**Ishfaq Ahmad Bhat**

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**By**

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**Analysis and Processing of Whale Acoustic Signal Data Report**

**Under Water Acoustics**

# **Introduction**

This document outlines the procedures and results of the acoustic signal processing employed to ascertain the spatial orientation of whales. Through the integration of hydrophone array information and sophisticated signal processing methodologies, we have successfully determined both azimuth and elevation angles associated with whale vocalizations. This advancement contributes to a more comprehensive comprehension of whale behaviour and communication patterns. The acoustic data was collected using a multi-hydrophone array, and the recorded signals were saved in the "wav" audio format. The raw data for our analysis was derived from precise time-of-arrival differences between the hydrophones. Following fig shows the position of hydrophones arrays.

A diagram of a structure

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# **2. Hydrophones coordinates**

The optimization algorithm computed the positions of five hydrophones by considering their inter-distances. The outcome is a three-dimensional configuration where H1 and H2 are positioned diagonally across each other in depth, while H3 and H4 form a horizontal line at the surface. Hydrophone H5 is situated directly beneath the centre of the array, establishing a vertical axis.

This configuration results in a cross-shaped hydrophone array, visually represented in a 3D scatter plot depicted in Figure below. This visualization highlights the crucial spatial arrangement necessary for underwater acoustic monitoring.

|  |  |  |  |
| --- | --- | --- | --- |
| **Hydrophone** | **X(cm)** | **Y(cm)** | **Z(cm)** |
| H1 | 9.373528 | -0.252987 | -102.515016 |
| H2 | -99.126165 | 0.000653 | -102.515016 |
| H3 | -0.247365 | 10.252332 | 0.000000 |
| H4 | 0.000000 | -100.000000 | 0.000000 |
| H5 | 0.000000 | 0.000000 | 100.000000 |

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# **3. Whale Position:**

The whale's location within a three-dimensional space is determined through two primary angular measurements – azimuth and elevation. The azimuth angle signifies the whale's directional heading on a horizontal plane, commencing from the 0x axis and rotating towards the 0y axis. This angle covers a complete circle, with potential values ranging from 0 to 360 degrees.

On the other hand, the elevation angle represents the whale's angle of ascent or descent from the horizontal plane. It originates from the 0x axis and extends towards the 0y axis. Values for the elevation angle can vary from 0, denoting a level position with the plane, up to 90 degrees, indicating a position directly above the horizontal plane.

## **3.1 With fixed speed (1450m/s):**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Samples** | **Time(sec)** | **φ** | **θ** | **Loss** |
| 1 | 1.848881 | 139.934334 | 28.77888392 | 2.211330611 |
| 2 | 5.713899 | 332.0515341 | 27.41545981 | 0.9061812541 |
| 3 | 7.650524 | 328.3825189 | 27.33299484 | 1.003352868 |
| 4 | 8.695825 | 331.9618086 | 27.39030378 | 0.9175235114 |
| 5 | 14.545618 | 329.243811 | 27.25877515 | 1.021551326 |
| 6 | 24.4744 | 329.0664057 | 27.26120125 | 1.027736135 |
| 7 | 34.716133 | 326.835857 | 27.21363676 | 1.127289676 |
| 8 | 50.644576 | 331.5981851 | 27.25937521 | 0.9510471181 |
| 9 | 74.041589 | 335.6551207 | 27.21128756 | 0.7958068798 |
| 10 | 76.310557 | 332.1233446 | 27.19462234 | 0.8800386794 |
| 11 | 80.111199 | 332.0737143 | 27.10406368 | 0.9246808002 |
| 12 | 93.1389 | 329.7677882 | 27.00257382 | 1.008419937 |
| 13 | 95.026798 | 335.8807801 | 27.15916201 | 0.7953195986 |
| 14 | 96.447575 | 332.6215861 | 27.32822731 | 0.9013758289 |
| 15 | 103.452519 | 334.4526448 | 27.22154671 | 0.8031779333 |
| 16 | 120.800559 | 338.5178364 | 27.31889709 | 0.6251953806 |
| 17 | 121.647166 | 335.5270425 | 27.19218465 | 0.7603195354 |
| 18 | 124.237632 | 336.7654152 | 27.24580613 | 0.6693001106 |
| 19 | 126.193057 | 337.726666 | 27.21913163 | 0.621176715 |
| 20 | 134.064329 | 144.530641 | 29.23218218 | 2.062460176 |
| 21 | 136.82453 | 144.4466966 | 29.00347228 | 1.933065477 |
| 22 | 142.785914 | 332.8415958 | 27.35993369 | 0.7496980906 |
| 23 | 156.110834 | 335.1584511 | 27.35587789 | 0.6690453178 |
| 24 | 163.471953 | 337.3447913 | 27.56678926 | 0.5570106019 |
| 25 | 165.168026 | 336.3068513 | 27.37286461 | 0.6228442833 |
| 26 | 172.367704 | 333.7135948 | 27.40459977 | 0.6722050614 |
| 27 | 174.518234 | 334.1342215 | 27.50537472 | 0.6684789988 |
| 28 | 175.526938 | 332.9773723 | 27.46966463 | 0.675182251 |
| 29 | 177.163734 | 332.9495687 | 27.43161737 | 0.7276360379 |
| 30 | 179.716239 | 334.0305825 | 27.45068101 | 0.6454218146 |

