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Data Processing and Analysis Support for the DASM Added Value Study

Call-Up Against the Noise Monitoring Standing Offer

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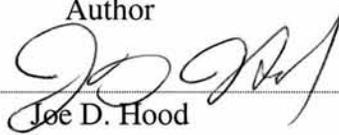*Contract Scientific Authority: J. Theriault (902) 426-3100 ext 376*

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Contract Report

DRDC Atlantic CR 2004-266

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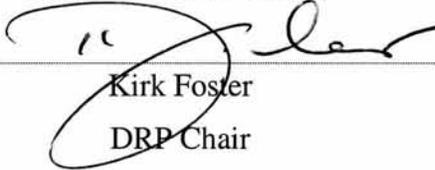
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Abstract

This report documents the work done to support the DASM Added Value study. The objective of the call-up was to provide data processing and analysis support as required to permit the study of the gain achieved when including the dipole sensors in the Directional Acoustic Sensor Module (DASM) array beamforming process in the presence of multistatic active data. The work involved a number of phases with most phases of work involving the generation of reusable software components and analysis processes, allowing future work to be performed more efficiently.

Résumé

Le présent rapport décrit les travaux effectués à l'appui de l'étude sur la valeur ajoutée du module de détection acoustique à effet directif (DASM pour *Directional Acoustic Sensor Module*). L'objectif de la commande subséquente était de fournir le soutien au traitement et à l'analyse des données nécessaire à l'étude du gain obtenu grâce à l'intégration des capteurs à doublets dans le processus de formation de faisceaux d'antenne réseau du DASM, en présence de données actives multistatiques. Les travaux effectués comprenaient un certain nombre d'étapes, et la plupart d'entre elles ont donné lieu à l'élaboration de composants logiciels et de processus d'analyse réutilisables, ce qui permettra d'effectuer les travaux de façon plus efficace à l'avenir.

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Executive summary

Introduction

Traditional passive-sonar towed-array receivers use a linear set of omni-directional hydrophones. Beamforming such a linear array achieves a reduction in effective background noise and allows the localization of targets within a steering direction. A major shortcoming, due to the linear geometry, is that the formed beams are conical with the axis coincident with the array axis. These conical beams result in an inability to resolve port versus starboard directions. More recent efforts have turned from passive sonar to active sonar using towed line-array receivers. By replacing the omni-directional hydrophone sensors with "left-right" directional sensors, beamforming can be undertaken with sets of "port" and "starboard" beams. For active sonar, this means that targets can be localized in range and in bearing without a port-starboard ambiguity. Furthermore, the increase in directivity due to the port-starboard beamforming has the benefit of reducing reverberation levels. The improvement in sonar performance in a homogenous reverberation environment is significant, but is even more dramatic in an inhomogeneous reverberation environment where capability may be severely limited by geoclutter.

Results

This contract presents software and methodology used for the study. The software developed can also be used for further studies of reverberation. In addition, an externally published paper on the added value of receiver arrays comprised of directional sensors as compared to arrays of omni-directional sensors has been included as an annex. Data collected with the analogue DASM (Directional Acoustic Sensor Module) receive array on Emerald Bank shows a significant gain compared to an array of omni-directional sensors. The data shows the gain from using the DASM array is as much as 20 dB.

Significance

The software and methodology used for the study greatly enhances DRDC Atlantic's capability to analyze reverberation data. The 20 dB reduction in reverberation demonstrated with the data directly equates to a 20 dB gain in the ability to detect a submerged target.

Future plans

These data were collected with an analogue array of directional sensors. A more recently constructed DASM array with larger aperture and 24-bit digital telemetry has been used to collect additional data. Further analysis of these data should demonstrate the detection potential of such systems.

Hood, J., Glessing, B., Jury, D. 2005. *Final Report for Data Processing and Analysis Support for the DASM Added Value Study,* DRDC Atlantic CR 2004-266. Defence R&D Canada - Atlantic.

Sommaire

Introduction

Les récepteurs de réseau remorqué de sonar passif utilisent un ensemble linéaire d'hydrophones omnidirectionnels. La formation de faisceaux, comme celle obtenue avec un réseau linéaire, permet de réduire le bruit de fond efficace et de localiser des cibles dans certaines limites par rapport à une direction donnée. Une lacune importante, en raison de la géométrie linéaire, est que les faisceaux formés sont coniques et que leur axe coïncide avec l'axe réseau. Ces faisceaux coniques font en sorte qu'il est impossible de distinguer entre bâbord et tribord. Des travaux plus récents ont délaissé le sonar passif pour se concentrer sur le sonar actif utilisant des récepteurs de réseau linéaire remorqué. En remplaçant les capteurs hydrophones omnidirectionnels par des capteurs directionnels « gauche-droite », il est possible de faire la formation de faisceaux avec des ensembles de « faisceaux bâbord » et de « faisceaux tribord ». Dans le cas du sonar actif, cela veut dire que les cibles peuvent être localisées (azimut-distance) sans qu'il y ait d'ambiguïté bâbord-tribord. De plus, l'amélioration de la directivité grâce à la formation de faisceaux bâbord-tribord a comme avantage de réduire les niveaux de réverbération. Le rendement du sonar se trouve amélioré de façon significative dans un milieu à réverbération homogène, et c'est encore plus le cas dans un milieu à réverbération non homogène, où les capacités du sonar peuvent se trouver sérieusement diminuées par le clutter géographique.

Résultats

Le présent rapport, découlant d'un contrat, décrit les composants logiciels ainsi que la méthode utilisés pour l'étude. De plus, on a joint comme annexe un rapport publié à l'extérieur portant sur la valeur ajoutée que représentent les réseaux de réception composés de capteurs directionnels par rapport à ceux composés de capteurs omnidirectionnels. Les données obtenues à l'aide du réseau analogique de réception (DASM pour *Directional Acoustic Sensor Module*) au banc d'Émeraude montrent un gain significatif comparativement aux données obtenues à l'aide de réseaux de capteurs omnidirectionnels. Selon les données obtenues, le gain apporté par l'utilisation du DASM peut aller jusqu'à 20 dB.

Portée

Une réduction de 20 dB de la réverbération peut se traduire directement par une capacité améliorée de détection d'une cible immergée. Le gain lié à cette réduction équivaut directement à une augmentation de 20 dB du niveau du signal et, par conséquent, à une augmentation significative de la probabilité de détecter une cible.

Recherches futures

Les données du présent rapport ont été obtenues en utilisant un réseau analogique de capteurs directionnels. De plus, un réseau DASM de fabrication plus récente ayant une plus grande ouverture et doté de circuits de télémétrie numérique à 24 bits a permis de recueillir des données supplémentaires. Une analyse plus approfondie de ces données devrait permettre de démontrer les capacités de détection de tels systèmes.

Hood, J., Glessing, B., Jury, D. 2004. *Final Report for Data Processing and Analysis Support for the DASM Added Value Study* (Rapport final concernant le soutien au traitement et à l'analyse des données pour l'étude sur la valeur ajoutée du DASM)*,* DRDC Atlantic CR 2004-266, R & D pour la défense Canada - Atlantique.

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1. Introduction

This final report outlines the work done under Noise Monitoring Software Regional Individual Standing Offer (RISO) No. W7707-032293/001/HAL for Data Processing and Analysis Support for the DASM Added Value Study, Call-Up Requisition No. W7707-3-2405. This work was performed at Defence Research and Development Canada (DRDC) under the direction of the Scientific Authority (SA), Jim Theriault, from approximately February 2004 to July 2004.

An externally published paper on the added value of towed arrays using directional sensors has been included in the Annex.

1.1 Background

The objective of this call-up was to provide data processing and analysis support as required to permit the study of the gain achieved when including the dipole sensors in the DASM array beamforming process in the presence of multistatic active data. The data processing and analysis work was performed using two software suites: Software Tools for Analysis and Research (STAR) and Signal Processing Packages (SPPACS). An overview of the two software suites is provided in the following subsections.

The STAR and SPPACS suites are configuration controlled using the concurrent versioning system (CVS), and issue and enhancement idea tracking is accomplished using the Bugzilla issue tracking software. CVS is a repository that allows developers to check-in revisions to software and documentation where they are archived in a common database. The tool allows all previous versions of the software to be maintained and aids resolution of new issues, while ensuring that current builds of the software are readily accessible to users and developers alike. Bugzilla is a web accessible database that offers both user and developer input to issues, priorities and solutions. It provides coherent tracking and recording of an issue over its entire lifecycle.

STAR and SPPACS components are documented in a combination of formats, each with their own purpose. Microsoft Word documents are maintained that describe functionality and algorithms of components. These are primarily intended for the end user. Enterprise Architect (EA) files are maintained, which document software design, interaction and dependencies. EA design information is intended primarily for developers. Hypertext Markup Language (HTML) library documentation is being developed that provides automatic extraction of the routine's Application Program Interface (API), purpose and description. This documentation is maintained to assist developers familiarize themselves with the existing libraries and components and is intended to support and encourage software reuse. Some users may also wish to refer to this information for use in their own custom applications. SPPACS also provides HTML and man page user documentation for each module.

The most current status of the SPPACS and STAR suites can be found at https://star.iotek.ns.ca. Users are also encouraged to refer to the electronic documentation provided with the software distribution for up to date information.

1.1.1 STAR Overview

The STAR suite was developed to support general research and analysis objectives at DRDC Atlantic. The primary objectives of the STAR suite are:

- Provide scientific grade analysis tools that allow for efficient, detailed quantitative and qualitative analysis of a data set.

- Support synergy between DRDC groups and the Department of National Defence (DND) by providing a common software base for analysis. This synergy encourages inter-group communication and simplifies user training, analysis process development, documentation and data portability.

- Support cost and analysis efficiency by providing software reuse and common tools and data formats. Examples of efficiency would be using the output of analysis from one group to feed the inputs of another, or using common software components to lower development cost of several custom analysis tools.

All STAR components are currently implemented using the Interactive Data Language (IDL), though the design is not restricted to IDL. The name STAR reflects the generic nature of the software. Applications in the STAR suite are built using a combination of reusable and custom components that meet the requirements of each task. The layered design and common components allow for rapid and logical development of new capabilities. Though currently focused on sonar data processing and analysis, the tools are capable of expanding to meet other analysis and research requirements.

1.1.2 SPPACS Overview

SPPACS is a group of software programs that are based on the C programming language and is implemented on Linux based Personal Computers (PC). Each program provides a specific processing function and a series of programs can be chained together to create a custom-processing stream using the command line or scripts. The output from SPPACS is stored in DREA formatted data files. SPPACS has slowly evolved to its present day state due to the efforts of several MacDonald Dettwiler and Associates Ltd. (MacDonald Dettwiler) personnel over the last 4 years.

SPPACS has been used to perform a number of mid-trial and post-trial processing functions such as the post-trial study of multistatic trial data and the mid-trial analysis of the Q265 sonobuoy test trial. SPPACS only performs data manipulation and does not provide an interface to examine the results. The processed data output is often imported into other applications that enable data display and are used to perform the detailed analysis of the results such as the STAR suite.

