

Spatial Resolution Enhancement via Hybrid Estimation Approaches

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Abstract

The CLEAN method can achieve better spatial resolution for a microphone array. However, the non-parametric peak estimation may not distinguish close noise sources. The MUSIC and ESPRIT parametric algorithms for initial peak detection overcome this.



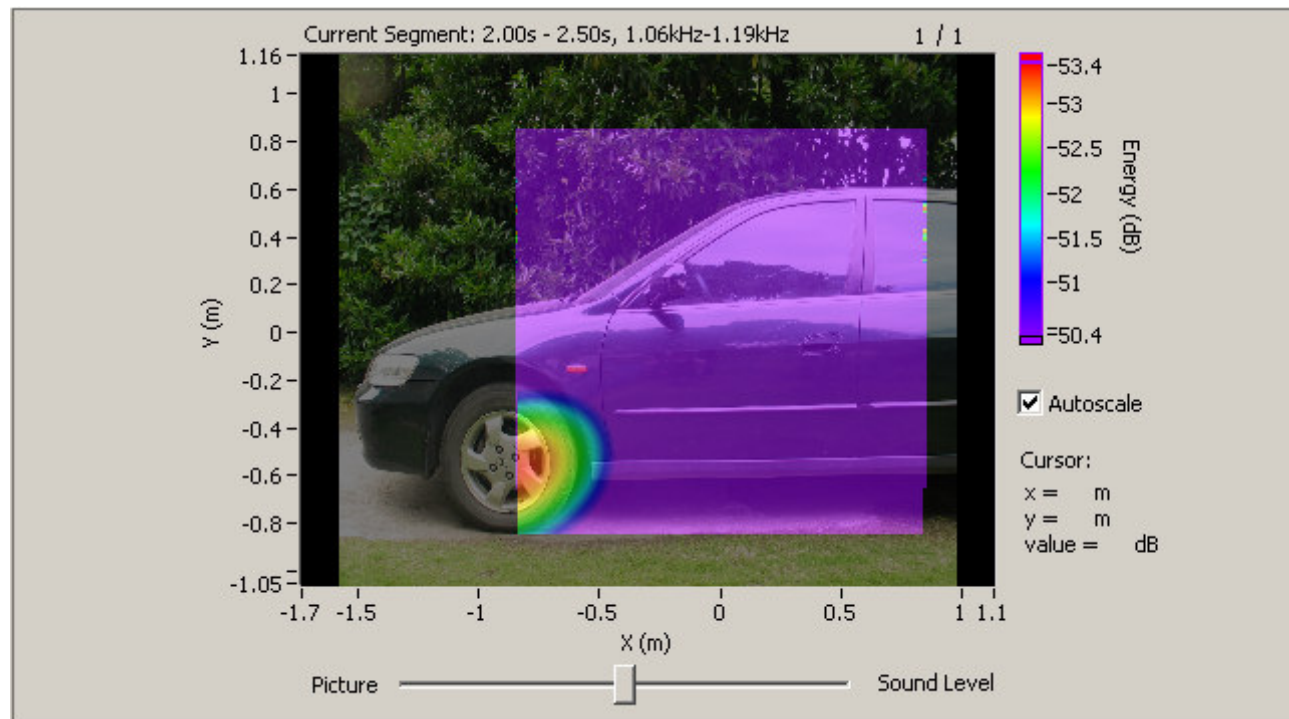
Agenda

- Introduction to Microphone Arrays
 - Limitations of Beamforming
- Overcoming Limitations
 - Parametric Methods (MUSIC, ESPRIT)
 - Non-parametric Methods (CLEAN)
 - Hybrid Parametric CLEAN Method
- Experimental Results



Microphone Arrays

- Ability to measure the sound field in the spatial domain



What is Beamforming?

