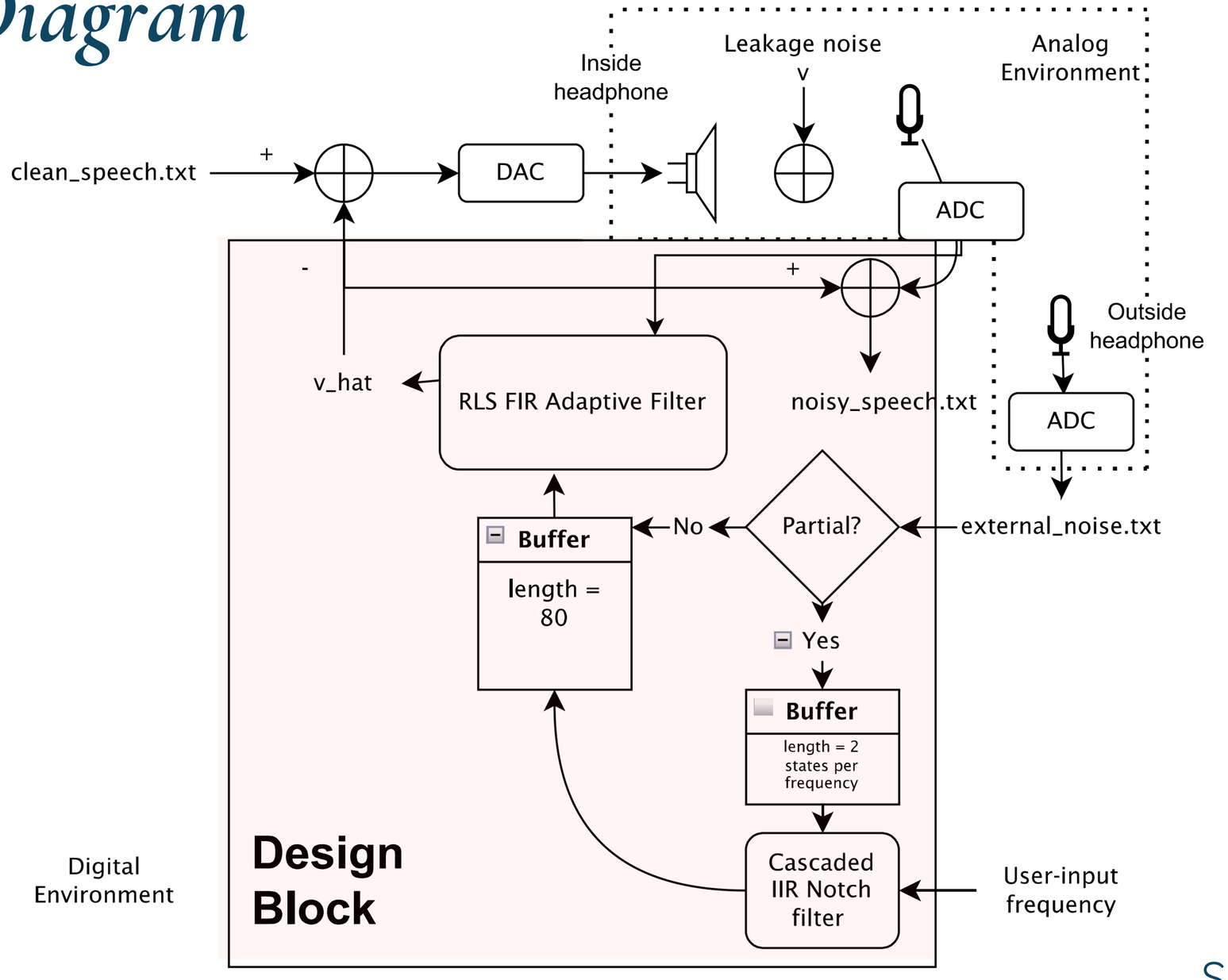
Block Diagram



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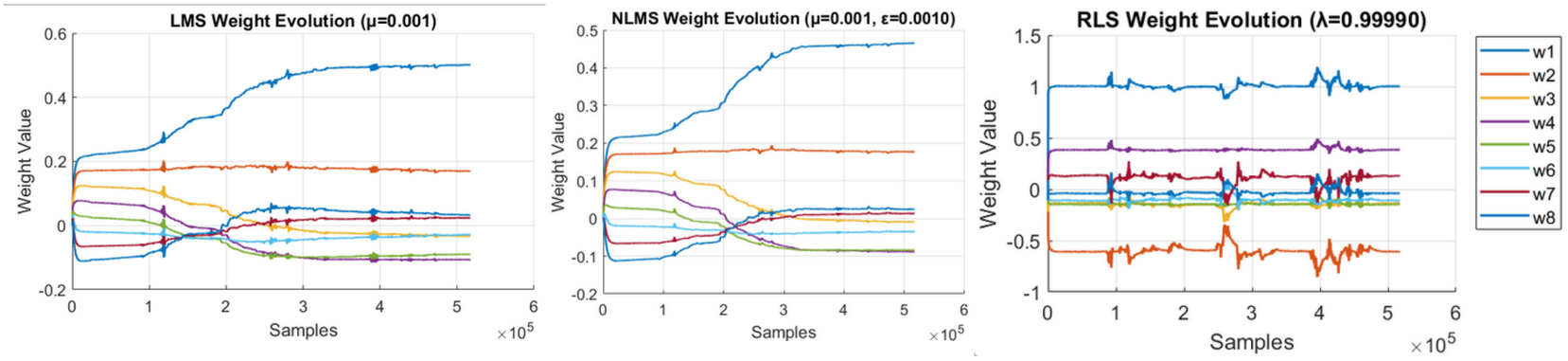
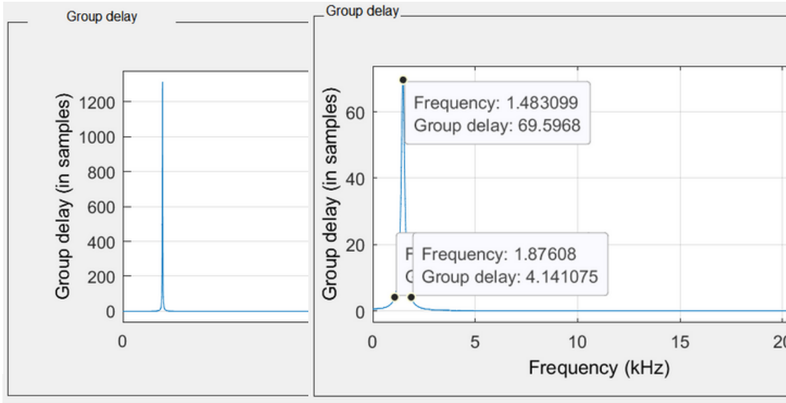
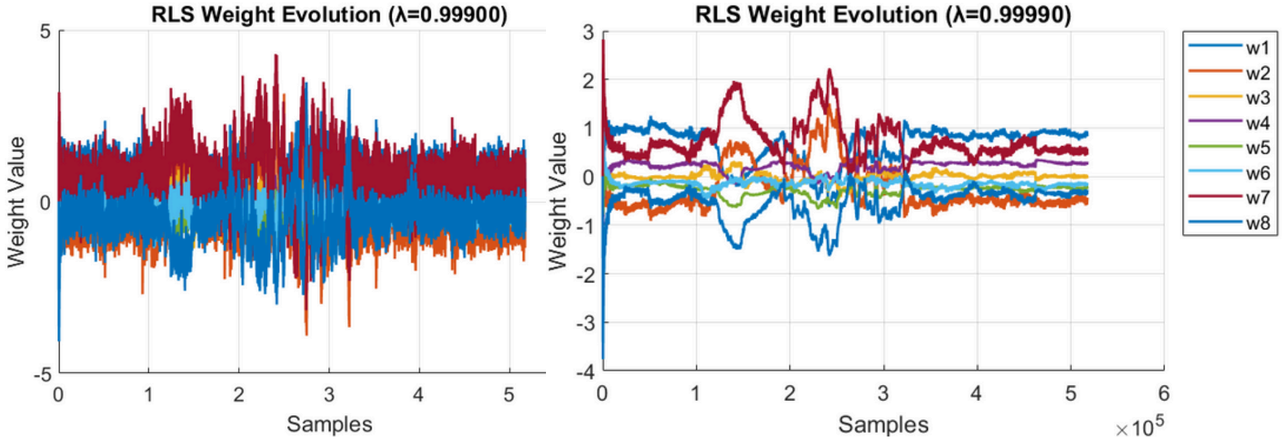
Design Choices



Plots of Weight Evolution for full suppression



- Chose r = 0.9857 because BW = 200Hz for each notch filter causes delay of 70 samples/1.5ms latency.



Plots of Weight Evolution for partial suppression for RLS with lambda as 0.999 and 0.9999. So the value of lambda chosen was 0..9999

Feature	RLS	LMS	NLMS
Algorithm Type	Recursive least-squares minimization	Stochastic gradient descent	Normalized gradient descent
Convergence Speed	Fastest (faster than LMS and NLMS)	Slow (needs many iterations)	Moderate (faster than LMS)
Computational Cost	High $\mathcal{O}(N^2)$	Low $\mathcal{O}(N)$	Low $\mathcal{O}(N)$
Key Parameter	Forgetting factor $\lambda \in [0.98, 1]$	Step size μ	Normalized step size $\mu/\|\mathbf{x}(n)\|^2$
Cost Function	$J(n) = \sum_{k=1}^{n} \lambda^{n-k} \cdot e^2(k)$	$J(n) = e^2(n)$	$J(n) = e^2(n)$

RLS Filter order = 5 gave best SNR but we chose filter order = 8 as it is power of 2 and easy to realise in hardware.