The SPPACS software suite consists of two types of software. One type is runtime executables that can be used to process DRDC Atlantic data files in a number of ways, including data management and signal processing. Each program performs a specific function and the programs are designed so that they can be used in conjunction to perform more complex processing tasks. The software has proven to be very useful in simplifying data management and sonar processing tasks by providing a set of tools from which to build the necessary processing streams. These streams can be run from the command line or assembled into scripts to perform batch-processing tasks allowing for large amounts of data to be automatically processed. The second form of the software is a group of library functions that can be used by other programs to efficiently perform standard tasks. These library functions are extensively used by the runtime software, but can also used for other applications. There are now three types of libraries. The first are utility routines for performing tasks such as header manipulation and command line parsing. The second are signal processing modules termed signal processing library (SPLIB). These are low level modules that each perform a low level signal processing task. A new SPPACS module typically consists of one or more SPLIB modules linked together with a SPPACS user interface. The final library type is a sonar processing module termed sonar library (SONLIB). These are more complex modules that combine several SPLIB modules to create a complex sonar module, such as passive processing. More generically reusable software was generated by separating the SPLIB and SONLIB modules from SPPACS. SPLIB and SONLIB are independent of the data header format, timestamping method, etc. and are suitable for integration in real time processing systems.

SPPACS is also supported by a set of signal processing libraries known at the Fastest Fourier Transform in the West (FFTW). These free open-source libraries provide optimized signal processing functions helping to ensure that the SPPACS software runs as efficiently as possible, while providing a significant reduction in coding effort.

2. Work Overview

This section presents an overview of the tasked work and a summary of the work that was completed. The contract requirements from the Statement of Work (SOW) are presented along with an indication of the degree of success. Other significant work is also listed.

The requirements for this call-up are listed in Table 1. All requirements listed in the table were implemented with the following exceptions:

- It was decided to normalize the displays for the "variance of signal level versus time display". This entails dividing the signal by the computed mean.

- It was decided to replace data logging with the capture of a single channel of user selected data to a DAT formatted data file. This data is taken directly from the processed data used for display allowing capture of reverberation and normalized Energy Time Indicator (ETI) data.

A number of other enhancements, functions and utilities were developed that are not directly reflected in the requirements. These changes were made to improve the utility and reusability of the software or to address known issues, under authorization of the SA. As this work is incremental, parts of the work described may have been started under other contracts. The additional work includes:

- Some of the replica generation software in STAR was used to create a new module that both the data extraction and replica generation features can use. This module was used to realize the data capture function previously described.

- A contract amendment required data quality verification to be performed. Manual verification was performed first to allow data processing tasks to continue then a more automated reusable process was used. Manual verification and repair of the file headers was performed. Manual quality assurance was performed on subsets of Q246 data for different trial times. A data consistency check was conducted to verify that the data maintained a reasonable level of consistency from the start of a data file to the end, ensuring that the channels were not mixed due to data dropouts. A receiver quality verification was performed to check for anomalies in the data across each receiver. Finally a bit-flip processing utility was developed and used to process all of the data to improve the consistency check and quantify some data quantization concerns.

More detail on the software developed under this contract and the test performed to verify that software is provided in Section 4, while the results of data quality assurance are provided in Section 5. MacDonald Dettwiler was also required to perform a number of data processing and analysis tasks, which are described in Section 3. Routine process driven requirements including configuration management and issue tracking are described in Sections 6 and 7.

Table 1. *Contract Requirements*

REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Correlation Processing:	• The contractor shall enhance the sp_correlate SPPACS module to fully support DAT32 formatted file processing. • The contractor shall support the generation of the required replica and processing script to produce beamformed correlated time series data in DAT32 format.

Signal Level Comparison Display:	• The contractor shall enhance the ETI analysis display in the STAR to display ETI data as:
	
	  o Mean signal level vs. time. The mean signal level shall be computed using a moving boxcar window of user defined length in seconds.
	
	  o Variance of signal level vs. time. The variance of signal level shall be computed using the difference between the ETI data and the mean generated from a moving boxcar of user defined length in seconds.
	
	  o Standard deviation of signal level vs. time. The standard deviation of signal level shall be computed using standard deviation of the data resultings from the difference between the ETI data and a moving boxcar window of user defined length in seconds. The standard deviation shall be computed using data from the same window size.
	
	• The user shall be able to switch between the regular ETI display and any one of the above three display using the user interface.
	
	• The ETI data shall be able to originate from more than one filename and / or processed data directory.

Data Logging:	• Analysis and log entries shall be generated as required by the Scientific Authority.

3. Data Processing and Analysis

The data processing and analysis involved several tasks including:

- Conversion of Non-Acoustic Data (NAD) to STAR format

- Processing trial and test data using SPPACS scripting

- Data Analysis

Each of these tasks are described in more detail in the following subsections.

3.1 NAD Formatting

NAD was required to annotate any data measurements with range and bearing data. The source ship was RV2 and the target was RV4. NAD was required for both of these platforms. As part of Data Processing and Analysis Support to Measure Active Signal Levels Call-Up Requisition No. W7707-03-2304, STAR NAD formatted data was created. This involved converting the provided American Standard Code for Information Interchange (ASCII)-based files with each platform's position over time to the STAR NAD format using the process described in, "Support to Multistatic FM Data Processing – The SPPACS / STAR Data Analysis Process and Toolset." Files were created for:

- Main trial file – provides trial area and time period information

- Source (RV2)

- Target (RV4)

- Receiver – set to match the RV2 position for all receivers; this provided the required geometric data from 'Echo' measurements

These files were copied to the analysis directory for this contract, and the ping file that links processed data types to a source was created.

3.2 Data Processing

The SA provided a number of raw data files spanning approximately 2 hours of trial data for Q246 from RV2. This data came from the DASM portion of the Towed Integrated Active Passive Sonar (TIAPS) array and consisted of omni and roll-resolved dipole sensor data. The objective of the data processing was to beamform the data as a conventional array of omni-directional sensors and then as a DASM array forming left and right beams for each conventional beam. Thirty-three beams were formed for each beamforming method resulting in beam time series data. The beam

time series data was then further processed to form short-term LOFARGRAM, correlation time series and energy time series data. Each of these processing stages is described in future paragraphs with more detail available in the trial processing scripts currently located in //spray/bigdisk/dasm_canuk_trial/scripts. These scripts were largely duplicates of previous analysis that were adjusted for the requirements of this task.

The following observations were made during data processing:

- The DASM data was on 64 sequential acoustic data channels starting at channel 6 (zero indexed).

- The dipole sensor data channels came before their corresponding omni sensor data channel.

- It was reported that the dipole sensor data channels were in the same form as the omni sensor data channels (velocity data) and that no gains needed to be applied to scale them to match the omni sensor data channel sensitivity for beamforming.

3.2.1 Data Pre-Processing

All data was byte-swapped to little-endian format prior to processing. The raw data files were also modified as described in Section 5 to repair problems with the data header. This included changing the date/time block and sampling rate.

3.2.2 Beamforming

DASM beamforming was performed using the following processing stages:

- Each dipole-omni channel pair were cardioid beamformed using a left or right beam. The cardioid weight was 0.5 on each channel and the dipole coefficient was 1 for left and -1 for right.

- The output from the cardioid beamformer was used as input to the beamformer to form beams 1 through 31. Beams 0 and 32 were formed using only the omni channels.

- After beamforming the left beams were merged with beams 0 and 32 to create a set of 33 left beams that were stored in a file with the suffix '_left'. A set of 33 right beams were formed in the same way and stored in a separate file with the suffix '_right'.

Omnidirectional beamforming was used to form 33 beams of omnidirectional data using conventional beamforming techniques.

3.2.3 Correlation Time Series

For this processing stream the waveforms of interest were written into a replica directory. All beamformed time series data files were then correlated against this data to produce correlation time series data. These output data files were the primary source of analysis data.

3.2.4 LOFARGRAM Processing

This stream was used to resolve the individual ping types in a LOFARGRAM to aid visual recognition and analysis of the pulses of interest. It proved very useful in identifying various ping types, multi-path and simultaneous source transmissions not available from the RV2 ping logs.

3.2.5 Energy Time Series

This stream could have been used to track incoherent energy levels over time, but was not used significantly for this contract.

3.3 Data Analysis

Data analysis for this contract was conducted in two passes. The first pass involved an available DND resource that made a pass over the data selecting main blasts, false alarms and echoes based on a brief instructional session. The second pass involved collaborative analysis of the correlation time series with several post-processing options applied to the data. Several pings worth of correlation time series data were also provided to Colin Calnan of XWAVE for use with environmental inversion software testing and evaluation.

The first analysis pass on the data produced significant log files, and independent validation and verification of the results by the contractor suggested that the resulting analysis logs are of mixed quality. The main blast entries appear to be of high quality. Many of the false alarms are also of high quality but it is very likely that some events were missed. Echo selections should be more closely examined once tools are available to quickly delete and modify log entries. Also a batch re-analysis run should be executed once a proper beam to bearing model is integrated for cosine spaced beams as are found in a towed array.

The second pass on the data involved a much smaller quantity of data with the focus being on extracting significant differences between the omnidirectional and DASM beamforming. The correlation time series was examined with the following post-processing options applied:

- Raw correlation time series

- Mean correlation time series – showed mean reverberation level versus beam and time / range

- Normalized correlation time series - showed signal excess (over mean reverberation level) versus beam and time / range.

- Standard deviation of correlation time series – showed that local standard deviation changed as expected reinforcing the use of normalization processing (this display wasn't found to be that generally useful)

The previously mentioned displays were used to compare the data between the left and right DASM beam sets and the omnidirectional beam set. The ability to superimpose the results from the three different processing streams proved useful for quantitative data comparison.

Previous analysis of this form has shown that images showing all beams versus time are useful for qualitative data comparison. The STAR suspend analysis feature was used to stop normal processing and copy all beam data from a particular processing stream into memory where it could then be plotted as an image using a quickly written custom IDL script. These images showed the overall structure of the data, including reverberation levels, and could intuitively be associated with geographical features. It is likely that this script will form the basis of future STAR enhancements that will allow for a function to generate this type of images for any data set.

Two products were produced for use in a scientific paper. The first was a combined plot of mean reverberation level versus time for the beamfire beam from the left and right DASM streams and the omnidirectional stream. The second was several beam versus time images for the DASM and omnidirectional streams. This second plot was produced for both raw data and mean reverberation level.

4. Developed Software Components

The following sections describe the developed software components in detail. Each subsection is derived from the software documentation stored in the docs/reports subdirectory of the SPPACS distribution or in the documents subdirectory of the STAR distribution. These reports are based on a standard format that is modified as required for each program and serves as the technical documentation of the program. The standard outline for each report contains:

- A short description of the program and recent work performed

- A list of the program's functional requirements

- A description of the software design

- The software test description detailing the testing used

- The software test report detailing the results of testing

Some new SPPACS utilities were developed under this contract, and some existing utilities were enhanced and utilized to complete the data processing requirement. Processing scripts were created to use the existing utilities to process the raw data. Sp_correlate was upgraded to use DREA DAT32 formatted data files. Sp_bitflip was created to help automate data quality checks.

