ONMEX'16 & MANEX'16 MCM TRIALS USING ULTRA WIDEBAND MULTIBEAM SONAR

Yan Pailhas[a] & Nicolas Valeyrie[a] & Chris Capus[b] & Samantha Dugelay[c]

[a]Ocean Systems Laboratory, Heriot Watt University, Edinburgh, Scotland
[b]Hydrason Solutions, Edinburgh, Scotland
[c]Centre for Maritime Research and Experimentation, La Spezia, Italy

Heriot Watt University Riccarton Campus, EH14 4AS, Scotland, United Kingdom
email: Y.Pailhas@hw.ac.uk, www: http://researchportal.hw.ac.uk/en/persons/yan-pailhas

Abstract: *Underwater mine countermeasures aims to detect explosive devices that can be found on the sea bottom. In a broad sense, an underwater mine countermeasure system brings together acoustic sensors and detection algorithms that operate on the data produced by the sensors. The capabilities of a mine countermeasures system have to be ultimately assessed on real acoustic data. The purpose of this paper is to present the wideband acoustic data that were collected during the ONMEX and MANEX sea trials, organised by the Centre for Maritime Research and Experimentation (CMRE) in September/October 2016. The data were collected with a new multi-beam wideband sonar that was mounted on a REMUS-100 autonomous underwater vehicle (AUV). The wideband sonar programme is the result of a combined effort between Hydrason Solutions and Heriot-Watt University. The sonar itself comprises two transmitters and two arrays of eight receivers that jointly operate over a broad range of frequencies from 20 kHz to 180 kHz. The sonar is able to elicit the resonances of natural and man-made objects, which makes it a sensor of choice for the mine countermeasures system. Several objects were deployed on the seabed at various locations over the course of the trials. These objects included three Manta-type mine-like objects (MLOs), two rocks, one cylinder and one Rockan-type MLO. The REMUS-100 AUV and wideband sonar were repeatedly flown over the objects in lawn-mower search patterns. The vehicle and sonar also performed circular reacquisition patterns over each object. A substantial data set containing the acoustic responses of the objects at all aspect angles was thus gathered.*

Keywords: *Wideband sonar systems.*

1. WIDEBAND SONAR

The wideband sonar is based on novel bio-inspired hardware and processing techniques originated from studies on bottlenose dolphins. Having developed their sonar systems through more than a million years of evolution, dolphins are highly proficient in the tasks we need to address in marine environments. In attempting to mimic at least some of the capabilities of dolphins, the wideband sonar offers an approach fundamentally different from conventional sonar systems. In most existing systems the wideband acoustic information used for identification and recognition of objects is thrown away in the process of image formation. By retaining all of the echo information, we aim to improve object recognition and diagnostic potential, see [1–7]. During the 2016 ONMEX and MANEX sea trials, wideband acoustic data of a variety of objects were collected with Hydrason's UWBS (Ultra WideBand Sonar) system. The system comprises two transmitters and two receiver arrays of eight elements each. Basic specifications of the system are listed in Table 1.

Hydrason UWBS: system sepcifications	
Operating frequency	20-180 kHz
Sampling frequency	1 MHz
Number of output channels	1
Number of input channels	8
Beamwidth (single element)	40°
Range	1.0-75 m
Power consumption	36 W
Depth rating	300 m

Table 1: Hydrason UWBS System Specifications

The UWBS array, as pictured in figure 1, is composed of 8 individual and independent elements. Each element has the same operating bandwidth of 1kHz to 200kHz, and the same horizontal and vertical beamwidth of 40° and 80° respectively at 60kHz. Each element is approximatively 5cm wide. The array is arranged in a linear configuration with all the elements

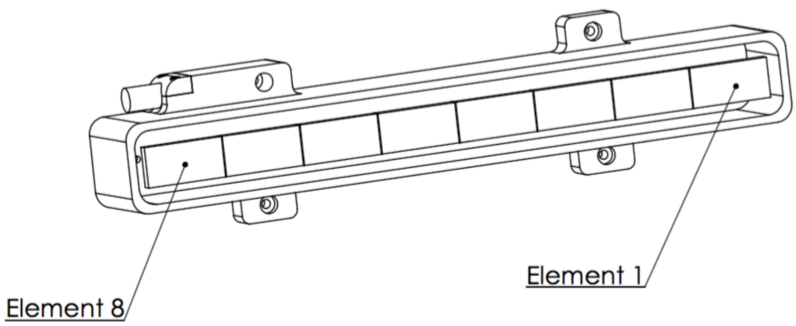


Fig. 1: 3D drawing of the UWBS receiver array.

juxtaposing each other. The echo signal arriving at each element is recorded independently through 8 independent channels.

