

Some New Developments in
Active Noise Control

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DARPA

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Two Kinds of Cancellation:

- **Signal Separation:**
Example: Army HMMWV Noise Canceller
- **Active Cancellation:**
(Noise or Vibration)
Example: Cancel Interior Noise in Aircraft

Dr. Martinez's

Commonly Asked Questions *(and our answers)*

- What are we trying to accomplish?
Effective multichannel noise cancellation.
- How is it done now, and with what limitations?
SFR-SVD algorithm. Robust, effective but > computing.
- What is truly new in this approach which will remove current limitations and improve performance? By how much?
Eliminates redundancies, ill-condition, permits accurate solution to filter equation, hence effective cancellation. Gain 15 - 20 dB vs. noise across band.
- If successful, what difference will it make?
Has greatly improved noise cancelling performance.

Noise Cancellation: State of the Art

Excerpts from 1995 Navy SBIR Solicitation

- “Active control of noise and vibration has received a great deal of attention and achieved a certain level of practicality. However, active control methods have some limitations and drawbacks that additional research and development efforts are needed . . .
- “Most important, current control strategy needs to be extended to off-resonant, and broadband vibration and acoustic control.”

Noise Cancellation: State of the Art

Excerpts from 1997 Air Force SBIR Solicitation

“Active Noise Control has advanced significantly in recent years, but most applications to date have addressed physical systems with relatively limited spatial or temporal complexity.

“For example, noise is reduced at a single headset location or only for small numbers of sources contributing narrowband or perhaps multi-tonal input.”

Noise Cancellation: State of the Art

Excerpts from 1993 Army SBIR Solicitation:

“Weapon platform and own-vehicle interference tend to degrade passive aero-acoustic sensor performance . . .

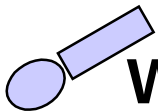
“ANC (Automatic Noise Cancellation) techniques such as the classic Widrow algorithm have been considered for cancellation of such interference, but . . . have not offered the degree of cancellation needed . . .”