Several enhancements were made to the STAR toolkit to support this call-up. They include mean signal level versus time, fluctuation signal level versus time, standard deviation of signal level versus time, data extraction to file and multi file display. The first three features were implemented as processing modules and integrated with the ETI analysis display. The data extraction to file feature was accomplished by creating a new reusable module that retrieves data from the current model for a selected display and writes that data to a DREA formatted file. Finally, the multi file display feature involved upgrading the ETI analysis display to allow each plot area to display data from different files. This feature was relatively easy to implement because the underlying software that the ETI analysis display is based on is quite modular and flexible.

4.1 sp_correlate

This application performs matched filtering on a time-series stream, producing an output channel for each input channel and each replica. Modifications were made to sp_correlate to make it DAT32 compliant.

4.1.1   Requirements information

The following requirements were addressed under this contract:

- The contractor shall enhance the sp_correlate SPPACS module to fully support DAT32 formatted files.

- Upgrade the command line options/arguments to match the SPPACS standard.

4.1.2   Software Design information

A number of modifications were made to sp_correlate. New command line options were added to match the SPPACS standard. The user can now use data files with DAT32 format headers. The generic module sp_data_stream_header was used for DAT32 compliance. The function sp_hdr_parse_dat32 was upgraded to deal with all the possible number types. Calls made to the process library had to be modified to meet the requirements under this task. Several functions were created to work with DAT32 format headers:

- sp_process_separate_dat32

- sp_init_correlate_dat32

- form_separate_multiplier_outputs_dat32

- sp_parse_calfile_dat32

4.1.3   Test Description

The following documents regression testing performed on sp_correlate. Pre-test action was to create a benchmark of the anal_test_synthetic2.cor file found in "opt/ssp/data/test_trial/processed/IMPACT/proc_rep_hfm_9_14_ls/anal_test_synthetic 2.cor".

Pre-test Steps:

- Check out correlate.c version 1.1 sp_process.h 1.2 and sp_process_dat32 1.5 and build SPPACS.

- Run the ./update_proc test script found in "/opt/ssp/data/test_trial/scripts".

- Benchmark the .cor output file from the processing chain by saving it as a new filename.

The following tests are used to test the updated processing software against the benchmark previously created.

- Compare to benchmark (DAT): This test case tests that the correlate function will output the correct data in DAT format. Run ./update_proc test script creating a new anal_test_synthetic2.cor file. Run sp_compare on both the bench marked version and the newly build version of anal_test_synthetic2.cor. Expect all samples to be the same. Headers will differ because of the gains.

- Compare to benchmark (DAT32): This test case tests that the correlate function will output the correct data in DAT32 format. Use sp_convert_header to convert the /opt/ssp/data/test_trial/raw_data/IMPAC/anal_test_synthetic2.dat file to DAT32. Run sp_cardioid using the new dat32 file. Run sp_correlate, on the output file from sp_cardioid, using the –header_dat32 flag. Finally, use sp_compare to compare the sp_correlate output file to the bench marked anal_test_synthetic2.cor created beforehand. Expect the sp_compare program to indicate that the samples of both files are the same. The headers may differ because of differences in the gain blocks but the header parameters will be the same. See <SPPACS ROOT>/sppacs/src/test/correlate_test.txt for help.

4.1.4 Test Report

Table 2. Test Result

UNIT TEST	RESULTS	NOTES
Compare to benchmark (DAT)	PASS	
Compare to benchmark (DAT32)	PASS	

4.1.5 User Instructions

The following user defined options and switches were added to the command line interface:

- --header_dat32 – input stream header in dat32 format.

- --replica_dat32 – indicates that the replica file is dat32 format. Dat format is the default.

- --version will print the CVS revision number of the file to standard output.

- --help will print a help message to standard output and exit.

4.2 Mean Level versus Time

A processing module was created to process the data so that it can be displayed as mean level versus time on the ETI display. Keyboard commands were added to the ETI display to enable and disable the processing module.

4.2.1 Requirements information

The following requirements were addressed under this contract:

- The mean signal level shall be computed using a sliding two-pass split-window mean estimation.

- The window shall be of user-defined length and gap size in seconds.

- The contractor shall enhance the ETI analysis display in STAR to display mean signal level versus time.

4.2.2 Software Design information

The mean signal level versus time is calculated in a processing module. This processing module can be chained together with other processing modules to create a complex processing chain.

The requests start and end times are padded with a window length on each end of the request to ensure that the correct amount of data required for the mean signal level calculation is returned from the lower level Input/Output (I/O) routines. A call is made to the next processing module in the processing chain to allow modules further down the chain to modify the request and process the retrieved data. When the next processing module returns the mean signal level is calculated on the data, the header is modified to correctly describe the data. The data is truncated to the correct size and then returned to the previous processing module.
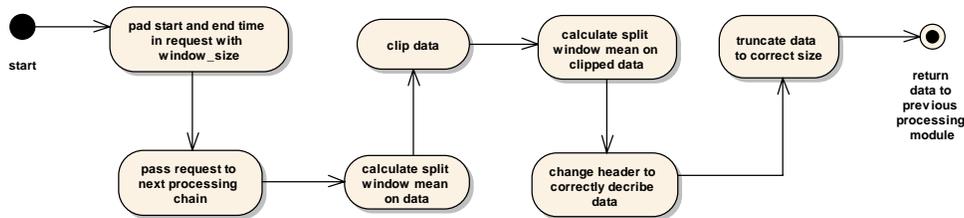

Figure 1. *Mean Signal Level Processing Module*

The mean signal level versus time processing module calculates the mean signal level by convolving a split window filter over the data, clipping signal levels greater than a preset percentage of the mean and finally convolving the split window filter over the clipped data. The clipping operation replaces the present level with the clipping threshold.

The actual calculation for the mean signal level is performed in a separate function to allow other processing modules to reuse it. The reusable mean signal level calculation function uses the built in IDL CONVOL function to calculate the split window mean signal level. The kernel is created based on the user defined window size and window gap.

Configurable parameters include:

- Window length in seconds (double)

- Gap length in seconds (double)

- Clipping factor (double)

4.2.3 Algorithm

Equation (1) defines the convolution algorithm used to calculate the mean on the first and third passes over the data. Where D (input data) is an n-element vector, W (split window filter) is an m-element vector (where $m < n$) and W is 1 for included portions of the window and 0 for points in the gap. S is the scale factor (which is equal to the number of non-zero elements in W). Note that the 0 element data is redundant due to padding and is removed from the returned data.

$$M_t = \begin{cases} \dfrac{1}{s}\displaystyle\sum_{i=0}^{m-1} D_{t+i-m/2} W_i \ if & m/2 \le t < n - m/2 \\ \qquad\qquad 0 & otherwise \end{cases} \tag{1}$$

Equation (2) defines the algorithm used to clip the data, which is done on the second pass. Where D (input data) is an n-element vector, c (percentage of mean i.e. 1.25 = 125%) is a constant and M (mean) is an n-element vector.

$$C_i = \begin{cases} D_i & D_i < (cM_i) \\ cM_i & D_i \ge (cM_i) \end{cases} \tag{2}$$

4.2.4 Test Description

The following test cases are used to test the mean level versus time processing module:

- Manual testing: The processing module is enabled and the processed data will be analyzed in the ETI analysis display to ensure that the processing module works correctly.

- Algorithm testing: The previously mentioned algorithms are prototyped and verified to ensure that the correct results are generated.

4.2.5 Test Report

Table 3. Mean Signal Level - Test Results

TEST CASE	RESULTS (PASS/FAIL)	NOTES
Manual testing	Pass	
Algorithm testing	Pass	

4.2.6 User Instructions

The mean signal level processing module can be enabled on the ETI analysis display by selected the 'a' key and disabled by selecting the 'A' key.

4.3 Fluctuation of Signal Level versus Time

A processing module was created to process the data so that it can be displayed as fluctuation of signal level versus time on the ETI display. Keyboard commands were added to the ETI display to enable and disable the processing module.

4.3.1 Requirements information

The following requirements were addressed under this contract:

- The fluctuation of signal level shall be computed using the difference between the ETI data and the mean generated from a moving boxcar window of user defined length in seconds.

- The contractor shall enhance the ETI analysis display in STAR to display fluctuation of signal level versus time.

4.3.2 Software Design information

The fluctuation of signal level versus time is calculated in a processing module. This processing module can be chained together with other processing modules to create a complex processing chain.

A call is made to the next processing module in the processing chain to allow modules further down the chain to modify the request and process the retrieved data.
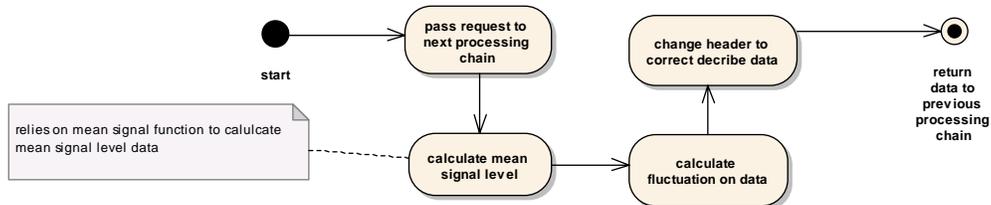
Figure 2. *Fluctuation of Signal Level Processing Module*

A call is made to a separate function to calculate the fluctuation. The fluctuation function calls another function to calculate the mean signal level. The fluctuation between the mean signal level and the input data is calculated, the header is modified to correctly describe the fluctuation data and returned to the previous processing module.

4.3.3 Algorithms

Equation (3) defines the fluctuation algorithm used to calculate the fluctuation between the data and its mean, where M (raw data) and $\overline{M}$ (mean signal level data) are n-element vectors.

$$D = \sum_{i=0}^{n} \frac{M_i}{\overline{M}_i} \tag{3}$$

4.3.4 Test Description

The following test cases are used to test the fluctuation of signal level versus time processing module.

- Manual testing: The processing module is enabled and the processed data is analyzed in the ETI analysis display to ensure that the processing module works correctly.

- Algorithm testing: The algorithms previously mentioned are prototyped and verified to ensure that the correct results are generated.

4.3.5 Test Report

Table 4. Fluctuation of Signal Level - Test Results

TEST CASE	RESULTS (PASS/FAIL)	NOTES
Manual testing	Pass	
Algorithm testing	Pass	

4.3.6 User Instructions

The fluctuation of signal level processing module can be enabled on the ETI analysis display by selected the 'v' key and disabled by selecting the 'V' key.

4.4 Standard Deviation of Signal Level versus Time

A processing module was created to process the data so that the data can be displayed as standard deviation of signal level vs. time on the ETI display. Key commands were added to the ETI display to enable and disable the processing module.

4.4.1 Requirements information

The following requirements were addressed under this contract:

- Standard deviation of signal level versus time. The standard deviation of signal level shall be computed using standard deviation of the data resulting from the difference between the ETI data and a moving boxcar window of user defined length in seconds. Fluctuation shall be computed using data from the same window size.

