A LOW COST (NEAR EXPENDABLE) UNDERWATER SOUND LOGGER USING AN MP3 PLAYER: TESTING IN SYDNEY HARBOUR

L.J. Hamilton and C. Lees
Maritime Operations Division
Defence Science and Technology Organisation (DSTO)
13 Garden Street, Eveleigh NSW 2015

A low cost, self contained, portable system based around a modified MP3 player has been constructed to record ambient underwater noise. High resolution acoustic data are stored in PCM WAV file format with a depth of 16 bits and 96 kHz sampling. The MP3 player, preamplifier, and battery are mounted in an underwater housing made of PVC pipe to which is attached a hydrophone on a short buoyed cable. This provides a near expendable package suitable for unattended deployments where equipment loss or damage are possible factors. System functioning was verified by several 24-hour deployments in Sydney Harbour, following which it was used for the international KONDARI ports and harbour security trial at Garden Island. Three characteristic sound regimes were observed: (1) a regular succession of ferry passage events from morning till midnight; (2) irregularly occurring high energy vessel events other than ferries; (3) lower sound levels from midnight to six a.m. dominated by snapping shrimp, and by pumps and ancillary engines on moored vessels and dockyards.

Figure 1. Components of the MP3 based underwater ambient noise recording system. The underwater housing is 16 cm in diameter and 42 cm in length.

INTRODUCTION

A low cost portable underwater noise recording system based on an MP3 player has been constructed. System functioning was verified by short term recordings made in central Sydney Harbour, prior to use of the system in the international KONDARI ports and harbour security trial at Garden Island. The MP3 player is used to record acoustic data in high resolution PCM WAV file format, not the lossy MP3 format, which is based on perceptual noise shaping and other compression algorithms. This paper describes the system and its development in brief. The nature of the acoustic time series obtained for system verification suggests they are typical of the central harbour ambient underwater noise conditions, and although uncalibrated for absolute levels, they are presented as being of interest in their own right. It is intended to calibrate the system at the DSTO calibration facility at Woronora Dam.

Measuring underwater noise in Sydney Harbour and other busy port areas provides special problems compared to land based work. The first problem is accessing the site, which usually involves a boat journey. Measurements at a fixed point may be made by anchoring, and lowering hydrophones into the water column, or a vessel can simply drift during measurements. However, in high density vessel traffic areas this technique may not be viable. If hydrophone cables cannot be run to shore in such cases then underwater housings must be constructed and deployed to enable measurements to be made. In busy waterways the instrument package must be deployed unattended on the seabed, without the luxury of a surface buoy for recovery. Retrieval of the package is by diver, or by use of an electro-mechanical acoustic release, which is triggered externally by a coded acoustic pulse to allow a small buoy and tether to rise to the surface. There is always the possibility that the package may be lost, either by simple failure to locate it, or by damage from boat or fishing operations. Trawling is no longer undertaken in Sydney Harbour, removing one potential problem for the present deployments. In some areas wave and current action must be considered, especially if these may cause burial of equipment in the seabed. Equipment cost then becomes a factor, with near disposable kit a desirable option. Details of the relatively low cost underwater noise recording system developed to meet this requirement are presented in Section 2. Descriptions of underwater sound regimes for Sydney Harbour gained from the system testing follow in Sections 3 and 4.

INSTRUMENTATION

The underwater ambient noise recording system consists of an ITC 1032 omnidirectional hydrophone, a custom built low noise preamplifier, and a modified MP3 player (Figure 1). The hydrophone is buoyed to float about half a metre above the seabed. In the open sea the package can be left to drift on the surface. The underwater housing is a section of PVC pipe with removable end caps sealed by double O-rings. The preamplifier is a custom design with a gain of 20 or 40dB, constructed with low input capacitance, low noise, and low power consumption as the design constraints. High resolution PCM WAV file format is recorded, with a depth of 16 bits. The MP3 player forms a convenient logging platform, having a real-time clock, and on-board programming capability. Exploiting these off-the-shelf capabilities enables simpler system development and reduced costs. For example, the system is set up for use by simple menu driven commands accessed through the MP3 screen displays.