- Nonparametric method
- Overview
 - A delay is added to each channel and then all are summed
 - The delay is adjusted to enhance signals from a desired position while other signals are cancelled
- Benefits
 - Widely used
 - Easy to implement
 - Error resistant even if SNR is low or array is inaccurate
 - Good results when frequency of interest is stable



Limitations of Nonparametric Method

- Low resolution with low frequencies

$$\text{resolution} = \frac{\lambda}{D} \cdot r$$

f=500Hz, D=1m, r=1m, resolution is only 0.7m

- Thus requires a large array & complex acquisition system
- Unusable with very low frequencies, thus preventing applications in many domains



Parametric Methods

- MUSIC, ESPRIT, etc.
 - Make use of the structure of correlation matrix
 - Can improve resolution significantly
 - Very popular in fields of Radar and Sonar



Problems with Parametric Methods

- Not as stable as Nonparametric method
 - Requires better signal quality
 - More vulnerable to errors
- Can not reveal the real signal strength
 - Good at locating position
 - Poor at estimating amplitude
 - Detected amplitude is not proportional to real amplitude



Hybrid Method

Combines the advantages of the parametric and nonparametric methods

Parametric
High Spatial
Resolution

Nonparametric
Accurate
Source Amplitude



Parametric CLEAN Method

- Derived from CLEAN Method by Jian Li and Petre Stoica, using nonparametric method.
- Modified to use Parametric method in locating source position.
 - Parametric for source position
 - Nonparametric for source amplitude



Procedure of Parametric CLEAN

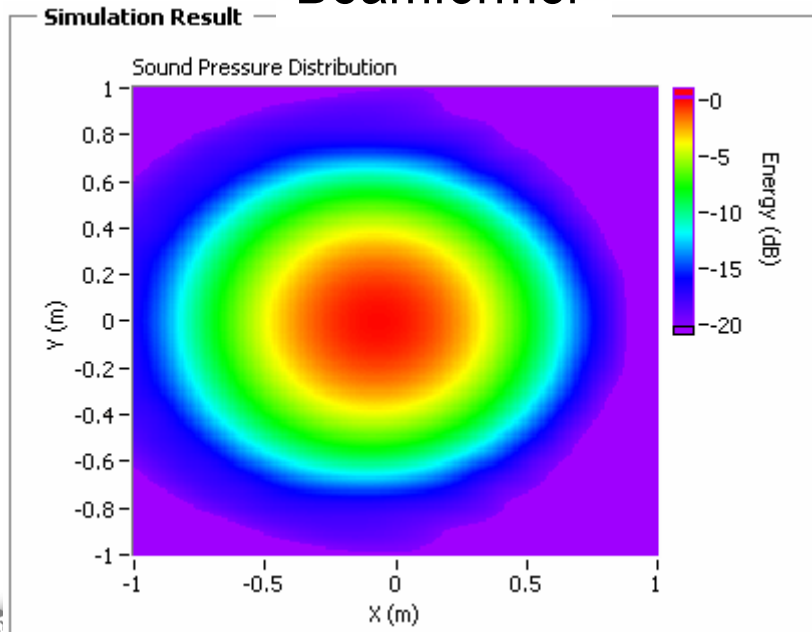
1. Estimate the location of a peak source by parametric method
2. Estimate the amplitude of a peak source by beamformer
3. Subtract the (part of) waveform of the recently obtained peak source from raw signals
4. Iterate through steps 1, 2, 3



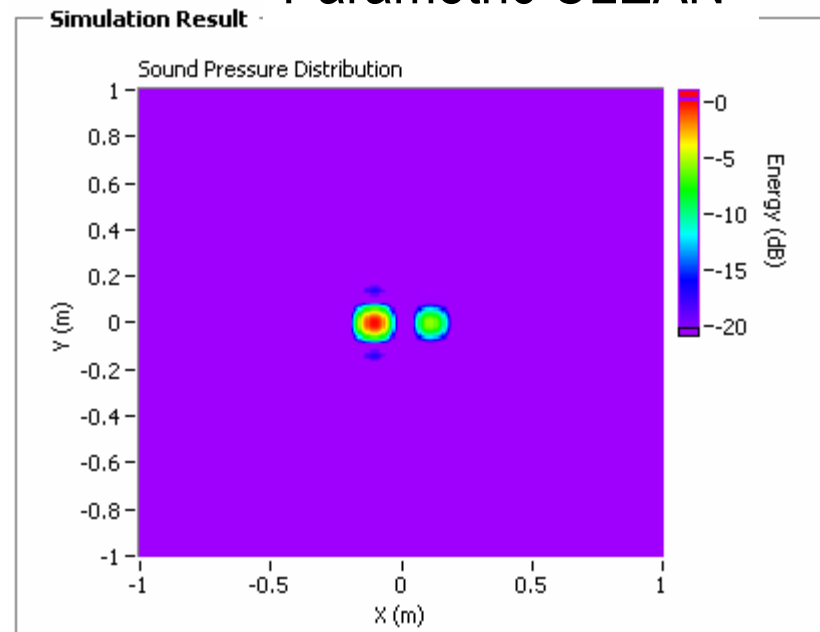
Performance Comparison (Simulation)

