Pilot experiments for monitoring ambient noise in Northern Crete

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Summary

In the framework of the QUIETMED project, pilot experiments for monitoring ambient noise were scheduled both at shallow and deep water depths. The first shallow water experiment took place May 24, 2017 in Northern Crete near the Iraklion port. A second experiment took place December 8, 2017 in the same location. At both experiments low-cost autonomous systems for underwater acoustic recordings have being used. These recorders were developed and manufactured at the laboratory of Underwater Acoustic Measurements of the Institute of Applied and Computational Mathematics of FORTH using custom made and off the shelf components. The systems were calibrated so that they can be used for measurements of ambient noise along with other potential applications. In this paper the systems components and their operation and features will be briefly descripted. Results of initial tests at the laboratory including calibration of the system in air at low frequencies will be presented. Finally results of the first two pilot experiments near Heraklion port will be presented and discussed. Comparing the ambient noise measured in the two experiments, the seasonal change between summer and winter of the ambient noise - at 1/3 octave bands - will be shown and discussed.

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1. Introduction

In recent years, there has been a growing concern about the possible impact of anthropogenic acoustic noise on marine life and the influence this noise has on marine ecosystems. An increase in environmental noise levels may have chronic effects on marine ecosystems (e.g. by covering biologically generated sound that is vital to communication and food search). The recording, monitoring and forecasting / estimation of the ambient noise in the marine environment is particularly important, especially near protected areas and areas of economic interest such as the coastal zone, tourist development zones, fishing and aquaculture areas, diving parks etc. [1-3]. One way to monitor the ambient noise is the use of autonomous acoustic recording devices [4-5].

Acoustic recording devices available at the market are expensive, with prices around €10K; their programming source code is unavailable, while it is difficult to make changes to individual parts and subsystems. Although their operating features such as sampling rate, maximum depth, storage space etc. depend on the manufacturer of the device, the stand-alone data loggers include at least one hydrophone placed outside a watertight shell. The analog signal of the hydrophone converts to digital through a sound card and the data are stored in a storage medium (hard disk, SD card, etc). Batteries, which are placed into the same shell, power the system. The programming of the system is done by a microcomputer.

At the Laboratory of Underwater Acoustic Measurements of the Institute of Applied and Computational Mathematics (IACM), prototypes of autonomous programmable recorders which are low cost and are characterized by flexibility, enabling the integration and use of devices and materials that are available in the market have been developed and used in experiments in the sea.

One of these recorders (UL1) was used in two shallow water experiments in the framework of the QUIETMED project. The experiments took place near the port of Heraklion in Crete at two different periods (spring and winder).

The purpose of this work is to present the analysis of the data collected during these experiments and discuss the measured noise levels of the area.

In what follows a short description of the recorder, its characteristics and operation is given. Results of initial tests at the laboratory including calibration of the system in air at low frequencies will be presented. Finally results of the first two pilot experiments near Heraklion port will be presented and discussed.

2. Description of the UL1

The UL1 consists of a hydrophone, a microcomputer, a sound card, a power management card and a power pack (batteries). Following the initial tests of the system in the laboratory a preamplifier was added to the hydrophone for improving the performance of the system.

The hydrophone is the H2c model manufactured by the Aquarian Audio Products with a sensitivity of -180 dB re 1 V/μPa (+/- 4dB, 20 Hz - 4 KHz) according to manufacturer. Its sensitivity drops to -220 dB re 1V/μPa at higher frequencies. Its frequency bandwidth is 10 Hz - 100 kHz and its maximum operating depth is 80 meters.

The motherboard of the system is a Raspberry Pi 3 Model B. Its processor is faster than the one in the previous version with 1GB memory. It has a Micro-SD slot, 4 USB ports, HDMI, Ethernet, Wi-Fi and runs on Linux. It can be connected with other boards through a slot with 40 GPIO pins.

The Cirrus Logic card used in the system is a 24-bit high quality sound card with a sampling rate up to 192 kHz and two 3.5mm ports for headphones, microphone and line inputs. It has an internal volume control from -8dB to +23 dB .

The Witty Pi card is a real-time clock and power management card. It can be programmed to start or shut down the Raspberry motherboard using different schedules and provides the Pi3 with an accurate (±2 ppm) real time clock.

A preamplifier was designed and constructed at IACM. Its response is flat in the audio spectrum (20 Hz to 20 kHz) with an amplification of 35 dB and it can be powered through the Raspberry motherboard.

All the components were tested at the lab and then assembled and put inside a custom made shell which can withstand pressure up to 25 bars. The whole system was tested in a pressure chamber in the laboratory at 7 bars pressure for one week for water tightness without a problem. Figure 1 shows the recorder UL1 ready for deployment. The H2c hydrophone is on the left.

