Underwater sound measurement

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Introduction

So far in Instrumentation Corner we've considered the measurement of sound in air and the measurement of vibration. This article is concerned with the measurement of sound in water.

There are a wide range of marine applications which use sound such as sonar, underwater positioning and navigation, geophysical surveying for oil and gas, hydrographic surveying, ocean sensing, oceanographic studies, and defence applications such as mine detection. The frequency range of these applications is very broad, ranging from a few hertz for geophysical applications, to a few megahertz for acoustic Doppler current profilers [1]. The many natural sources of sound can in themselves make the ocean a noisy environment, but the levels of man-made sounds in the ocean (whether deliberately generated or not) have led to increasing concern over marine noise pollution [2]. The causes of greatest environmental concern are high energy low-frequency sources of sound such as geophysical surveying using airgun arrays, construction noise (for example, marine piling for offshore wind farms), explosive decommissioning, and low-frequency naval sonar. Although individual ships do not radiate high noise levels, shipping noise is nevertheless of concern because of the large number of commercial vessels and the projected increase in traffic levels in the future.

The effects of anthropogenic noise on marine fauna are usually categorised as either physical, or behavioural [3]. High noise levels may also cause: barotrauma [4]; hearing damage (temporary or permanent) [5]; bleeding and/or organ damage; structural or cellular damage of non-auditory tissues or impair the growth of fish [6].Lower levels of anthropogenic noise may also mask animal-produced sound, such as that used for communication or echolocation; it may also cause changes in reproductive, feeding, resting or migration behaviour; changes in cardiac rate and respiratory patterns [7];

There are many differences in the propagation of sound in air and in water. These are some of the influencing factors:

- the wider range of frequencies of interest (naturally produced sounds can be as high as up to approximately 200 kHz for toothed whales [8], and man-made sounds can be even higher),
- the much faster sound speed in water (the speed of sound in air at 20°C is approximately 343 ms-1 and in pure water is typically 1480 ms^{-1}[9]),
- the sound speed in the ocean is affected by pressure (depth), salinity and temperature, leading to complex variations of sound speed with depth and location, and substantial refraction of the sound rays, especially in deep water,
- there is a strong interaction with the seabed and sea surface for propagation in shallow water,
- in general, absorption increases with frequency but is much less than in air, and low-frequency sound can travel large distances.

Instrumentation

Whereas an acoustician measuring and analysing sound in air can use a sound level meter comprised of a self-contained handheld instrument with an attached microphone and built-in display device(as described in BS EN 61672-1:2003) [10], there are no such instruments for the measurement of sound in water. Instead, the different elements (for example, transducer (hydrophone), amplifier, data acquisition unit and processing device (e.g. laptop)) have to be brought together individually (see Figure 1). Recently, in response to the requirement to make long-term measurements of ocean noise, autonomous noise recorders have been developed which are self-contained battery-powered units containing a hydrophone and solid-state recorder.

There are also practical considerations such as the fact that water and electricity do not mix well (so that hydrophones need to be encapsulated in water-proof acoustically-transparent coatings).

Hydrophones operate differently to a standard microphone and are typically piezoelectric, sometimes with an integral preamplifier to the drive long connecting cables needed for deployment. Piezoelectric transducers develop a voltage across their electrodes proportional to the stress caused by acoustic waves. Some hydrophones can also be used in the reverse and can emit sound when excited by an electric current.

Differences between analysis of sound in air and in water

Much of the analysis undertaken is similar to air acoustics, with frequency analysis commonplace, and third-octave band analysis frequently used in assessment of impact of noise on marine life. As with air acoustics, quantities are commonly expressed in decibels, and the primary measured quantity is sound pressure level. As an acoustic consultant primarily interested in measurement of sound in air, perhaps the most obvious differences in the assessment of sound in water are:

- The reference sound pressure is different (20 μPa for sound in air and 1 μPa for sound in water),
- The much wider frequency range means that analysis is often undertaken at ultrasonic frequencies far greater than the audible frequency range commonly used in air acoustics, and such analysis requires hardware and software with higher bandwidths and sampling frequencies,
- The acoustic output of a source is rarely described in terms of sound power (as in air acoustics), and instead the concept of "source level" is used. This parameter originates in the so-called "sonar equations" and is determined by measuring the received sound pressure level in the acoustic far-field and correcting for the propagation loss between the receiver and the source;
- The greater acoustic impedance in water than in air means that the acoustic pressure is much higher in water for the same acoustic power or energy input into the medium. Combined with the different reference pressure level used, this means that when expressed in decibels the sound pressure level values encountered are much greater than those encountered in air acoustics. It is also difficult to make meaningful comparisons of perceived levels between humans in air and marine animals in water.