Proof of Concept

HMMWV Instrumentation



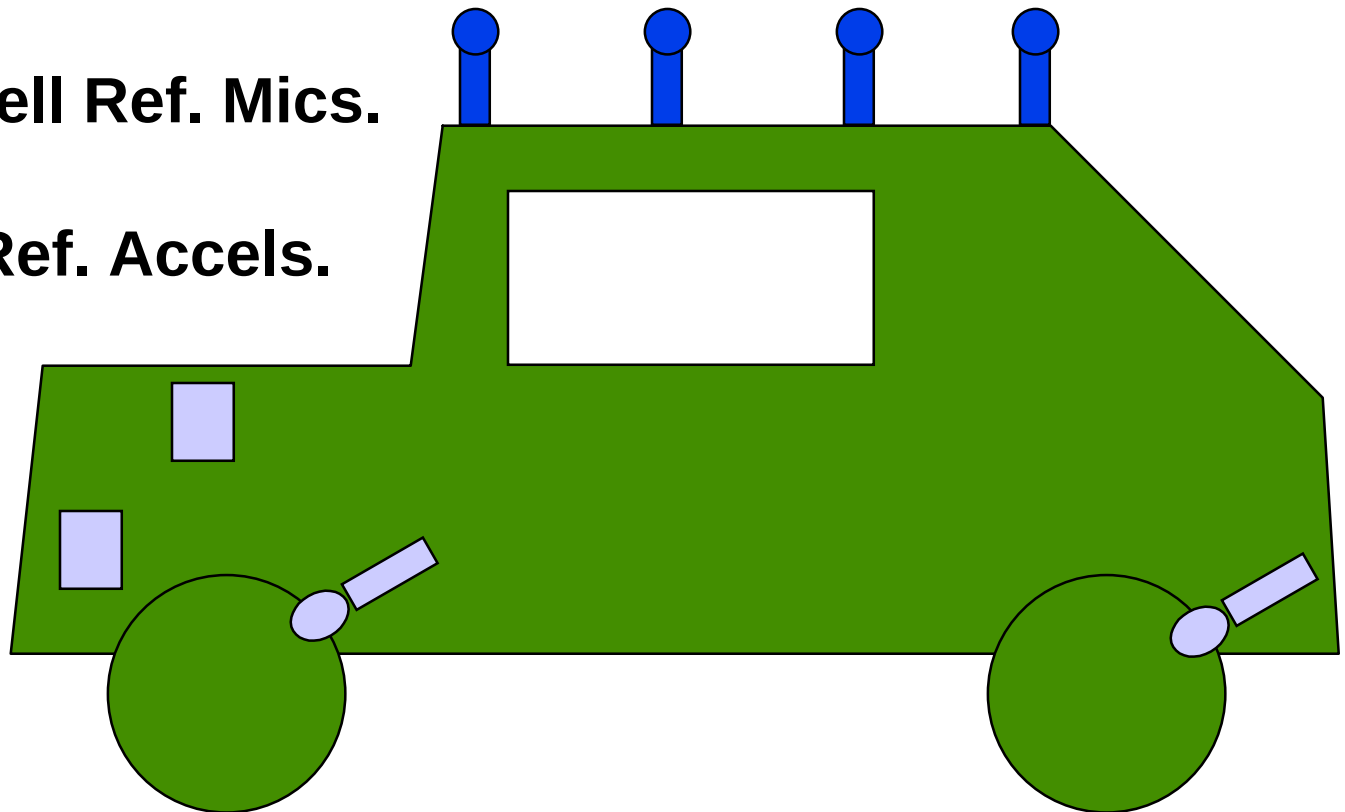
