AMBIENT NOISE MEASUREMENTS USING SONOBUOYS

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1 INTRODUCTION

The idea of an expendable sonar system or, sonar buoy, was first proposed by the Admiralty as a means of detecting submarines in May 1941. This lead to the first operational sonobuoy, the AN/CRT-1, when on March 7, 1942, two RCA ship-launched sonobuoys were monitored from a blimp as they tracked the S-20 submarine off New London, Connecticut. For the first time, an aircraft in flight detected a fully submerged submarine through acoustics using a sonobuoy. Operational use began in August of that year and this system had six available radio frequencies, the hydrophone was omni-directional and the buoy was capable of six hours of operation.

As the submarine threat has changed over the decades, so has the sonobuoy, along with the antisubmarine warfare (ASW) receivers, processors, aircraft and concepts of operation. New challenges have been met with innovative responses, and air ASW acoustic sensors have transformed to meet each new situation.

Nevertheless, although originally aimed at ASW applications, sonobuoys have a number of potential advantages for ambient noise measurement: they are compact, lightweight and easily deployed by a single person from a small vessel; drifting with the current means that flow noise is minimised; transmission ranges of several kilometres are possible with a basic marine band receiver. On the down side, they are one-shot devices so re-use is not straightforward and their characteristics are aimed at detecting submarines in the open ocean, not necessarily suitable for measuring high noise levels in continental shelf waters.

2 CURRENT SONOBUOYS

The range of sonobuoys in use today includes a number of very sophisticated devices. However, in their off-the-shelf form, the systems potentially most useful for ambient noise measurements are the basic general purpose passive buoys known generically as LOFAR (Low Frequency Analysis and Recording), which has an omnidirectional hydrophone, and DIFAR (Directional LOFAR), which includes a compass, two orthogonal dipole acoustic receivers and an omnidirectional channel, allowing the sound source bearing to be resolved.

Common features for standard LOFAR and DIFAR systems include:

- Passive Search Sonobuoys
- 'G' size package, 16½ inches (419.1mm) length x 4⅞ inches (123.825MM) diameter

Figure 1 Hand launching a LOFAR buoy

- Packaged sub-assemblies to withstand environmental requirements, dispense from aircraft, and water entry shock
- Two event safety criteria for deployment
- 99 RF channels, 1Watt, 1 to 7 hour life
- Hydrophone depths 30m, 140m & 300m
- GPS option

Because these buoys are intended primarily for detecting quiet submarines in the open ocean, they are not totally suited to monitoring ambient noise in their standard form, particularly in the noisier shallow water environment where much of today's interest lies. The main limitations may be summarised as follows:

- LOFAR bandwidth limits monitoring to 20kHz.
- DIFAR bandwidth limits monitoring to 2400Hz.
- Dynamic range of analogue systems inadequate for noisy environments.
- ASW processing not necessarily appropriate for mammal DCL.
- Telemetry range limited to line of sight.
- Hydrophone depth settings are intended for deep water use.
- Sonobuoys are one-shot/disposable devices.

It is noted that many of these limitations could easily be overcome with minor modifications. However, the major problems of bandwidth and dynamic range are more substantial. This is discussed further in Section 4. The use of the available dynamic range is maximized in most analogue sonobuoys by applying a "pre-whitening" filter to the signal before transmission.

3 EXAMPLE NOISE MEASUREMENT

Despite the limitations listed above, standard sonobuoys are capable of making legitimate ambient noise measurements in water depths greater than 35m and where the noise levels do not exceed saturation level in the hydrophone preamplifier. An example is presented in Figure 2, which shows results from measurements carried out off the coast of Madagascar using a freely drifting LOFAR buoy and a reference hydrophone suspended from the work boat.

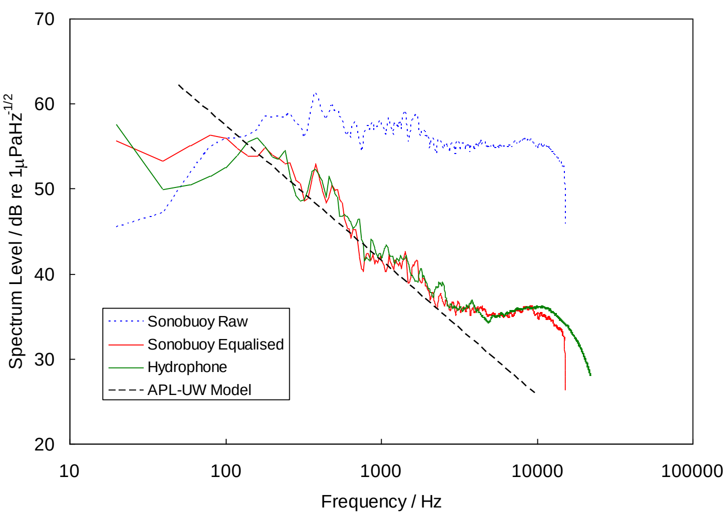

Figure 2 Spectra computed from raw sonobuoy data (dotted blue), equalised sonobuoy data (solid red) and hydrophone data (solid green), compared with the APL-UW model [1] (black dashes).

Here, spectra computed from the raw sonobuoy data (blue dotted line), the sonobuoy data equalized to remove the pre-whitening filter (solid red line) and the hydrophone (solid green line) are compared with the APL-UW 9407 noise model [1] prediction for 2kt wind and zero rainfall. For both sonobuoy and hydrophone, the sampling rate was 44.1kHz and spectra were computed for a ten minute period, averaging FFTs of 4096 point Hanning windowed blocks of data, with 50% overlap.

Clearly, there is good agreement between the buoy and the hydrophone, and the model prediction fits well over the frequency range 200Hz – 2kHz. The peaks in the spectra at around 500Hz are due to vocalising humpback whales, and the raised level above 2kHz is caused by snapping shrimp. Because of the relatively short data segments used for this rapid analysis, the spectra below 100Hz are not reliable, but this is easily remedied by averaging over longer periods and using larger FFTs, perhaps with zero padding to gain the required length.

4 DISCUSSION AND CONCLUSIONS

This paper has presented a first look at the feasibility of using military sonobuoys for the measurement of ambient noise, and the results presented in Figure 2 show that valid measurements are possible within the limitations discussed in Section 2. Further analysis is needed to fully assess the capabilities of these devices in this application, but it is worth considering how the limitations might be ameliorated.

The two main problem areas are dynamic range and bandwidth. The standard range of depth settings is also a potential problem, but these can be changed by simple mechanical arrangements when the buoy is assembled. The dynamic range and bandwidth, however, are largely dependent on the FM transmission scheme. Automatic Gain Control (AGC), adjusting the hydrophone pre-amplifier sensitivity to the noise level when the buoy is deployed would make the most of the available dynamic range, but a more significant solution would be to digitize the hydrophone signal and to carry out the required processing on-board before transmission.

This approach would allow the use of a broad band hydrophone and an audio bandwidth of, say, 100kHz or more. However, the processing product required is the noise spectrum and, even transmitting spectra at intervals down to a second, this would require considerably less bandwidth than sending the raw acoustic data.

The overall conclusions can be summarized as follows:

- Current military sonobuoys are capable of valid ambient noise measurements.
- Existing systems suffer from limitations, principally dynamic range and bandwidth.
- Dynamic range could be improved with AGC.
- On-board processing to generate noise spectra for transmission would provide a more substantial improvement.

5 ACKNOWLEDGEMENTS

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6 REFERENCE

1. Applied Physics Laboratory, University of Washington, *APL-UW High Frequency Ocean Environmental Acoustic Models Handbook*, APL-UW TR 9407 (1994).