

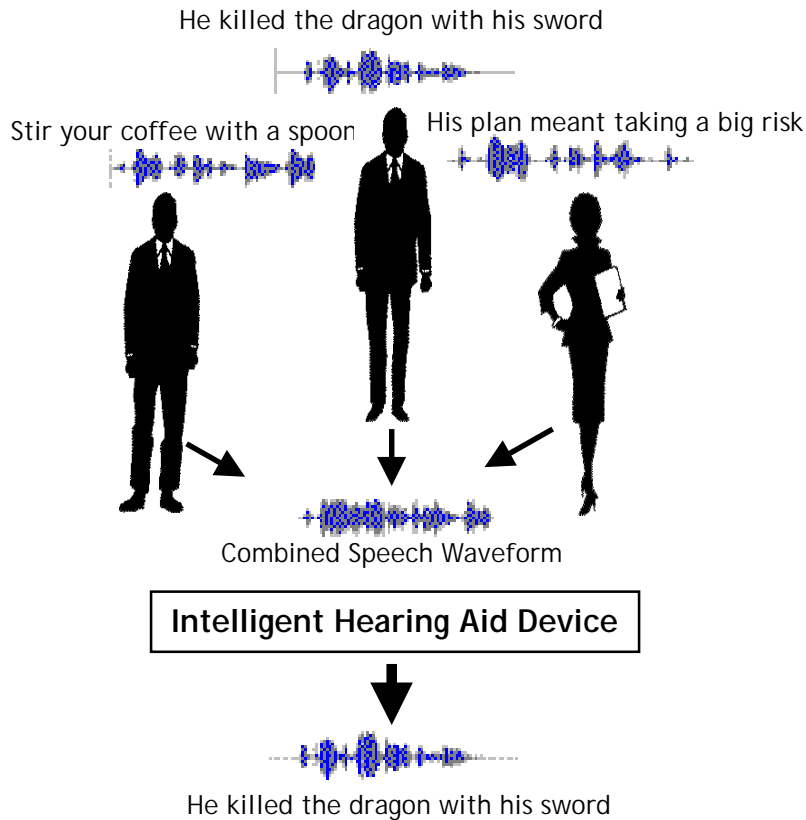


# Intelligent Hearing Aid Project

Beckman Institute  
University of Illinois at Urbana-Champaign

Douglas Jones

Collaborators: C. Liu, A. Feng, B. Wheeler,  
W. O'Brien, C. Lansing, R. Bilger



**Goal:**

Develop high performance auditory processors which can effectively extract a desired speech signal in the presence of multiple competing sounds.