- The contractor shall enhance the ETI analysis display in STAR to display standard deviation of signal level versus time.

4.4.2 Software Design information

The standard deviation of the signal level is calculated in a processing module. This processing module can be chained together with other processing modules to create a complex processing chain.

The request is padded by a half of one window length at each end to ensure that the correct amount of data required for the standard deviation calculation is returned from the lower level I/O routines. A call is made to the next processing module in the processing chain to allow modules further down the chain to modify the request and process the retrieved data.
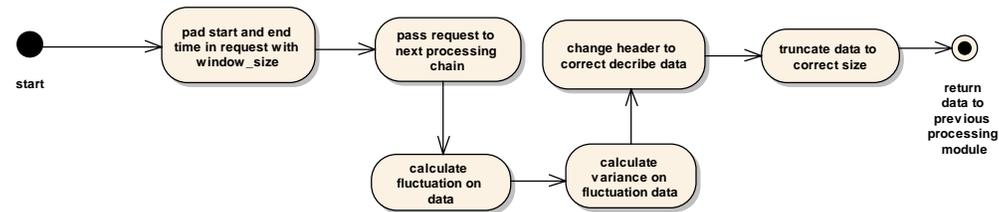
Figure 3. Standard Deviation of Signal Level Processing Module

A call is made to a separate function to calculate the signal fluctuation 1. The variance is calculated on the fluctuation data (using equation (4)). The standard deviation (using equation (5)) is calculated by convolving over the variance data with a preset window filter (not split). The header is modified to correctly describe the fluctuation data. The standard deviation data is truncated to the correct size and returned to the previous processing module.

Configurable parameters include:

- Window length in seconds (double)

---

[1] See 'fluctuation of signal level vs. time.doc'.

4.4.3 Algorithms

Equation (4) defines the algorithm used to calculate the variance. Where M is n-element vector.

$$v = \left(M - \overline{M} \right)^2 \qquad (4)$$

Standard deviation of signal level:

$$d_t = \begin{cases} \sqrt{\dfrac{1}{s-1} \displaystyle\sum_{i=0}^{m-1} v_{t+i-m/2^{W_i}}} & if \quad m/2 \le t < n - m/2 \\ 0 & otherwise \end{cases} \qquad (5)$$

4.4.4 Test Description

The following test cases are used to test the standard deviation of signal level versus time processing module:

- <u>Manual testing:</u> The processing module will be enabled and the processed data will be analyzed in the ETI analysis display to ensure that the processing module works correctly.

4.4.5 Test Report

Table 5. Standard Deviation of Signal Level - Test Results

TEST CASE	RESULTS (PASS/FAIL)	NOTES
Manual testing	Pass	
Algorithm testing	Pass	

4.4.6 User Instructions

The standard deviation of signal level processing module can be enabled on the ETI analysis display by selected the 'd' key and disabled by selecting the 'D' key.

4.5　Data Extraction to File

This was an enhancement to the ETI analysis window. It gives the user the ability to save data displayed on the ETI analysis display to a DREA .dat file by clicking on a plot area.

4.5.1　Requirements

The following requirements were addressed under this contract:

- The contractor shall provide the ability to write an exact copy of the data in a selected display panel (post IDL processing - such as mean calculation) out to a DREA data file.

4.5.2　Software Design information

The extract plot data functionality has been added to the ETI display. This functionality has been combined with the existing copy replica [2] functionality. Both the existing and new functionality has been rewritten to be modular.
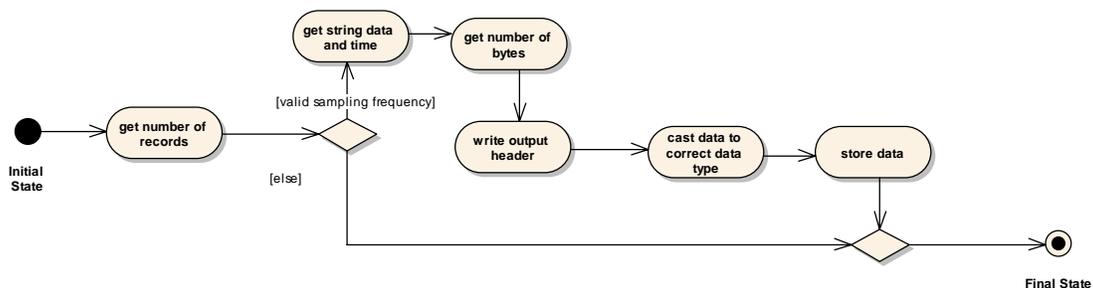
Figure 4. Data Extraction to File

4.5.3　Test Description

The following test cases were used to ensure that the data extraction to file feature works correctly:

- ETI extract plot test case: This test case is to determine if the extract plot functionality of the ETI display will output replica data to file. Run the ETI program and select 'j' for plot output. Click on the plot to output and choose a filename. Expect the file to be greater than zero bytes.

---

[2] For more information see 'Replica generation.doc'

- Sp_dh test case extract ETI plot: This test case is to determine if the extract ETI plot data contains the correct header. Inspect the header values to ensure they are correct. Expect the header values to be correct.

- Dispx test case extract ETI plot: This test case is to determine if the ETI plot output is correct. Load the file you created in dispx and visually compare it to the plot you click on in the ETI analysis window. Expect the ETI plot to be the same as the dispx plot.

4.5.4 Test Report

Table 6. Test Results – Data Extraction

TEST CASE	RESULTS (PASS/FAIL)	NOTES
Dispx test case extract ETI plot	Pass	
Sp_dh test case extract ETI plot	Pass	
ETI extract plot test case	Pass	

4.6 ETI Multiple Data Files

The ETI analysis has been upgraded to allow the user to specify (in the initialization script) different data files for each display pane. Specifically the ETI display will now accept multiple data files, chosen by the user, and display data from each data file in its own analysis windowpane.

4.6.1 Requirements

The following requirements were addressed under this contract:

- Modify ETI display to accept multiple data files for requests (one for each request). (NOTE: One request is associated to each display pane.)

4.6.2 Software Design

The software has been modified to allow the user to choose multiple data files. This involved making slight modifications to several exiting components.

Modifications were made to the template program eti_anal_template.pro. A new flag, multi_data_files, was added to this file. This flag must be set to one or zero. A value of

one indicates that the user wishes to run with multiple data files. A value of zero indicates that the user wishes to run with only one data file and one or more analysis displays.

The eti_analysis_macro was modified to check for the multi_data_files flag and to check whether or not the user has specified filename(s). If no filenames are specified and the multi_data_files flag is set to 1 or 0 then the user is prompted to either pick multiple data files or just one data file with one or more data plots. If the user fails to specify multi_data_files in the template program they will not be able to specify multiple data files.

The array of file names is passed to the eti_analysis_window module for request generation in the eti_analysis_window_create_initial_requests function. Modifications were made to allow for the multiple data files case. Instead of replicating multiple requests from one data file we now generate one request for each data file. Furthermore the function call display_support_realign_requests is only invoked if the user has specified one data file.

4.6.3 Test Description

The following test cases were used to ensure that the multiple file feature works correctly:

- Non-matching number of data files: This test case ensures that the number of user chosen data files is equal to the number of files indicated by Nb_points. In the template program set the multi_data_files flag to 1, set Nb_points to 4, and specify two valid data files. Run the template program. The program will display an error ("The number of files names does not equal Nb_points") and exit.

- Single data file multiple plots: This test case ensures that the user can specify one data file with multiple plots of that data. Furthermore it tests what happens if the user does not specify a data file in the template program. In the template program set Nb_points to 8, multi_data_files to 0 and do not provide any filenames. Run the template program. The program will ask for one data file and display eight plots of the data.

- Single data file invalid Nb_points: This test case ensures that the user can run the program with out specifying Nb_points. In the template program comment out Nb_points, set multi_data_files to 0, and do not specify a filename. Run the template program. The program will ask for one data file and then display that data file in eight plots. You will be able to view the realigned data in each window. Rerun this test case and specify Nb_points equal to zero. Same results expected. Rerun this test case with multi_data_files set to 1 and Nb_points equal to 0 or commented out. Same results expected.

- Odd number of Nb_points: This test case ensures that an odd number of Nb_points will not crash the program. In the template program set Nb_points to 3,

multi_data_files to 1, and no filename specified. Run the template program. Expected the program to crash because it cannot handle an odd number of plots.

- Multi data files: This test case ensures that multiple data files will be plotted on the ETI display. In the template program set Nb_points to 4, multi_data_files to 1 and do not specify filenames. Run the template program. The tester is asked to pick four data files and the ETI displays all four data files. Rerun this test case but set Nb_points to 8. Expect the same results.

- One plot for multiple data files: This test case ensures that the program will function when the user only specifies one for Nb_points. In the template program set Nb_points to 1, multi_data_files to 1 and do not specify filenames. Run the template program. This will result in two windows of the same data on the ETI display.

- Specify filename single data file: This test case ensures the program will operate as expected when the user specifies a data file. In the template program set Nb_points to 8, multi_data_files to 0 and specify a data file filename. Run the template program. This will result in the ETI displaying that data file in eight plots.

- Specify filenames multiple data files: This test case ensures the program will operate as expected when the user specifies a data files. In the template program set Nb_points to 8, multi_data_files to 1 and specify the data file filenames. Run the template program. This will result in the ETI displaying eight data files in the eight plots.

- Test Multiple Data Files: This test case ensures that multiple data files are displayed in the ETI window when the user uses the template program correctly. Ensure the data files you are about to use are different using the dispx program. This will allow you to ensure that the data files you specify for ETI are being displayed in the ETI window correctly. Run the ETI template program specifying MULTI_DATA_FILES equal to one and Nb_points equal to the number of data files. Expect to see one analysis widow for each data file.

4.6.4 Test Report

Table 7. Test Results – ETI Analysis Window

TEST CASE	RESULT (PASS/FAIL)	FAILURE DETAILS/ NOTES
Test multiple data files	Pass	
Non-matching number of data files	Pass	
Single data file multiple plots	Pass	

Table 7. *Test Results – ETI Analysis Window*

TEST CASE	RESULT (PASS/FAIL)	FAILURE DETAILS/ NOTES
Single data file invalid Nb_points	Pass	
Odd number of Nb_points	Pass	
Multi data files	Pass	
One plot for multiple data files	Pass	
Specify filename single data file	Pass	
Specify filenames multiple data files	Pass	

4.6.5 User Instructions

The purpose of these instructions is to indicate how to use the new multiple data files feature added to the ETI program. For further instructions on using the ETI program refer to the final report.

The multi_data_files flag can be set to 1 or 0. A value of 1 indicates that the user wishes to run the analysis display using multiple data files. A value of 0 indicates that the display should be run with only one data file. If the user does not specify multi_data_files then it is assumed that one data file with multiple plots is desired.

