

# Utilization of Shipboard Transducers To Create Single Ping Three Dimensional Bathymetry

A. Marino, M. DiLemmo, L. Smith

Naval Command Control & Ocean Surveillance Center  
RDT&E Division, Warminster Detachment  
Code 333  
Warminster, PA 18974-5000

**Abstract** - This paper describes an experiment utilizing existing shipboard sonar system transducers to obtain along and across track ocean bottom profiles from single return echoes. A short, sparse two dimensional receiving array was formed with sections of both the athwartships hydrophones and alongships projectors, of the vessel's wide swath SASS bathymetry system. A standard navy BQN-3 transducer, of the ship's along track profiling system, served as the transmitter. The limited data from the short arrays of 5 elements each were applied to the Burg implementation of a high resolution algorithm and an FFT beamformer for every sample or snapshot. Processed snapshots resulting from a single ping were then combined to form the along and across track profiles.

specific ocean bottom contours of interest, without the installation of additional costly hull mounted sonar arrays. The large number of vessels requiring a solution to this problem currently utilize a single BQN-3 type transducer as both transmitter and receiver which generates only an along ship's bottom profile. They have at their disposal however a two dimensional array that is used for other purposes. The short receiving array described above was formed to simulate this existing two dimensional array. The successful results of the experiment will enable utilization of the existing hull mounted equipment and lead to an improvement in contour location efficiency by a factor of six. Additionally, it demonstrates the ability of small arrays to obtain better angular resolution using the Burg algorithm than with conventional FFT beamformers.

## I. INTRODUCTION

The tests were performed on board a U.S. Navy oceanographic survey ship operating off the west coast of the United States during sea trials the week of 8/9/92. The approximately 10 square nautical mile area selected, for SASS contour repeatability and the BQN-3 experimental tests, contained a mountainous feature which had been formed by a volcano. The survey ship, operating SASS, traversed the area on 8/10/92 with reciprocal runs on North/South and East/West lines. The following day, BQN-3 experimental data was collected during East/West reciprocal runs close to one of the SASS lines. The BQN-3 pings were initiated, and navigation data was also collected, on the GMT clock minute marks. The SASS sonar and navigation data for one of the most northerly lines was retained for use as the reference against which the BQN-3's results would be compared. The experiment was conceived to address the problem of how best to minimize the number of pings, and the time required for vessels to locate

## II. SHIPBOARD EQUIPMENT UTILIZATION

### 1) Transducers

The two dimensional receiving array which it was required to simulate consisted of 16 hydrophones arranged in a 5 X 5 four foot square pattern. We had

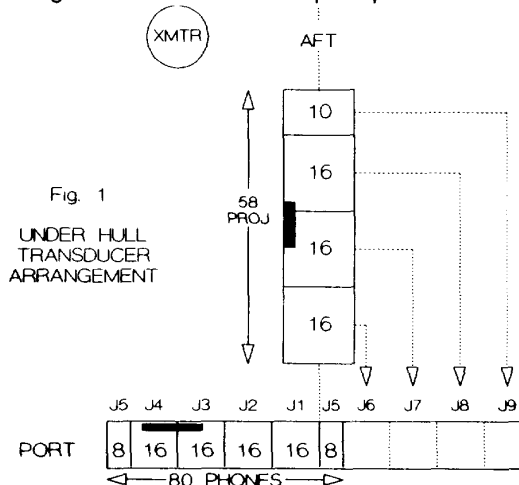


Fig. 2

RELATIVE SIZE OF ARRAYS & ELEMENTS USED FOR SIMULATION

33  
31  
29  
27  
25

AFT  
5 PROJ.  
FWD

61 57 53 49 45

PORT 5 PHONES STBD

RELATIVE SIZE  
OF ARRAYS  
& ELEMENTS USED  
FOR SIMULATION

One of the problems that had to be addressed early on, was the receiving sensitivity of the SASS projector elements. Measurements were made at the then NAVAIRDEVCEEN Test Quarry in Orland Pennsylvania in March of '91. Projector output impedance at 12 KHZ was measured as (94 - j18) ohms. The sensitivity at 12 KHZ was determined to be -180 dBV/uPa with a Port/Stbd directivity response as shown in

NAVAIRDEVEN DIRECTIVITY RESPONSE BUOY#  
2 mtr SEPARATION  
CLOCKWISE  
DATE: 03/13/91 FREQUENCY: 12000 H  
TIME: 10.12 10 dB / DI

330 320 310 300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

710 pt MAXI=22.7 MINI=62.7 BW: --- DI: ---

FIG. 3 RECEIVE PATTERN

The 25 inch diameter BQN-3 transmitting transducer, which is normally operated at 18 KHZ, was tuned to the 12 KHZ SASS receiver operating frequency by adding series inductance.