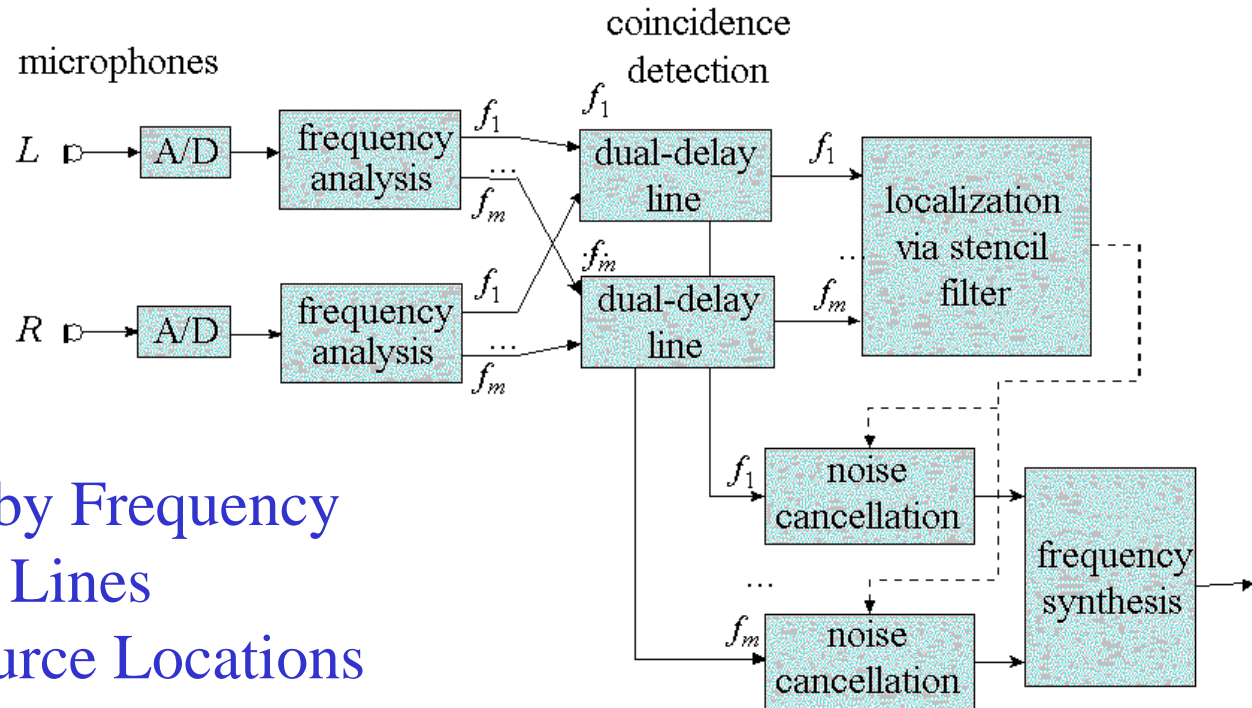
## Report Documentation Page

*Form Approved*  
*OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

|   |                                    |  |                                 |
|---|------------------------------------|--|---------------------------------|
| 1. REPORT DATE<br><b>24 AUG 1999</b>  | 2. REPORT TYPE<br><b>N/A</b>       | 3. DATES COVERED<br><b>-</b>             |                                 |
| 4. TITLE AND SUBTITLE<br><b>Intelligent Hearing Aid Project</b>   |                                    | 5a. CONTRACT NUMBER                      |                                 |
|   |                                    | 5b. GRANT NUMBER                         |                                 |
|   |                                    | 5c. PROGRAM ELEMENT NUMBER               |                                 |
| 6. AUTHOR(S)  |                                    | 5d. PROJECT NUMBER                       |                                 |
|   |                                    | 5e. TASK NUMBER                          |                                 |
|   |                                    | 5f. WORK UNIT NUMBER                     |                                 |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><b>Beckman Institute</b>  |                                    | 8. PERFORMING ORGANIZATION REPORT NUMBER |                                 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)   |                                    | 10. SPONSOR/MONITOR'S ACRONYM(S)         |                                 |
|   |                                    | 11. SPONSOR/MONITOR'S REPORT NUMBER(S)   |                                 |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br><b>Approved for public release, distribution unlimited</b>   |                                    |  |                                 |
| 13. SUPPLEMENTARY NOTES<br><b>DARPA, Air-Coupled Acoustic Microsensors Workshop held on August 24 and 25, 1999 in Crystal City, VA., The original document contains color images.</b> |                                    |  |                                 |
| 14. ABSTRACT  |                                    |  |                                 |
| 15. SUBJECT TERMS   |                                    |  |                                 |
| 16. SECURITY CLASSIFICATION OF:   |                                    |  | 17. LIMITATION OF ABSTRACT      |
| a. REPORT<br><b>unclassified</b>  | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b>      | <b>UU</b>                       |
|   |                                    |  | 18. NUMBER OF PAGES<br><b>7</b> |
|   |                                    |  | 19a. NAME OF RESPONSIBLE PERSON |

