MATCHED BEAM PROCESSING SENSITIVITY TO ARRAY ELEMENT LOCALIZATION

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1. INTRODUCTION

Modern developments in underwater acoustics include the assessment of employing rapidly deployed, bottom moored vertical and/or horizontal hydrophone arrays for target detection and localization. While these arrays are economical in both cost and time for deployment, their autonomy presents a problem in effectively processing data recieved from a sensor which is not precisely located. Because these rapidly deployed systems (RDS) are deployed under tension from surface vessels and then lowered to the bottom, deployment geometry is vulnerable to the effects of wind and waves at the surface, as well as currents during array descent. The resulting uncertainty in the deployed array position can have a detrimental effect on subsequent processing of received acoustic signals.

This paper will discuss the array element localization (AEL) of a bottom-moored ultra-light (ULITE) horizontal array deployed during the RDS-2 trial. As well, the sensitivity of source localization to improper AEL will be demonstrated with a synthetic example of matched beam processing (MBP), an array processing technique which compares measured and calculated plane wave beams from a linear array to determine target position.

2. EXPERIMENT

In November, 1995, a multi-national trial was conducted to 'test and demonstrate advanced deployable array technologies and advanced data recovery methods and to test rapid array deployment techniques.' [1] The trial, called RDS-2, was conducted in the Timor Sea, approximately 160 km west of Darwin, Australia. Numerous arrays were deployed including an ultra-light (ULITE) Y-shaped horizontal array with three 468 m arms, each containing a nested configuration of 32 hydrophones.

Deployment of the ULITE array was carried out by three surface vessels, each paying out an arm under tension as they diverged from the central node position, and then lowering the fully extended array 107 m to the bottom. As is shown in Fig. 1, the intended and actual array positions differed significantly. Unequal cable tensions between the deploying ships as a result surface conditions, combined with strong currents resulted in individual hydrophones being in excess of 300 m from the planned positions.

After array deployment, an array element survey was conducted in which light bulbs were lowered from a surface vessel and imploded as sound sources at selected locations at an estimated depth of 52 m (Fig. 1). The light bult geometry was based on the intended array position. However, because of the disparity between intended and actual array positions, the source locations were less than ideal.

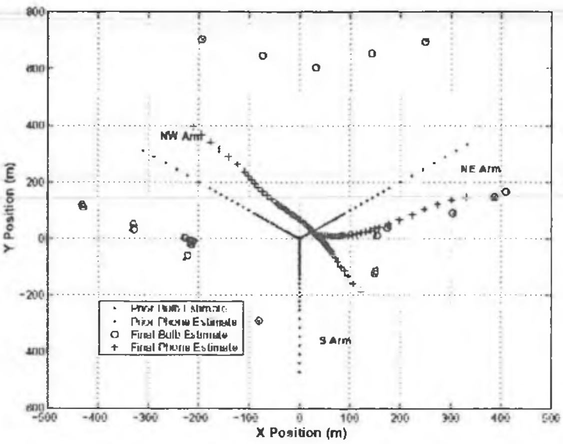

Fig. 1. Plan view of intended and recovered ULITE hydrophone positions. (Prior and final estimate of light bulb positions included)

3. ARRAY ELEMENT LOCALIZATION

Relative arrival times were measured for the light bulb implosion transients at each hydrophone by peak picking of direct path arrivals. The inverse problem of determining source and receiver positions from the arrival times is solved using the method of linearized inversion [2], [3]. *A priori* estimates are assigned to source and receiver positions in an iterative algorithm which seeks to minimize the modelled and real data misfit. Convergence criteria of the algorithm stipulate that the χ^2 misfit reduce to N (the number of equations generated for n transient arrivals at m hydrophones), and that the rms change of hydrophone positions between iterations be small in comparison to the expected solution accuracy. The inversion solution provides the best fit to the data, while explicitly minimizing array structure to only that which is resolvable from the acoustic information.