Fig 4 is a block diagram of the

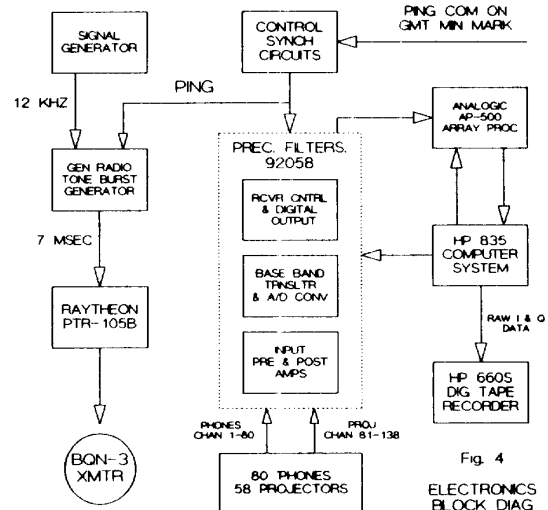


Fig. 4

ELECTRONICS  
BLOCK DIAG

transmitting and receiving electronics used for obtaining raw in-phase and quadrature phone/proj data for post time analysis. A simple TTL circuit, manually activated on the GMT minute mark, was used to synchronize the transmit and receive sections and initiate each ping cycle.

The transmit section was very straight forward. It consisted of a Signal Generator operated at 12 KHZ feeding a General Radio Tone Burst Generator set to produce a pulse width of 7 milliseconds. This signal was then used to drive the transmitting portion of a Raytheon PTR-105B Transceiver.

The receiver section consisted of the standard SASS bathymetric equipment operating in a manual gain and range gate mode with special software. Input signals to channels 1-80, (Hydrophones), and channels 81-138, (Projectors), of the Precision Filters 92058 System, were amplified, base banded, filtered, and digitized. The 92058 had the following fixed settings: Sample Rate = 415 microseconds, Samples = 1000, Bandwidth = 150 HZ, and Center Frequency = 12 KHZ. System gains and range gates were periodically adjusted to accommodate the bottom. Simple data transfer programs running in the HP-835 and Analogic AP-500 transferred the 12 bit in-phase and quadrature data from the 92058 to HP-835 disc files. The files were ultimately recorded on digital data cassettes via an HP-660S tape drive.

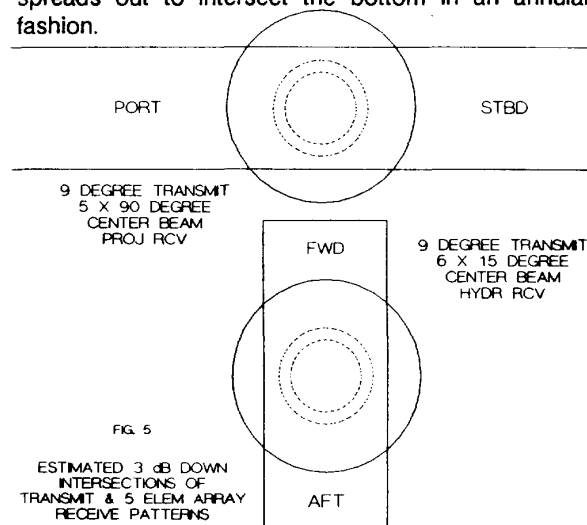
### 3) Data Collection Software Operation

As we stated above, the sample rate and number of samples were set to 415 microseconds and 1000 samples respectively. Assuming a round trip travel rate for sound of 400 fathoms/second, the 1000 sample received data capture window equals approximately 166 fathoms. Since the terrain being mapped contained both flat and sloped regions, it was necessary to continually monitor the bottom depth using the vessel's Narrow Beam Digital Sonar, NBDS, to determine the starting depth of the 166 fathom range gate. The procedure, prior to start of each ping, consisted of measuring depth with the NBDS, converting from fathoms to sample count delay, and entering the Delay into the Precision Filters 92058.

