

Combined Acoustic Echo Cancellation, Dereverberation, and Noise Reduction: A Two Microphone Approach

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I. INTRODUCTION

OBJECTIVE:

Multi-microphone system for echo cancellation and noise reduction.

APPROACH:

Combination of a conventional acoustic echo canceller with a coherence selective filter.

II. Two microphone system for noise reduction and dereverberation

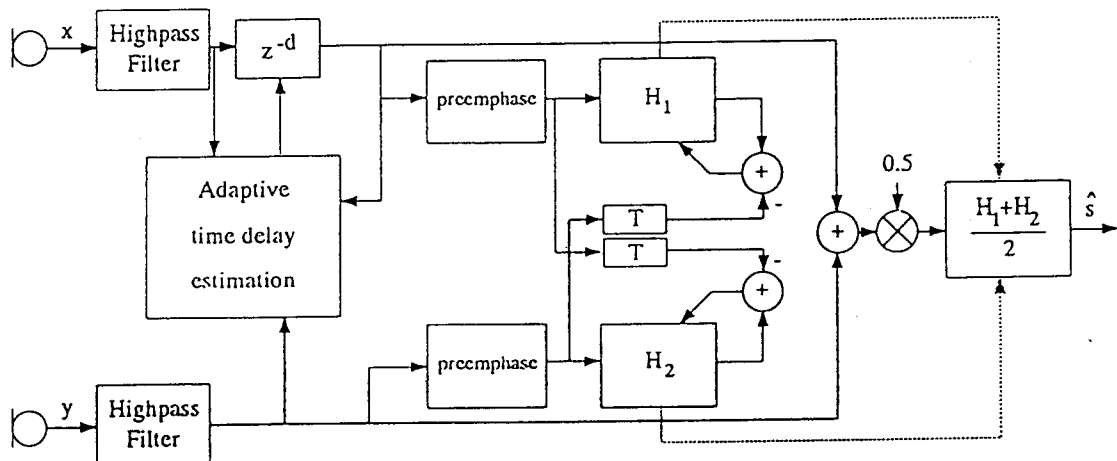


Figure 1: LMS-adapted two microphone speech enhancement system [1], [2]

Principal Features:

- Highpass filters to cut off low frequency noise
- Two independent linear phase adapted LMS filters
- Low complexity, low delay

Noise Reduction and Dereverberation:

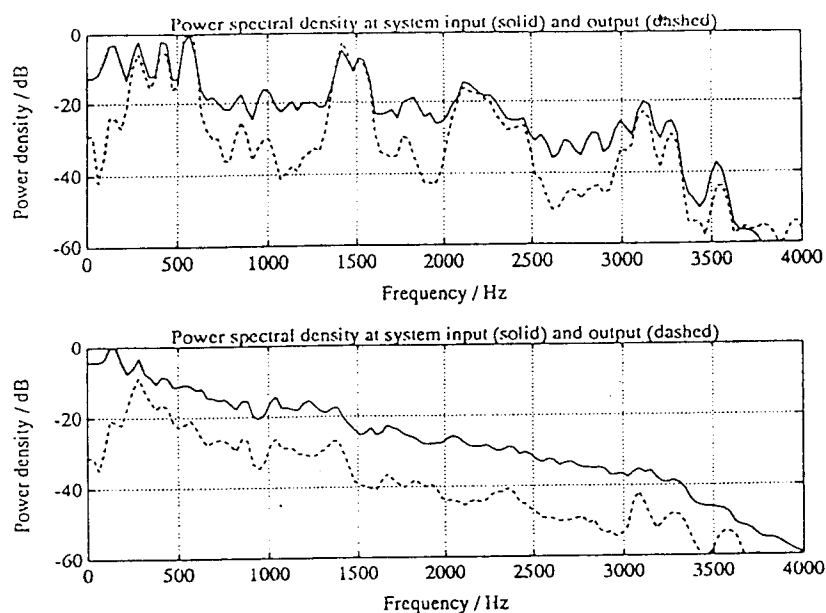


Figure 2: Power spectra of input and output signals during speech activity (upper graph) and speech pause (lower graph), microphone distance $m=40\text{cm}$, car noise