Hydrophone positions were located to within an average absolute rms error of 2.4 m horizontally, and 0.6 m vertically. Relative uncertainties were determined by a Monte Carlo appraisal [2],[4]. In the appraisal, the recovered position of the array is treated as the 'true' model to generate travel time data for simulated implosions at recovered source positions. Simulated data is then perturbed by adding random errors to create numerous data sets. Each set is inverted using the linearized algorithm and the resultant rms errors are averaged, providing average relative errors of 0.5 m horizontally and 0.6 m vertically. Fig. 3 depicts absolute and relative errors for each element.

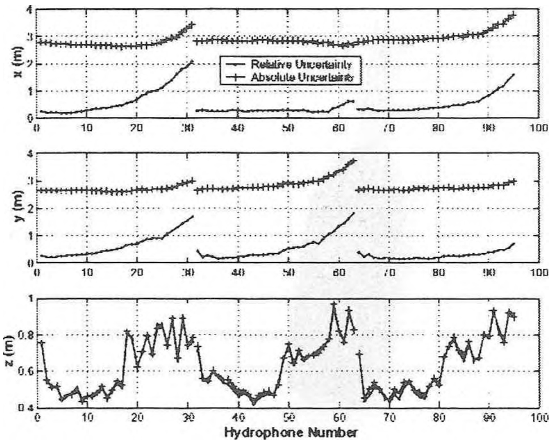

Fig. 2. Relative and absolute uncertainties (1 standard deviation) for ULITE element positions.

4. AEL IMPACT ON MBP

To demonstrate the impact of inaccurate AEL, a example is presented in which MBP is applied to simulated receptions from the recovered positions of the NE and NW ULITE arms. For the simulation, a 200 Hz source is located at 50 m depth, 80° (ref. true north) from the ULITE node, at a range of 3 km. Simulated acoustic data were generated using the ORCA normal mode propagation model [5], to which random noise was added resulting in a signal to noise ratio of 20 dB.

Fig. 3 depicts the effect of range, bearing, and depth correlations between the simulated *true* model (receiver positions are exact), and *estimated* model in which normally distributed errors of specified standard deviations have been added to the receiver positions. For the first run (solid line), *estimated* receiver positions are the same as *true* positions, thus correlations of 0.99 are achieved at correct bearing, range, and depth. Random horizontal errors drawn from a Gaussian distribution with standard deviation equal to that of the relative errors for the AEL inversion are added to the *estimated* receiver positions for the second run (dotted line). The correlation is reduced to 0.92, peaks remain at the correct bearing, range and depth. Doubling the standard deviation of the hydrophone perturbations begins producing range and depth estimation errors, and by the third run (dashed line) in which the standard deviation of induced errors is tripled ($\leq$ 7 m), significant degradation is seen in both range and depth. The source is falsely located at range 2.75 km and depth 10 m. Finally, using the prior hydrophone positional estimates in the MBP precluded any meaningful localization in range, bearing, or depth (not shown).

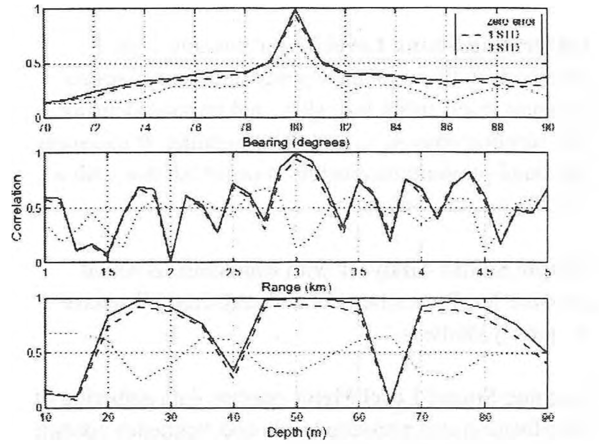

Fig. 3. MBP bearing, range, and depth correlations as a function of receiver positional error.

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AUTHOR NOTES

This work was conducted as part of the primary author's MSc thesis research in matched beam processing of ULITE acoustic data collected during RDS-2. AEL algorithms were developed and implemented by the second author.