Primary Microphones



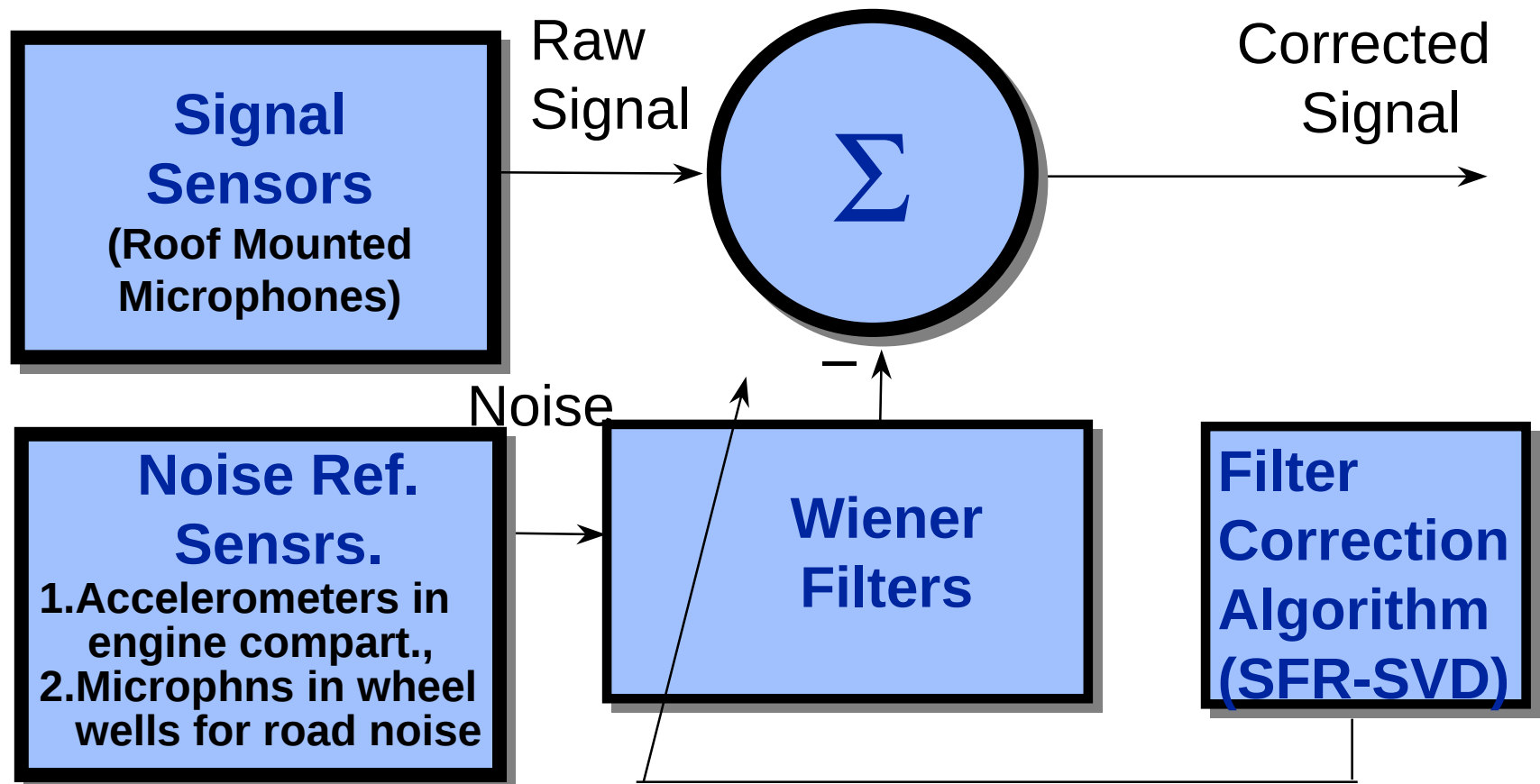
Wheel well Ref. Mics.



