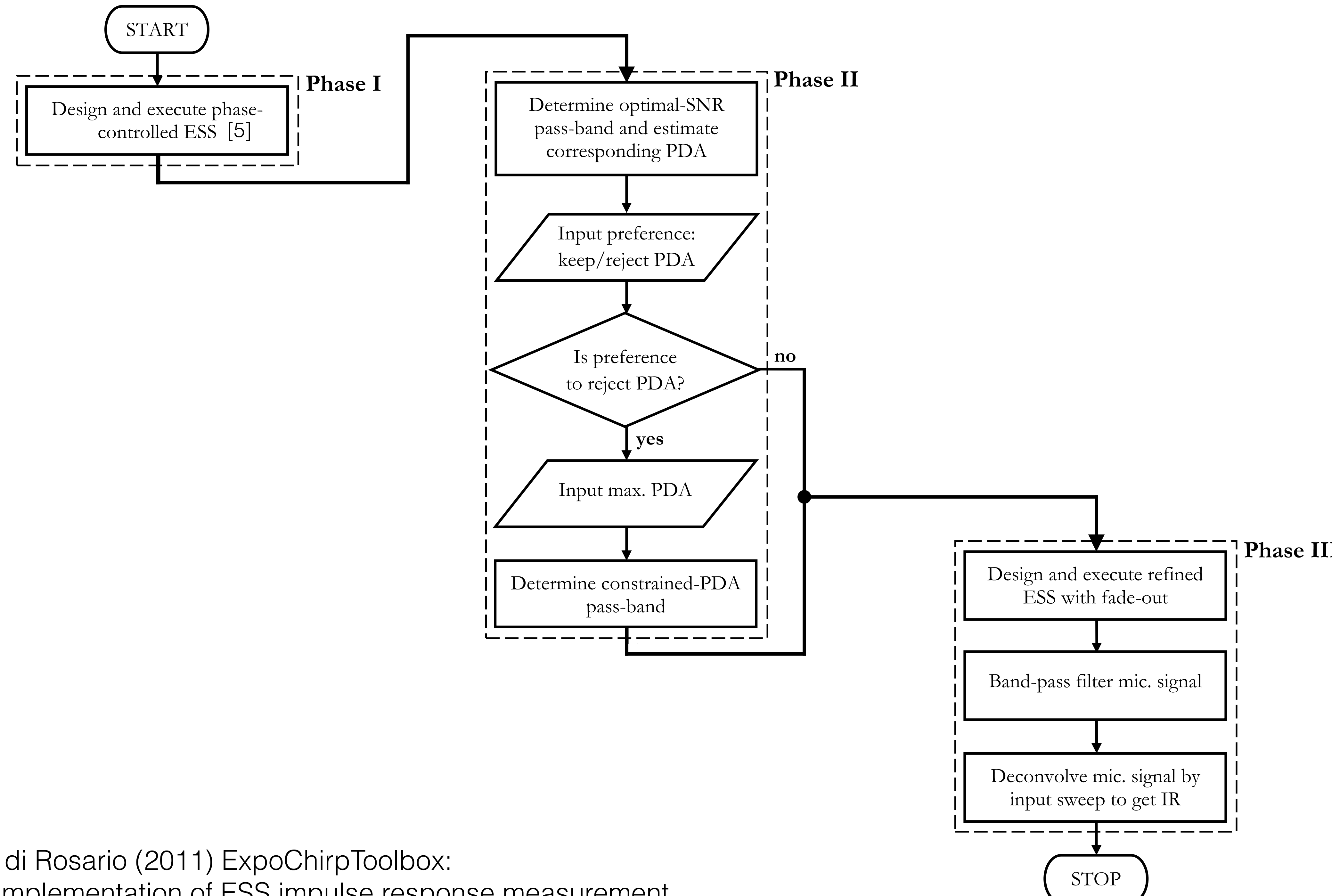
Magnitude (dB)
Signal and Noise
Signal
Noise
Frequency (Hz)
Pass-Band

