DEVELOPMENT OF LOW-COST UNDERWATER ACOUSTIC ARRAY SYSTEMS FOR THE NORTHERN WATCH TECHNOLOGY DEMONSTRATION PROJECT

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1. INTRODUCTION

1.1 RDS Array Technology

In the recent past Defence Research and Development Canada (DRDC) undertook a project to develop low-cost underwater array systems for research and other applications that were complete with on-board processing, acoustic messaging, and battery-powered operations. The project was a major effort requiring over $7.5m in research funding that was known as the Rapidly Deployable Systems (RDS) Technology Demonstration Project (TDP). MacDonald Dettwiler & Assoc. was the lead contractor [1]. The RDS project led to the development of a flexible digital array technology, which is often just called RDS today.

Developments since the end of the TDP project include upgraded quantization from 16 to 24-bits, an increased sampling rate range from a few Hertz to 240 kHz, reduction in power requirements for each node (typically 20 mW) and the array controller (1.5W), improved digital bus structures with extra data and power pairs, and modernized interfaces including Ethernet and universal serial bus. Other changes relate to the packaging of the various sensors and the production of larger and smaller arrays (typically 64 nodes/array), as well up to 5000-m depth capability [2,3].

The RDS technology has been licensed by Omnitech Electronics Inc. [4] and eleven arrays have been sold to defence science organizations and contractors to date. RDS technology has also been applied to produce long-range acoustic homing systems for the autonomous underwater vehicles that have been used by Canada in the mapping of the seafloor under Arctic ice cover [5]. It has been used in the development of DRDC Starfish systems for underwater research that incorporate both electromagnetic and acoustic sensors [2]. And RDS technology is being applied to provide underwater acoustic sensing for Northern Watch.

1.2 The Northern Watch TDP

The Northern Watch TDP is multi-million-dollar, multi-laboratory project to demonstrate integrated surveillance over a portion of Barrow Strait near the southwest corner of Devon Island for an extended period of up to 1-year duration. The original project concept is described in reference [6]. The biggest difference between the original project and the current plan is the requirement for up to a 1-year period of unmanned operation. This change in the project goal has required a steady series of improvements to the base camp on Devon Island and an expanded role in system integration and autonomy. As a result of the changes, the project timeline has been extended through to 2015.

The underwater sensing portion of the Northern Watch TDP is being provided by ruggedized RDS array systems. Two nested-aperture 160-m long linear arrays will be deployed on the seafloor near the southwest corner of Devon Island in summer of 2013 or 2014.

The arrays must operate continuously for up to 1 year and may have to remain operational for a period of at least two years during which they may be turned on or off depending on requirements of the TDP. These arrays must be cost effective and employ a low-cost set of cables and telemetry repeaters to supply power to the arrays, provide a command and control path, and return the array data to the shore where it will be processed and integrated with data from other systems. Further details are provided in an initial array sensor design concept document [7].

2. Northern Watch RDS Arrays

The arrays for the Northern Watch project have been developed by Omnitech Electronics Inc. as prime under contract to DRDC. The arrays have undergone two prototype developments. The original array design was based on an absolute minimum cost and made extensive use of standard plastic piping and resin materials for the mechanical structure.

Although the mechanical design was sufficient for pressure and stresses of deployment, the arrays began to allow water to leak into the hydrophone nodes after they were deployed. The arrays operated for approximately 2 weeks before they were permanently shut down. While the arrays functioned, valuable supporting data were collected by the operating hydrophone nodes [8].

Even as one or more nodes began to short the main digital bus, data from other nodes was still received. The system was able to maintain partial array operation. As the water found additional leak paths and seeped along the interior of the cable we were able to watch a slow degradation occur.

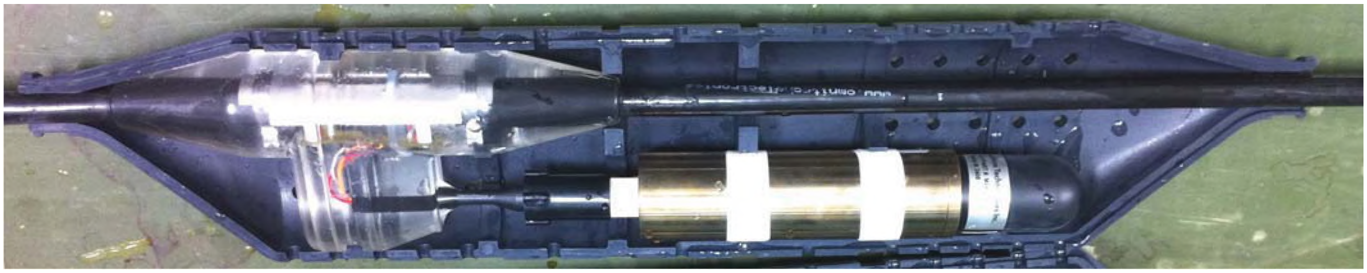

Figure 1. Second generation cantilevered hydrophone node mechanical design.