5. Q246 Data Quality Verification

The purpose of this task was to perform basic quality verification on subsets of Q246 data from different points in time from the trial. The following files were examined during this task:

- q246_02JUN98_2106.DAT

- q246_02JUN98_2115.DAT

- q246_02JUN98_2136.DAT

- q246_02JUN98_2206.DAT

- q246_02JUN98_2236.DAT

- q246_02JUN98_2243.DAT

5.1.1 Header Repair

During processing it was found that there were a number of problems with the DREA headers in the supplied data. Specifically the sample rate and date/time were incorrect. These were manually repaired by converting the files from DAT32 to DAT format and using sp_ph (patch header) to correct the header fields. Sp_ph was later upgraded to work directly with DAT32 files.

5.1.2 Data Consistency Verification

The purpose of this task was to verify that data maintained a reasonable level of consistency from the start of a data file to the end. Channel 3 is an auxiliary channel that could be visually inspected. Verifying consistency in Channel 3 data ensured that no data was lost during transcription causing a mixing of data from other channels. Each file was visually inspected in STAR for every ping step ensuring that there was no change in the signal.

The ETI analysis display in STAR was used to perform the verification. The ETI analysis display was configured with four plot areas aligned by ping. The ping length (ping_length_default) was set to 0.25 seconds to make it easier to visually inspect the signal. The ping step (ping_step_default) was set to 30 seconds for q246_02JUN98_2106.DAT, q246_02JUN98_2136.DAT, q246_02JUN98_2206.DAT, q246_02JUN98_2236.DAT and q246_02JUN98_2243.DAT. The ping step was set to 5 seconds for q246_02JUN98_2115.DAT because the file contained a smaller amount of data (~58MB file).

No change in Channel 3 was observed in the following files:

- q246_02JUN98_2106.DAT

- q246_02JUN98_2115.DAT

- q246_02JUN98_2136.DAT

- q246_02JUN98_2236.DAT

- q246_02JUN98_2243.DAT

A slight change was observed in q246_02JUN98_2206.DAT at 22:24:42.839, but this was later found to be acceptable.

5.1.3 Receiver Quality Verification

The purpose of this task was to record anomalies in the data for a subset of data across each receiver. The ETI analysis display in STAR was configured to display ten plot areas aligned by receiver. The ping length (ping_length_default) was set to 60.0 seconds. The ping step (ping_step_default) was set to 30 seconds for all data files. Table 8 through Table 13 document the results of this analysis. A brief description of the observations is included for each type of data. This analysis also showed that the channel assignments for the supplied data files were different than those found in the trial logs allowing the processing scripts to be repaired. Without this analysis the errors in the output data may have been subtle enough to prevent detection of the problem.

5.1.3.1 q246_02JUN98_2106.DAT

Table 8. q246_02JUN98_2106 QA Results

RECEIVER	RESULTS
1	Constant at –1296
2	Constant at 12800
3	Constant repeating signal
4	Constant at 10752
5	Constant at 0
6	Jump/drop in signal every 60.0 seconds starting 35.0 seconds into file
7 to 72	Acoustic data with coarse quantization, every second channel is different
73	Range –360 to 160

Table 8. *q246_02JUN98_2106 QA Results*

RECEIVER	RESULTS
74	Range 80 to 160
75	Range −270 to 210
76	Range −160 to 20
77	Range −260 to 175
78	Good

5.1.3.2 q246_02JUN98_2115.DAT

Table 9. *q246_02JUN98_2115 QA Results*

RECEIVER	RESULTS
1	Constant at −1296
2	Constant at 12800
3	Constant repeating signal
4	Constant at 10752
5	Constant at 128
6	Jump/drop in signal every 60.0 seconds starting 40.0 seconds into file
7 to 73	Acoustic data with coarse quantization, every second channel is different
74	Range 80 to 160
75	Range −340 to 350
76	Clipping
77	Range −500 to 450
78	Good

5.1.3.3 q246_02JUN98_2136.DAT

Table 10. q246_02JUN98_2136 QA Results

RECEIVER	RESULTS
1	Constant at –1296
2	Constant at 12800
3	Constant repeating signal
4	Constant at 10752
5	Constant at 192
6	Jump/drop in signal every 60.0 seconds starting 35.0 seconds into file
7 to 52	Acoustic data with coarse quantization, every second channel is different
53	Range -200 to –300
54 to 72	Clipping
73	Range –275 to 60
74	Range 80 to 160
75	Range 50 to 80
76	Range –225 to 0
77	Range –80 to 0
78	Good

5.1.3.4 q246_02JUN98_2206.DAT

Table 11. q246_02JUN98_2206 QA Results

RECEIVER	RESULTS
1	Constant at –1296
2	Constant at 12800
3	Constant repeating signal
4	Constant at 10752
5	Constant at 2048

Table 11. *q246_02JUN98_2206 QA Results*

RECEIVER	RESULTS
6	Jump/drop in signal every 60.0 seconds starting 35.0 seconds into file
7 to 58	Acoustic data with coarse quantization, every second channel is different
59	Range 80 to 160
60 to 72	Clipping
73	Range −160 to 0
74	Range 80 to 160
75	Range −50 to 70
76	Range −160 to −70
77	Range −80 to 0
78	Good

5.1.3.5 q246_02JUN98_2236.DAT

Table 12. *q246_02JUN98_2236 QA Results*

RECEIVER	RESULTS
1	Constant at −1296
2	Constant at 12800
3	Constant repeating signal
4	Constant at 10752
5	Constant at 2240
6	Jump/drop in signal every 60.0 seconds starting 11.0 seconds into file
7 to 52	Acoustic data with coarse quantization, every second channel is different
53	Range −300 to −200
60 to 72	Clipping
73	Range −175 to 0
74	Range 80 to 160
75	Range −10 to 50

Table 12. q246_02JUN98_2236 QA Results

RECEIVER	RESULTS
76	Range −130 to 70
77	Range −60 to 0
78	Good

5.1.3.6 q246_02JUN98_2243.DAT

Table 13. q246_02JUN98_2243 QA Results

RECEIVER	RESULTS
1	Constant at −1296
2	Constant at 12800
3	Constant repeating signal
4	Constant at 10752
5	Constant at 2000
6	Jump/drop in signal every 60.0 seconds starting 6.0 seconds into file
7 to 52	Acoustic Data with coarse quantization, every second channel is different
53	Range −270 to −240
54 to 72	Clipping
73	Range −175 to 0
74	Range 80 to 160
75	Range −20 to 50
76	Range −130 to −80
77	Range −80 to 0
78	Good

5.2 Sp_bitflip

A utility was created to collect bit flip statistics on a DREA DAT or DAT32 format data files. The utility outputs the results to a comma-delimited file that can be loaded into Microsoft Excel or manually examined. This module is only designed to work with files that have a multiplex length of 1.

This utility is useful in that it produces data on the percentage of time that a particular bit is set to 1. It allows users to see which bits are being used and therefore how much dynamic range is being used in a particular dataset. It also allows users to see if a bit that should be toggling is consistently set to 1 or 0, indicating a 'stuck' bit.

5.2.1 Requirements information

The following requirements were implemented under this contract

- Create a signal processing module using the SPLIB design that collects bit flip statistics from a data stream.

- Create an SPPACS utility that uses the bit flip processing module.

- The utility will read DREA DAT or DAT32 format files.

5.2.2 Software Design information

The utility makes use of existing support libraries to handle user interaction. Several processing modules handle the signal processing. These processing modules are based on the design approach in SPLIB. The processing modules are chained together to produce a processing chain as shown in Figure 5.
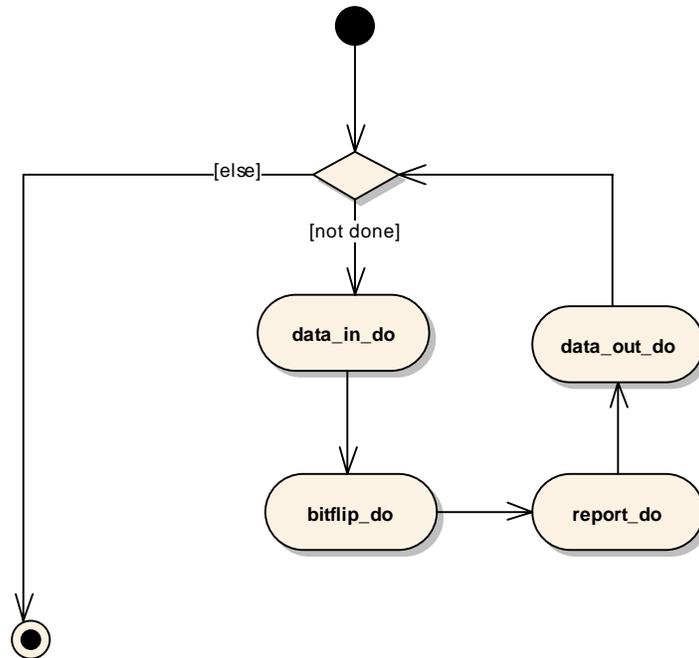
Figure 5. *Bitflip – Program Flow*

5.2.2.1 Bitflip Processing Module

The utility uses a processing module to collect bit statistics from a DREA DAT or DAT32 files. To make it generic, the processing module iterates over the data using a character pointer (char*). The number of samples to average and number of bytes per sample is determined by the controlling function. Statistics are collected by incrementing a counter each time a bit is enabled. Samples are read until the number of records to read or the end of the file is encountered. The module then computes the mean for each channel and writes the results to its output buffer.

Both of the data_out and report processing modules are attached as readers to the bitflip-processing module's output buffer.

5.2.2.2 Binary Statistics Report (data_out)

This processing module writes the results to a DREA DAT32 or DAT file. The percentage of enabled bits (0.0 – 1.0) is written for each bit in each channel. An existing processing module (data_out), from SPLIB, was utilized to write the data to the output file. A single record is written to the file that contains the same number of channels as the input file and a multiplex length equal to the number of bits in a sample.

5.2.2.3 ASCII Statistics Report (report)

This processing module writes the results to an American Standard Code for Information Interchange (ASCII) file that can be opened with Microsoft Excel or manually examined. This processing module decodes the data stream and writes a line to a comma-delimited file (user defined). Each row holds the statistics for each channel. The percentage (0.0 – 1.0) for each bit is displayed in each column.

Example:

```
,channel 0,,,…,
record,bit 0,bit 1,bit 2,…,bit n
1,1,0.67,0.23,0.12,..,0.45
```

Extra commas are added to sparse lines such as the channel data to ensure annotation alignment if imported into Microsoft Excel or another spreadsheet.

5.2.3 Test Description

The following test cases are used to ensure that the utility functions correctly:

- Constant repeating signal: Use a data file that has a defined signal. Calculate the expected percentage prior to using the utility. Ensure that at least one channel contains only zeros.

- DAT32 Compliance: Copy and convert the same dataset from the previous test case to DAT32 format.