Optimal SNR



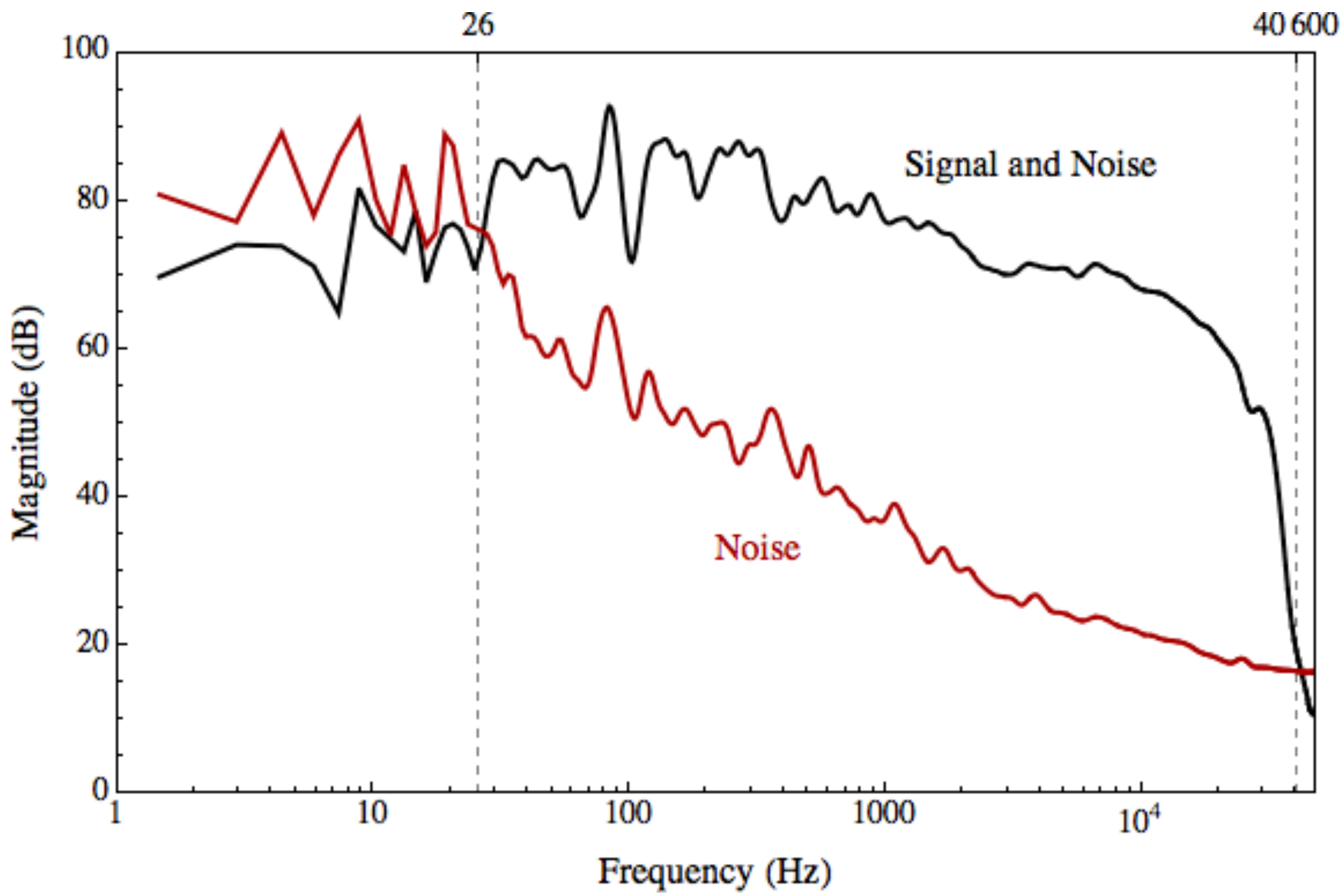
Magnitude (dB)
Signal and Noise
Signal
Noise + 2.1 dB
Frequency (Hz)
Pass-Band

Example Implementation



[5] K. Vetter and S. di Rosario (2011) ExpoChirpToolbox:
a Pure Data implementation of ESS impulse response measurement

Optimal SNR


26
40 600
100
80
60
40
20
0
Magnitude (dB)
Signal and Noise
Noise
1
10
100
1000
10^4
Frequency (Hz)

Results

Note: all measurements were performed with an output level of 75 dB SPL (1 kHz, 1 m)

	Sweep Length (s)	Frequency Range	Raw SNR (dB)	BPF SNR (dB)	Pre-response Peak (%)
Initial Measurement	~1	23 Hz — 48 kHz	21	—	—
Optimal SNR	5	26 Hz — 40.6 kHz	24	37	<0.2
Conventional ESS	5	20 Hz — 24 kHz	25	32	16

Exact deconv.

Time-reversed deconv.

Summary

- IR measurements at high sampling rates (>48 kHz)
- Customizable measurement procedure
- SNR improvement with minimal filtering artifacts

Acknowledgements

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Thank You

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References

1. A. Farina, "Advancements in Impulse Response Measurements by Sine Sweeps," presented at the AES 122nd Convention, May 2007.

2. S. Müller and P. Massarani, "Transfer-Function Measurements with Sweeps," J. Audio Eng. Soc., 49(6):443-471, 2001.

3. P. G. Craven, "Antialias Filters and System Transient Response at High Sample Rates," J. Audio Eng. Soc., 52(3):216-242, 2004.

4. A. W. Mills, "On the Minimum Audible Angle," J. Acoust. Soc. Am., 30(4):237-246, 1958.

5. K. Vetter and S. di Rosario, "ExpoChirpToolbox: a Pure Data implementation of ESS impulse response measurement," presented at the 4th Pure Data Convention, 2011.