



C H R O N I C L E

XXIII Symposium on Hydroacoustics Krynica Morska, May 23–26, 2006

The Symposia on Hydroacoustics already have their own history. The last one was held in Krynica Morska, May 23–26, 2006. Krynica Morska is an attractive seaside resort, located on the sandy strip of the Vistula Bay, separating the waters of the Vistula Lagoon from the Bay of Gdańsk.

The Symposium traditionally was organized jointly by Gdańsk University of Technology and Naval University in Gdynia. Lech Kilian was the chairman of the Organizing Committee and Roman Salamon was the chairman of the Scientific Committee.

XXIII Symposium on Hydroacoustics was organized under the auspices of the Acoustic Committee of the Polish Academy of Sciences and the Polish Acoustical Society.

The main symposium topics were:

- sound propagation in the sea,
- ambient and ship noise,
- nonlinear hydroacoustics,
- ultrasonic transducers,
- sonar systems,
- other topics related to underwater acoustics,
- environment.

29 papers were presented including 5 invited papers and one plenary. All accepted papers were published in the periodical “Hydroacoustics”, vol. 9. “Hydroacoustics” is publication which contents the newest achievements of Polish and foreigners hydroacousticians.

The symposium was attended by 71 scientists from Poland and there were a few scientists from foreign countries.

Apart the scientific programme there was organized boating trip to Frombork. In the participants opinion it was very interesting to see the unique Polish city.

The next XXIV Symposium on Hydroacoustics will be held in Jurata at the Delfin Hotel, May.

Abstracts

1. Numerical analysis of the finite amplitude plane wave propagation problem

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The paper presents the results of theoretical investigations of the finite amplitude plane wave propagation problem. The case of harmonic plane pressure wave of megahertz frequency propagating in water is discussed. Mathematical model and some results of numerical calculations are shown. The nonlinear acoustics equation was considered to build the mathematical model. To solve the problem numerically, the finite-difference method was applied. The influence of discrete model parameters on the numerical calculations accuracy was studied. The results of computer calculations for different values of physical parameters were also analyzed.

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2. The analysis of the system towing rope with long underwater object

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The paper describes a solution of the boundary problem for a system of a long rope with object density insignificantly greater than the density of the water and small rigidity. There is only known a point of hooking the rope on the ship and depth on which the end of the towed object is sunk. Article presents the analysis of the system described above with calculation of his forms and forces of weights, buoyancy force and lift with changeable longitudinal rope's tension. The results of calculations show capabilities and manners steering form. But what is more important it shows how to steer with the sink of the object on the water of different depths and allows safe maneuvering of the object. Besides, employment of described method and/or similar (see [1]), for calculating the geometry of the system towed by a maneuvering ship will give better accuracy of the executed measurement by the towed object.

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3. 3D imaging software tools for multibeam sonar data

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Nowadays, the techniques of 3D computer graphics are developing dynamically. They find application not only for creating the computer games, but often for three-dimensional data visualization systems. Application of these techniques makes the graphical operations more effective and consequently, these systems become more efficient. The paper presents the system of 3D seafloor visualization using multi-beam sonar data. In the presented system, three programming techniques for 3D graphics were used: C++ OpenGL, Java3D, Java OpenGL. The problems related to the system development and the methods of their solution are presented.

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4. The Mathieu functions applied to some problems in underwater acoustics

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The purpose of this paper is to present examples of application of the Mathieu functions to solving problems in the field of acoustics, mainly underwater acoustics.

The Mathieu functions have application to the waves related to ellipses and elliptical cylinders: elliptical membrane vibration, vibration of water in elliptical containers, etc. The reason why these functions have attracted little attention so far is mainly the complexity of the issues they involve. Among all the other functions occurring during separation of the variables in a wave equation (with partial derivatives) in various co-ordinate systems, the Mathieu functions were the first non-hypergeometric ones. Hence, there are difficulties in the theory of these functions, as well as in the calculations involved.

The reflection of a sound wave is studied at an inhomogeneous layer with parallel surfaces separating two homogeneous semi-infinite media having different indices.