Prior to running the data collection program, which recorded data on GMT minute marks, it was necessary to determine the Channel Gain setting of the 92058 for a given power level out of the BQN-3 transmitter. This was done during a preliminary run over the area by utilizing a scaled down version of the data collection program which stored data from four of the 138 transducers available.

### III. BOTTOM COVERAGE & THE RECEIVED DATA SET

Figure 5 indicates the estimated 3 dB down intersections of the xmitting and the two 5 element array center beam receiving patterns. The 'phone fore/aft beam width of 15 degrees and projector port/stbd beam width of 90 degrees are controlled by the characteristics of the individual array elements. The hydrophone port/stbd and projector fore/aft beam widths are functions of the array lengths. The dotted circles inside the transmit beam pattern represent adjacent 415 microsecond samples of the return echoes as the transmitted spherical wavefront spreads out to intersect the bottom in an annular fashion.



Because element spacing in the short arrays is greater than  $1/2$  Lambda, ambiguous returns due to the effects of grating lobes must be considered. The  $2$  Lambda 'phone element spacing produces a first null in the athwartship's array beam pattern at 15 degrees. At 2000 fathoms, the approximate operating depth during the tests, slant range to the bottom 15 degrees from nadir is 2070 fathoms. At 400 fathoms/second round trip sound velocity this corresponds to 5.1764 seconds. Ignoring the effects of ray bending, this means that 0.1764 seconds after the echo at nadir is received, the echoes at 15 degrees will be received. Since the sampling rate is 415 microseconds, the 15 degree echoes will be received 425 samples later. The number of 'phone samples selected for analysis was 400 to eliminate the possibility of ambiguous returns. In a like manner, because the  $2.45$  Lambda proj. element spacing produces a first null at about 12 degrees, The number of proj. samples selected for analysis was 260.

#### IV. DATA REDUCTION

The four East/West track lines along which data were collected were each one hour in length. Since pings were initiated on the GMT minute marks there were 60 data sets per line. The first steps in reducing the data were the separation of the 'phone and the proj. data, and the extraction of the 400 and 260 samples respectively containing the information of interest. The resulting 120 data sets for a single track consisted of 60 'phone files 400 samples long of the athwartships array of 80 'phones, and 60 proj.files 260 samples long of the alongships array of 58 projectors. The final step, prior to analysis, was the extraction of the 5 element simulation groups from each 'phone and proj. file.

#### V. DATA ANALYSIS

##### 1) Full Array Vs. 5 Element Array

The initial part of the investigation consisted of an examination of only BQN-3 data. Across track and along track profiles were first calculated and plotted utilizing the full arrays of 80 and 58 elements respectively. Standard SASS algorithms based on spacial FFT beamforming were modified for this purpose. The short 5 element array data was then applied to the Burg implementation of a high resolution algorithm. Track plots of the short arrays compared very favorably with those of the full arrays from which they were extracted. Figures 6 and 7 show typical comparisons. This result indicates that short array data when applied to a Burg based beam former can produce profiles as accurate as long array data applied to standard FFT beam formers. The key to this is seen in Figure 8 where the "spacial power spectral density" of a single sample of 5 element data is processed with the FFT and the Burg. Note the high resolution Burg result.