5.2.4 Test Report

Table 14. Test Results – sp_bitflip

TEST CASE	RESULT (PASS/FAIL)	FAILURE DETAILS/ NOTES
Constant repeating signal	Pass	
DAT32 Compliance	Pass	

6. Maintain Configuration Management

STAR and SPPACS are maintained using CVS. The most recent release version is maintained as a code branch and bug fixes are applied to that version, as required, ensuring that a stable release is always available. Simultaneously, software enhancements are applied to the development version and bug fixes are periodically merged with this version from the release version. Once a call-up nears completion or a release of the software is otherwise required a new release version is branched off of the development stream for final integration, release testing and delivery.

STAR release 4.3.0 (tag release_4_3_0, STAR module) was created under this contract to serve as a baseline while the analysis work was being conducted. The STAR module now contains STAR, SPPACS, SONLIB and SPLIB. Creating a branch release allowed development to continue on the trunk of the distribution. (NOTE: The trunk usually contains newly implemented software, which may not be stable enough to allow for operational use so branches of stable code are created for distribution to users and analysts.)

7.   Track Software Issues

Defect Tracking Systems allow users to keep track of outstanding bugs in their product effectively. STAR and SPPACS' issue tracking is performed using a web accessible tool called Bugzilla. This tool can be accessed using a secure web interface at https://star.iotek.ns.ca. Once the appropriate security procedures, detailed on the web page, have been followed, users and developers can use this site to add, view or modify issues related to the software packages. If required, the EADAQ and Noise Monitoring Software packages can also be added to the site.

A breakdown of the current issues for the STAR and SPPACS distributions are shown in Table 15. The total number of unresolved issues in shown in the NEW/ASSIGNED/ REOPENED column. The total number of opened issues is broken into to classes of severity. Issues classified as BLOCKER/CRITICAL/MAJOR are issues that should be addressed in the short term. Blockers are always addressed immediately to ensure that the user community can continue with their work. Issues classified as NORMAL/ MINOR/TRIVIAL are issues that can be dealt with in the long term.

Table 15. *Distribution Issue Summary (/06/2004)*

PRODUCT	NEW/ASSIGNED/ REOPENED	BLOCKER/CRITICAL/ MAJOR	NORMAL/MINOR/ TRIVIAL
SPPACS	36	0	35
STAR	64	2	67

The following gives a more detailed description of the SPPACS BLOCKER/ CRITICAL/MAJOR column:

- None at this time

The following list gives a more detailed description of the STAR BLOCKER/ CRITICAL/MAJOR column:

- Issue # 193 (critical) **tacplot does not cleanup before exiting**. The work around for this issue is to run heap_gc after the analysis window has closed.

- Issue # 107 (critical) **problems capturing close button**. A solution exists for this but has only been incorporated into the tactical plot.

8. References

1. Support to Multistatic FM Data Processing – The SPPACS / STAR Data Analysis Process and Toolset

2. James A. Theriault and Joe Hood, *Using Directional Sensors to Enhance the Performance of the Towed Receiver Array of Active Sonar, Proc. Undersea Defence Technology Conference, Hawaii, October 2004.*

Annexes

The following paper was presented at the Oct 2004 Undersea Defence Technology Conference.

Using Directional Sensors to Enhance the Performance of the Towed Receiver Array of Active Sonar

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Abstract

Traditional passive-sonar towed-array receivers use a linear set of omni-directional hydrophones. Beamforming such a linear array achieves a reduction in effective background noise and allows the localization of targets within a steering direction. A major shortcoming, due to the linear geometry, is that the formed beams are conical with the axis coincident with the array axis. These conical beams result in an inability to resolve port versus starboard directions. More recent efforts have turned from passive sonar to active sonar using towed line-array receivers. By replacing the omni-directional hydrophone sensors with "left-right" directional sensors, beamforming can be undertaken with sets of "port" and "starboard" beams. For active sonar, this means that targets can be localized in range and in bearing without a port-starboard ambiguity. Furthermore, the increase in directivity due to the port-starboard beamforming has the benefit of reducing reverberation levels. The improvement in sonar performance in a homogenous reverberation environment is significant, but is even more dramatic in an inhomogeneous reverberation environment where capability may be severely limited by geoclutter. This paper will demonstrate the added value of such receive arrays as compared to omni-directional hydrophone arrays. Data collected with the DRDC Atlantic DASM (Directional Acoustic Sensor Module) receive array in an environment where geoclutter dominates one side of the array will be presented.

Introduction

In order to meet the Canadian Navy's continuing requirement to detect acoustically both surface vessels and submarines, it is necessary to improve the performance of both passive towed array sonars and active sonars. In searching for the modern, quiet submarine, the detection range of current active sonars is inadequate; the emerging solution involves low-frequency active (LFA) sonars. Low frequency (LF) sound propagates in the ocean and is difficult to counter using anechoic coatings. Typically, tactical LFA sonar would employ a towed-array receiver and a towed LF source.

Canada's long-term requirement for a tactical sonar has driven the employed frequency to be significantly higher than that desirable for a surveillance system. A lower frequency surveillance system would have greater detection range, but would also be larger and more difficult to employ based on the current Canadian naval vessel assets and roles.

Whatever advantages an LFA sonar may provide, there remains a role for the covert, passive towed array sonar. The full requirement for acoustic detection is therefore met by integration of an LFA sonar with a passive towed-array sonar: a Towed Integrated Active-Passive Sonar (TIAPS) [1,2].

The receiver for the LFA sonar consists of a linear array of directional sensors (DASM: Directional Acoustic Sensor Module) towed in line with a source and the passive linear array. Beyond the obvious tuning of the receive array to active frequencies, an important difference between the active sonar receiver and the passive sonar receiver is in the choice of individual sensors. In the case of the TIAPS system and its predecessors, the directional sensors, known as CORDS (Combined Omni Resolved-Dipole Sensor.

The remainder of this paper will give a description of the research system, the environment, and a comparison of the performance of an omni-hydrophone array with the performance of the DASM array. Though this paper focuses on the results obtained from the specific system, the results are easily generalized to other arrays of directional sensors [3]. It will finish with a brief description of current and future work.

Experimental Apparatus

Figure 6 shows the tow configuration used to collect the data. This system was a predecessor to the current TIAPS system. The DASM array consisted of a 24 m module containing 32 directional sensors with 0.5 m spacing. The signals from these 64 analogue channels were processed in real time for display to an acoustics operator. Sixty-four beams were formed with equal spacing in $\sin(\theta)$ space assuming a sound speed of 1500 m/s. Beams 1 and 33 were forward and aft endfire beams, Beams 2 to 32 represent the starboard beams from forward to aft, and Beams 34 to 64 represent the port beams from aft to forward.

The source consisted of a vertical array of Free Flooding Ring (FFR) projectors [1,4,5]. Each of these projectors yields an azimuthally independent directivity, with mild vertical directivity. The projector array was capable of source levels exceeding 220 dB re 1μPa @ 1m.

The Combined Omni-Resolved Dipole Sensor (CORDS) [1,2,6,7,8] is used as the directional sensor for the DASM array. The sensor consists of an omni-directional pressure sensor and a roll-resolved horizontal dipole particle accelerometer (HD). Adding or subtracting the integrated HD from the omni-directional pressure sensors can form left and right "looking" cardioids. For example if $x(t)$ and $y(t)$ are the pressure sensor and the integrated HD time series respectively, then $s(t) = \alpha x(t) + (1-\alpha)\gamma y(t)$ represents a cardioid time series when $\alpha = 0.5$ and $\gamma = \pm 1$. For the purposes of this paper, only the case where $\alpha = 0.5$ will be considered. In doing so, the terms α and $(1-\alpha)$ can be ignored. The results will be not referenced to 1 μPa in this case, but only relative levels are of interest for the purposes presented here. By varying the constant γ, the associated null and relative weighting direction can be adjusted. By varying $\gamma = \cos(\phi_0)$, where ϕ_0 is the steering direction (from broadside) of a conventional line array beamformer, the CORDS sensor has the maximum response in the direction of interest. $\gamma = 0$ and $\gamma = \pm 1$ will be used in this paper to represent the array with only omni directional hydrophones and with directional sensors, respectively.

The HD sensor consists of two-cantilevered beams with orthogonal piezo-electric ceramic on the outside of the beams (See Figure 7). The two cantilevered beams form a cross-dipole sensor. The roll resolver consists of a mercury-filled tube with sine and cosine shaped electrodes. The version of the sensor shown has the roll resolver inside the cantilevered beams. Older versions had the roll resolver as a completely separate sensor. Figure 8 shows a picture of a second generation CORDS sensor.
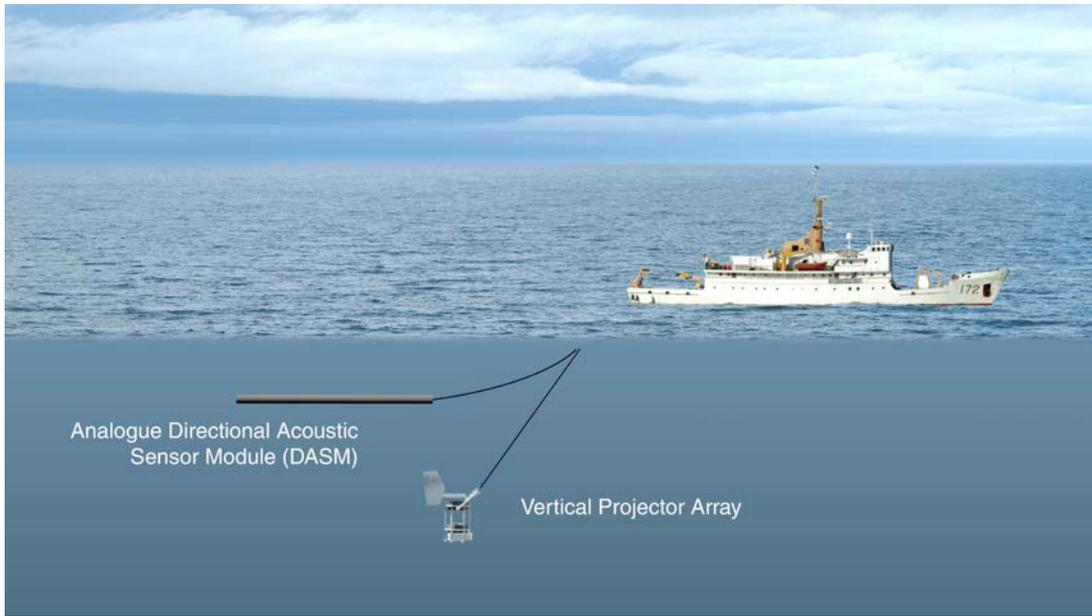
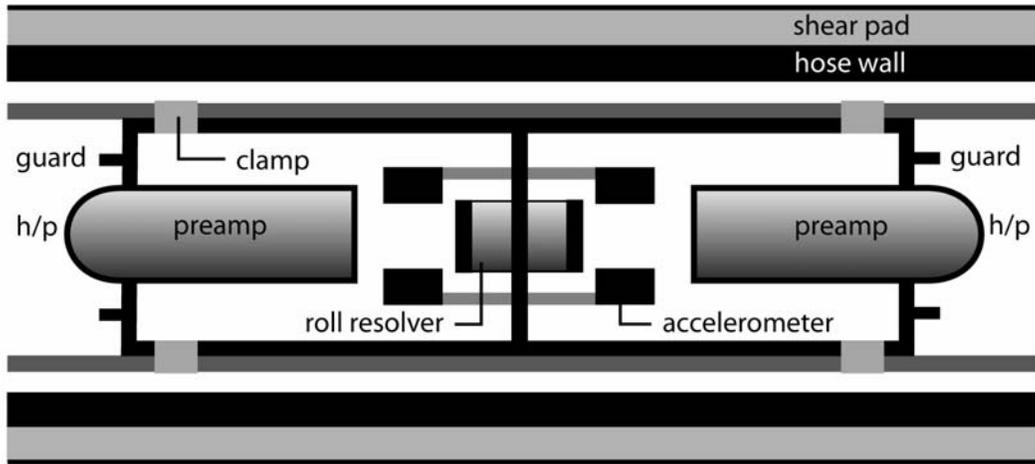**Figure 6: Ship with Towed LFA System (not to scale)**