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5. The difference-frequency acoustic scattering from nonlinear objects

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The difference-frequency acoustic scattering from nonlinear objects such as bubbles was studied for many years and used for bubble diagnostics. In the present paper we consider theoretically two problems. The first one is the difference-frequency scattering from the nonlinear layer in a linearly stratified medium. The second problem is the difference frequency scattering from the system of periodic nonlinear layers. In both problems the resonance phenomena are studied and their influence on characteristics of the scattered fields are analyzed. In the third part of the paper we describe an experimental method of acoustic difference-frequency vision of large-scale bubbly objects.

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6. Setting time periods of concentration of the acoustic energy generated to water by ships

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Generation of the acoustic energy into the water environment through the hull of the ship and the ship propeller usually remains in the frequency of the range of single hertz to a few or several kilohertz. In the range of the frequency that was analyzed, there appear discrete components that are connected with the work of ship's mechanisms as well as with broad-band "noise" that is relevant to the phenomenon of cavitation, that in some range of work of ship's propeller can mask discrete components connected for example with the work of the main engine. Fixing the ranges of frequencies in which the acoustic energy

of ship's equipment are concentrated, we can facilitate the remote diagnostics of the ship as well as its identification.

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7. 2D FFT algorithm for Frank sequence processing

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The paper presents a new fast algorithm enabling to calculate periodic auto- and cross-correlation functions of Frank sequences. It is based on a 2-dimensional representation of the sequences and a combination of the spectral and direct correlation function calculation methods. In this case the computational accuracy is enhanced and the number of the required complex operations is reduced by 50%.

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8. Multistatic systems

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This paper describes key features of a multistatic operation in the littoral beginning from multistatic system (MS) configuration, his performance model and constraints imposed by environment of shallow water. The architecture of MS, features and requirements of MS basic sub-system has been presented. Essential role as during MS operation is fulfilled by data fusion and tracking methods as well a communication between MS units, has been protruded. The application of MS, especially for underwater protection systems, in the form of barriers protecting anchorage, harbour, straits or entries to the harbour, has been presented. Other applications are connected with military operation, especially Anti-Submarine Warfare (ASW) in littoral areas. Attention was paid to the possibility of cooperation among the different acoustics devices in MS.

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9. Research and development of underwater acoustic systems at the Polish Naval Academy and the Gdańsk University of Technology

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The article begins with an overview of how the Universities and the Polish Navy have benefited from nearly fifty years of cooperation. The article goes on to discuss the last decade's hydroacoustics projects for the Navy. The Naval Academy's contribution involves measurements and analyses of ships' hydroacoustic fields including the technical applications of the projects as well as the application of propagation nonlinear effects of acoustic waves in water. The University of Technology's primary contribution has been the modernisation of the Polish Navy's underwater acoustic systems.

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10. Phase conjugation for underwater acoustic communications

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In this paper, a multipath problem in shallow water acoustic channel and phase conjugation technology are presented. Acoustic communications in shallow water were a difficult problem due to the characteristics of the underwater acoustic channel. The shallow water channel is the environment which is of particular interest for many researchers workers and presents the problem for the designers of communication systems. Underwater acoustic channels are characterized by multipath phenomena variable in time. This is the main factor that limits the underwater acoustic communication performance. Communication systems can be categorized as using either incoherent or coherent modulation strategies. This paper presents the phase conjugation technique, also called “time-reversal”, which is the subject of active research in many fields of acoustics. This is a new method for coherent underwater acoustic communication. Preliminary results confirm the potential utility of the phase conjugation in underwater acoustics with applications to underwater communications. This method effectively mitigates the multipath propagation and can be used to solve this problem.

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11. Are the Knudsen curves acceptable in the Baltic Sea?

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Results of ambient noise measurements performed in the southern part of the Baltic Sea are presented. An autonomous measurement buoy was deployed in two Baltic Deeps under dissimilar sound propagation conditions – at the Bornholm Deep in winter and at the Gdańsk Deep in summer.

The sound was registered and analyzed in the frequency range from 350 Hz up to 35 kHz. The parameters of dependence of the ambient noise sound pressure level versus the wind speed were determined.

It was found that the measured ambient noise spectrum level depends not only on wind speed and location but also on the depth of observation.