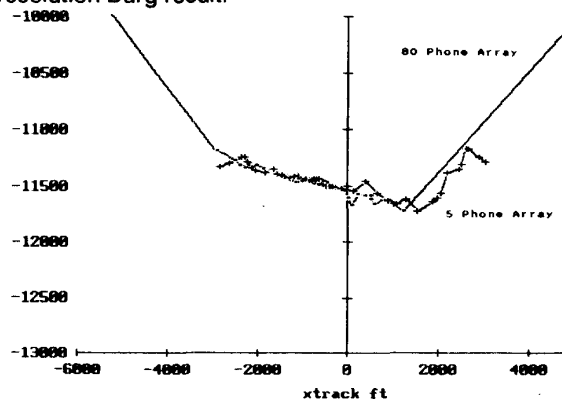


FIG. 6

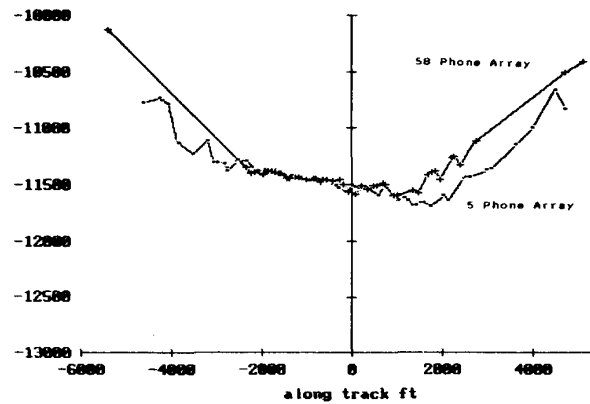
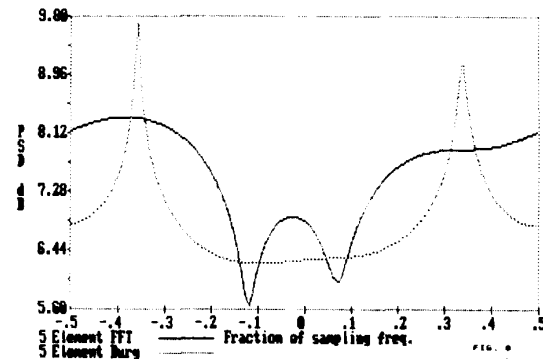


FIG. 7



##### 2) SASS Vs. 5 Element Array

Utilizing the navigation data from the corresponding SASS and BQN-3 East/West runs, SASS across track profiles from pings as close as possible to the BQN-3 pings were generated. Typical across track plots of SASS and the corresponding BQN-3 short array appear in Figures 10 through 12. The BQN-3 coverage is seen to be much smaller than SASS being limited by signal to noise ratio to about 2500 feet at the depths shown. All of the BQN-3 data is shown for completeness. This erroneous data could easily be rejected through thresholding. Figures 10 through 12 show good agreement between SASS and BQN-3 in the valid data region.

Typical along track plot comparisons are shown in Figures 13 through 15. The SASS curves were generated from a single beam in each of 12 consecutive pings spaced 15 seconds apart. The BQN-3 curves are from a single ping. These along track results illustrate how contour slope information can be gathered from a single ping and an along track array, whereas a number of SASS pings are required to obtain a similar result.