The system employs the highest sampling rate of the MP3 player of 96 kHz. Lower sampling rates may also be selected e.g. 8 kHz. The two stereo channels record the same signal, but to maximise dynamic range gains of 0dB on the first channel and 12dB on the second are used. This allows one channel to avoid overload during energetic events, and allows the other channel to record useful signals during quiet times. The 12 dB for this particular system was chosen after preliminary field tests. The redundancy in the recording provides verification of more unusual transient events, and possible allowance for some hardware failures. The system was designed for burst sampling, e.g. 1 minute sampling in every 10 minutes. This allows a representative time series to be obtained whilst minimising the amount of data recorded. Other logging selections are 5, 10, 20, 60, and 120 seconds at intervals of 2, 5, 10, 20, or 60 minutes. However, if e.g. 120 seconds is selected at 2 minute intervals, the system will generate an error message, and request another setting. An error message is also output if the selections would cause the buffer length to be exceeded. The specifications are:

Preamplifier
Noise: -166dBVrms/√Hz
Input capacitance: 25pF
Gain: selectable 20dB and 40dB

MP3 player
Model: Iriver H10 20GB
Storage: 20GB 1.8 inch hard disk (a modification allows use of a compact flash card, with consequent saving in power usage, and elimination of moving parts)
Software: Rockbox (www.rockbox.org) with a custom recording plugin. Rockbox supply open source replacement firmware for portable audio players.
Gain: selectable -12dB to 12dB in 3dB steps
Channels: Two with independent gain settings
CODEC: Wolfson WM8731
Power Supply: a 12V, 12Ah rechargeable switchmode lead-acid battery provides several days of recording
Data format: 16 bit PCM WAV. Maximum individual recording length is restricted by the available internal RAM (approximately 30MB) as the entire recording is buffered before being written to disk.

An earlier recording system used a DAT tape recorder, but the advantages of tape were offset by system unreliability. The MP3 player is cheaper than the DAT recorder, and purchase of DAT tapes is not required. Data archiving requirements are modest, as twenty-four hours recording of one minute in every ten sampled at 96 kHz and 16 bits in stereo fits comfortably on a DVD.

Frequency Response

The system has not been fully calibrated, so this information is imperfectly known. The recommended operational hydrophone frequency range is 10 Hz to 45 kHz. A hydrophone calibration using the reciprocity method confirms good receive voltage response from 500 Hz to 40 kHz, with a 10 db rolloff from 40 to 50 kHz, and upper 3db point at 42 kHz. Linearity of response is specified by the manufacturer from 500 Hz to less than 10 Hz, depending on the input impedance of the preamplifier. Preliminary measurements indicate a lower frequency 3 db system response of 23 Hz. Testing of the MP3 itself indicates linear response at 96 kHz sample rate from DC to 25 kHz, with the upper frequency 3db point at 42 kHz. The combined hydrophone and MP3 information indicates the 3 db upper frequency point of the system as 33 kHz.

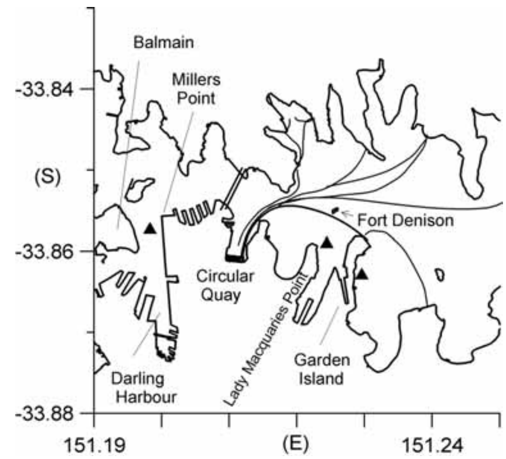

Figure 2. The three measurement sites in Sydney Harbour (▲) and general routes of ferries passing near Lady Macquaries Point, and east of Garden Island.