Figure 1. The UL1 autonomous recorder.

3. Calibration

Before deployment at the sea the UL1 was calibrated in the Lab in order to calculate the sensitivity of the whole system. Since for the purpose of measuring ambient noise the frequency range of interest was less than 1 KHz, the UL1 was calibrated in air (since at low frequencies the behavior of hydrophones is the same on air or in the water [6]), at frequencies between 50 Hz and 1 kHz. The method used was the comparison method with the RESON's TC4032, a low noise hydrophone, used as a reference hydrophone. For this, the periodogram of the signal received at the hydrophones was calculated and the ratio of the amplitude at the specific frequency was used to calculate the sensitivity of UL1.

During the first pilot experiment UL1 was once more calibrated in-situ using a LUBBEL source applying the comparison method again. The source was deployed to a depth of 10 meters and continuous waves at certain frequencies were emitted for a short period of time. The results of both calibrations are shown in figure 2. The red

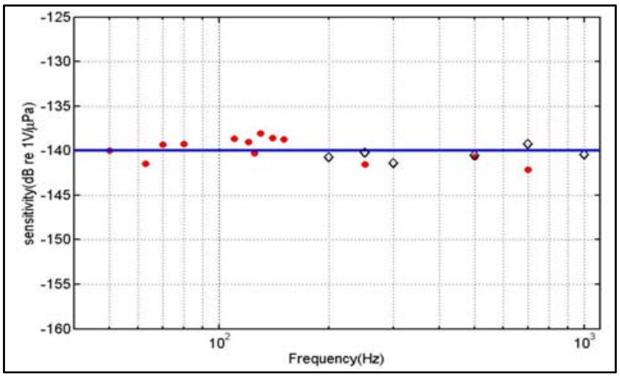

Figure 2 Calibration during first experiment. Red dots: calibration in air at the Laboratory. Black diamonds: calibration in-situ.

dots represent the results of the calibration at IACM in air and the black diamonds the ones at the sea. It is apparent that the sensitivity of the whole system was -140 dB (±3dB).

Analyzing the data of the first pilot experiment it was noted that the recorded signal has been clipped during the calibration procedure due to high source level. So it was decided to lower the sensitivity of the system to about -145dB. This was done by adjusting the volume of the sound card.

The calibration results during the second pilot experiment are shown in figure 3. In this figure the

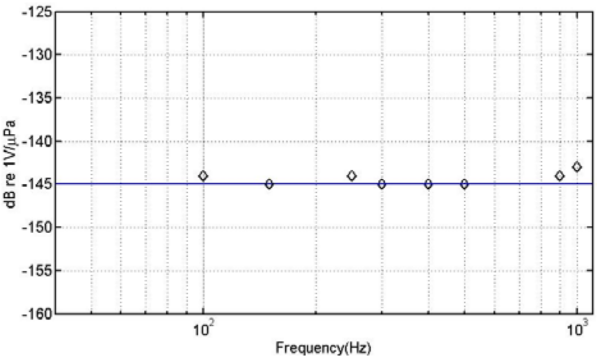

Figure 3 Calibration during the second experiment

black diamonds represent the calculated sensitivity values during the in situ calibration (Frequencies: 100, 150, 250, 300, 400, 500, 90, and 1000 Hz) and the solid line the sensitivity value -145 dB. This value was used for the calculation of the noise levels during the second experiment.

4. Description and analysis of the first pilot experiment

The first pilot experiment in the framework of the QuietMED project, took place on 24 May 2017 at the Northern coast of Crete between the port of Heraklion and the Dia Island, at a distance of about 4 nautical miles from the port (figure 4). The water depth in that area is about 190 m. A reference low noise hydrophone (RESON's model TC4032) was attached next to the UL1 and both there were deployed at depths of 30, 50 and 70 meters, using a float. Figure 5 presents a sketch of the experimental setup. During the sea trial two different kinds of experiments were performed. First the source was deployed at 10 meters depth emitting continuous wave signals for a short period of time at different frequencies (200, 250, 300, 500, 700 and 1000 Hz). Thus it was once more confirmed that the sensitivity of the UL1 system was -140dB.

