In this project to locate the sound source we used the concept of TDOA.For carrying out the procedure we assumed the following conditions.

- Assumed a 2-D cartisean coordinate system with sound source located at (8,6)
- A linear array of 5 microphones is considered along x-axis with reference microphone located at (0,0) and each microphone is separated by distance d=2 meters
- sampling frequency is taken as 10000 Hz
- speed of sound in air is 343 m/s

Based on the above assumptions the time delays of microphones with respect to reference microphones are calculated analytically.

$$dt_1 = \frac{\sqrt{(8-1(2))^2+6^2} - \sqrt{8^2+6^2}}{343} = -0.0044 seconds \tag{1}$$

$$dt_2 = \frac{\sqrt{(8-2(2))^2+6^2} - \sqrt{8^2+6^2}}{343} = -0.0081 seconds \tag{2}$$

$$dt_3 = \frac{\sqrt{(8-3(2))^2+6^2} - \sqrt{8^2+6^2}}{343} = -0.0107 seconds \tag{3}$$

$$dt_4 = \frac{\sqrt{(8-4(2))^2+6^2} - \sqrt{8^2+6^2}}{343} = -0.0117 seconds \tag{4}$$

The analytically calculated time delays are

[-0.0044; -0.0081; -0.0107; -0.0117] seconds

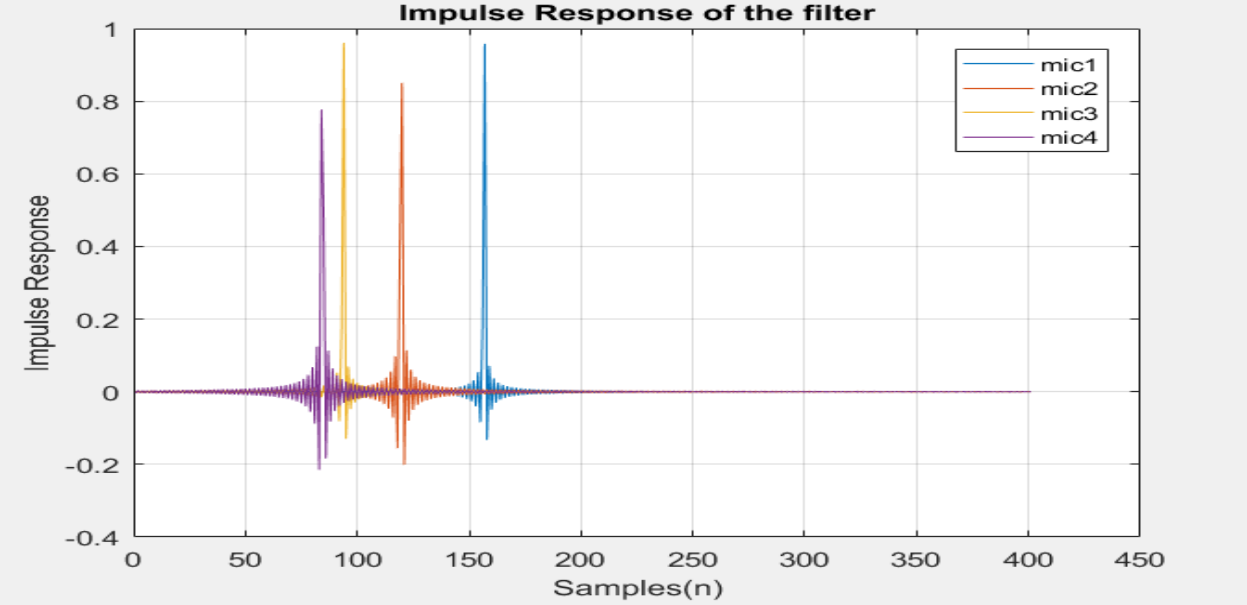

Figure 1: Sinc Filter impulse response used for delaying the reference signal

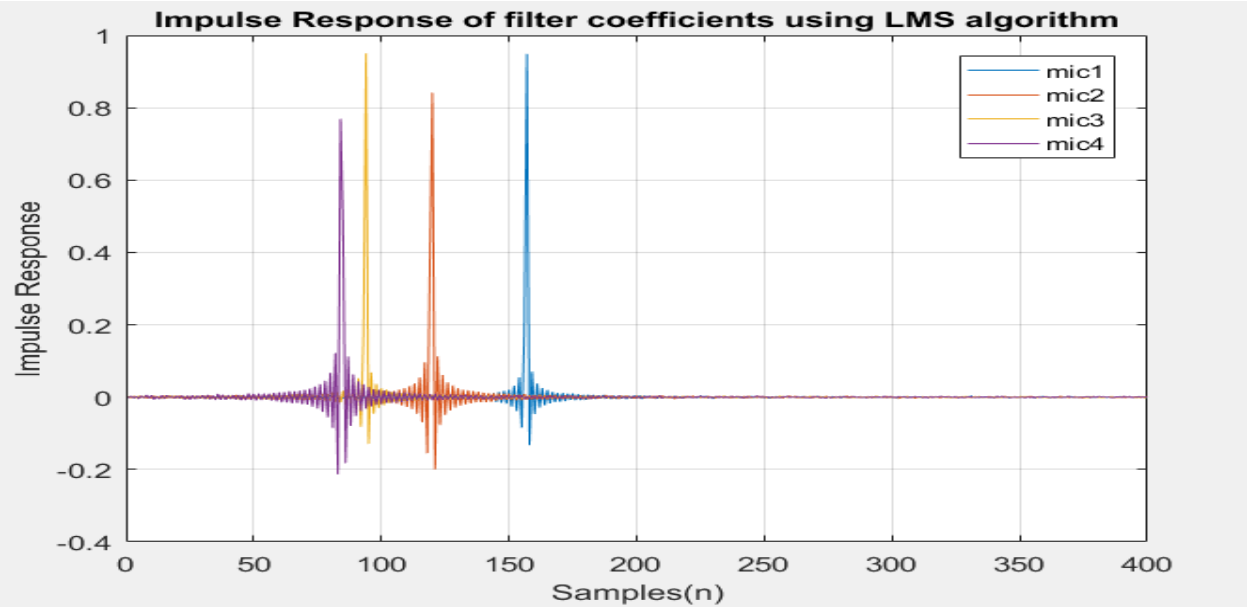

Figure 2: Impulse response of LMS Filter weights estimated from the delayed signals

From the Above two figures it is observed that the impulse response used for delaying the signal and the impulse response of LMS Filter weights estimated from the delayed signals are approximately same.