Conclusion

It can be seen from the above that the measurement of sound in water is different from that in air and that care must be taken when an acoustician familiar with measurement in air expands into measurement in water. In addition, those requiring such measurements should be aware of the complexities and ensure that a suitably competent acoustician is instructed.

References

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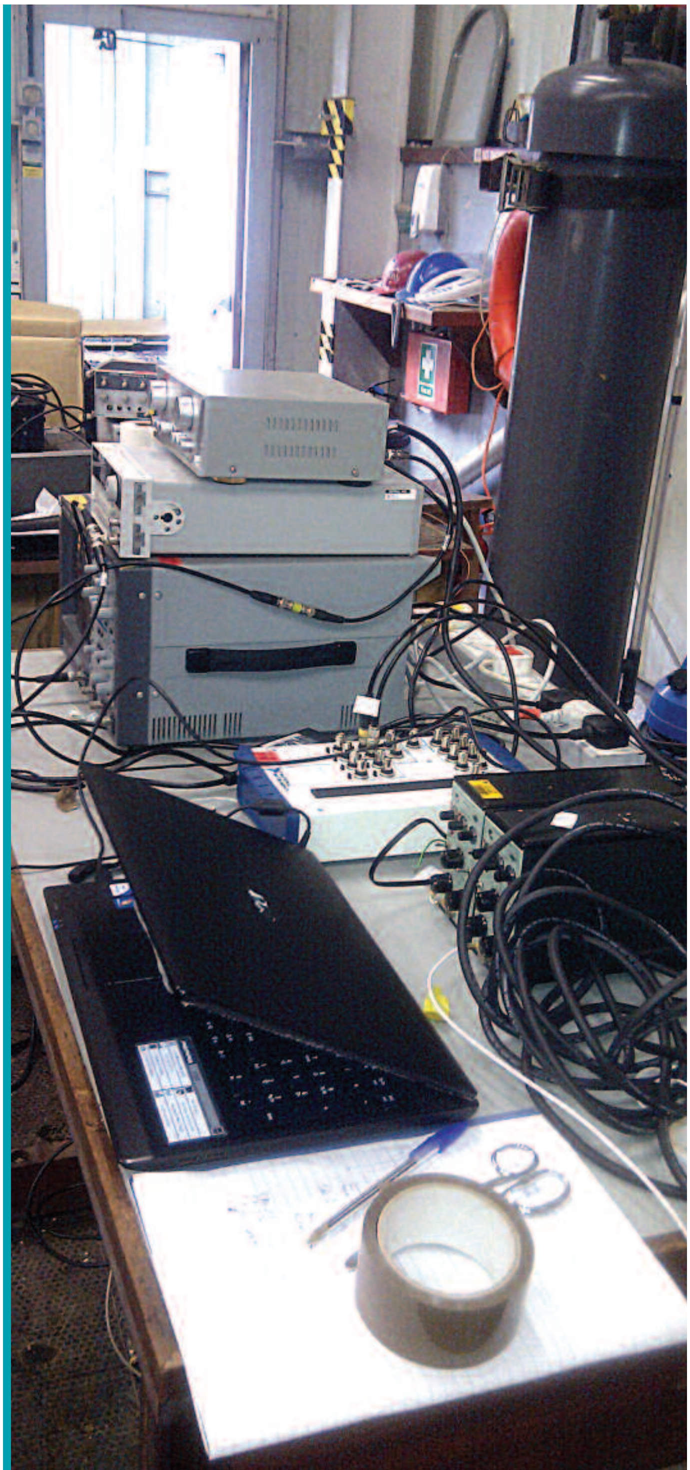

Figure 1. Typical instrumentation in underwater acoustics measurement