Figure 7: Combined Omni Resolved-Dipole Sensor (CORDS)
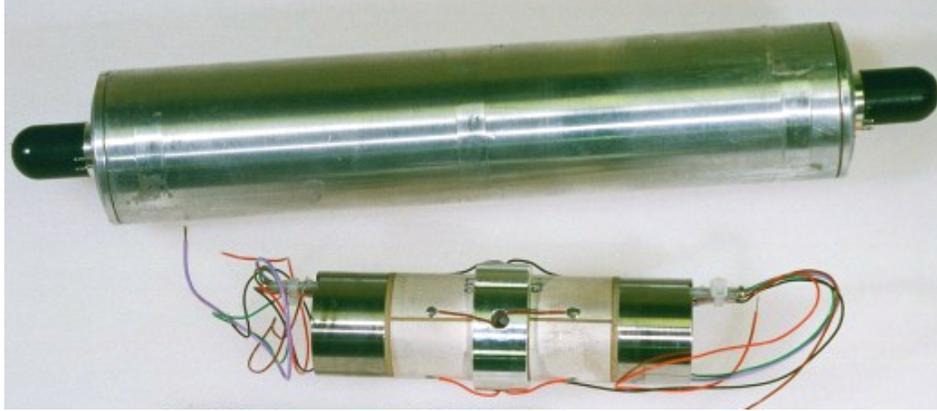
Figure 8: Combined Omni Resolved-Dipole Sensor (CORDS)

Beamforming

Conventional beamforming [9] is used for the purposes of this paper. Improved performance may be achieved in some situations through adaptive techniques [10]. A conventional time delay beamformer for a discrete linear array would produce the time series,

$$h(t, \phi_0) = \frac{\sum_{i=1}^{n} w_i s_i (t - i \frac{d}{c} \cos(\phi_0))}{\sum_{i=1}^{n} w_i}$$

where w_i represent the relative weights, n is the number of sensors, d is the inter-sensor spacing, and c is the speed of sound. The time series, $s_i(t)$ is defined in the previous section for each of the n sensors.

Using this approach, in the case where $w_i = 1/n$ the array beam pattern as a function of steering angle ϕ_0, arrival angle θ, and frequency f, is given by

$$D(\theta, \phi_0, f) = \frac{\sin(n \pi df [\sin(\theta) - \sin(\phi_0)]/c)}{\sin(\pi df [\sin(\theta) - \sin(\phi_0)]/c)}.$$

Using the Product Theorem [11], $D(\theta, \phi_0, f)$ may be multiplied by the directivity of the sensor $(\gamma + \cos(\theta))^2$ to achieve the directivity of the uniformly-weighted DASM array.

Experiment

The data shown in the next section was collected on the research vessel CFAV Endeavour on the Scotian Shelf, near Emerald Bank, in 1998. Figure 9 shows a chart with the position of the vessel at the time of the measurements. CFAV Endeavor held a steady course at 340^0 T with a speed of 7.6

The vessel traveled along a seabed slope with the seabed having a small slope downward on the port side and upward on the starboard side. The water depth varied between 100 m and 140 m in the area. The seabed slope near the

vessel may cause higher scattering angles on the starboard side as compared to the port side. Assuming Lambert scattering, this would result in higher scattering strength, and therefore reverberation, on the starboard side at short ranges.

The vertical FFR array was used to transmit a 2s Hyperbolic FM (HFM) waveform, sweeping from 1100 Hz to 1150 Hz.
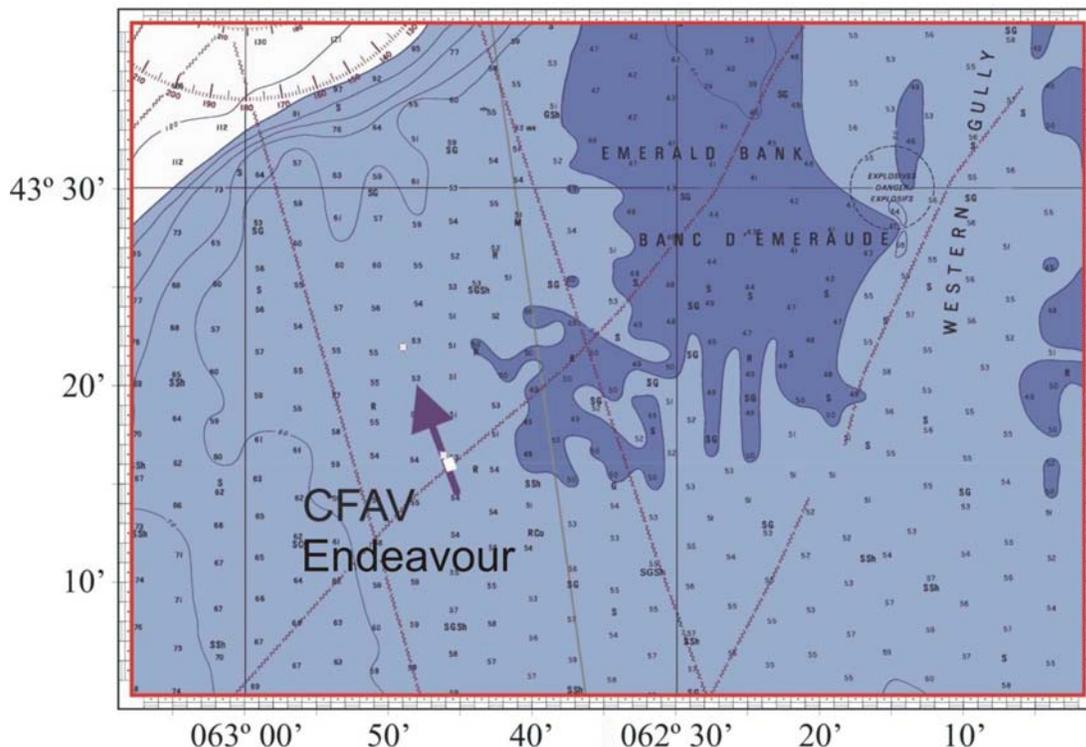

Figure 9: Ship Track

Example Data

By setting the coefficient, $\gamma = 0$, the array becomes an array of omni-directional sensors. Figure 10 shows the beam map for the array of omni-directional sensors. The horizontal axis represents the beam steering angle with 0 representing the forward endfire direction. Port and starboard beams are represented on the left and right side of forward endfire direction, respectively. The left and right boundaries represent the aft-endfire direction. The beam steering angles are equally spaced in the cosine domain and therefore non-linearly spaced in the angular domain. Hence the beam steering axis is non-linear. Time is represented on the vertical axis. The color scale has an arbitrary reference. The figure shows the matched filter output including significant clutter. Notice the port-starboard ambiguity in the image; any scattering generated on one side of the array is shown on both port and starboard.

By setting the coefficient, $\gamma = \pm 1$, (with +1 representing the port direction and –1 representing the starboard direction) the array becomes an array of cardioid sensors. Figure 11 shows the corresponding beam map for the array of directional sensors. The axis and colour scale are the same as in the previous figure. The figure shows the matched filter output.

Figure 11 shows that at times up to approximately 80s, the higher reverberation is realized on the starboard side, while clutter dominates the port side at greater times. The previous discussion of the local slope may explain the

reverberation observations out to 80s. The endfire beams are treated as a special case (with $\alpha = 0$) regardless of the value used for other beams, and so the own-ship generated noise in the forward direction is the same in Figures 5 and 6. With the reduction in levels on the nearby beams, the own-ship noise becomes more noticeable in Figure 6 than in Figure 10.
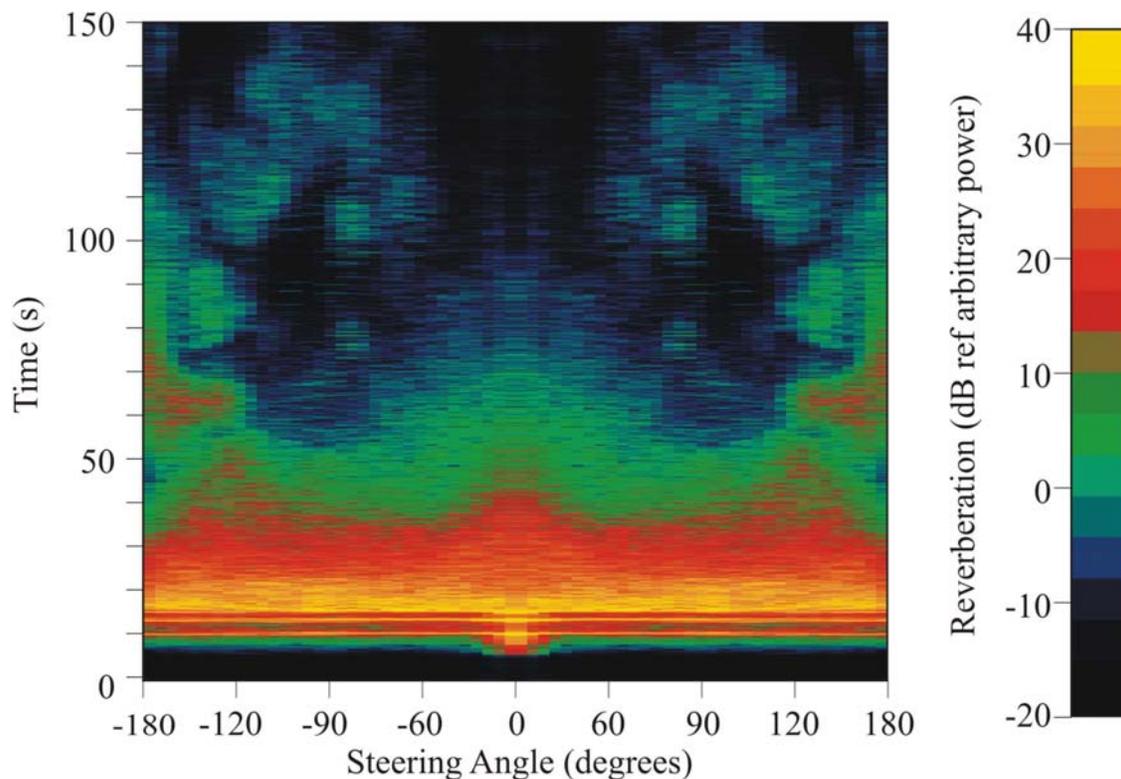