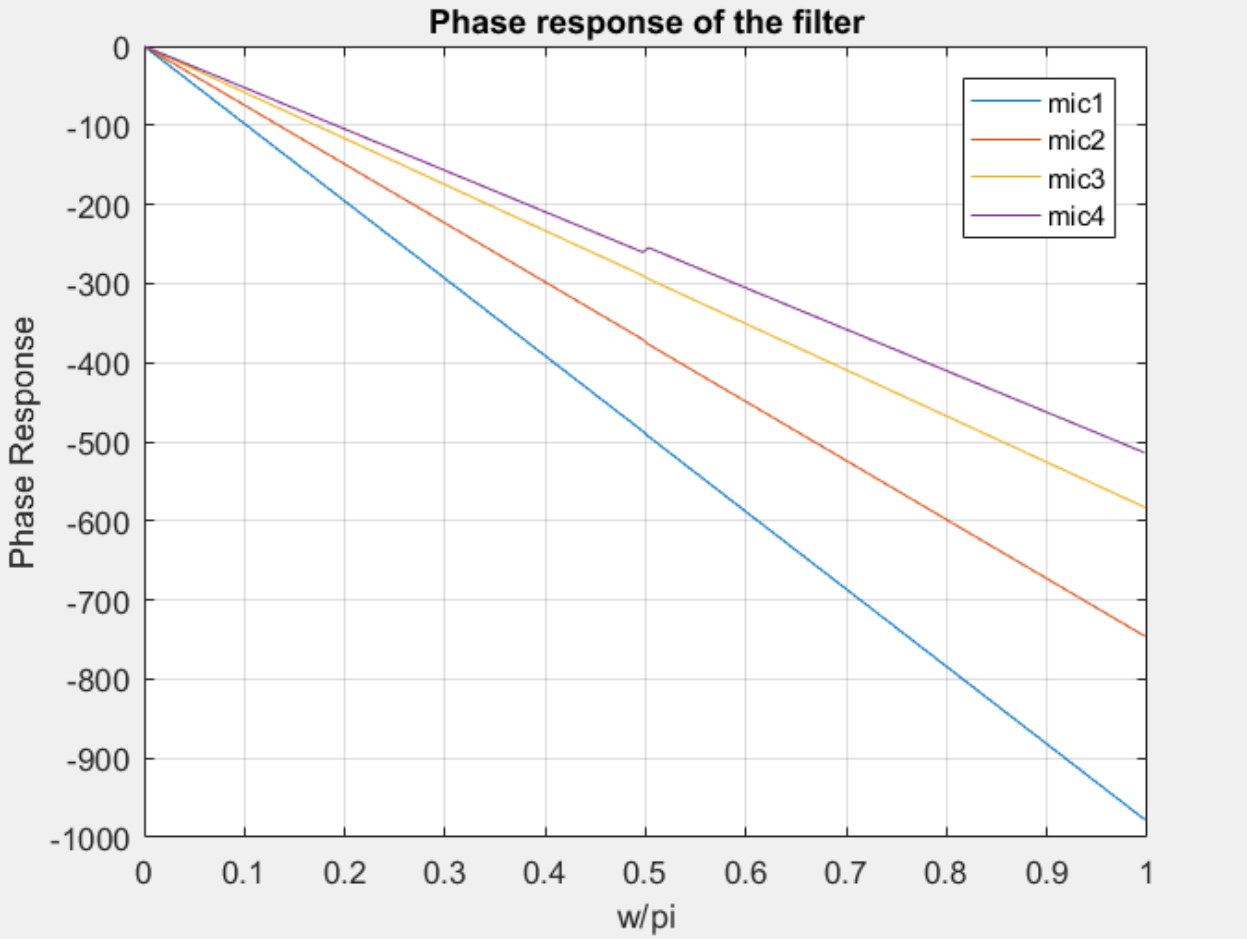

Figure 3: phase response of the LMS Filter weights

The phase response of the filter is approximately linear and the time delays are estimated from the slope of the phase of the filter.

[-0.0044; -0.0081; -0.0107; -0.0119] seconds

The theoritically calculated time delays are matched with the eestimated time delay using the LMS algorithm.The results are tabled for different sound source location ,number of microphones and the distance between each microphones.

source	Number of microphones	Distance between microphones	calculated Time Delays	Estimated Time Delays	Estimated source
[8,6]	5	2	[0,-0.0044,-0.0081,-0.0107,-0.0117,]	[0,-0.0044,-0.0081,-0.0107,-0.0119]	[8.0160,5.9469]
[10,5]	6	3	[0,-0.0075,-0.0139,-0.117,-0.0169]	[0,-0.0075,-0.0139,-0.117,-0.0169]	[10.016,5.048]
[12,8]	7	3	[0,-0.0069,-0.0129,-0.0171,-0.0187,-0.171,-0.0129]	[0,-0.0072,-0.0129,-0.0171,-0.0187,-0.171,-0.0129]	[11.993,8.004]
[5,3]	5	2	[0,-0.0046,-0078,-0.0078,-0.0046]	[0,-0.0049,-0078,-0.0078,-0.0049]	[5.042,3.006]
[9,3]	7	2.2	[0,-0.0060,-0.0116,-0.0165,-0.0189,-0.0171,0.0126]	[0,-0.0060,-0.0116,-0.0164,-0.0189,-0.0171,0.0126]	[9.000, 3.029]
[12.2,7.5]	7	3.5	[0,-0.0083,-0.0151,-0.0193,-0.0193,-0.0150,-0.0080]	[0,-0.0083,-0.0151,-0.0193,-0.0192,-0.0150,-0.0083]	[12.298,7.639]