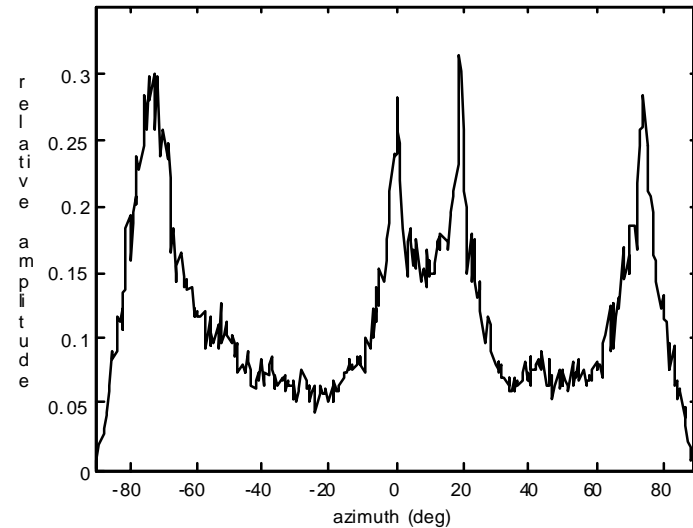
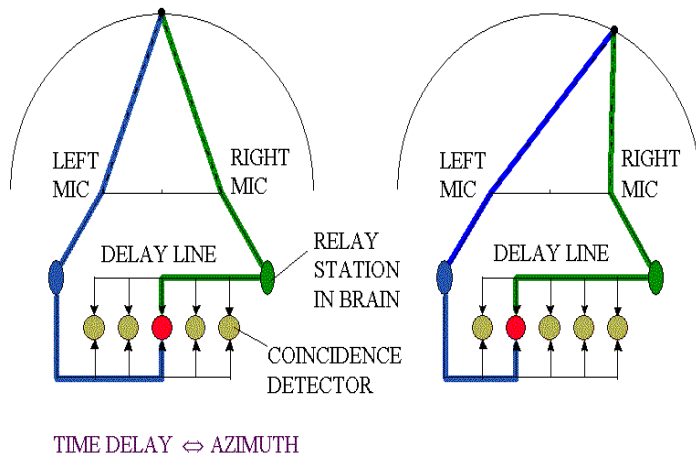
# Algorithm 1: Localization and Cancellation



- Separation by Frequency
- Dual Delay Lines
- Identify Source Locations
- Cancel Noise by Steering Nulls



# Algorithm 1: Localization and Cancellation



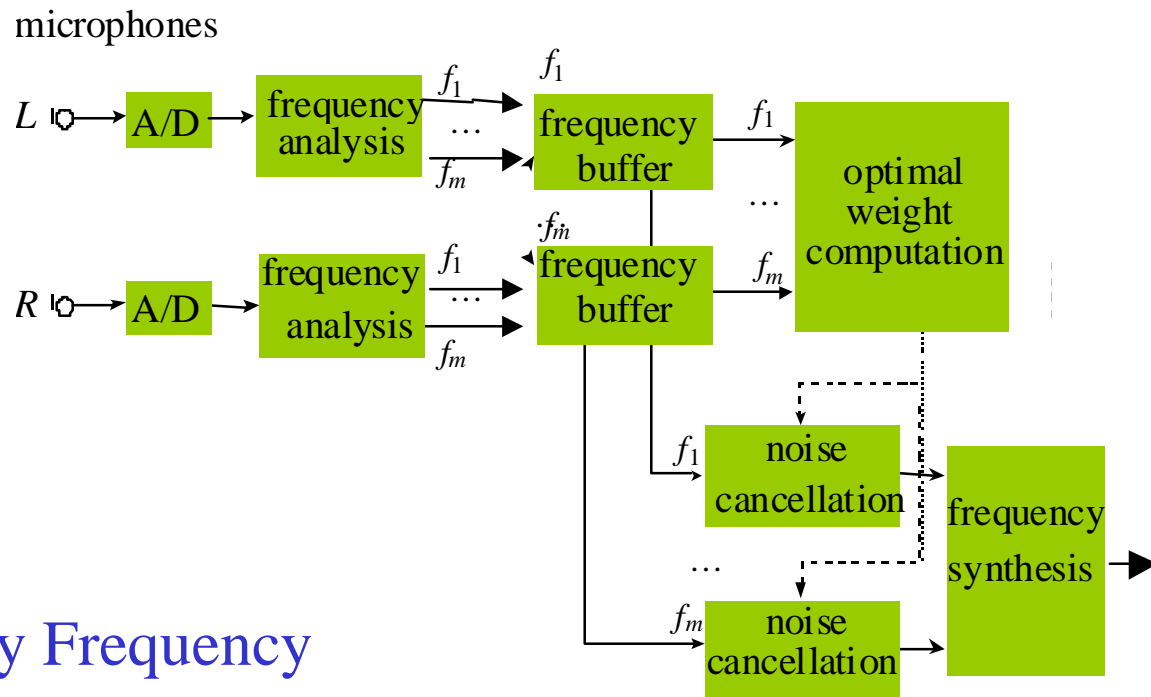
Localization in the Brain

Localization by Computer  
(measure of coincidence vs. azimuth)



