Project Presentation
Acoustic and Audio Signal Processing
Indian Institute of Information Technology Design and Manufacturing, Kancheepuram

Acoustic source Localization

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Introduction

- Acoustic source Localization or direction of arrival estimation refers to the process of retrieving the direction information of several electromagnetic waves/sources from the output of the sensors.
- An array antenna system with innovative signal processing can improve the resolution of direction of arrival estimation instead of using a single antenna.
- Multipath fading and cross-interference become more critical difficulties in estimating the direction of arrival.

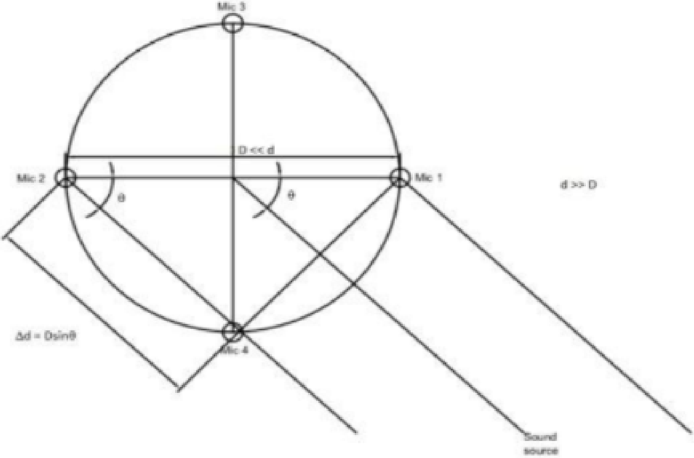
Techniques

These are the techniques we are using to find the angle of arrival:

- Correlation Technique
- Capons Technique

Correlation Technique

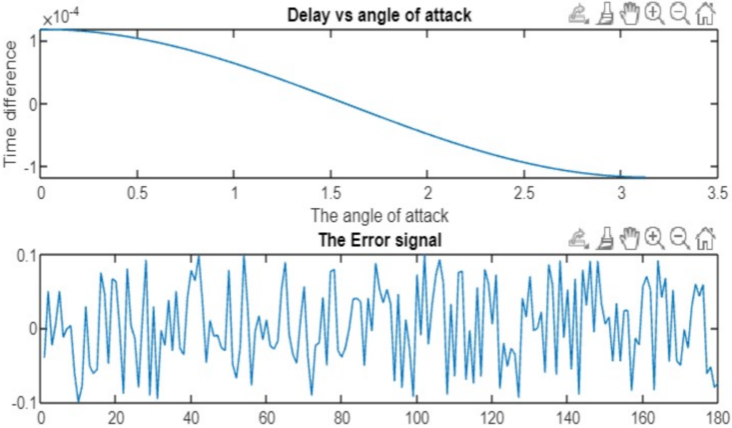
Sensor placement considered:



Calculation

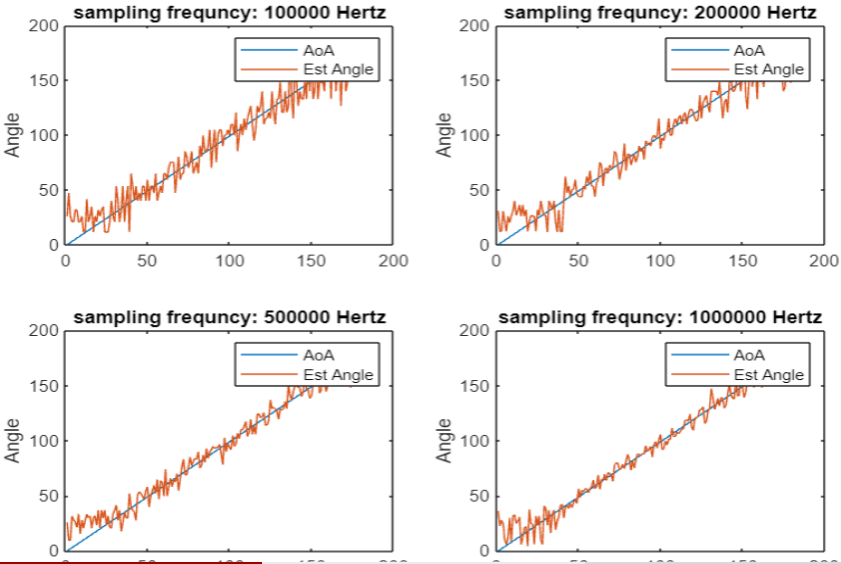
- Let the distance between the microphones be 'D' and the distance between the center of array and sound source be 'd'.
- Since we place the mics very close, we can assume that d ¿¿ D.
- Let the angle of arrival be q.
- Then the difference between distance can be approximated as $\triangle d = D \sin q$.
- Let the speed of sound be $v = 340 m/s$.
- $\triangle = \triangle d/v$
- Then $q = acos[v\triangle/D]$.

Delay vs DOA



Delay vs angle of attack
×10^-4
Time difference
1
0
-1
0
0.5
1
1.5
2
2.5
3
3.5
The angle of attack
The Error signal
0.1
0
-0.1
0
20
40
60
80
100
120
140
160
180

DOA Estimation



Inference

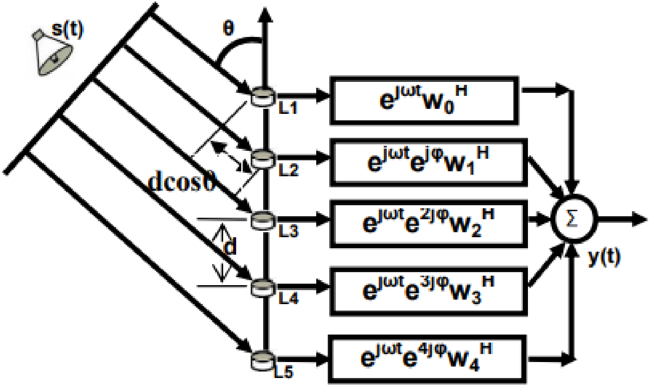
Here I have considered a signal and added a random noise as we don't get a pure signal in real time implementation and found the angle of arrival using the delay of the signal w.r.t the other sensor and I have plotted the delay vs the angle of attack. Also I have implemented with different sampling frequencies and we can see that as the sampling frequency increases the accuracy is increasing as we will be dealing with more accurate signal.

Capon's technique

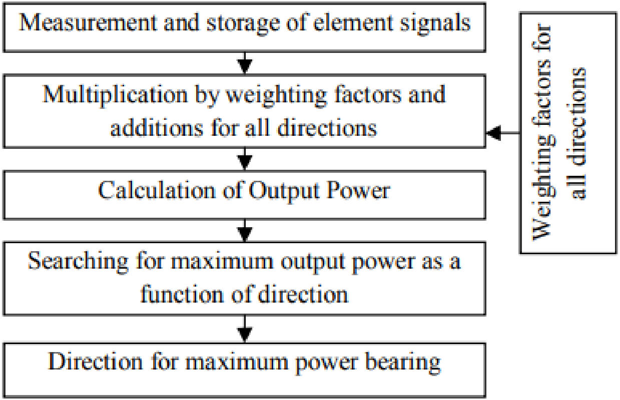
Beamforming

- Beamforming is the process of combining sounds or electromagnetic signals that come from only one particular direction and impinges different sensors at the receiver.
- Due to the coherent combining after the appropriate phase compensation at each sensor the resultant signal provides higher strength.
- This concept is used in different communication, voice and sonar applications.

