Can a MEMS piezo microphone perform as an alternative to a hydrophone?

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SUMMARY
There are currently over a billion miniature microphones produced every year to feed the global market for smartphones. There is a growing trend to develop smartphones with water-resistant capabilities. One of the significant points of weakness for a water-resistant smartphone is the microphone. A capacitive microphone can be very susceptible to both dust and water egress. This has motivated the development of cheap piezo MEMS (micro-electro-mechanical system) microphones, which are less susceptible to dust and water egress. As a selling point, the manufacturer of the Vesper piezo MEMS microphone indicates that the device can work underwater as a hydrophone. Small, cheap, low-power and reliable MEMS hydrophones could prove incredibly useful in the underwater domain, enabling a variety of IoT (internet-of-things) type applications. We test the Vesper piezo MEMS microphone in an underwater environment to assess the manufacturer's claims with regard to its use as a hydrophone. We compare both the sensitivity and the directionality of the microphone to a standard hydrophone.

1 INTRODUCTION

Developments in manufacturing techniques and decreases in cost have seen a massive proliferation of MEMS sensors (Judy 2001). In the smartphone and IoT market there are compelling reasons for a shift from capactive microphones to piezo MEMS microphones, including protection from dust and water egress and greater reliability. Vesper has developed what they claim are the most durable, waterproof, shockproof, and both dust- and particle-resistant microphones on the market (see Figure 1). These microphones have dimensions of only 3.76 x 2.95 x 1.1 mm, and are rated to IP57, and as a marketing gimmick the manufacturer of the Vesper microphone used the device as a hydrophone (Perry, 2017). In this work we test the voracity of the manufacturer's claims.

(a) (b) (c)

Source (http://vespermems.com/products/vm1000/, 2018)
Figure 1: VM1000 Vesper piezo MEMS microphone (a) outer case, (b) surface-mount face showing air inlet, (c) inner components showing microchip and piezo MEMS diaphragm

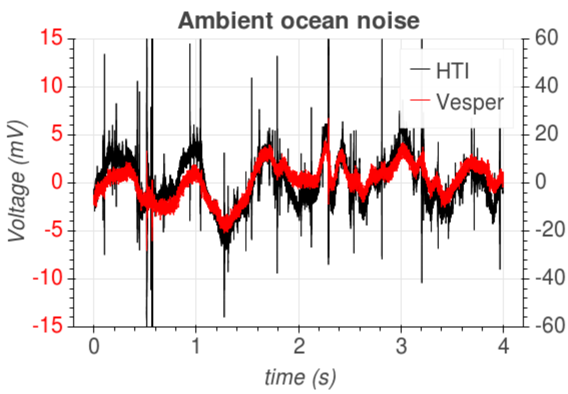
There are several potential advantages for the use of a piezo MEMS hydrophone over a traditional hydrophone including a reduction in size, the potential for on-chip digitisation and a reduction in cost. These benefits would make such a device attractive for a variety of underwater applications such as low-cost expendable UUVs (unmanned underwater vehicles). Although in its infancy, development of piezo MEMS hydrophones has already begun (Rudra Naik, M., et al. 2018).

2 METHOD

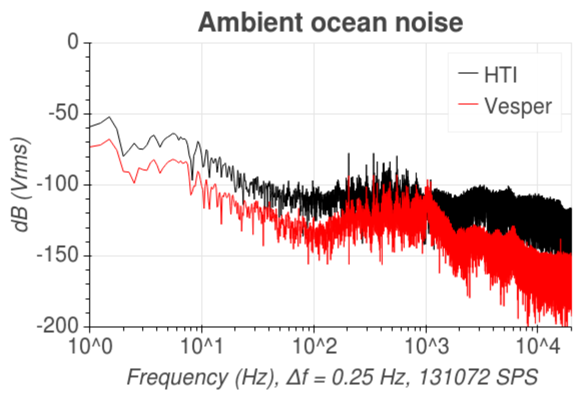
The Vesper is IP57 rated, however the analog output line and the power supply line need to be isolated from the salt water to prevent loss of signal or a power short. We soldered a waterproof cable to the Vesper, then waterproofed the connections using rubber paint, leaving the microphone diaphragm open. We tested the microphone in air to verify that the device was performing as expected. We then tested the device in a fresh-water tank, comparing it's output to a commercially available hydrophone (HTI-96-Min series) before using the device in an ocean environment, recording ambient ocean noise off the coast of Western Australia. The data from both devices were collected on a Brüel and Kjær Type 3050-B-060 acquisition system.

3 RESULTS

As the manufacturer suggested, the Vesper was indeed able to perform as a hydrophone. Although the IP57 rating specifies that the device shall be protected against immersion at depths of less than 1 metre for durations less than 30 minutes, we found that the Vesper continued to function after several hours of immersion, and functioned at a depth of over 1.5m. Figure 2 (a) depicts some time-series data gathered from both the Vesper and HTI, whilst Figure 2 (b) shows frequency spectra of the data. As expected, the frequency response of the device is quite different from that of a commercial hydrophone - the Vesper is designed to work (in air) over a frequency range of 100 Hz to 10 kHz, whereas hydrophones typically function up to much higher frequencies. The sensitivity of the Vesper is only roughly 12 dB below the sensitivity of the HTI at low frequencies, however the sensitivity of the Vesper quickly drops off with increasing frequency.



(a)



(b)

Figure 2: Ambient ocean noise recorded using a Vesper piezo MEMS microphone and HTI hydrophone. (a) time-series data, (b) frequency spectra

4 CONCLUSIONS

Although the Vesper microphone was able to perform as a hydrophone, it obviously was not designed for this purpose and there are several reasons against using this particular MEMS device as a hydrophone. It does not have the sensitivity required at the frequencies of interest in an underwater environment, it has not been pressure tested at depths greater than about 1 metre, and there are likely to be durability issues with longer term use. It seems likely that biofouling would quickly render this particular device inoperable. However, there appears to be great potential for piezo MEMS hydrophones if the design can be altered to allow for increased sensitivity at higher frequencies and issues with durability can be resolved.

REFERENCES

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