2. METHODOLOGY

2.1. DATA GATHERING PURPOSE

The main objective of these trials was to collect a vast amount of acoustic data using the UWBS array system and three sidescan sonars to study the problem of coherence. The UWBS array system covers a very broad band of frequencies (20-180kHz exploitable). It also has a very wide beam pattern (40deg @ 60kHz). In a way similar to SAS systems, the UWBS array system "sees" every particular point in the scene numerous times. It is therefore particularly well adapted to measure spatial coherence. The multi-element aspect of the array system allows us, via adaptive processing, to maximise the SRR (Signal over Reverberation Ratio), and thereby to track a cleaner measurement of the coherence of a particular point in the scene. We aimed to carry out repeated measurements at different grazing angles and different aspects in a number of different types of environment to assess the limit of coherence loss and its dependency on look-angle, frequency, seabed type, etc. A special emphasis has been put on any man-made targets present in the environment and polygonal/circular target re-acquisition have been performed to maximise information gain. The output of the trials will deliver a necessary data set to answer fundamental questions about coherence as well as material to develop recognition algorithms based on coherence processing.

2.2. MISSION PLANNING

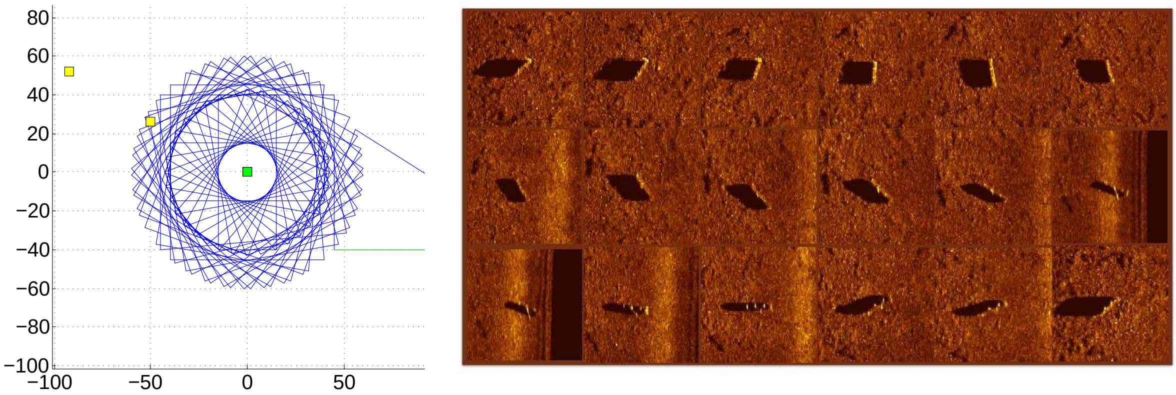
Mission planning of the REMUS-100 vehicle played an important role during the trials. As explained earlier, the main goal was to gather data to study acoustical coherence and more specifically the limits of decoherence, in particular the angular limits. Two strategies were adopted for data gathering:

- discrete acquisitions: The vehicle run in straight lines over the same area with different angles. The advantage of these patterns is that the distortion is minimum allowing easier registration. Figure 2(a) shown an example of such pattern: the target here is "seen" 36 times with 10° angle difference between each views. Figure 2(b) pictures 18 sidescan views of the cylinder target.

- continuous acquisitions: the UWBS array system acquired continuous echoes for all 360° angles. The vehicle runs co-centrical octagons around a specific area or target. There are two advantages to this re-acquisition pattern: the target is "seen" continuously over all 360° angle, and the re-acquisition time is greatly reduced compared to discrete acquisitions [8]. Figure 3 pictures an UWBS image of the cylinder target using such pattern. The target is "seen" for around 1km.

