Measuring the frequency characteristic of underwater sound recorders ST500 and ST600 from Ocean Instruments

A.N. Gavrilov (1), I.M. Parnum (1), E. Sidenko (1) and C. Tollefsen (1)

(1) Centre for Marine Science and Technology, Curtin University, Western Australian, Australia

Abstract - The underwater sound recorders SoundTraps ST500 and ST600 from Ocean Instruments have been used for numerous underwater sound studies. The declared bandwidth of sound recording by both standard versions of SoundTraps is from 20 Hz to 60 kHz, and 20 Hz to 150 kHz for high-frequency model. Although calibration of the recorders' sensitivity to sound pressure is made for both recorder models at 250 Hz through utilising a Center 327 pistonphone, the frequency characteristic of recorders over the entire recording band is varying, especially at lower frequencies where the hydrophone capacitance and input impedance of the hydrophone preamplifier connected in series work as a high-pass filter with a roll-off of 6 dB per octave. To examine the frequency characteristics of both SoundTrap models and experimentally derive the sensitivity correction at low frequencies, measurements were carried out in a large pool using a water pump as a low-frequency source of underwater sound. Spectral levels of noise recorded by the SoundTraps were compared with those recorded by a fully calibrated hydrophone recording system. Results show that the sensitivity of ST500 STD, ST600 STD and ST600 HF have a significant roll-off at frequencies below approximately 30 Hz. Suggested corrections of the frequency characteristic for these three recorder models are proposed. Similar calibration measurements are planned to carry out for the ST202 and ST300 recorder models from Ocean Instruments.

1 INTRODUCTION

Underwater sound measurements have been used for various applications, such as acoustic oceanography (Medwin and Clay, 1997), defence science (Cato and McCauley, 2002), and marine mammal ecology (Erbe et al., 2017). Hence, autonomous underwater sound recorders (USRs) that are capable of being deployed in the ocean for long periods of several months, are an effective way to further our understanding of the marine environment (Erbe et al., 2015; McCauley et al., 2017). Consequently, there are several commercial-off-the-shelf USRs available on the market, including the SoundTraps ST500 and ST600 models from Ocean Instruments (https://www.oceaninstruments.co.nz/). The sensitivity and frequency response are key parameters of a USR. Ocean Instrument USRs are factory calibrated to determine the end-to-end recorder sensitivity to sound, including hydrophone sensitivity and electronic gain of the system at the calibration frequency. This calibration process involves placing the USR hydrophone in a Center 327 pistonphone emitting sound at 250 Hz (Ocean Instruments, 2021). Additionally, a series of calibration tones can be made audible at the beginning of each SoundTrap recording, which can be used to check the calibration of the recording (Ocean Instruments, 2020). The frequency characteristic is assumed to be flat within +/-3 dB over the quoted bandwidth of the USR, which is 20 Hz – 60 kHz for the ST500STD (standard version) and ST600STD models and 20 Hz - 150 kHz for the ST600HF high-frequency (HF) version (Ocean Instruments, 2021; and Ocean Instruments, 2024). However, most USRs do not have a flat response, especially at low frequencies, where the combination of the hydrophone capacitance and preamplifier impedance acts as a high-pass filter. Moreover, the internal electronics of recorder may introduce additional filtering of the sound signal. In this study the frequency characteristics of ST500 and ST600 USRs from Ocean Instruments was measured by comparing spectral levels of recorded broadband underwater noise with those recorded by a fully-calibrated USR.

2 METHODS

Three SoundTraps models, ST500STD, ST600STD and ST600 HF, recorded underwater noise in a swimming pool, using a water pump and water flow with air bubbles as a broadband low-frequency source. Urban noise from local traffic also contributed to noise levels at low frequencies. For each ST model, a low-noise HTI-92WB hydrophone (High Tech Inc.) of an LS1 USR from Loggerhead Instruments was placed near the ST hydrophone, as shown in Figure 1. Underwater noise was recorded by each ST model and the LS1 recorder over long time to obtain data statistically reliable for long-time averaging. A comprehensive calibration procedure described in McCauley et al. (2017), was used to calibrate the frequency characteristic of the LS1 USR, which is shown in Figure 2. The active HTI-92WB hydrophones were also checked for calibration in the pool using a calibrated reference hydrophone (Gavrilov, 2014).

All USRs were programmed to simultaneously make recordings of 9-minute length followed by a 1-minute pause over nearly 2 hours. The difference between power spectral levels at low frequencies was averaged over the entire recording time and then smoothed by polynomial spline. This difference was then used to correct the ST500 and ST600s USR's frequency characteristic.