A forensic analysis of array failure was conducted [9]. Careful inspection and dye penetrant testing revealed that material chemical incompatibilities had provided unexpected leakage paths. The compatibility of the many plastics and resins along with some resin contamination, off-gas bubbling, and construction practices led to the array failures.

A second generation array design was undertaken that limited the role of plastics and resins. The new mechanical design employs Nickel-Aluminium-Bronze canisters for the electronics, commercially constructed hydrophones with screw mountings and O-ring seals, new transparent resin materials for cable breakouts with an internal metal support skeleton, a tough clam-shell protective casing, and a cantilevered hydrophone arrangement as shown in Fig. 1.

The new array design also makes use of connectors to allow for hydrophone replacement. The use of connectors, commercially manufactured hydrophones, and pressure canisters has roughly tripled the cost of the original minimal cost array design; however, every part of the array is now serviceable and is much more robust. The electronic components remain largely similar, except that additional data buses are added to provide for an isolation capability in the event of bus shorts. The mechanical and electrical changes have resulted in a very robust, and still relatively low-cost, array design.

To ensure that the arrays are long-lived, short prototype array segments and component assemblies have been produced and subjected to extensive pressure, strain, and temperature tests. The array segments have been repeatedly acoustically calibrated at intervals during the stress testing to ascertain not only mechanical survivability, but also electronic and acoustic reliability.

The new array segments have been pressure tested to ten times their operational depth requirement of 200 m over 24 cycles. Interspersed among the pressure tests have been a sequence of freezing and heating of wet soaked components. The intent was to try to open cracks and create leakage paths. The arrays were operated continuously during testing to ensure stable data telemetry and acoustic sampling.

In addition, the array segments have been operated while being mechanically strained to more than four times the stress loads expected during deployment. All tests were successfully passed by the prototype units. Finally, the segments were mechanically strained to destruction while still operating to determine the failure mode, symptoms, and ultimate cable strength.

3. CONCLUSIONS

Throughout the production and operation of over 1800 hydrophones based on RDS technology there has never been an electronic failure except for damage due to water leakage or crush damage. The new mechanical array design for Northern Watch appears to bring the system packaging development in line with the electronic development. Extremely robust, low-cost arrays are now possible.

REFERENCES

[1] Heard, G.J., Kennedy, T., and McInnis, J., Rapid Deployable Systems (RDS) for Underwater Surveillance: Final Report. DRDC Contractor Report CR2006-223, 121 pages, 18 December 2006.
[2] Ebbeson, G.R., Heard, G.J., Desharnais, F., Lucas, C.E., and Matthews, M-N,R. Hardware and Software Progress in Deployable Systems. Proc. of the 36th TTCP MAR TP-9, DSTO Edinburgh, South Australia, 12-16 Nov 2007.
[3] Rapidly Deployable Systems Array Technology. DRDC Atlantic Fact Sheet NetALS0108, 2008.
[4] http://www.omnitechelectronics.ca/products/under-water-systems/custom-sensor-arrays.html
[5] Kamninski, C., Crees, T., Ferguson, J., Williams, J., Hopkin, D., Heard, G., 12 days under ice - an historic AUV deployment in the Canadian High Arctic. Proc. of Autonomous Underwater Vehicles (AUV), 2010 IEEE/OES, 1-3 Sept 2010.
[6] Forand, J.L., Larochelle, V., Brookes, D., Lee, J.P.Y., MacLeod, M., Dao, R., Heard, G.J., McCoy, N., Kollenberg, K., Surveillance of Canada's High Arctic. Proc. OCEANS 2008, 15-18 Sept 2008.
[7] Heard, G.J., Pelavas, N., Northern Watch Underwater Sensor System Design Concept. DRDC Atlantic TM 2010-248, Sept. 2010.
[8] Heard, G.J., Pelavas, N., Ebbeson, G.R., Hutt, D.L., Peraza, I., Schattschneider, G., Underwater Sensor System 2009 Field Trial Report: Northern Watch Technology Demonstration Project. DRDC Atlantic TM2010-241, July 2011.
[9] Cameron, C.G., Northern Watch: Summary of the Material Investigations. Jan-Nov 2010. DRDC Atlantic TN2010-343, 2010.