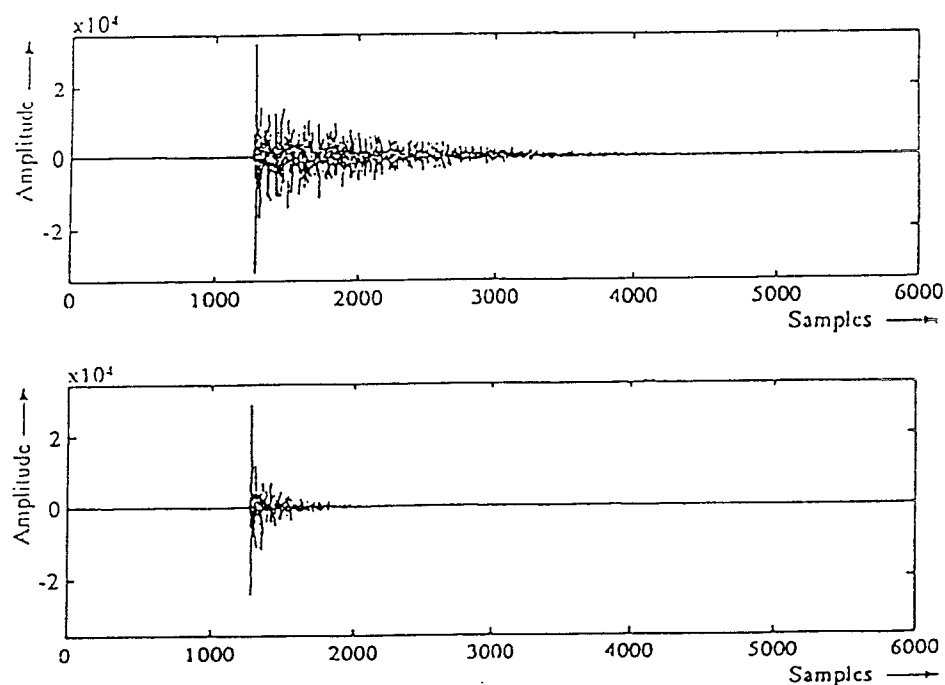
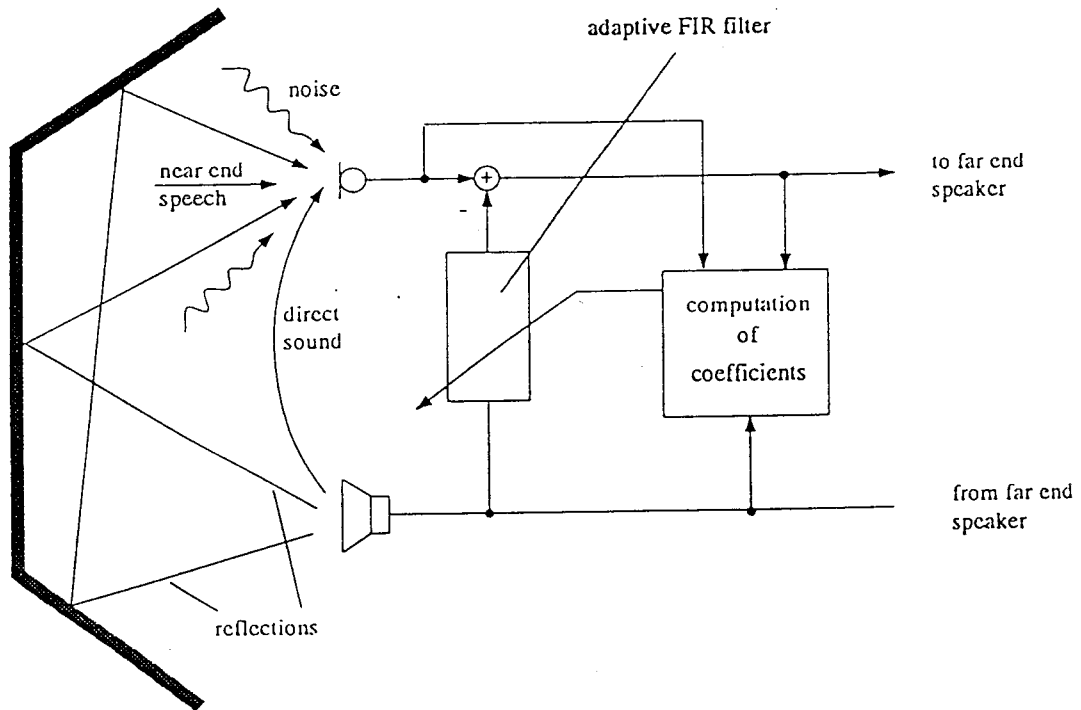


Figure 3: Room impulse response before (upper graph) and after (lower graph) dereverberation