The results show that the wind-dependent ambient noise component in the Baltic Sea frequently does not match the Knudsen curves and we have found that at some specific location, the sound level at low frequencies does not depend on wind. The collected data on the noise levels are discussed and compared with other historical and contemporary data on the noise level in the Baltic Sea.

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12. Acoustic estimation of macrophytes in the Hornsund Fjord (The Svalbard Archipelago)

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In this paper we examine the use of side-scan sonar for estimation and spatial distribution of macrophytes in Arctic conditions. Acoustic observation were verified by video recordings and biological samplings. Single beam echosounder was also used. The Hornsund Fjord represents a periglacial environment with great diversity of morphodynamic processes and sensitivity to global warming changes, so it is one of the most promising areas to research the influence of the climate’s impact on the ecosystem. Side-scan

sonar is a very effective and economic tool for mapping marine vegetation on the seafloor, but interpretation of data still causes many problems, especially the specific conditions of the Arctic fjords (underwater rocks, postglacial sediments, steep slopes). We have created a segmentation and classification algorithm based on the two-dimensional discrete wavelet decomposition of echo signals and fuzzy c-means data clustering. The algorithm was verified using biological data.

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13. Influence of vibration of ship's generating set on the emitted acoustic energy

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The article presents the investigations of influence concerning vibration of generating sets on the hydroacoustic spectrum's structure generated by the hull of ship to water environment. The investigations were conducted on anchor and during movement of the ship, with characteristic parameters of motion of the ship. The influence of change of speed governor driving engine was considered on produced the voltage's frequency under of load variations the ship's electrical system. In the tests, there were conducted the vibrations' measurements on engine-bed of the individual generating set, on the ship's hull of directly under sets, as well as the measurements of underwater noise under hull of ship. The analysis consist with the qualification of levels of the measured parameters and the changes spectrum's vibrations of underwater noise as well as their correlations. It was analysed with possible exploational states of the ship, number of working generating sets, and their reconfigurations. In the paper we described the guidelines to methodology of investigations of generating sets near state exploational variables of the ship. This joins closely with qualification of possible state of exploational ship, which is important for military regards.

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14. 3D visualisation and monitoring of marine pollutant aggregations in web-based GIS

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The paper presents the visualisation and monitoring of marine pollutant aggregations as the sample application of the real-time, remotely accessible marine GIS. The system is dealing with instantaneous integration, processing and visualisation of marine data acquired by direct sampling, satellite remote sensing and underwater acoustic systems. The developed Web-based GIS is capable of producing 2D maps with overlaid various types of data, as well as generating the composed, time-varying 3D scenes presenting different elements of marine environment. As the sample application of the system, the visualisation of the 3D modelling of an oil spill drift and spreading within the southern Baltic area is presented. The data were obtained from the composed 3D modelling system CAROCS. The developed GIS, due to its remote accessibility and the on-line data processing, may be applied as a useful tool for maritime domain awareness and emergency management supporting, with respect to hazards of a different kinds: pollution, ecological catastrophes, natural disasters. The system utilises the SQL spatial database for data storage and the Scalable Vector Graphics (SVG) and Virtual Reality Modelling Language (VRML) standards for remote presentation of geographical objects, and requires only the WWW browser with SVG and VRML viewer on the client side.

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15. Experimental evaluation of high frequency side-scan sonar as object search and identification tool

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The paper presents initial results of laboratory tests of the sonar selected as a short-range tool for an underwater vehicle. It is intended for bottom-located object search and identification. To evaluate the sonar imaging capability expressed by its resolution, several parameters were investigated. First group of parameters concerns the sonar itself, while the second regards an object material, its dimensions and shape. Their cross-influence was investigated for different distances from hydrophone to the object of interest and different hydrophone elevation angles. Experiments were performed in a shallow water laboratory tank.

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16. Electronic stabilization of beams in a sonar with cylindrical array

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The paper presents the principle of operation of the beamformer of a sonar with a cylindrical array. It demonstrates that a modified beamformer can be used for electronic beam stabilization. The paper presents the algorithm of a digital beamformer used to ensure that the beam's axis is maintained in a horizontal plane when the ship's pitch and roll are known. Finally, the article gives an overview of the technical problems of electronic beam deflection.