Beckman Institute  
University of Illinois at Urbana-Champaign  
Douglas Jones, August 1999

# Algorithm 2: Minimum Variance Cancellation



- Separation by Frequency
- Minimize Off-Axis Signal Strength



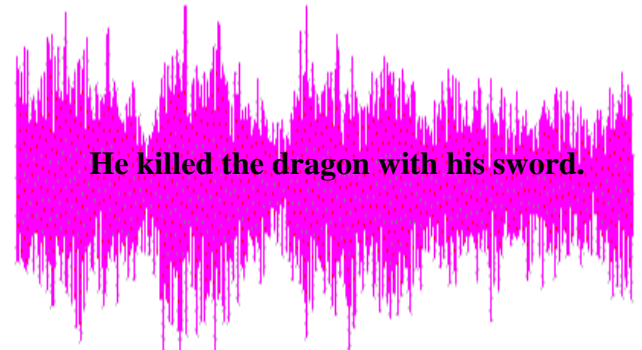
# Experimental Examples

The old train was powered by steam

Target  
@ 0°



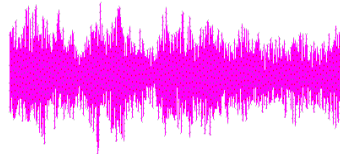
Interferor  
@ 65°



He killed the dragon with his sword.

Target  
@ 0°

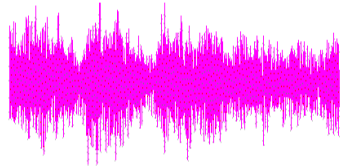
Twelve talker babble



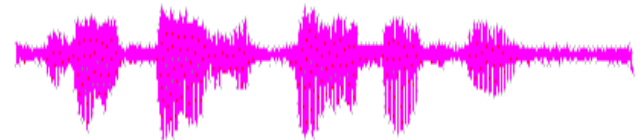
Interferor  
@ 22°

His plan meant taking a big risk. His pl

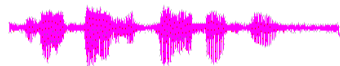
Combined  
Waveform



Combined  
Waveform



Reconstructed  
Waveform



Reconstructed  
Waveform



Beckman Institute  
University of Illinois at Urbana-Champaign  
Douglas Jones, August 1999

# Experimental Summary

(ALGORITHM 2)

| Expmt # | Position<br>Attenuation | Position<br>Attenuation | Position<br>Attenuation | Position<br>Attenuation | Average<br>Gain |
|---------|-------------------------|-------------------------|-------------------------|-------------------------|-----------------|
| 1       | -75°<br>4.8 dB          | Target: 0°<br>0.6 dB    | 20°<br>4.1 dB           | 75°<br>2.1 dB           | 6.2 dB          |
| 2       | 30°<br>6.3 dB           | -45°<br>4.2 dB          | 60°<br>3.1 dB           | Target: -10°<br>0.6 dB  | 6.7 dB          |
| 3       | Target: 10°<br>1.1 dB   | -80°<br>3.9 dB          | -50°<br>2.9 dB          | 45°<br>2.7 dB           | 4.6 dB          |
| 4       | -30°<br>6.3 dB          | 15°<br>0.9 dB           | Target: 5°<br>0.9 dB    | -60°<br>3.6 dB          | 5.3 dB          |
| 5       | -25°<br>5.7 dB          | Target: 25°<br>0.7 dB   | -70°<br>4.3 dB          | 80°<br>2.9 dB           | 6.3 dB          |

Recordings made in a Conference Room

Beckman Institute  
University of Illinois at Urbana-Champaign  
Douglas Jones, August 1999



# Current and Future Work

- **Real-Time Implementation**
- **Microphone Compensation**
- **Dereverberation**

Thanks to Dr. Chen Liu (now at Motorola), Dr. Marc Goeygou (now at U. Lisle) and grad students Mike Lockwood and Mark Elledge



Beckman Institute  
University of Illinois at Urbana-Champaign  
Douglas Jones, August 1999