Engine Ref. Accels.

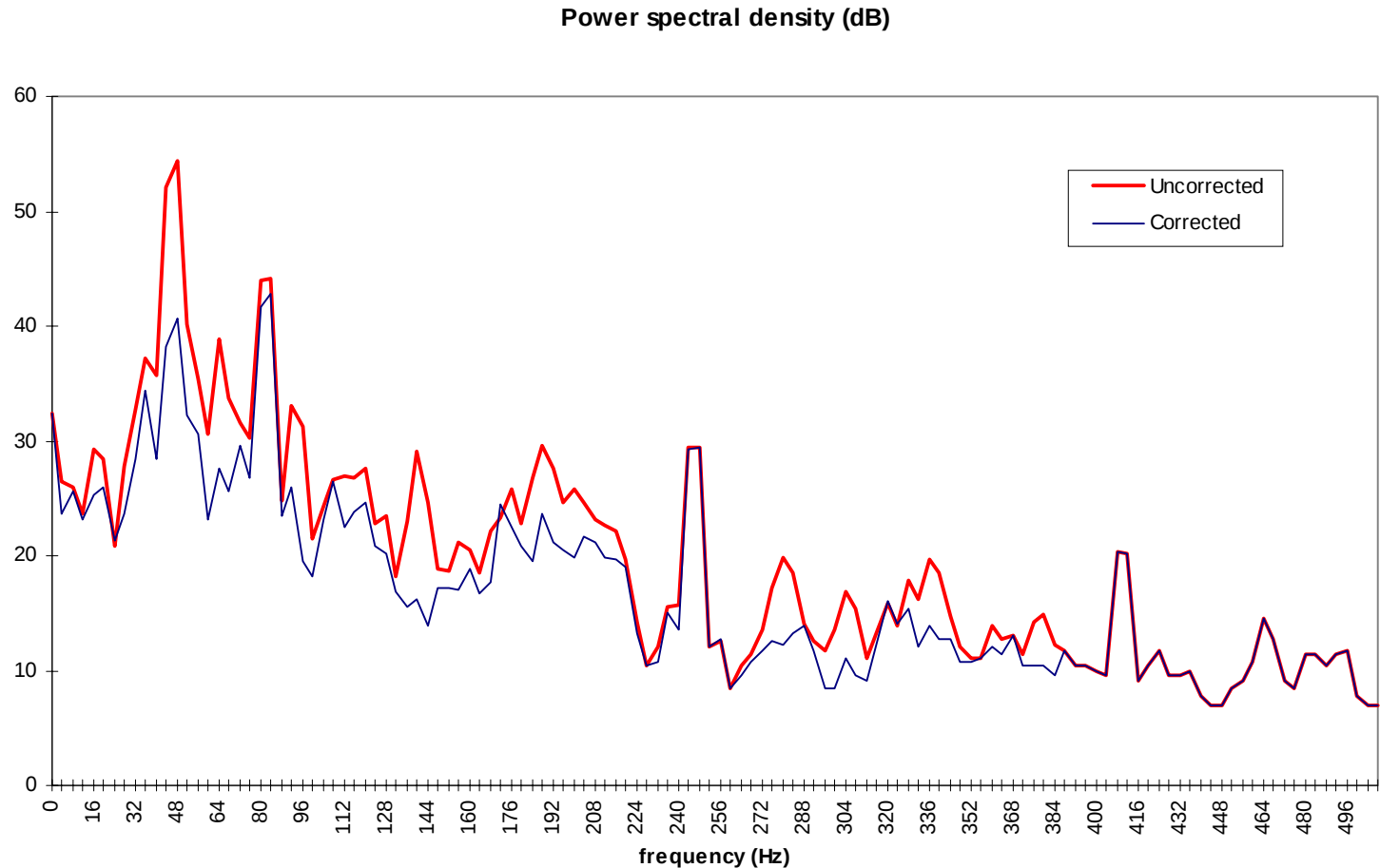


Signal Separation: How It Works



Proof of Concept

HMMWV Idling Using 5 Noise References



Noise References:

- Transmission fluid accelerometer
- Valve Cover accelerometer
- Tailpipe accelerometer
- Starter motor microphone
- Alternator microphone

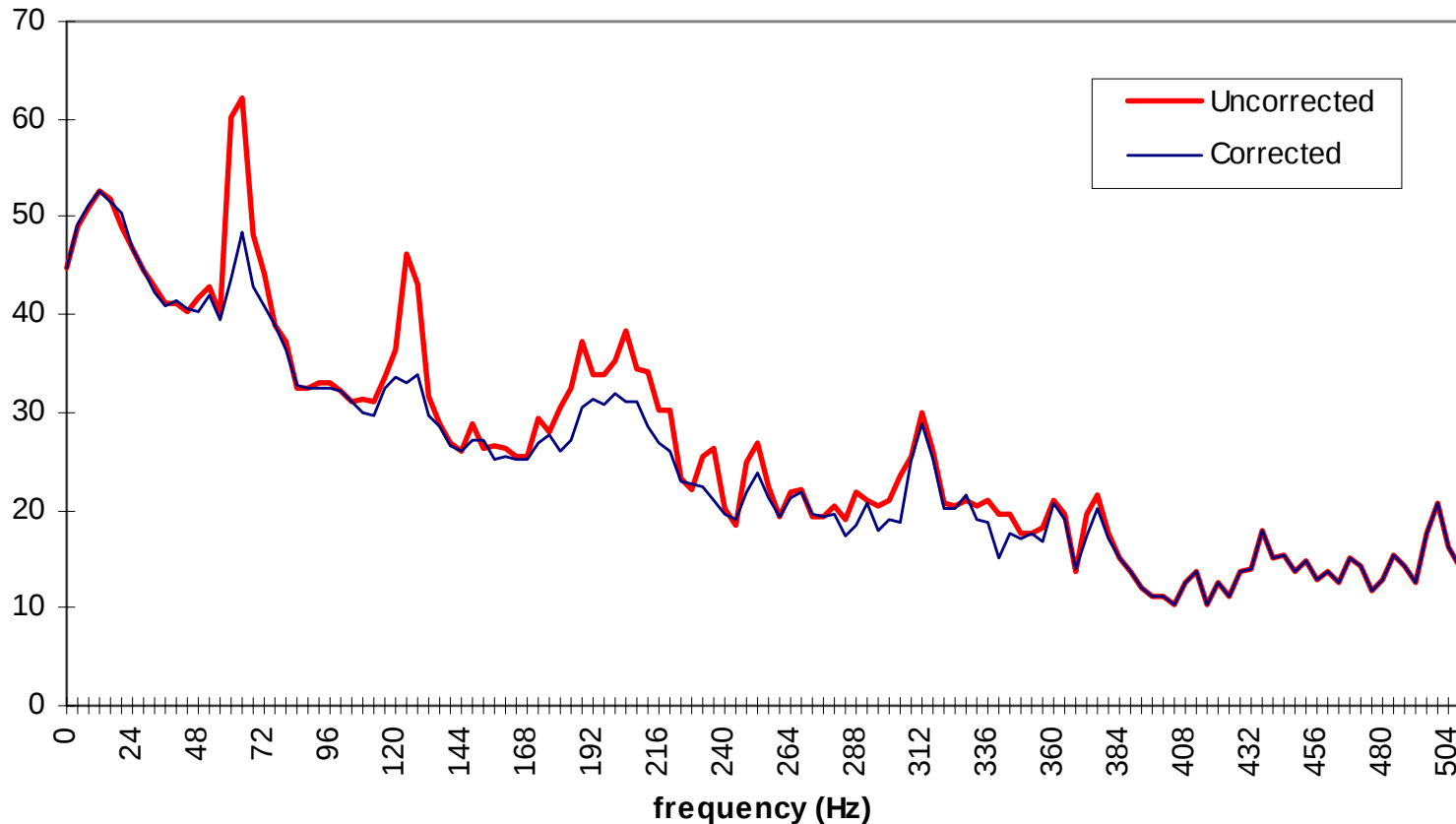
Signal:

- 82 Hz tone from loudspeaker
- 30 yards away

Proof of Concept

HMMWV Moving at 10 mph, 5 Noise References

Power spectral density (dB)



Noise References:

- Transmission fluid accelerometer
- Valve Cover accelerometer
- Tailpipe accelerometer
- Starter motor microphone
- Alternator microphone

No Signal

SVD Calculations

Filter Equation:

$$R w = p \quad \text{or} \quad w = R^{-1} p$$

Diagonalize R
with unitary U,

$$R = U D U^\dagger$$

where D
is diagonal.

$$D = \begin{bmatrix} d_{\text{big1}} & 0 \\ & d_{\text{big2}} \\ 0 & & d_{\text{small}} \end{bmatrix};$$

Pseudo-inverse:
0 inst. of reciprocal of d_{small} .

$$D^{-1} = \begin{bmatrix} 1/d_{\text{big1}} & 0 \\ & 1/d_{\text{big2}} \\ 0 & 0 \end{bmatrix}$$

Calculate w
using pseudo-
inverse of D:

$$w = U D^{-1} U^\dagger p$$

SFR-SVD Cancelling Algorithm

Ref. Sensor Measurements can be Redundant:

- Occurs when **noise references** exceed no. of effective **noise sources**

Such redundancies must be eliminated:

- Failure to do so **degrades noise canceling performance.**

SFR-SVD Method Eliminates Redundancies.

SFR-SVD has been thoroughly tested off-line:

- **Army HMMWV Acoustic System:** Engine, road noise reduced 20-30 dB;
- **NASA aircraft Interior (active) Noise Reduction:** 30 dB reduction;
- **Navy towed array sonar:** Accelerometers cancel vibration effects;
- **Fetal electrocardiography:** Maternal heartbeat removed.

Army HMMWV Project is First time realtime:

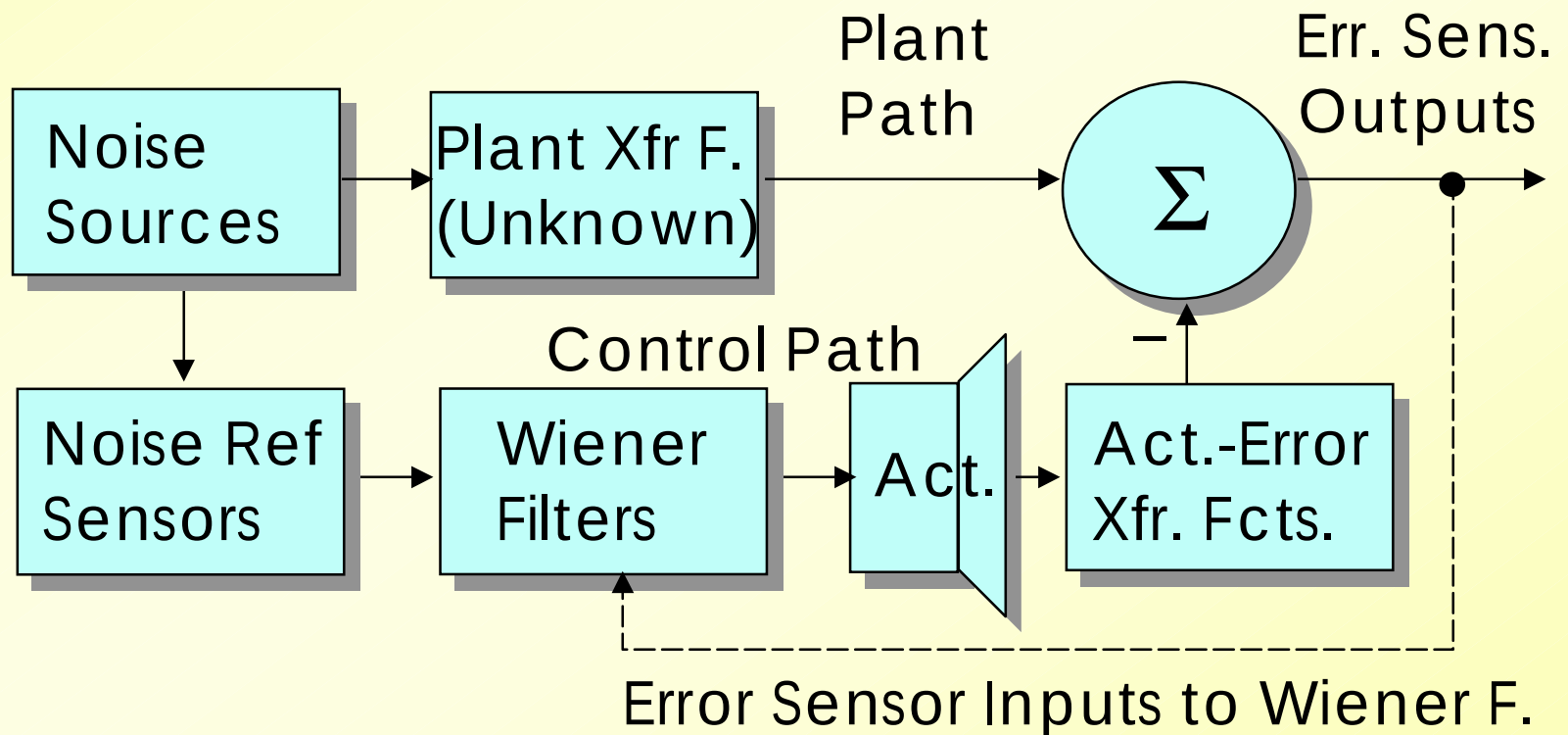
- Developing world's most capable multi-channel cancellation computer.