III. “Conventional” acoustic echo canceller



Principal Features:

- LMS-adapted FIR filter with $N=200-4000$ coefficients
- Linear predictive filters for signal decorrelation [2]
- Complexity $\sim 2N$

Echo canceller with prediction filters [2]:

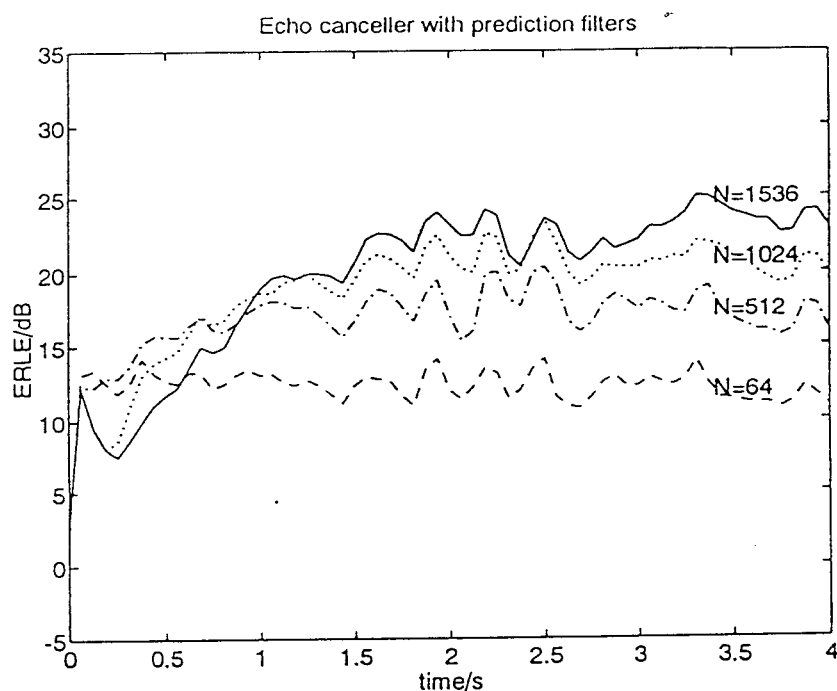


Figure 4: ERLE in noise free environment

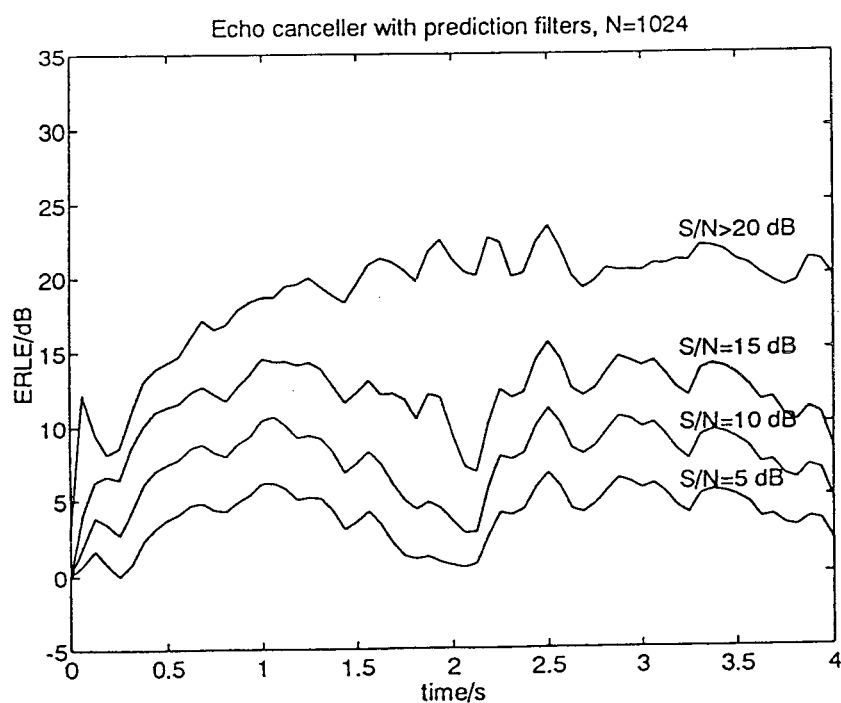


Figure 5: ERLE in noisy environment (car noise)