RESULTS OF SYDNEY HARBOUR TESTING

The system was deployed at various Sydney Harbour locations (see Figure 2) to verify mechanical and acoustical functioning in the field. Measurements from three sites are presented. These were made northwest of Garden Island in November 2008; west of Millers Point in January 2009; and east of Garden Island. Several days of recordings were made at the last named site for the international KONDARI ports and harbour security trials (see e.g. the web site http://www.dsto.defence.gov.au/news/5580/).

Northwest Of Garden Island

On November 25, 2008 the system was deployed on the seabed at 14 m depth for a 24 hour period between Fort Denison and Lady Macquaries Point, a well known Sydney landmark (Figure 2). One minute was recorded in every ten minutes. Ideally, concurrent visual or video observations would be made of ship traffic and other activities, to correlate major sound events arising from unscheduled shipping movements to events in the recordings. However, this was not carried out for the present data. An assessment of underwater sound conditions and frequency of events over a typical day in this busy working harbour was required, rather than detailed knowledge of the causes.

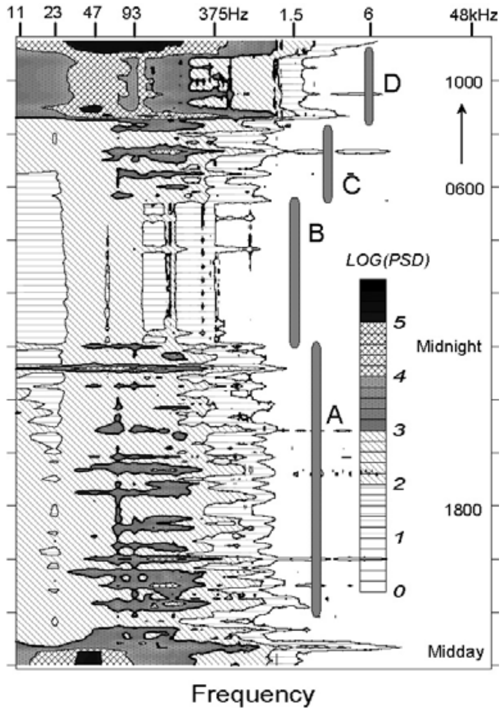

Figure 3. Logarithm of PSD (Power Spectral Density, uncalibrated) as a function of frequency and elapsed time for a day's recording off Lady Macquaries Point on 25 November 2008. Letters A-D identify particular persistent noise conditions or sound sources. A = ferry traffic, B = moored vessel noise and equipment at Garden Island, C = ferry traffic, D = local vessel traffic.

A plot of power spectral density with frequency and elapsed time (Figure 3) summarises the time history of underwater noise at the site. Selected WAV files were replayed on a PC fitted with a DVD reader to identify the major noise events noted in this record. Three main sound regimes are experienced at the site. These are (1) a succession of regularly spaced episodes of higher sound levels from early morning till midnight generated by ferries, (2) a relatively quiet period from midnight till 6 a.m. dominated by sound from moored vessels and industrial machinery at Garden Island dockyard, and (3) higher sound levels from local ship traffic other than ferries, e.g. barges, passing close to the recorder.

From deployment at 1 p.m. to midnight a succession of higher noise power events centred on 50 to 375 Hz reflects the passage of screw-driven ferries, Jetcats (high speed catamarans), and other vessels. Movements of larger vessels (generally ferries) cease at midnight. Noise levels at frequencies below 23 Hz begin to drop after 8 p.m. and reach a minimum by 10 p.m. except for two high energy vessel events near 11 p.m. and midnight. These low frequencies reappear after 6 a.m. the following morning when industrial machinery is switched on at nearby Garden Island dockyard. Almost constant sound levels are seen in particular frequency bands from midnight till 6 a.m. at frequencies below 93 Hz, coupled with a regularly spaced series of events near 300 Hz. This latter signal is attributed to pumps and other ancillary engines on vessels moored at Garden Island, or on land based facilities. A near continuous background low level broadband crackle is attributed to snapping shrimp. This location is therefore never truly quiet, but is always subject to both natural and anthropogenic noise sources.

Particular types of craft may be identified by their acoustic signatures. The records of passing Jetcats and screw-driven ferries in Figure 3 are associated with peaks in noise power levels near 47, 71, 95, 132, and 184 Hz, although it is not immediately clear which ferry type is responsible for which frequency, as different models appear to have some energetic frequency bands in common. In between the passage of ferries, a distinctive drop in sound levels about 23 Hz is noted.

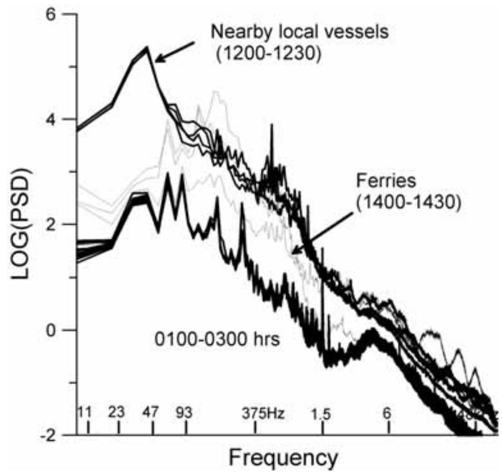

Figure 4. Examples of characteristic acoustic spectra off Lady Macquaries Point for the quietest times in the record (0100-0300 hrs), for the passage of ferries (1400-1430 hrs), and for vessels passing close to the measurement site (1200-1230 hrs).

Examples of individual spectra in Figure 4 provide a different view of some of the ambient noise regimes and events observed in Figure 3. For example, peaks in sound levels at particular frequencies are more readily identified. The quietest part of the record for 0100-0300 hours shows a sound level decreasing at frequencies below 23 Hz, and several distinctive peaks attributed to Garden Island machinery and vessels. The noise levels from ferries for 1400-1430 hours in Figure 4 often do not surpass the peaks in the quietest part of the record for 0100-0300 hours. This is not the case for other vessels near the measurement site, as shown for 1200-1230 hours, but whether or not because they are closer or louder is unknown.

Millers Point

A 24 hour recording of one minute at five minute intervals between Millers Point and Balmain shows similar results to the site at Lady Macquaries Point (Figure 5). Three ferry routes pass this location transiting in and out of Darling Harbour, to parts of Balmain, and upriver to the west to Parramatta. The measurement site is closer to the ferry routes than at Lady Macquaries Point, leading to more high frequency detail in the acoustic record. The data from this site were used to plan optimal deployment times for other types of underwater surveying equipment.

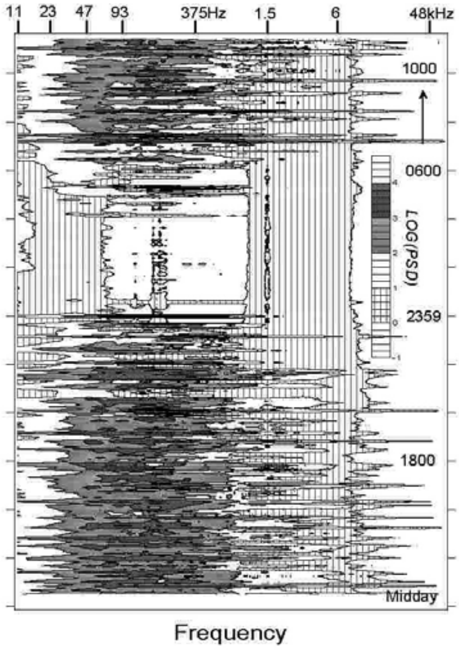

Figure 5. Logarithm of PSD (Power Spectral Density, uncalibrated) as a function of frequency and elapsed time for 24 hours acoustic recording between Millers Point and Balmain on 20 January 2009.

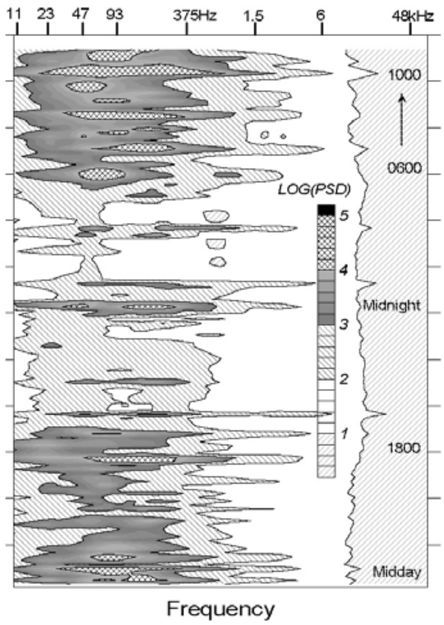

Figure 6. Logarithm of PSD (Power Spectral Density, uncalibrated) as a function of frequency and elapsed time for 24 hours acoustic recording east of Garden Island on 09 February 2009.

East Of Garden Island

The system was deployed off Garden Island as part of the international KONDARI ports and harbours security trial. One day on 09 February 2009 from a three-day record sampling one minute in every ten to the East of Garden Island (see Figure 2) is presented (Figure 6). Only one ferry route passes near this location, travelling between Circular Quay to the West and Watsons Bay in the eastern harbour, leading to fewer major events in the record than at Lady Macquaries Point and Millers Point. Ferry services on this route commence near 0700 hrs, and the last evening ferry docks at Circular Quay at 1932 hrs. The site is about 1.7 times farther from the closest point of ferry approach than the other two test sites, which is expected to reduce received ferry sound levels. According to ferry timetables, an apparent broadening in time of ferry signatures compared to the two other test sites may be caused by inbound and outbound ferries on this route regularly passing each other near Garden Island. Unlike the other two sites there is no well defined structure in the nighttime portion of the record, attributed to the absence of larger moored vessels east of Garden Island, and the absence of major wharves.

DISCUSSION

Underwater ambient noise recordings have been made at several locations in central Sydney Harbour with a low cost, purpose built, low noise amplifier coupled to an MP3 player. The acoustic equipment is housed in a sealed section of weighted PVC pipe, which is placed on the seabed. The acoustical recordings indicate successful system mechanical, acoustical, and software functioning. The on board capabilities of the MP3 recorder provide a range of sophisticated functions accessed through the open source Rockbox firmware project (see the web site www.rockbox.org).

West of Garden Island near Lady Macquaries Point the harbour is never completely quiet. Continually active snapping shrimp provide a broadband background noise floor, which has been rather aptly described as sounding like the frying of bacon. Machinery and moored vessels provide a regular and continuous source of sound, with higher intensity during daylight hours. Regularly scheduled ferry and tourist vessel events add to this background from early morning till midnight. Some component of ferry noise is received almost continually during this period, both from ferries passing near Garden Island landwards of Fort Denison, and from particular energetic frequency bands from more distant ferries elsewhere in the harbour. Most ferry traffic arrives at or departs from the busy Circular Quay area, which is a relatively short distance to the west of the measurement site (see Figure 2). Highest sound levels at the measurement site originate from occasional shipping other than ferries. The same general underwater sound regime is seen west of Millers Point. The area east of Garden Island experiences fewer ferries, and larger moored vessels are generally absent, resulting in a quieter ambient noise record. Engineering works, strong winds, and times of rain will increase underwater sound levels. Otherwise the acoustic results are expected to represent the typical underwater sound events and regimes of the middle reaches of Sydney Harbour.

ACKNOWLEDGEMENTS

Mr Tony White of DSTO is thanked for assistance with deployment and recovery of equipment. Mr Mark Savage of DSTO provided hydrophone calibration.