This information is covered by U.S. Patents 5,209,237, 5,917,919, and foreign patents.

Summary

- The LMS and FXLMS (for active control) algorithms do not work well in a multi-channel control scenario, either for signal separation or for active control.
- The SFR-SVD algorithm has been shown to overcome the problems of redundancy and ill-condition.
- A real-time signal separation controller built for the Army has been found to be extremely effective.
- Use of SFR-SVD for active control was tested off-line for NASA; work on a real-time active vibration controller continues under an NSF SBIR grant.

Feed-Forward Active Cancellation: How It Works



Proof of Concept

SFR-SVD Computer is Proven Technology

1995: Phase I SBIR: Off-line Tests Using Real Data from Army HMMWV Demonstrate SFR-SVD Method's Ability to Enable HMMWV Air Acoustic Sensor System.

1996-97: Phase II SBIR: SST Builds Real-time Signal Separation Noise Canceller.

1997: Laboratory and HMMWV Field Tests Successful; Noise Canceller Performance Exceeds All Expectations; Final Report is Issued.

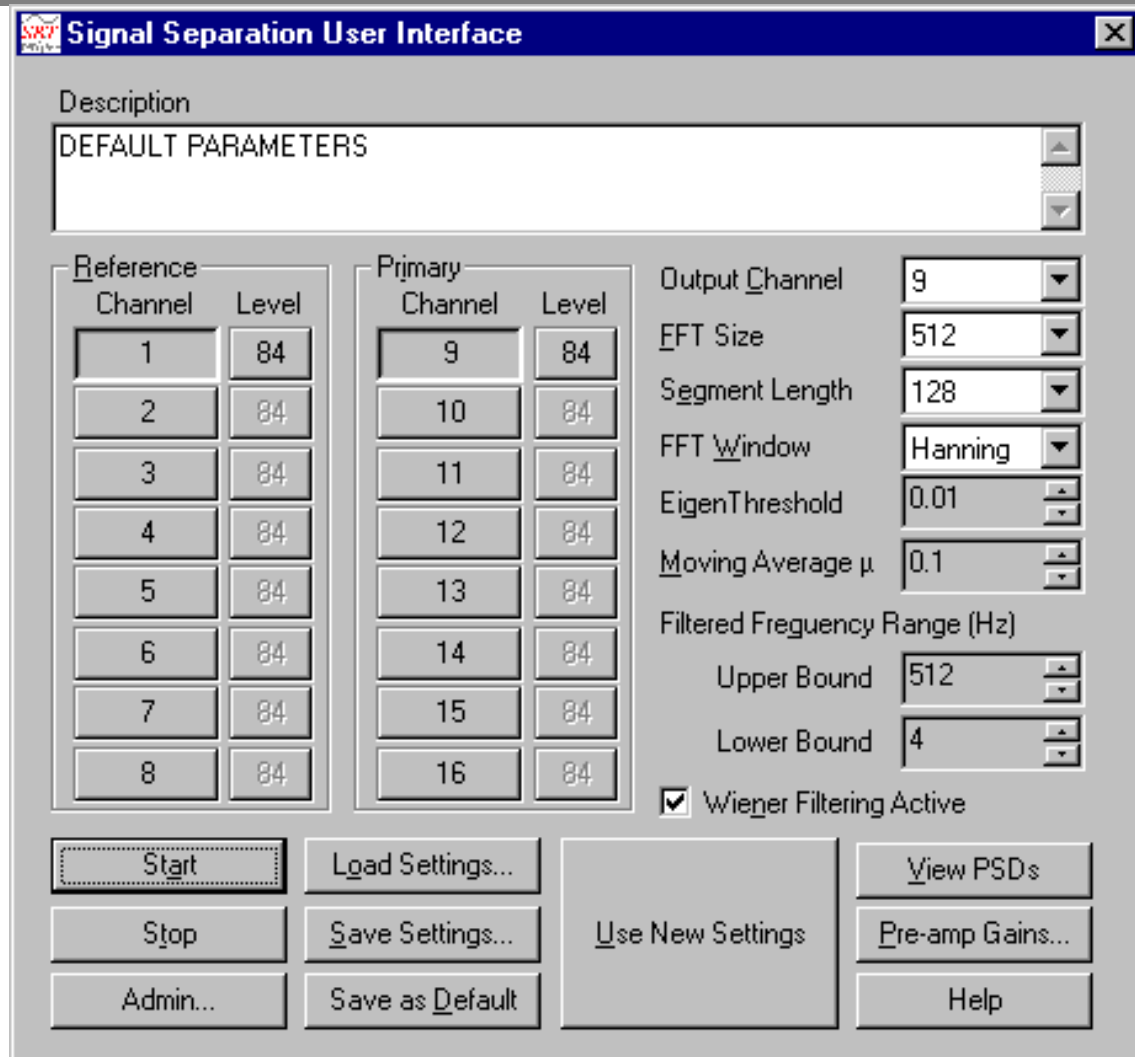
NSF Phase I SBIR: Application of SFR-SVD to Active Control of Vibrations.

1998: NSF Phase II SBIR: Active Control of Vibrations

1999: NSF Phase I SBIR: Noise Cancelling in Automotive environment.