IV. Combined Systems

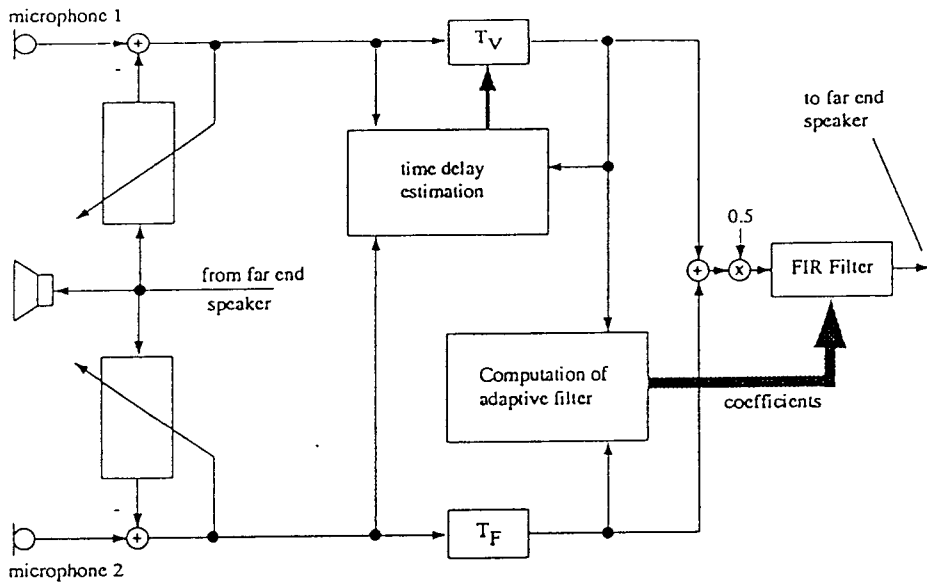


Figure 6: Noise reduction after echo cancellation

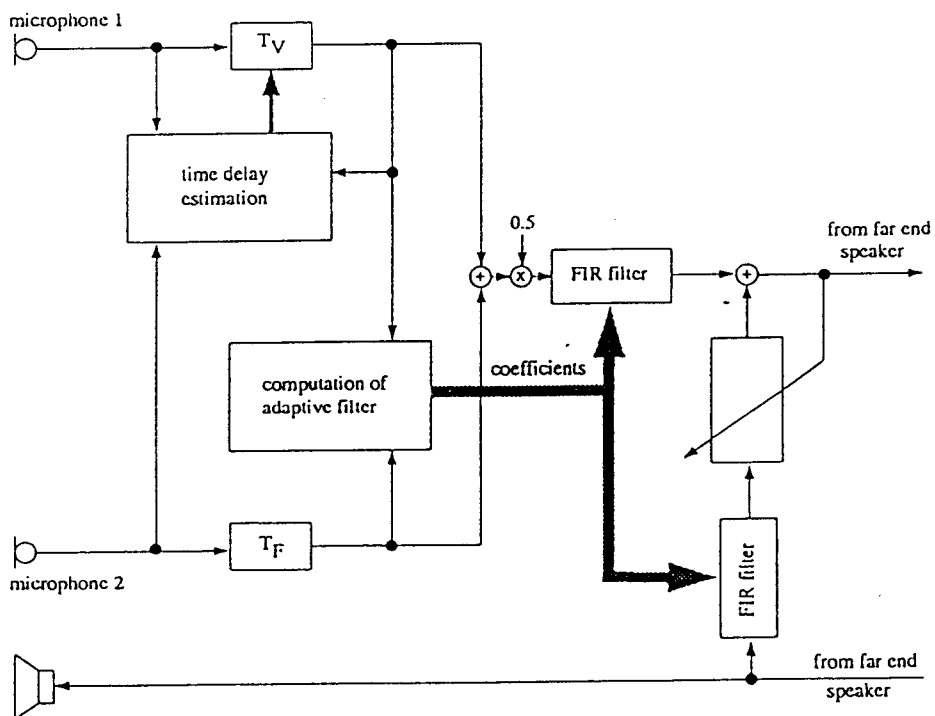


Figure 7: Noise reduction before echo cancellation

V. Performance of Combined System

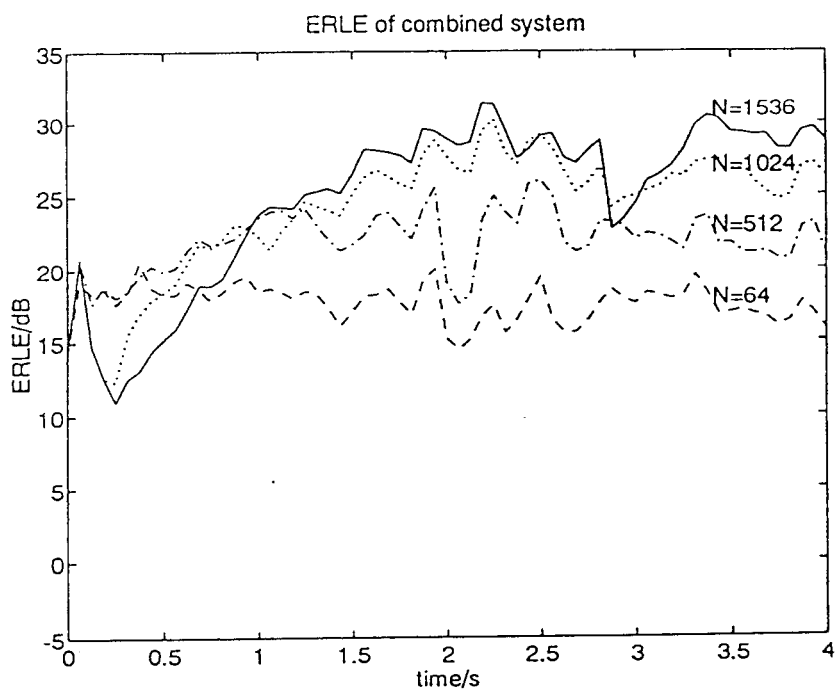


Figure 8: ERLE of combined system (no noise)

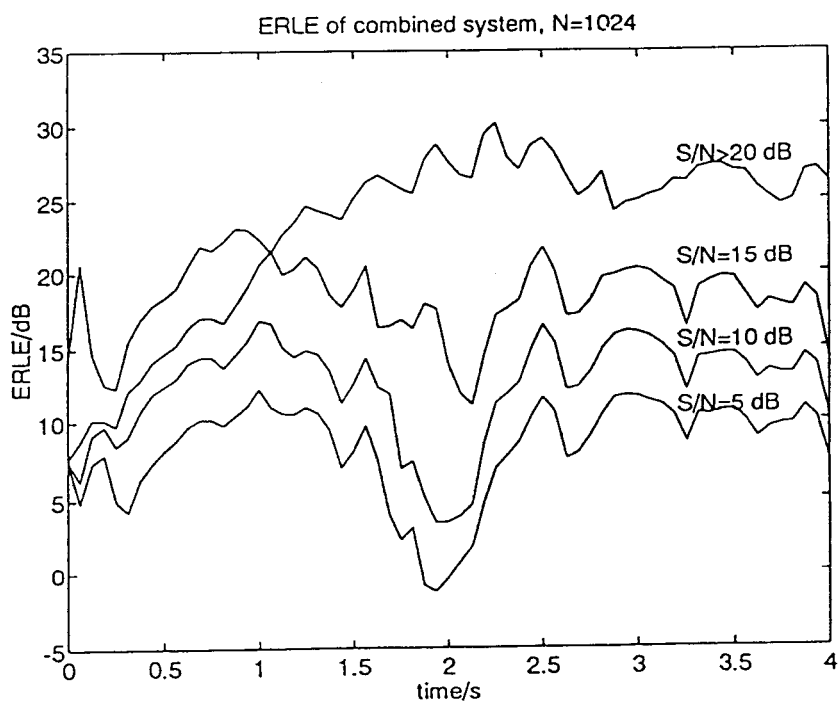


Figure 9: ERLE of combined system (car noise)

VI. Conclusion

The proposed combined systems achieve higher ERLE than the echo canceller alone. They are also more robust in a noisy environment.

References

- [1] R. Martin and P. Vary: "A Symmetric Two Microphone Speech Enhancement System — Theoretical Limits and Application in a Car Environment", Proceedings of the Fifth IEEE Signal Processing Workshop, Starved Rock State Park, Illinois, September 13, 1992.
- [2] R. Zelinski: "Noise Reduction Based on Microphone Array with LMS Adaptive Post-Filtering ", Elect. Lett., Vol. 26, No.24, pp. 2036-2037, November 1990.
- [3] C. Acker and P. Vary: "Combined Implementation of Predictive Speech Coding and Acoustic Echo Cancellation", Signal Processing VI: Theories and Applications, J. Vandewalle et al. (eds.), pp. 1641-1644, EURASIP, Elsevier 1992.