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4aUWa2. Source signature characterization and detection of open-circuit SCUBA regulators

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A goal of the Center for Island, Maritime, and Extreme Environment Security is to develop passive acoustic methods to monitor harbor and near-shore environments. To study detection of open circuit SCUBA divers, several regulator configurations were recorded and characterized under ideal conditions in a pool environment. Sound Pressure Levels (SPL) and Sound Spectral Levels were calculated over the 300 Hz to 80 kHz band. Preliminary results include SPL range over selected recordings. Regulator broad-band signatures were used to test detection algorithms under varying synthetic and real ambient noise conditions. The first detector is an envelope detector exploiting a priori knowledge of the underlying signal length, corresponding to the divers's fundamental breathing frequency and require at least two breaths for a positive result. In order to maximize signal to noise ratio (SNR), regulator signatures were band-pass filtered to exploit their respective dominant features. Receiver operating characteristic curves were calculated to compare detector performances.

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INTRODUCTION

Classification and detection of divers using underwater breathing apparatus (UBA) such as SCUBA and rebreathers with passive acoustics is of interest to a broad community of researchers. UBA is one of the main tools for observing aquatic species and applications range from diver-animal interaction to detection of divers in no entry environments such as protected reefs and secure port and near shore areas. Vessels (McKenna et al. 2012), the ocean environment (wind and waves), snapping shrimp (Legg et al. 2007) and other elevated background noises make detection of sources with low signal to noise ratio (SNR) difficult.

Previous research has focused on detection of SCUBA in port (Lennartsson et al. 2009; Johansson et al. 2010) and estuary (Stolkin et al. 2006; Stolkin et al. 2007; Sutin et al. 2010) environments with the goal of estimating the performance of a hardware/software detector against increasing noise levels. The few reported diver source levels (Radford et al. 2005; Donskoy et al. 2008) are not comparable due to large differences in the analysis methods and experimental procedures.

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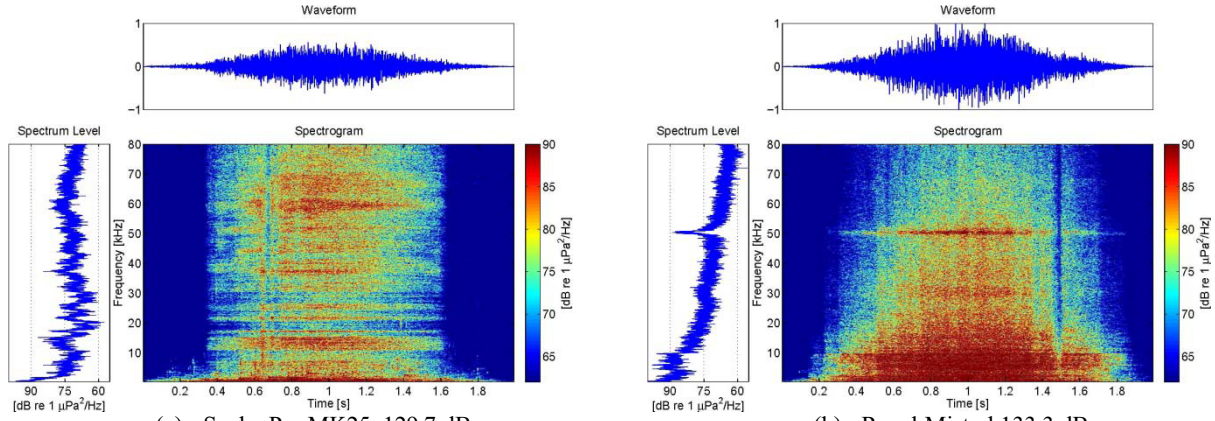
(a) ScubaPro MK 25 (2nd Stage G250)



(b) Royal Mistral (single stage, ca. 1962)

FIGURE 1. Tested Regulators attached to their tanks.

SOURCE SIGNATURES



(a) Scuba Pro MK25, 129.7 dB

(b) Royal Mistral 133.3 dB

FIGURE 2. Spectrogram (2048 frequency bins), Spectrum Levels and Waveform of tested SCUBA Regulators

To estimate the source signature of SCUBA divers, several preliminary experiments were conducted in a diving well at the University of Hawai'i at Manoa. Signatures of several regulators (2 of them shown in FIGURE 1) were recorded with a custom build analog-to-digital-converter (Fedenczuk and Nosal 2011) capable of recording 12

channels at 192 kHz digitized at 24 bits. It is equipped with an anti-aliasing and a 10 Hz high-pass filter. Sound pressure levels (SPL) were integrated over the 300 Hz to 80 kHz band and reported units of decibels are referenced to 1 µPa at 1 m. SPLs were calculated for selected breaths throughout the recordings. SPLs were around 129 dB for the Scuba Pro and 134 dB for the Royal Mistral. Two signatures are shown in FIGURE 2.

SIGNAL DETECTION

To estimate detection ranges for the recorded diver signals, characteristic operation curves (ROC) were computed to allow comparison between different detectors and for different noise environments. For the preliminary analysis, a total of 36 signals were used, each being ten seconds long. Two diver breaths were present in 18 of the signals; the remaining 18 signals were recordings of pool background noise. For plots, the probability of detection is plotted against SNR at a fixed false alarm rate of 10%.

FIGURE 3 shows the probability of detection versus SNR using an envelope detector (Stolkin and Florescu 2007). The signal (see FIGURE 2a) was filtered from 11 kHz to 15 kHz at a specific SNR using a Kaiser band-pass filter. The band was chosen based on a strong energy feature seen in several of the tested regulators in that region. As expected, the detector performs worse using white noise and slightly better with pink noise. For pink noise, the detector performs well until about -14 dB SNR, for white noise detection performance is 100% until about -11 dB.

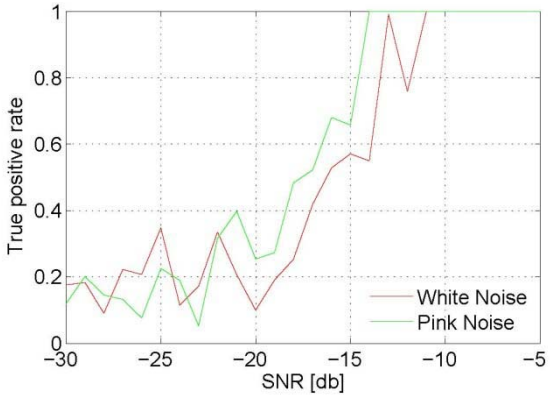


FIGURE 3. Probability of detection versus SNR for Scuba Pro, exploiting a strong feature around 13 kHz

FUTURE WORK

This paper presents a preliminary analysis of selected data of the experiment only. A more comprehensive review of all data and corresponding analysis will provide a better picture of the difference between several regulators and their detection distance, using other detectors as well. For ROC analysis, increasing the number of files with and without signal (from 38 to several 100) will increase the resolution and hopefully be a more trustworthy indicator of detection range.

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