Table 1: Showing the calculated time delay and estimated time delay are approxmatly equal

If Number of microphones increases to get better approximation of the sound source location the distance between the microphones has to be decreased.The resultant source location is tabulated by varying the distance between the microphones.

source	Number of microphones	Distance between microphones	Estimated source
[8,6]	3	5	[7.9561,5.8963]
[8,6]	4	4	[7.9698,5.8437]
[8,6]	5	3	[7.9863,5.9917]
[8,6]	6	2	[8.0192,6.0023]

Table 2: Shows that if Number of microphones increases to get better approximation of the sound source the distance between the microphones has to be decreased.

The effect of sampling frequency over the estimated sound source location is observed and tabulated.The sampling frequency is varied from the 1000Hz to 11000Hz,the resultant sound source location is observed and tabulated.

Microphones=7;Source=(8,7);distance=2;filter length=200;stepsize=0.001;U=0.1

Sampling Frequency	Estimated source
1000	[8.1819,6.1533]
3000	[8.0482,6.3288]
5000	[8.0738,6.9782]
7000	[7.9847,7.0341]
9000	[7.9907,7.0026]
9500	[8.0002,7.0104]
10000	[8.0468,7.3513]
11000	[8.1210,8.2065]

Table 3: The table shows the effect of change in the sampling frequency on estimated source location

The effect of change in the filter length on the estimated source location is observed and tabulated.The filter length is varied from 200 to 1200 we get good approximation of sound source till 600 and after 600 we get the results that are near to actual sound source location.

Microphones=7;Source=(8,7);distance=2;stepsize=0.001;U=0.1

Filter Length	Estimated source
200	(8.0512,7.3652)
250	(8.0095,7.0663)
300	(8.0041,6.9733)
400	(8.0041,6.9733)
500	(8.0041,6.9733)
600	(7.9827,6.8919)
900	(7.9628,6.7774)
1000	(7.9073,6.2424)
1100	(7.7924,6.0481)
1200	(7.7906,4.7082)

Table 4: The table shows the effect of change in the filter length on the estimated source location

As the number of iterations increases the better we get approximation.The iteration number is varied and the resultant sound source location is observed and tabulated.

Microphones=7;Source=(8,7);distance=2;filter length=200;
stepsize=0.001;U=0.1;initial source=[1,1]

Number of Iterations	Estimated source
100	(8.7631,9.3682)
200	(8.2547,7.781,)
300	(8.0601,7.1557)
500	(8.0041,6.9733)
1000	(8.0018,6.9660)
5000	(8.0018,6.9660)
10000	(8.0018,6.9660)
15000	(8.0018,6.9660)

Table 5: The table shows the effect of change in the Number of iterations on estimated source location

The effect of change in the stepsize used in steepest descent algorithm on the estimated source location is tabulated.The resultant sound source location for differnt values of stepsize is noted and tabulated.

Microphones=7;Source=(8,7);distance=2;filter length=200;
stepsize=0.001;initial source=[1,1]

Step Size(U)	Estimated source
0.05	(8.0018,6.9660)
0.01	(8.0017,9.655)
0.005	(7.9931,6.9373)
0.001	(7.6966,5.9494)

Table 6: The table shows the effect of change in the step size of the steepest descent algorithm on Estimated source location

The effect of change in the stepsize used in Least Mean Square algorithm on the estimated source location is tabulated,if the stepsize decreases we get better approximation of sound source location.The resultant sound source location for differnt values of stepsize is noted and tabulated.

Microphones=7;Source=(8,7);distance=2;filter length=200;initial source=[1,1]

Step Size	Estimated source
0.01	(9.2453,1.4412)
0.01	(8.0018,6.9660)
0.0005	(7.9978,7.0945)
0.0001	(7.9978,7.0945)
0.00001	(7.9979,7.0947)

Table 7: The table shows the effect of change in the step size of the LMS algorithm on Estimated source location