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## **3.2 With estimated speed:**

The speed of sound estimated through our acoustic signal analysis closely matches the provided fixed value. This correlation implies that our estimation method is reliable, and the fixed value serves as a credible approximation for the speed of sound in this context. Consequently, the resultant data exhibits negligible differences, whether using the estimated or fixed value.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Samples** | **Time(sec)** | **φ** | **θ** | **Loss** |
| 1 | 1.848881 | 140.0119935 | 28.75066356 | 2.202922161 |
| 2 | 5.713899 | 332.2799942 | 27.49101229 | 0.89381288 |
| 3 | 7.650524 | 328.6085689 | 27.40895255 | 0.9879499161 |
| 4 | 8.695825 | 332.1886555 | 27.46591868 | 0.9046528752 |
| 5 | 14.545618 | 329.4673407 | 27.33516053 | 1.005246067 |
| 6 | 24.4744 | 329.2924151 | 27.33781666 | 1.011381066 |
| 7 | 34.716133 | 327.0604406 | 27.29043017 | 1.108473326 |
| 8 | 50.644576 | 331.8175531 | 27.33542377 | 0.9359154324 |
| 9 | 74.041589 | 335.8665059 | 27.28668265 | 0.7836310135 |
| 10 | 76.310557 | 332.3313272 | 27.27011038 | 0.8649315692 |
| 11 | 80.111199 | 332.2870084 | 27.18054669 | 0.9089307137 |
| 12 | 93.1389 | 329.9743816 | 27.07909377 | 0.9900488533 |
| 13 | 95.026798 | 336.090729 | 27.23478595 | 0.7827745001 |
| 14 | 96.447575 | 332.8312958 | 27.40329779 | 0.8860646211 |
| 15 | 103.452519 | 334.6600894 | 27.29666027 | 0.790172624 |
| 16 | 120.800559 | 338.7149034 | 27.39211644 | 0.6162800732 |
| 17 | 121.647166 | 335.7271953 | 27.2667894 | 0.7476872276 |
| 18 | 124.237632 | 336.9629216 | 27.3196798 | 0.6587097266 |
| 19 | 126.193057 | 337.9256346 | 27.29291316 | 0.6125330649 |
| 20 | 134.064329 | 144.616249 | 29.19775586 | 2.055012862 |
| 21 | 136.82453 | 144.5092931 | 28.97319082 | 1.926550404 |
| 22 | 142.785914 | 333.0406482 | 27.43337587 | 0.7374495926 |
| 23 | 156.110834 | 335.3587177 | 27.42901827 | 0.6597602868 |
| 24 | 163.471953 | 337.5406064 | 27.63810785 | 0.5506907384 |
| 25 | 165.168026 | 336.5094951 | 27.44586874 | 0.6153281524 |
| 26 | 172.367704 | 333.9113022 | 27.47720693 | 0.662687498 |
| 27 | 174.518234 | 334.3333018 | 27.57747488 | 0.6597038209 |
| 28 | 175.526938 | 333.1728589 | 27.5417873 | 0.6652447003 |
| 29 | 177.163734 | 333.1479533 | 27.50418656 | 0.7171614796 |
| 30 | 179.716239 | 334.226438 | 27.52291316 | 0.6362326272 |

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# **4. Summary**

The azimuth and elevation angles, vital for determining the whale's position, were obtained from the time differences in signal arrival at the hydrophone array. Despite small deviations in hydrophone coordinates and the assumption of a planar wavefront for signal propagation, the estimated speed of sound closely aligns with the expected 1450 meters per second. This proximity indicates minimal impact on the results, whether using the estimated speed value or the fixed speed value.

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