3. TARGETS

During the 2016 ONMEX and MANEX trials, targets were deployed at pre-determined locations. Seven targets were laid on the seabed in total. Figure 4(a), (b) and (c) shows pictures of three concrete replicas of Manta mines. Two concrete rocks of about the same size as the Manta mines were also deployed. Figures 5(a) and (b) show images of the rocks being recovered at



(a) (b)

Fig. 2: (a) Example of a discrete target re-acquisition pattern. (b) Views of the cylindrical mine with a sidescan sonar.

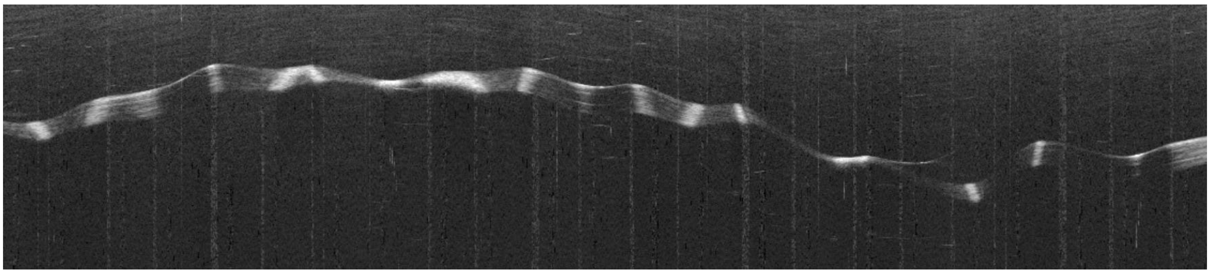
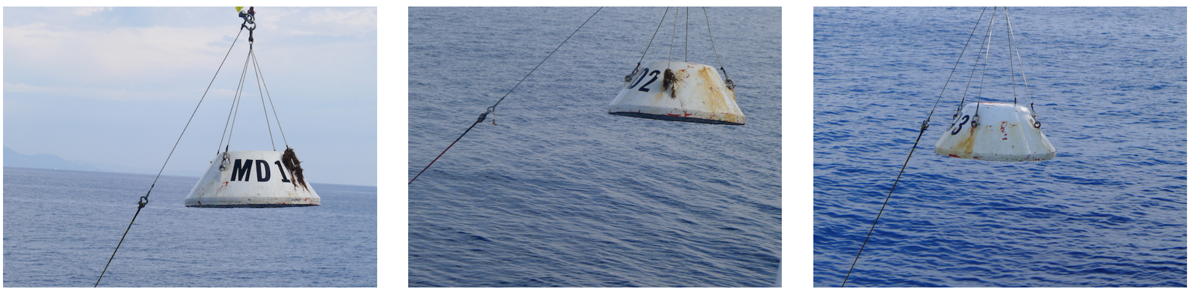


Fig. 3: UWBS image of the cylindrical mine continuously tracked during 1km.

the end of sea trials. Finally, a concrete replica of a cylindrical mine (pictured in figure 6(a)) and a rockan mine (pictured in figure 6(b)) were also deployed.

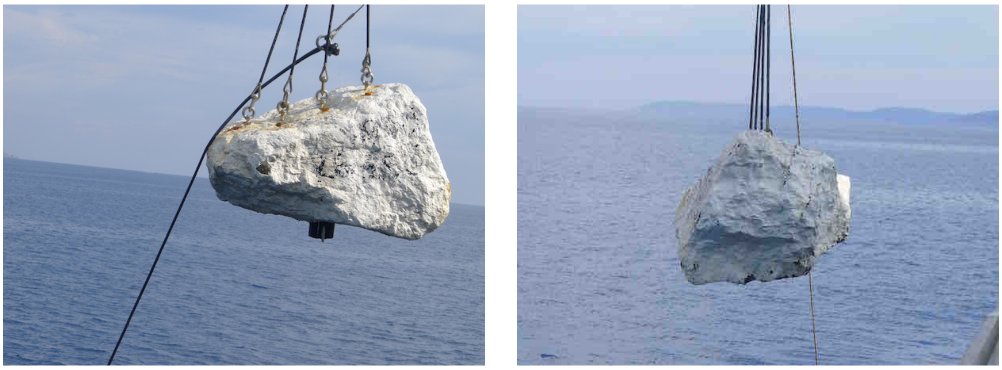


(a) (b) (c)

Fig. 4: Pictures of the concrete replicas of Manta mines.