System model for beamforming



Block Diagram



Calculation

- x(t) = a(θ)s(t)
- s(t) = exp(jωt) and $a(\theta) = [1, exp(j\phi), ..., exp(j(L-1)\phi)]$.
- $x(t) = \sum_{m=1}^{M} a(\theta_m) s_m(t)$.
- $A(\theta) = [a(\theta_1), a(\theta_2), ..., a(\theta_M)]$ and $s(t) = [s_1(t), s_2(t), ..., s_M(t)]^T$.
- In the presence of an additive noise n(t)

$$x(t) = A(\theta)s(t) + n(t)$$

.

- $y(t) = \sum_{l=1}^{L} w_l^* x_l(t) = w^H x(t)$
- The output power is:

$$P(w) = \frac{1}{N} \sum_{t=1}^{N} |y(t)|^2$$
$$P(w) = \frac{1}{N} \sum_{t=1}^{N} w^H x(t) x^H(t) w$$
$$P(w) = w^H R w$$

.

Cont.d

- $maxE[w^H x(t)x^H(t)w] = max(w^H E[x(t)x^H]w)$
  - $w_{BF} = \frac{a(\theta)}{\sqrt{a^H(\theta)a(\theta)}}$

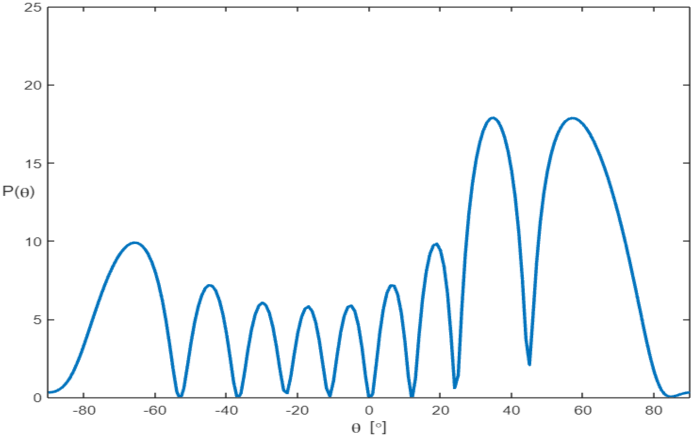
    $P_{BF} = \frac{a^H(\theta)Ra(\theta)}{a^H(\theta)a(\theta)}$

In Capon's method:

- Min P(w) subject to $w^H a(\theta) = 1$
  - $w_{CAP} = \frac{R^{-1}a(\theta)}{a^H(\theta)R^{-1}a(\theta)}$

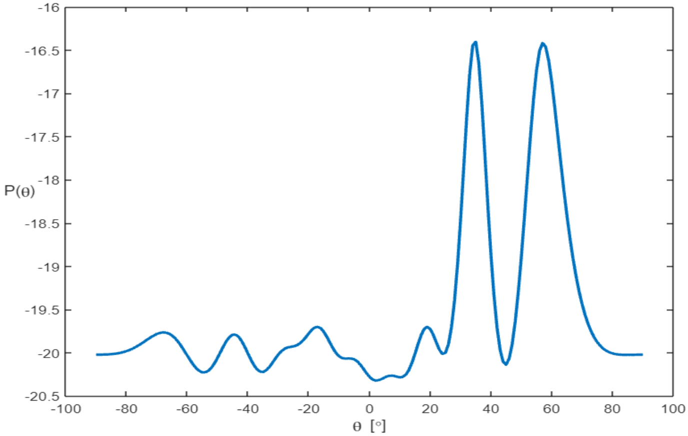
    $P_{CAP} = \frac{1}{a^H(\theta)R^{-1}a(\theta)}$

Conventional Beamforming:



Output

Capon's Beamforming:



Inference

From the above outputs we can see that the power of the noise as well as the power of the signal in other direction is less in capons beamforming method compared to the conventional beamforming method and also if the two sources are at a angular distance less than $2\pi/L$ where L is no.of sensors then the conventional beamforming can't resolve them better than capons beamforming.

Thank You!