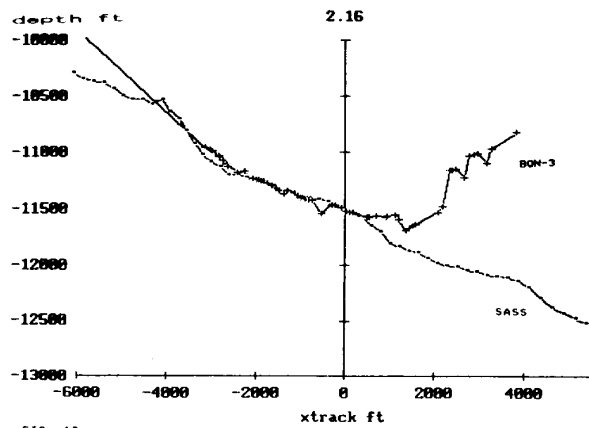


FIG. 10

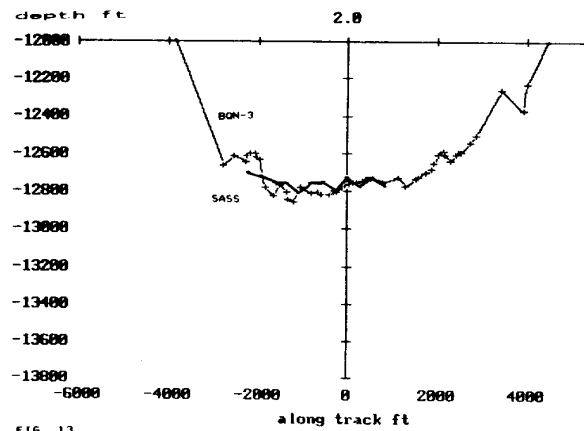


FIG. 13

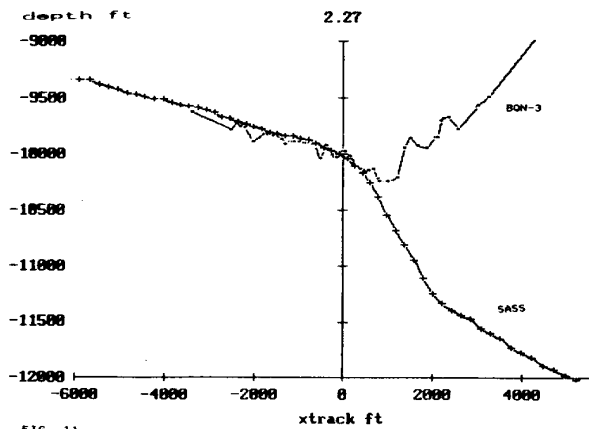


FIG. 11

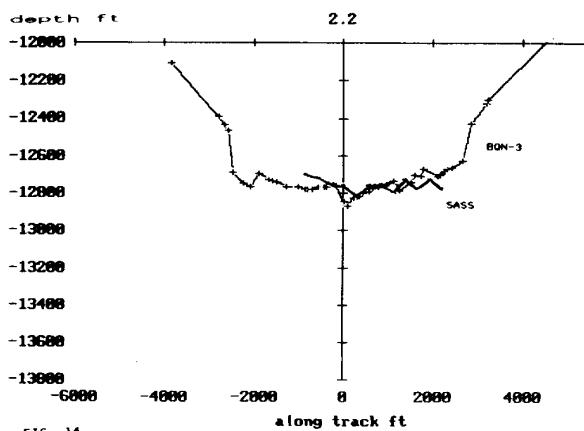


FIG. 14

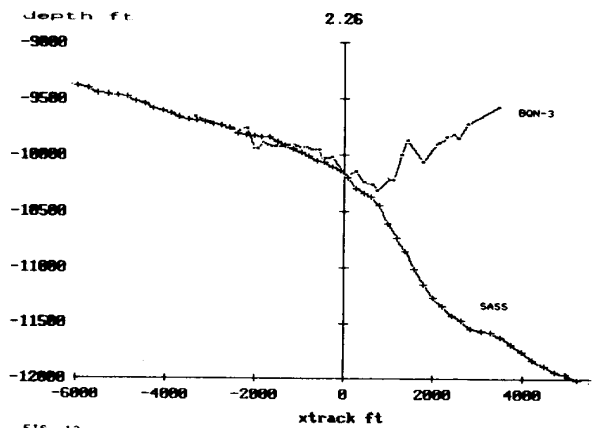


FIG. 12

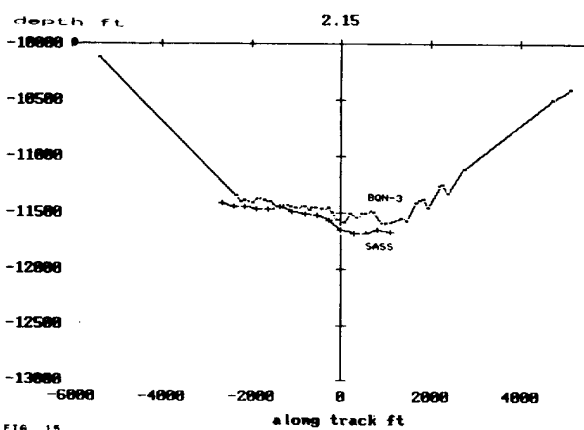


FIG. 15

## VI. CONCLUSIONS

It is clear from this experiment that a BQN-3 transmitter and a pair of short arrays, one across track and one along track, can be used to quickly determine contour slopes in two directions as well as bottom depth. The square hydrophone array we have partially simulated can be used similarly but with better results. There are many more ways in which data from a square array can be utilized. In its simplest form, it may be considered as two pairs of across and along track arrays. In its most sophisticated form it may be considered as a two dimensional array.

What kind of improvement in contour location efficiency over a single beam along track sonar can be expected? Considering a mountainous feature similar to what was surveyed during these tests, it would require at least three pings with an along track system to obtain a reliable slope in one direction. This information would not be sufficient however to determine if the mountain was to the left or the right of ship's track. It would require another three pings in an orthogonal direction, or a total of six pings. The same information could be obtained using the square array in its simplest slope/depth determination form with a single ping. Therefore an improvement in contour location efficiency by a factor of six is not unreasonable.

## ACKNOWLEDGMENTS

We would like to express our appreciation to John Ambrose of Computer Sciences Corporation for the use of his beam forming and track profiling algorithms and software without which the analysis would have been impossible. We also want to thank Mike Rizzo of Seabeam Instruments for his dedication and stamina during the shipboard data collection phase of the experiment.

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