- 2 sources @ 600Hz, 0.2m apart
- Array setup: 1m aperture, 64ch

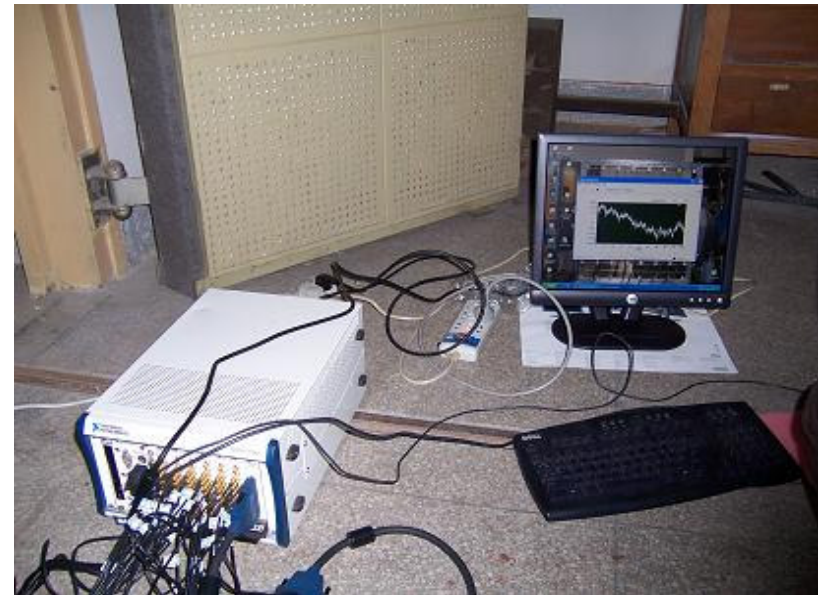
Beamformer



Parametric CLEAN



Real World Experiment



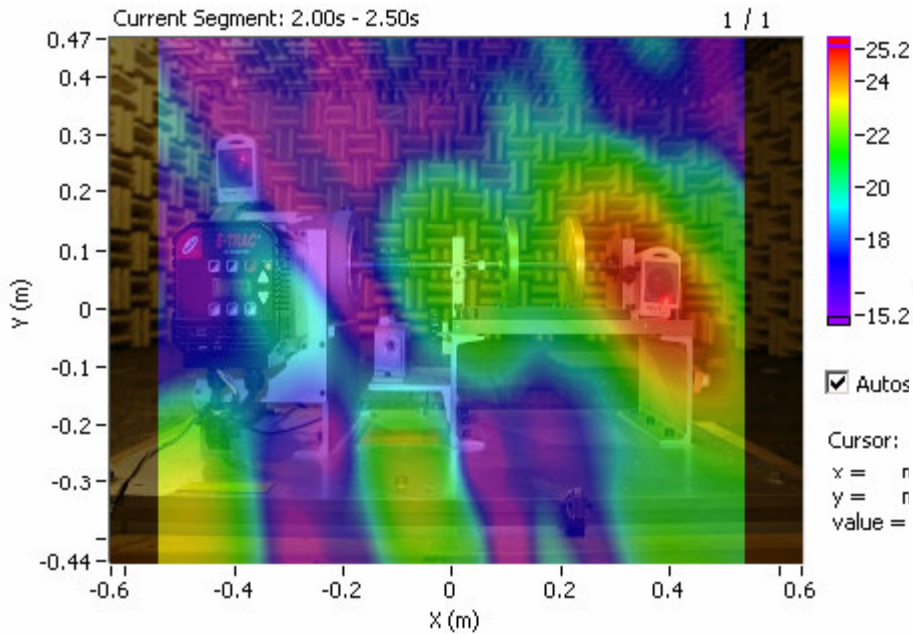
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Real World Experiment

- Performance Comparison

Beamformer



Parametric CLEAN