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17. A hybrid optimization method for designing polyphase sequences

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Polyphase sequences which have a low autocorrelation ensure an easily detectable peak in the output of a matched filter of a radar receiver. The low autocorrelation for polyphase codes is usually described in terms of the maximum magnitude of its sidelobes level. In this paper, an evolutionary algorithm combined with a local optimizer is used to search for polyphase codes with a small sidelobe level of an aperiodic autocorrelation function. The evolutionary algorithm is based on a floating-point representation and the Gaussian mutation is used to produce an off-spring for the next generation. The local optimizer is applied to find polyphase sequences which are good starting points for the evolutionary algorithm. This research demonstrates that optimization methods can effectively determine the polyphase codes with low autocorrelation and seems to be very promising for future research in the area of computer optimization for radar polyphase codes synthesis.

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18. The estimation of Norwegian cod size distribution from acoustic data

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The paper presents an algorithm for estimation the fish length distribution from acoustic target strength data. The theory of scattering from a tilted cylinder is used for modelling the fish directivity pattern of swimbladdered fish. The model allows for formulating the dependence of target strength on two main components; the maximum target strength and the fish directivity pattern. As both terms depend on fish length, the inverse technique is used when processing is performed on introduced conditional distributions. The effect of fish tilt angle is in this way removed, or deconvolved from the target strength distribution.. The resulting fish maximum target strength distribution is further converted into fish length distribution using equivalent parameters for swimbladder morphology. The method is verified on actual data acquired during the Lofoten 2004 survey on spawning grounds of North East Arctic cod (*Gadus morhua*).

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19. Acoustic classification of Southern Baltic benthic habitat

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Seabed characteristics applied for classification was based on analysis of echo recordings collected aboard RV "Baltica" during regular surveys in 1995-2003 period. Hypothetical effective angle of a bottom echo $\theta'/2$, corresponding to its normalized length, was applied to characterize the complex seabed acoustic reflecting and scattering properties. The $\theta'/2$ values were determined for each EDSU. Classification of southern Baltic area was provided by comparison of two acoustically measured factors: statistical distribution of $\theta'/2$ and correlated depth structure within the selected standard areas. Both factors are very closely related to biological characteristics of the benthic habitat. Joining them gives a wide possibility of differentiating the habitat according to its basic ecological properties. The classification applied gave a unique identification and comparison of dynamics of seabed structures, useful for benthic surveys and helpful in ecologically friendly administration of the zone.

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20. Nonredundant 2D and 3D sonar systems based on gold ring bundles

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The paper presents a new method for configure systems of non-redundant two-dimensional and three-dimensional aperture antenna. The method is based on the Perfect Combinatorial Sequencing theory, namely the concept of Gold Ring Bundles (GRB)s for finding the optimal placement of array antenna elements for acoustic or underwater acoustic systems. It is shown that the method provides many opportu-

nities of the concept for novel design of nonuniform array with non-redundant aperture of array systems, including acoustics and hydroacoustics.

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21. Approximation of underwater channel impulse response by non-orthogonal functions

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This paper presents the idea and methods of approximation of underwater channel impulse response by non-orthogonal functions. The family of functions that correctly estimate the response of underwater channel is chosen. For these functions, the method of calculation of parameters and coefficients is introduced. Besides that, two examples are presented. The first one is the approximation of response in deep reservoir, the second one concerns approximation of response in a shallow reservoir, where problems of reflections from the surface of water and the bottom of reservoir appear.

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22. The ichthyofauna of the degraded vendace lakes Mielno and Maróz studied using hydroacoustic and monitoring catch methods

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In 2005, the distribution, density, and structure of pelagic fish resources was studied in lakes Mielno (363 ha) and Maróz (332 ha) located in the Łyna catchment basin through which the Marózka River flows. The studies were conducted using a Simrad EY-500 echosounder (120 kHz, 7×7 deg, 0.3 ms, split beam version) and a pelagic trawl for monitoring catches. At the out-set of the 1990s, vendace dominated the commercial catches of both lakes reaching about fifteen kg ha^{-1} . Significant changes have occurred in the structure of the pelagic ichthyofauna in recent years in the studied lakes; the disappearance of vendace and the dominance of bleak and roach in the catches indicates that the tempo of eutrophication has increased.

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23. Spatial SAS signal filtering by means of polar format processing

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Synthetic Aperture Sonar (SAS) is the high-resolution acoustic imaging technique which allows to improve the cross-range resolution. The main possibilities of SAS data gathering are the stripmap and spotlight modes. The stripmap system is only considered and analyzed in this paper. However, the results can be easily copied to the last one. In this specific mode, the sonar beam always points in the same direction (e.g. perpendicular to the direction of the travel) during imaging. The fundamental problem with the extraction of the echoes from the finite seafloor area appears in such a system. In order to deal with this inconvenience, we can take advantage of the well-known polar formatting, what is done in this paper. After that, the Omega-k algorithm is used to show some results of the numerical stripmap SAS system simulation. The outcomes confirm the possibility of usage of the polar format processing to filter out the SAS signal from the undesirable contributions.

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24. Synthesis and wavelet analysis of side-scan sonar sea bottom imageryTEGOWSKI Jarosław¹, tegowski@iopan.gda.plZIELIŃSKI Adam², adam@uvic.ca¹Institute of Oceanology, Polish Academy of Sciences

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A backscattered side-scan sonar signal contains indirect information about the scattering surface, namely, the bottom sediment, character of bottom surface, and seafloor relief. This paper presents a method of automatic estimation of height of seafloor characteristic objects and micro-relief reconstruction applying the measured shadow length. The proposed method utilises coefficients of two-dimensional discrete wavelet decomposition of a side-scan sonar image as the input to the self-organised neural network classification algorithm. The heights of seafloor characteristic objects were the basis for synthesis of a three-dimensional map of the bottom surface. The computations were conducted for the data recorded in Hornsund Fjord (Spitsbergen Island, Svalbard Archipelago) during a habitat mapping experiment and for synthetic data. The verification of the proposed algorithm was made by comparison of the computed results with the calibrated video recordings.

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25. The new underwater acoustic communication algorithm based on an approximation method

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In the paper has been presented a new algorithm for the underwater acoustic transmission. The algorithm is based on the approximation method. The transmitter and receiver block diagrams have been described. Finally, the future research areas have been presented. The aim of the paper is the algorithm description and the receiver and transmitter structure consideration.

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26. Diurnal and seasonal fish horizontal migrations in the Sulejów reservoir, PolandWOJTALIK Jakub¹, Godlewska Małgorzata²FRANKIEWICZ Piotr¹, franek@biol.uni.lodz.plZALEWSKI Maciej², margogod@wp.pl¹Łódź University

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Horizontal fish migrations in the Sulejów reservoir were studied acoustically. The SIM-RAD EY500 echo sounder was used with transducer looking horizontally at three sites of the reservoir located along its longitudinal axis. Fish began to migrate horizontally in June and stopped in October. The diurnal cycle was very well pronounced, with fish going to open water at night and coming back to littoral in early morning. The timing of migrations was correlated with light conditions; the longer were the nights, the longer-fish stayed off the shore. Starting from August, apart from diurnal migrations between pelagial and littoral, also some movement of fish towards the upper part of the reservoir was observed. It has been hypothesised that it was caused by unfavourable environmental conditions in the lower part of the reservoir, where the *Microcystis aeruginosa* bloom was observed, and the oxygen concentrations were much lower than in the

upper part. These observations confirm that acoustics provides a good tool for controlling the behaviour of fish, that are essential indicators of the water quality.

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27. Quadrature phase detection in an acoustic positioning system

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A novel acoustic navigation method is described. The method is based on a continuous waveform transmitted from a tethered object being tracked and received by a bottom node. Accurate range and bearing measurements are made by differential phase detection and phase unwrapping of the received signals. Phase detection is performed using a quadrature phase sensitive detector (QPSD). The paper investigates, using computer simulation, the performance of the system in the presence of noise. The RMS error in the phase estimate was found to be 14° for range estimation and 17° for angle estimation, even with a poor SNR of 0 dB. These estimates represent a theoretical equivalent range error of 5.8 mm and angle error of 0.5° , respectively, for an operating frequency of 10 kHz and 5λ hydrophone separation. These results indicate potentially a much better accuracy than that offered by the conventional ultra-short baseline system.