Proof of Concept

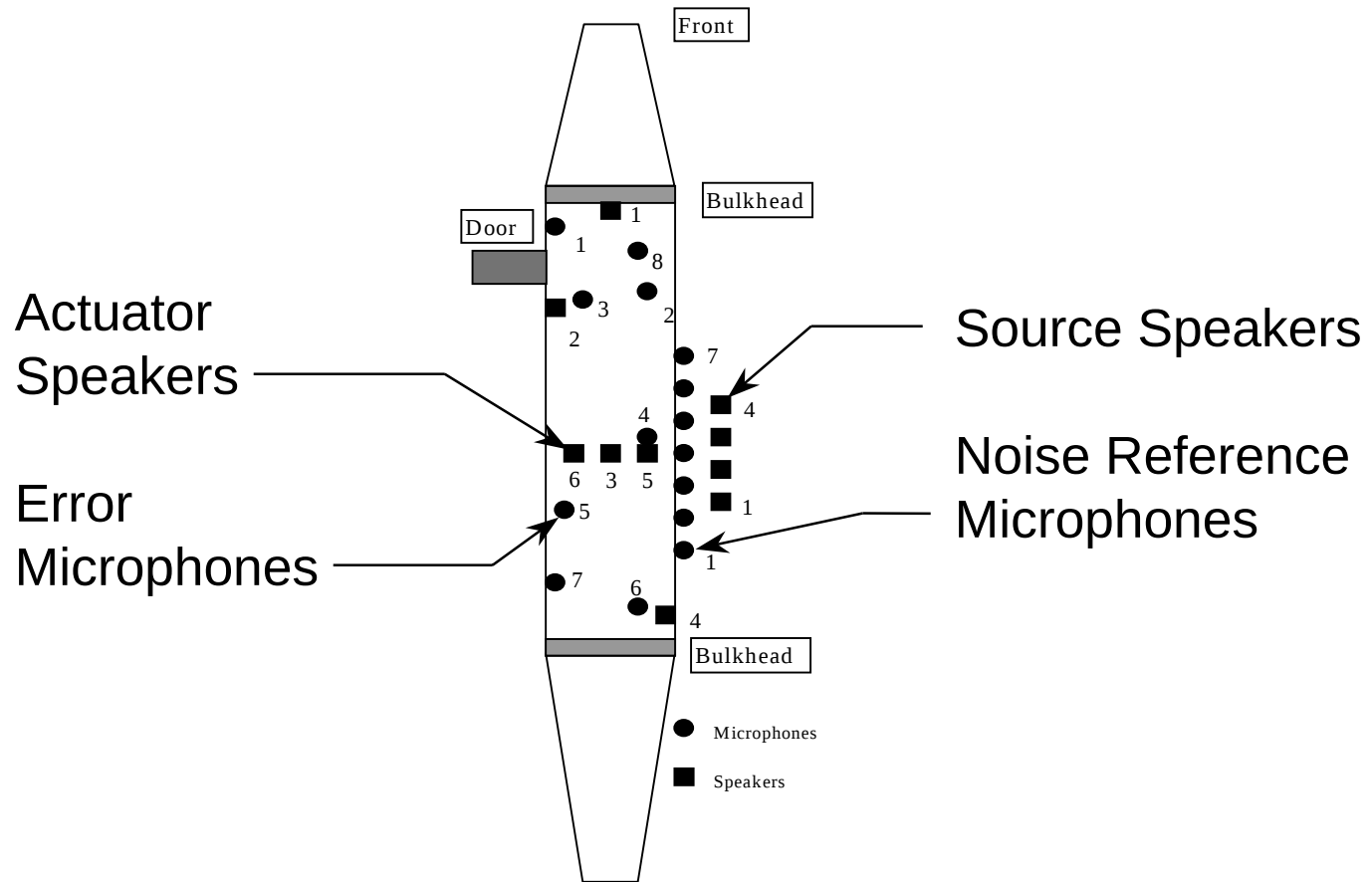
The Graphic User Interface



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Active Control of Noise/Vibration

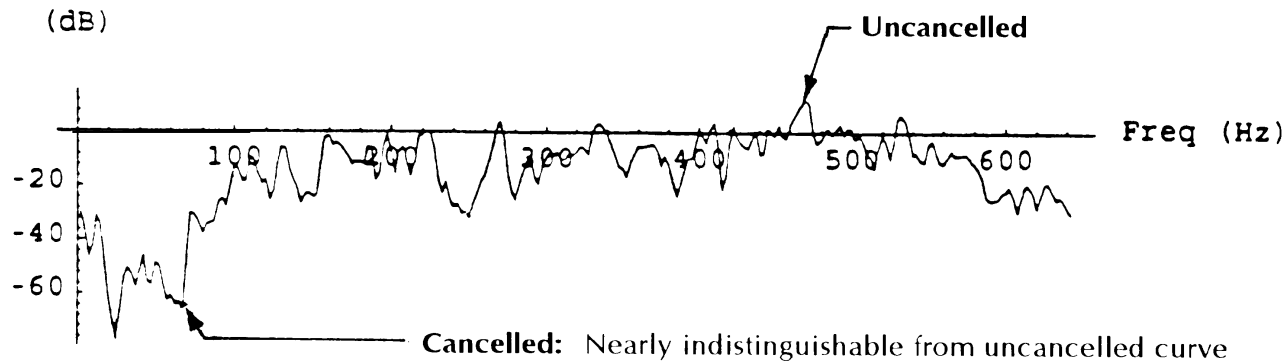
Active Noise Control in an Aircraft Fuselage **Experimental Setup**



Active Control of Noise/Vibration

Active Noise Control in an Aircraft Fuselage Comparison of Gains Achieved

➔ Gain Against Noise When Using Classical LMS:



➔ Gain Against Noise When Using SFR-SVD Method:

