Compensation of Phase Error Using Efficient Hydrophone Array Arrangement in Synthetic Aperture Sonar

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Abstract— The primary objective of this article is to enhance phase error correction in critical directions. Previous studies indicate that phase correction methods face significant limitations when addressing unwanted platform movements, leading to a degradation in output image quality. This research proposes a novel approach that focuses not solely on improving phase correction techniques but on achieving an efficient geometry for hydrophone array arrangement. The innovative goal is to increase the likelihood of receiver presence and improve the reception of returning signals, which can substantially mitigate the adverse effects of phase error. This issue is addressed by reducing the impact of unwanted impulses in critical degrees of freedom, complementing existing phase error enhancement methods. The findings suggest that optimizing hydrophone array configurations can lead to significant advancements in synthetic aperture sonar (SAS) applications, ultimately improving imaging performance and accuracy.

Keywords —Synthetic Aperture Sonar, Hydrophone Array Arrangement, Efficient Geometry

INTRODUCTION

In Synthetic Aperture Sonar (SAS), phase information is essential for enhancing image quality and accuracy. It refers to the position of a point in time within a waveform cycle, which is crucial for reconstructing images from collected data. Phase information plays a vital role in image reconstruction by allowing for target differentiation and improved resolution. It also aids in compensating for unwanted platform movements, ensuring data integrity and high-quality imagery. Additionally, analysing phase shifts in returned signals is key for detecting and identifying targets. SAS applications include underwater military surveillance, environmental monitoring. Overall, effectively utilizing phase information is fundamental to advancing SAS technologies, leading to enhanced imaging performance and operational effectiveness.

PHASE ERROR SENARIO

Swath refers to the strip or area covered by a sensor during a single pass. It denotes the width of the ground area that is imaged or scanned at one time. The size of the swath is crucial for determining the efficiency of data collection.

As the sonar moves along a defined path with a specific time delay corresponding to the round trip of signals, a chirp signal is generated in the azimuth direction. The compression of this chirp signal results in image formation. However, if unwanted platform movements or disturbances occur, they can induce phase changes in the signal, disrupting the formation of chirps in the azimuth direction.

When isolating a line from the received signal corresponding to a slow time step, the resulting information represents a complex signal that can be mathematically expressed. Each sample represents the sonar return from points within the swath at a corresponding delay. The relationship between distance from the sonar to the swath is given by:

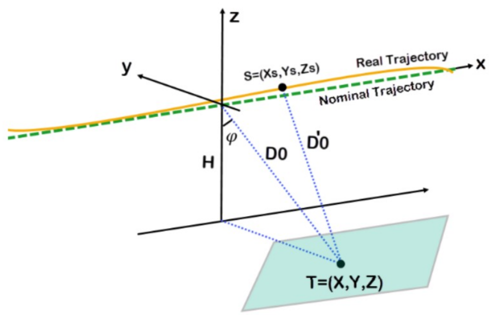

Fig. 1 Effect of translational motion error

where c is the speed of sound in water. The ideal phase from each point within the swath can be determined since both transmitter and receiver positions are known.

PROPOSED METHOD

To address phase errors induced by unwanted impulses, various methods have been proposed, including deploying multiple receivers arranged optimally. In SAS systems, two types of fast time and slow time, are utilized to derive received signals at the end of matrix scanning based on these two timings.

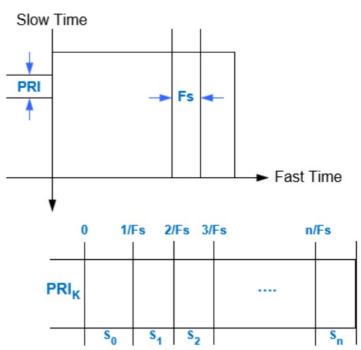

Fig. 2 Steps for Creating a Raw Data Matrix

If disturbances occur without altering the sonar's distance from the swath for each pulse, no phase difference arises. In this geometric scenario centred around a target within a sphere, having multiple receivers increases the probability that at least one receiver will have a phase close to the ideal value. This redundancy allows for effective compensation for any induced phase discrepancies.

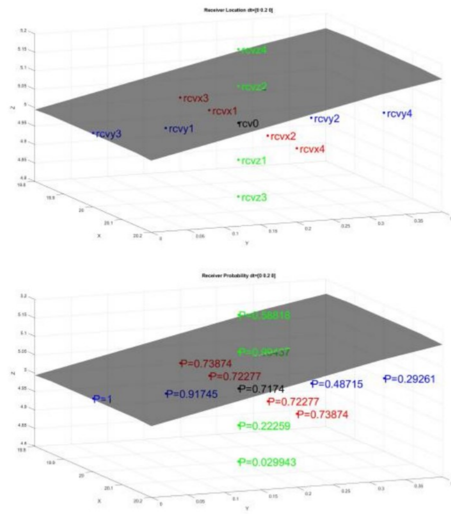

Fig. 3 Efficient correction for any induced phase misalignments

CONCLUSION

The proposed approach suggests that by optimizing hydrophone array configurations and leveraging multiple receivers, it is possible to model and compensate for phase discrepancies effectively. By analysing probabilities associated with each receiver's proximity to ideal phases, we can design efficient decision-making algorithms to correct these errors. This methodology not only enhances imaging performance but also ensures greater operational effectiveness in synthetic aperture sonar applications. In summary, optimizing hydrophone arrangements based on geometric considerations significantly contributes to mitigating phase errors caused by unwanted movements, thereby improving overall imaging quality in SAS systems.

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