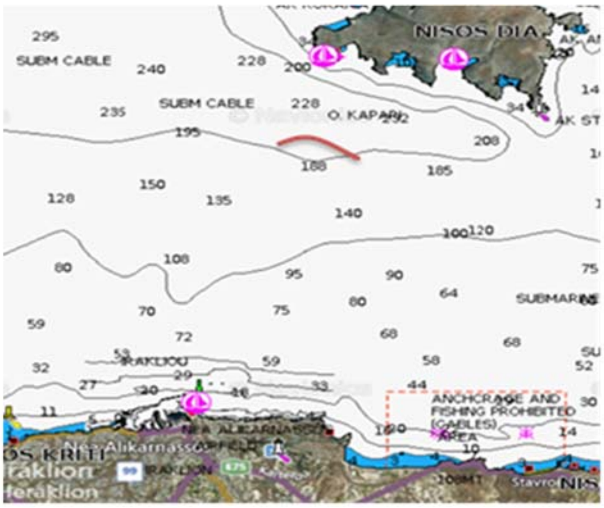

Figure 4: The site of the experiment. The vessel's movement is shown in red.

Then a noise recording experiment took place during which the ambient noise was recorded for about 10 minutes. This setup was repeated with the instruments at the three different depths.

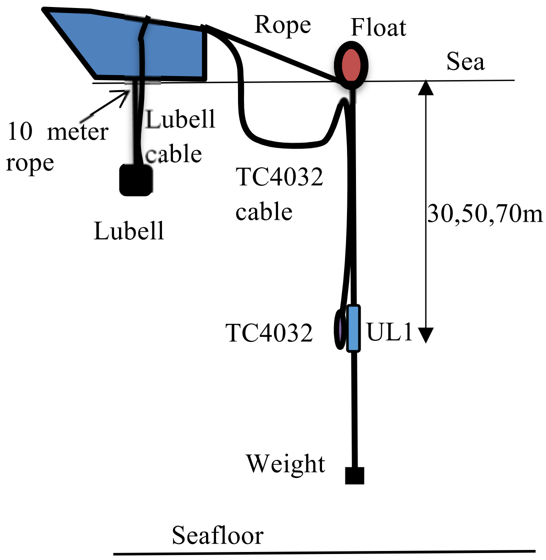

Figure 5: A sketch of the experimental setup.

The acoustic data recorded during this time were used along with the above mentioned sensitivity value, in order to calculate one-third octave band noise levels. Figure 6 shows the noise levels at the central frequency of each 1/3 octave band up to 1 kHz with the instruments at 30 meter depth. The levels calculated using the data from both the reference hydrophone (blue diamonds) and UL1 (red dots) are presented in this figure. It can be seen that the measured values differ by less than 3 dB.

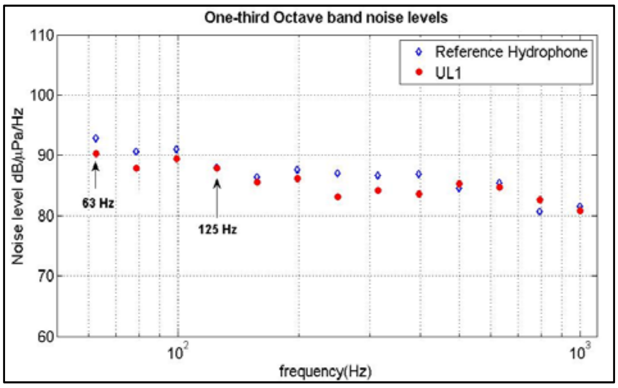

Figure 6 Noise levels during the first pilot experiment

5. Description and analysis of the second pilot experiment

The second pilot experiment took place at the same location on December 8 2017. The experimental setup was the same as in the first experiment. The sensitivity of UL1 was now calculated using the LUBELL source at the frequencies 100, 150, 250, 300, 400, 500, 90, and 1000 Hz. The average sensitivity value at these frequencies was -145dB. Once more noise recording were made with both the TC4032 and UL1 and 1/3 octave curves were calculated. Figure 7 presents the noise levels during this experiment. The blue diamonds represent the noise levels calculated using the data from the TC4032 reference hydrophone and the red dots those using the UL1 autonomous recorder. It can be seen that the values between the TC4032 and UL1 differ less than 3 dB.

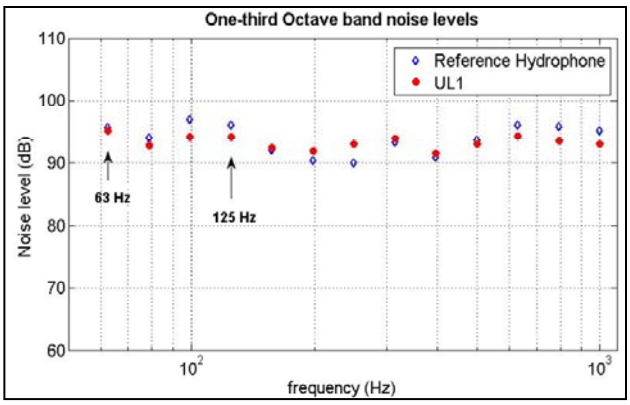

Figure 7 Noise levels during the second pilot experiment

6. Comparison of the noise levels and discussion

In figure 8 the noise levels calculated using the data recorded by UL1 during the two experiments are shown. It can be seen that the noise levels during the first experiment which took place in May are about 5 to 10 dB less than those during the December experiment. This difference can be attributed to any or all of the following reasons:

- The sound speed profiles were different. As it can be seen in Figure 9 the sound speed profile during May 24 (a) is downward refracting whistle the one at December 7 (b) is not. Noise prediction models [7] (using adiabatic modes) with typical summer and winter profiles in eastern Mediterranean show lower noise levels at 50 meters depth during the summer especially in deep waters.
- The shipping traffic during the second experiment was heavier than at the first experiment.
- The duration of the measurements was insufficient to extract long term results.
- The experimental site is close to Iraklion city its harbor and airport, so other sources of noise could be present during the second experiment.

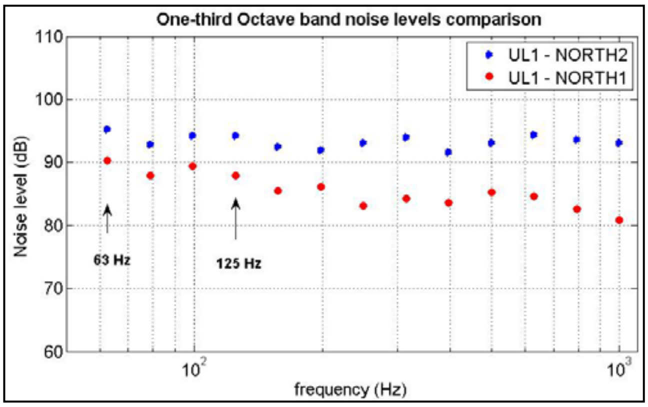

Figure 8 Comparison of the noise levels calculated from thr UL1 data during the two pilot experiments

Thus a more elaborate study is needed in order to explain the cause of the noise levels differences. This study must include long term noise measurements during different seasons.

Acknowledgement

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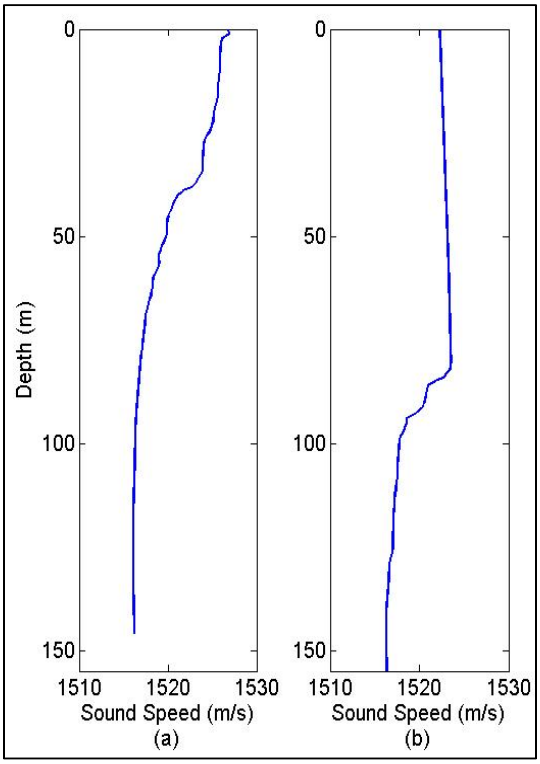

Figure 9 The sound speed profiles during (a) May 24 and (b) December 8 at the experimental site.

References

[1] K. Lucke1, et al: International harmonization of approaches to define underwater noise exposure criteria J. Acoust. Soc. Am. 135, 2404 (2014).

[2] T. B. Gabrielson: Underwater acoustics at the Naval Air Development Center J. Acoust. Soc. Am. 137, 2307 (2015)

[3]Marine Strategy Framework Directive. Available: http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm

[4] Develogic GmbH. Sono.Vault Acoustic Recorder and Signal Analyzer. Available from: http://www.develogic.de/products/ss-r/sonovault/

[5] Multi-Électronique (MTE) Inc. AURAL-M2. Specification Sheet. Available from: http://www.multi-electronique.com/files/AURALspecsheet_EN.pdf

[6] R.J. Bobber: Underwater Electroacoustic Measurements. USA, Peninsula Press,(2nd edition), 1989

[7] E.K. Skarsoulis, G.S. Piperakis, E. Orfanakis, P. Papadakis and M. Taroudakis: Modelling of Underwater Noise Due to Ship Traffic in the Eastern Mediterranean Sea, In proceedings of the 4th Underwater Acoustics Conference and Exhibition (UACE2017), pp. 889-896, (2017).