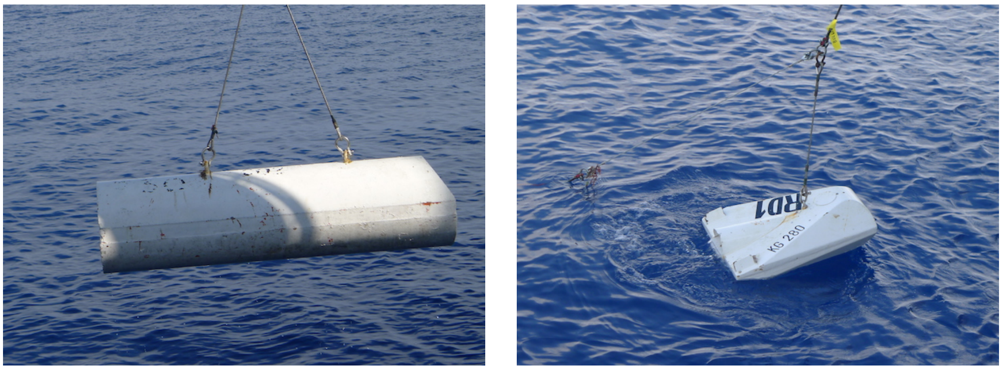
4. SEA TRIALS

The Remus-100 vehicle and the UWBS system were repeatdly flown over the targets during the sea trials. More than twenty missions were conducted in total. Figure 7 shows an example of a circular acquisition pattern over five targets. The mission lasted for 45 minutes. Figure 8



(a) (b)

Fig. 5: Pictures of the concrete rocks.



(a) (b)

Fig. 6: Pictures of the concrete (a) cylindrical mine and (b) rockan mine.

shows an example of a discrete acquisition pattern a single target. The mission lasted for 1h and 20 minutes.