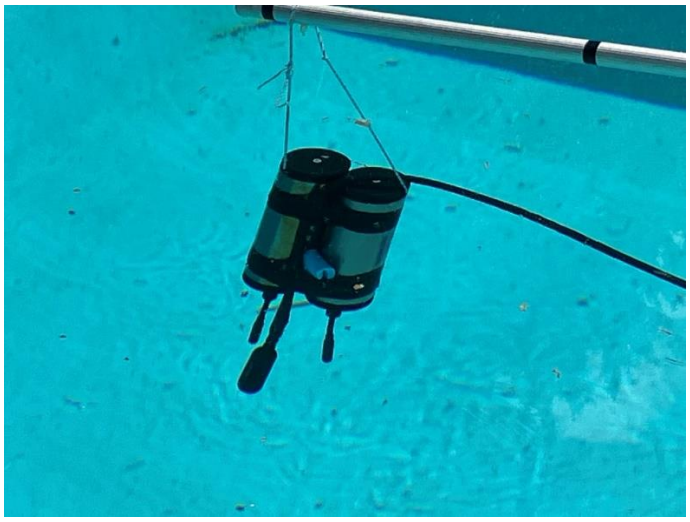

Figure 1 - Two ST500 STD and the hydrophone of the Loggerhead LS1X recorder in the swimming pool.

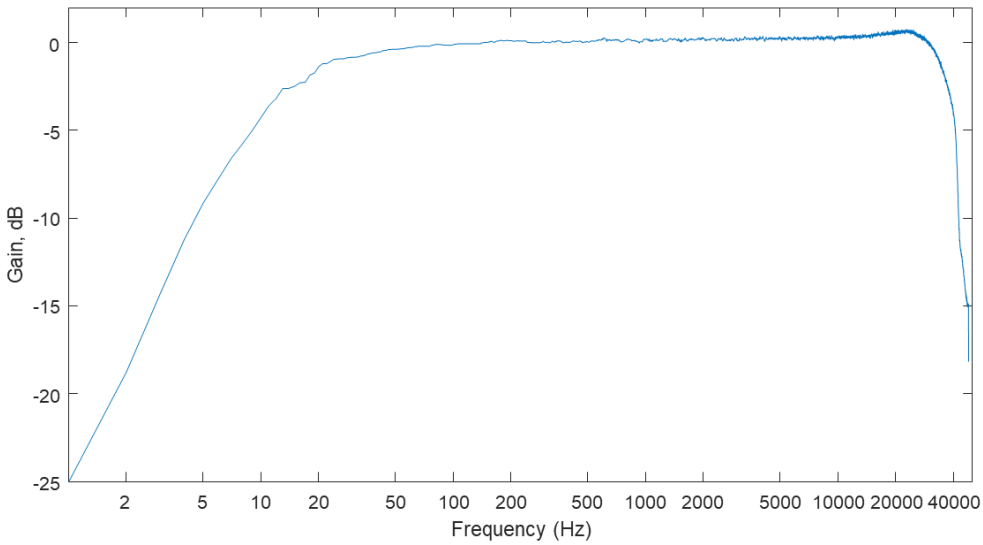

Figure 2 - The Frequency characteristic of LS1X recorder at 0 dB gain setting pool.

3 RESULTS

The power spectral density (PSD) of the water pump and urban noise in the swimming pool recorded by the LS1X USR compared to that measured by the ST500STD, ST600STD and ST600HF are shown on the right panels in Figures 3, 4 and 5 respectively. Also shown in Figures 3-5, are the noise PSD measured by Sound Traps and corrected for low-frequency roll-off. The correction curves are shown on the left panels.

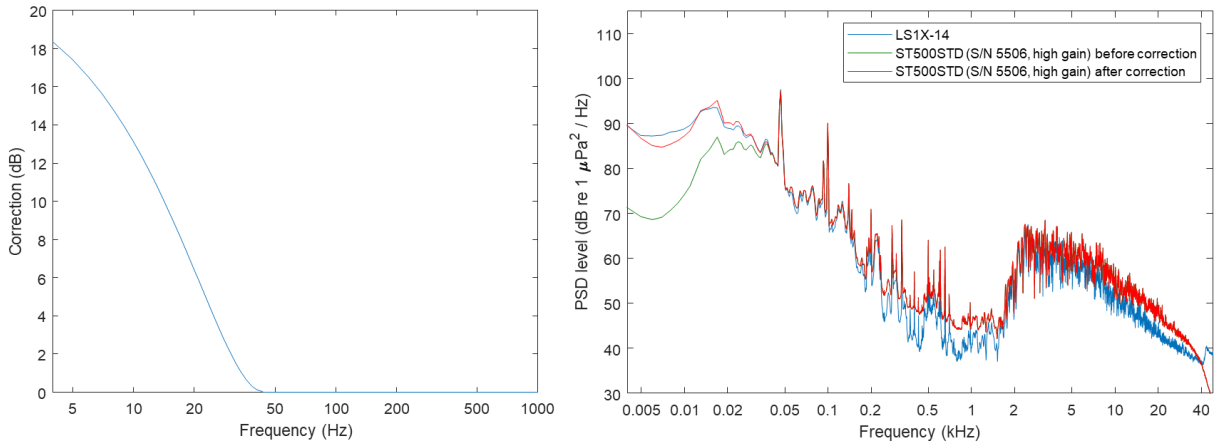

Figure 3 – Comparison of the Power Spectrum Density level of underwater noise measured in the pool by LS1 and the ST500STD: smoothed difference (left), measured noise PSD (right).