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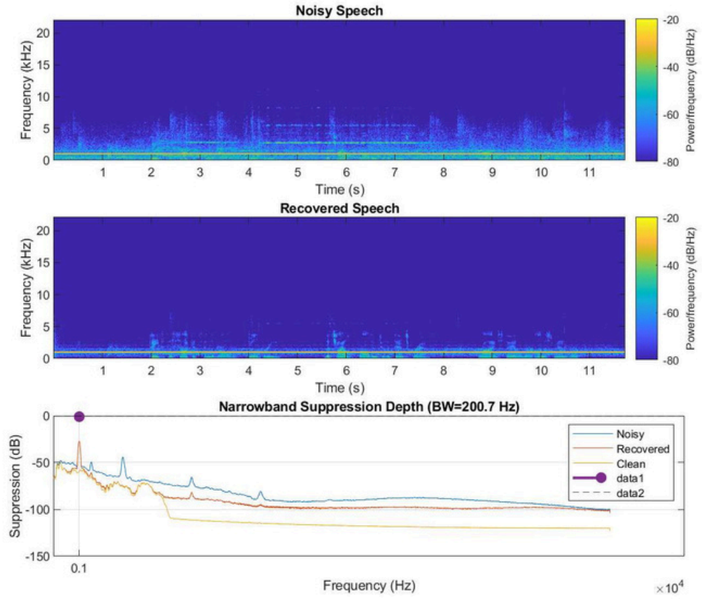
Pros

- Achieved SNR gain of 45.66dB for full suppression
- Achieved ΔTNR = 8.3 dB for partial suppression (single frequency)
- The notch filter is implemented as Transposed Direct Form II and hence buffer size = 2 samples per cycle per notching frequency.
- The tonal reduction from noisy speech is around 1-2dB at user specified tonal frequencies for partial suppression.
- The design was optimised for latency, high SNR, high TNR, low buffer size, convergence stability.
- All the design guidlines are met.

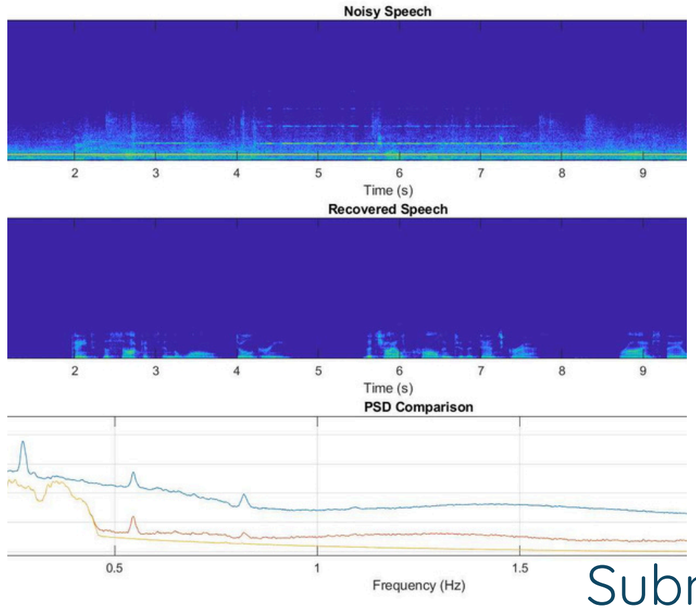
Cons

- Buffer size for RLS with order 8 is 80 samples per cycle.
- Fixed Filter Order: 8th-order RLS may underfit complex noise or overfit simple noise.
- Low TNR values when more than 3 frequencies are entered.
- Time to run the main loop in matlab: Full - 1 second, Partial - 2 seconds.
- RLS may lead to numerical instability and is sensitive to computer round off errors.

Partial suppression results



Full suppression results



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References

- Paulo S. R. Diniz, ”Adaptive Filtering: Algorithms and Practical Implementation”, 5/e, Springer 2020. (Algorithm 5.1 Conventional RLS algorithm)
- Digital Signal Processing John G. Proakis Dimitris K. Manolakis Fourth Edition (Pg 347-Eq4.31)
- THIRD EDITION Discrete-Time Signal Processing Alan V. Oppenheim Ronald W. Schafer (Pg140-Fig6.28, Sec9.2, Example 10.11)
- Signal Processing Toolbox in Matlab: https://in.mathworks.com/help/signal/ref/
- Digital Signal Processing: A Practical Approach: Book by Barrie W. Jervis and Emmanuel C. Ifeachor (Pg 559-560)

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