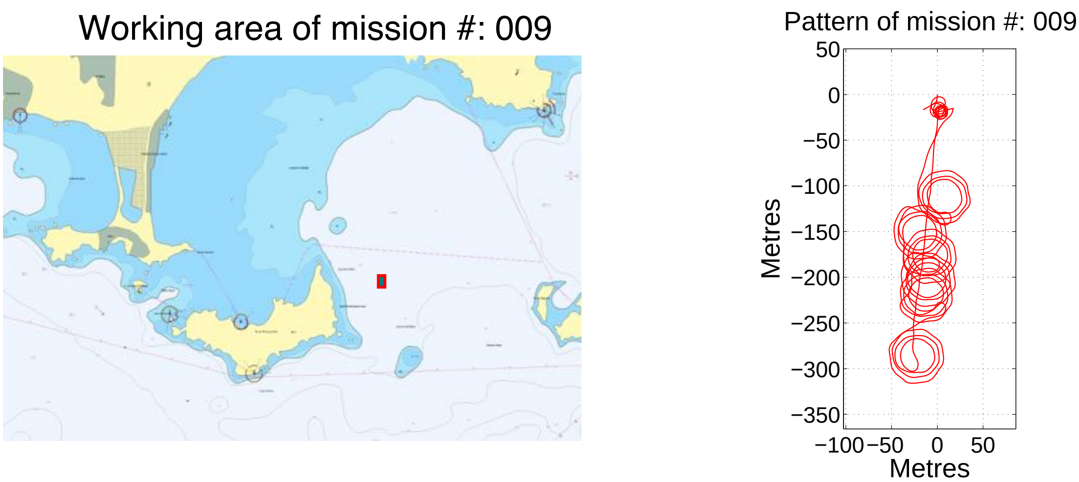


Fig. 7: Continuous target acquisition

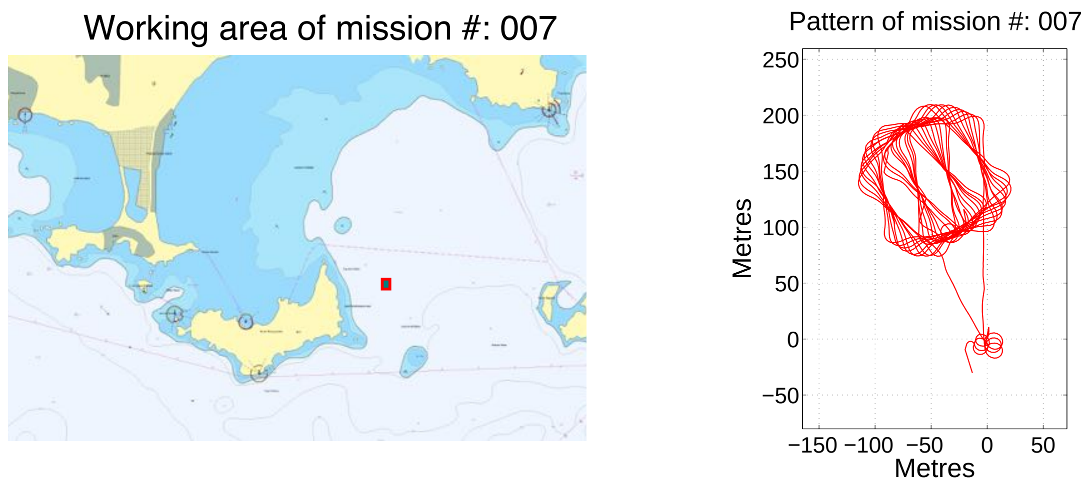


Fig. 8: Discrete target acquisition

5. CONCLUSIONS

The purpose of this paper was to present the wideband acoustic data that were collected during the 2016 ONMEX and MANEX sea trials, organised by the Centre for Maritime Research and Experimentation. Several objects were deployed on the seabed at various locations over the course of the trials. The REMUS-100 AUV and wideband sonar were repeatedly flown over the objects. A substantial data set containing the acoustic responses of the objects at all aspect angles was thus gathered. This will deliver a necessary data set to answer fundamental questions about coherence as well as material to develop recognition algorithms based on coherence processing.

6. ACKNOWLEDGEMENT

This work was partly supported by the Engineering and Physical Sciences Research Council (EPSRC) Grant number EP/J015180/1 and the MOD University Defence Research Collaboration in Signal Processing. The authors would like to thank all members of the Centre for Maritime Research and Experimentation who helped them invaluably during the sea trials.

REFERENCES

[1] C. Capus, Y. Pailhas, K.E. Brown, D.M. Lane, P. Moore, and D. Houser. Bio-inspired wideband sonar signals based on observations of the bottlenose dolphin (tursiops truncatus). *J. Acoust. Soc. Am.*, 121(1):594–604, 2007.

[2] C. Capus, Y. Pailhas, K. Brown, and D. Lane. Detection of buried and partially buried objects using a bio-inspired wideband sonar. In *Oceans 2010 IEEE-Sydney*, pages 1–6. IEEE, 2010.

[3] Y. Pailhas, C. Capus, K. Brown, and P. Moore. Analysis and classification of broadband echoes using bio-inspired dolphin pulses. *J. Acoust. Soc. Am.*, 127(6):3809–3820, 2010.

[4] K. Brown, C. Capus, Y. Pailhas, Y. Petillot, and D. Lane. The application of bioinspired sonar to cable tracking on the seafloor. *EURASIP Journal on Advances in Signal Processing*, 2011:2, 2011.

[5] Y. Pailhas, C. Capus, and K. Brown. Dolphin-inspired sonar system and its performance. *Radar, Sonar Navigation, IET*, 6(8):753–763, October 2012.

[6] Y. Pailhas, C. Capus, K. Brown, and Y. Petillot. Design of artificial landmarks for underwater simultaneous localisation and mapping. *IET Radar, Sonar & Navigation*, 7(1):10–18, 2013.

[7] Y. Pailhas, C. Capus, K. Brown, and N. Valeyrie. Identifying content of low profile target in cluttered environment using the biosonar. In *Underwater Acoustics conference, UA2014*, 2014.

[8] Y. Pailhas, Y. Petillot, and B. Mulgrew. Increasing circular synthetic aperture sonar resolution via adapted wave atoms deconvolution. *The Journal of the Acoustical Society of America*, 141(4):2623–2632, 2017.