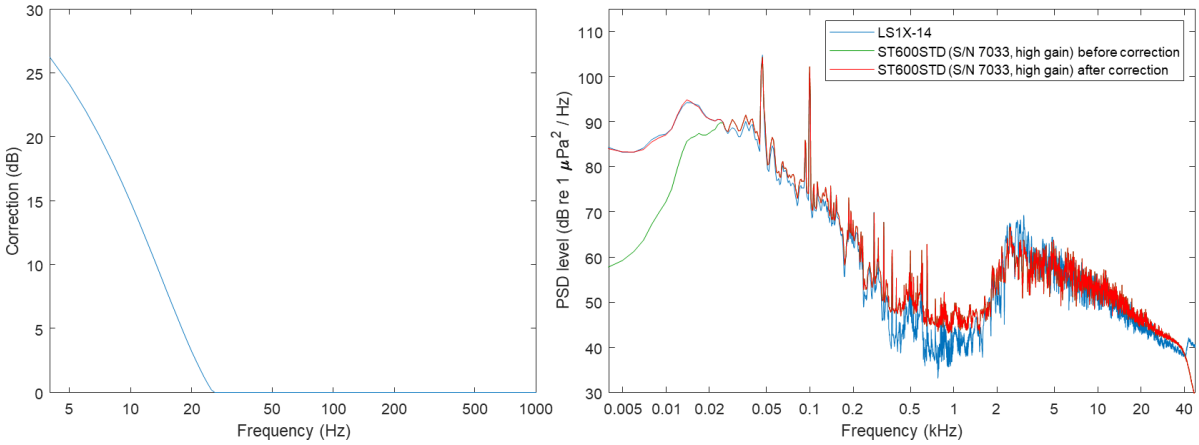

Figure 4 - Comparison of the Power Spectrum Density level of underwater noise measured in the pool by the LS1X and ST600STD: smoothed difference (left), measured noise PSD (right).

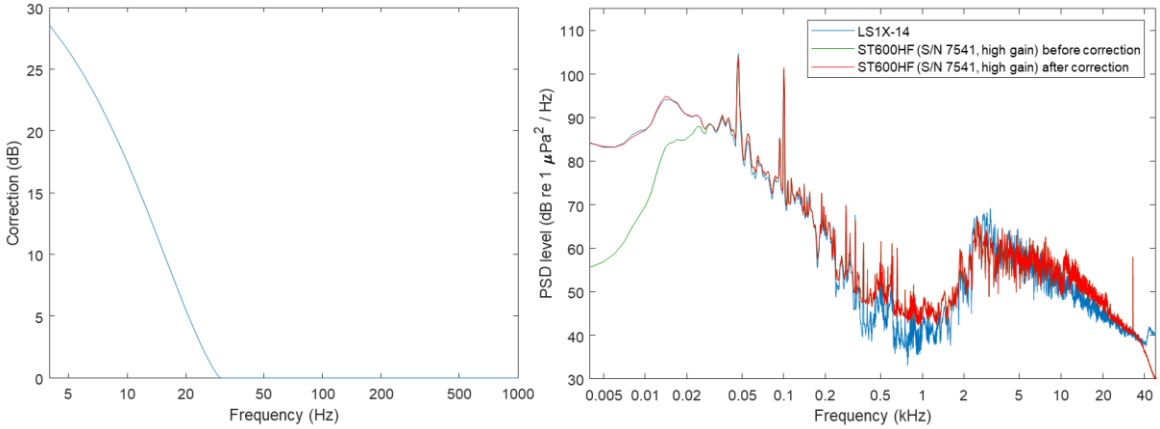

Figure 5 - Comparison of the Power Spectrum Density level of underwater noise measured in the pool by LS1X and the ST600HF: smoothed difference (left), measured noise PSD (right).

4 CONCLUSIONS

The aim of this study was to experimentally derive the low-frequency roll-off in the frequency characteristic of the ST500STD, ST600STD and ST600HF recorder models from Ocean Instruments. It appears that the cut-off frequency of the ST500STD model is slightly below 50 Hz, whereas it is about 30 Hz of both ST600 models. Moreover, the roll-off slope is steeper, nearly twice as much, than 6 dB per octave. This implies that there is another high-pass filtering applied in the ST electronics. The higher roll-off frequency in the ST500 HF could be due to the different hydrophone used compared to the ST600. The correction curves derived in this study can be applied to future sea noise recordings to provide more adequate measurements of ocean noise in the low frequency range, which is used by several species of great baleen whales producing their communication sounds. It is also important to notice that the effect of the high-frequency roll-off due to the antialiasing low-pass filter below the Nyquist frequency in the ST recorders was not measured in this study and added to the correction curve for correction of the frequency characteristics.

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