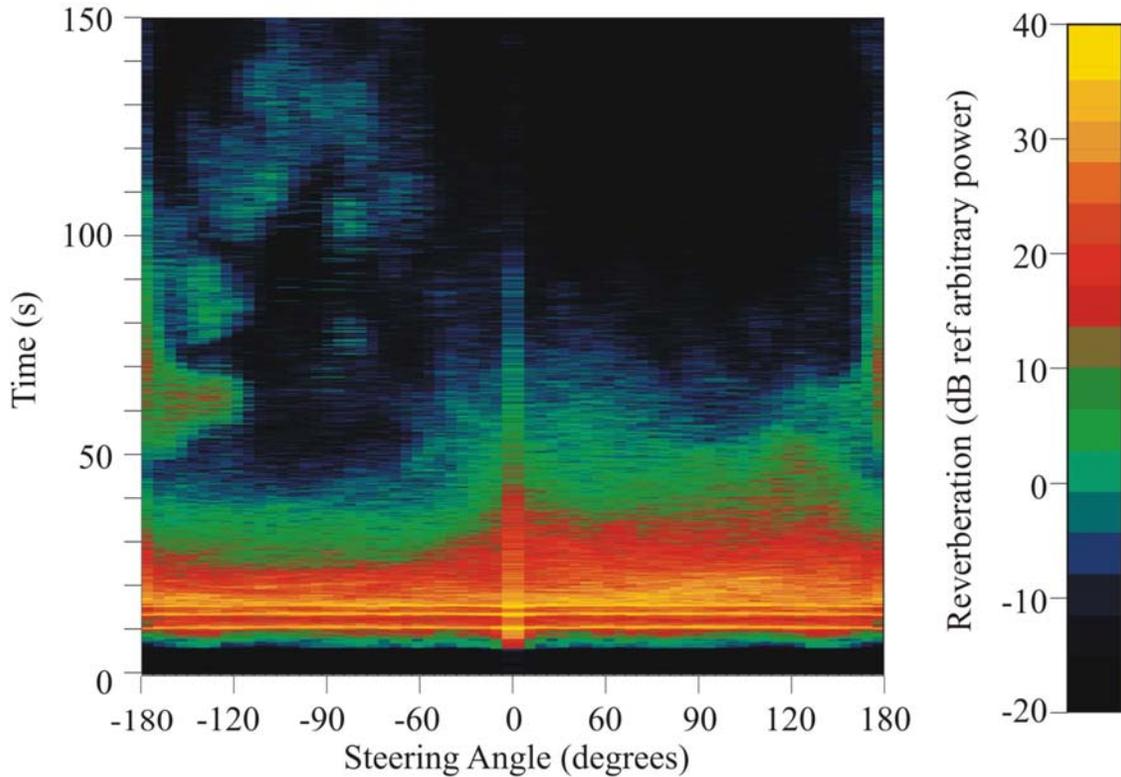**Figure 10: Time - Bearing Plot of Matched Filter Output for Array of Omni-Directional Sensors**

Figure 11: Time - Bearing Plot of Normalized Matched Filter Output for Array of CORDS Sensors

A direct comparison of the performance improvements can be achieved by considering only the broadside beams ($\phi_0 = 90$). Figure 12 shows the averaged broadside beam time series for the omni-array (port and starboard are the same), the port beam of the DASM array, and the starboard beam of the DASM array. As previously considered, for times out to 80 s, the scattering from the starboard side of the array dominates the reverberation from the omni array. Beyond this time, the scattering from the port side dominates. Without the benefits of the array of directional sensors, the overall performance would be limited by the dominant scattering regardless of which side of the array it was located on. In this case, the reverberation processing gain available by having the directional sensors is as much as 20 dB (50s and 130s). Hence, as shown in this figure, significant improvements in performance can be achieved with arrays of directional sensors.
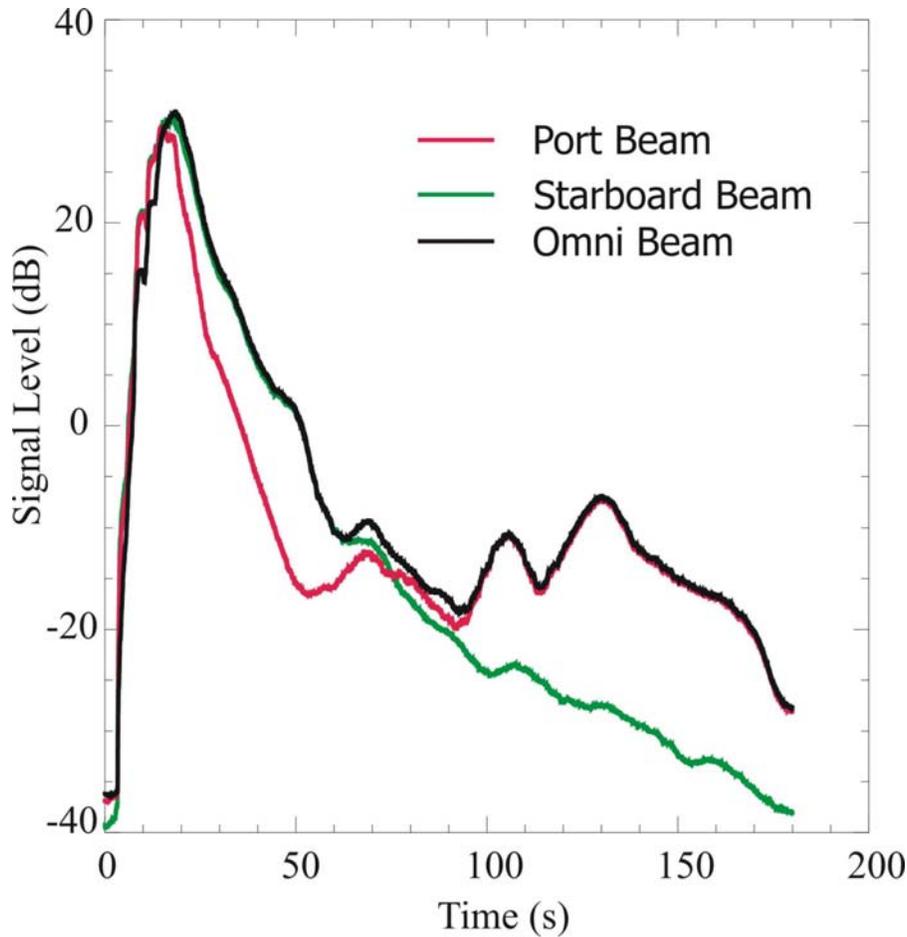
Figure 12: Broadside Beam Reverberation Time Series Comparison

Conclusions and Future Effort

This paper has shown the added value of linear arrays of directional sensors for reverberation reduction and hence improved target signal to reverberation ratios as opposed to comparable linear arrays of omni-directional sensors. In addition to the reverberation reduction, resolving port versus starboard beams also has an impact on signal and target trackers.

"The future is already with us" best describes the next evolution. The receiving array used for this paper is an early prototype of the DASM array used by the TIAPS (Towed Integrated Active-Passive Sonar) Technology Demonstration Project. TIAPS now uses a high-dynamic-range digital array of improved CORDS Sensors. The aperture of the current TIAPS DASM array is three times that of the array presented in this paper. As the TIAPS project nears completion, a further improved CORDS sensor is being trialed. All of the earlier sensors used mercury as the conductor for the analogue roll resolver. The updated CORDS sensors use a digital roll resolver, which eliminates the need for mercury in the array. The updated DASM array will form the cornerstone of this effort.

References

1 Cotaras, F.D., "Towed Integrated Active Passive Sonar, TIAPS," *in Undersea Defence Technology Proceedings,* June 1997.
2 James A. Theriault, "Low Frequency Active Sonar in Shallow Water," Proc. of Submarines & Anti-Submarine Warfare, 4-5 Sept. 2000, London, UK.
3 Y. Doisy, "Port-starboard discrimination performance of active towed array systems," in Proceedings of UDT, Cannes, France, 1995. pp. 125-129.
4 Barry, P.J., Hutton, J.S., Franklin, J.B., "Dual Free Flooding Ring Towed Projector Array," DREA TM 92/214, 1992
5 Bonin, Y.R., Gallaher, A.B., Purcell, C., Hardie, D.J.W., "Comparing Predictive Methods for a Ring Projector," in *Proc. Inst. of Acoustics,* Vol.17, Pt.3, p. 44-53, 1995. (Modelling of FFR, VP-2, VP-4)
6 Franklin, J. B., and Barry, P. J., "Acoustic Particle Acceleration Sensors," Proceedings of the Acoustic Velocity Sensor Focused Workshop, Mystic, CT, USA, 12 & 13 September, 1995.
7 Franklin, J.B., "High sensitivity accelerometer for crossed dipoles acoustic sensors," US Patent 4,827,459. May 1992
8 Franklin, J.B., "High Sensitivity Accelerometer for Crossed Dipoles Acoustic Sensors," CA Patent 1,299,387. April 1992.
9 Richard O. Nielson, "Sonar Signal Processing," Artech House, Norwood, MA, 1991.
10 J.N. Maksym, "Directivity and Ambiguous Signal Suppression in Linear Arrays of Directional Sensors," Private Communication, 2001.
11 Robert J. Urick, "Principles of Underwater Sound," 3rd ed., McGraw-Hill, New York, 1983.

List of symbols/abbreviations/acronyms/initialisms

API	Application Program Interface
ASCII	American Standard Code for Information Interchange
CVS	Concurrent Versioning System
DASM	Directional Acoustic Sensor Module
DND	Department of National Defence
DRDC	Defence Research and Development Canada
DREA	Defence Research Establishment Atlantic
DRP	Document Review Panel
EA	Enterprise Architect
EADAQ	Environmental Acoustics VME-based acoustic data acquisition system
ETI	Energy Time Indicator
FFTW	Fastest Fourier Transform in the West (C subroutine library)
HTML	Hypertext Markup Language
IDL	Interactive Data Language
I/O	Input/Output
NAD	Non-Acoustic Data
PC	Personal Computer
RISO	Regional Individual Standing Offer
SA	Scientific Authority
SONLIB	Sonar Library
SOW	Statement of Work
SPLIB	Signal Processing Library
SPPACS	Signal Processing Package
STAR	Software Tools for Analysis and Research
TIAPS	Towed Integrated Active Passive Sonar

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This report documents the work done to support the DASM Added Value study. The objective of the call-up was to provide data processing and analysis support as required to permit the study of the gain achieved when including the dipole sensors in the Directional Acoustic Sensor Module (DASM) array beamforming process in the presence of multistatic active data. The work involved a number of phases with most phases of work involving the generation of reusable software components and analysis processes, allowing future work to be performed more efficiently.

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