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Wind Noise Reduction for Microphones Behind Small Ports

by W.C. Kirkpatrick Alberts II and Gregory W. Lyons

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14. ABSTRACT
Single and multiple microphones in small or handheld devices (such as mobile phones) are often single-port and without windscreens, acting like bare microphones. In a typical outdoor situation, bare microphones can be subject to strong, impulsive wind noise. The significant computational power of mobile phones can sometimes be used for sophisticated signal processing reduction or removal of wind noise. When battery conservation is paramount and computational processing resources are severely limited, alternative wind noise reduction (WNR) strategies must be used. This report details an experimental effort to determine materials and configurations to passively reduce wind noise on microphones inside a ported enclosure. Bare microphones, rough surface treatments, and porous materials were investigated for their WNR capabilities, and it is found that porous metal in place of the port significantly reduces wind noise over a broad frequency range at multiple wind speeds.

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Contents

List of Figures iv

List of Tables iv

1. Introduction 1

2. Experimental Configuration and Methods 1

3. Analysis 4

4. Conclusion 8

5. References 9

List of Symbols, Abbreviations, and Acronyms 10

Distribution List 11

List of Figures

Figure 1. a) Drawing of enclosure used during the experiment and b) photograph of SparkFun microphone board showing the rear of the microphone (tan rectangle at the right of the chip). 2

Figure 2. The enclosures: a) upward-facing bare, b) side-facing, c) 50 grit, d) 100 grit, e) dimpled, f) porous cloth, g) open-cell foam, and h) sintered metal. 3

Figure 3. The experimental setup. Inserts at top show closer images of the enclosures and mounting bars. 3

Figure 4. Time series plots of the a) upward-facing bare and b) bare B&K microphones. 4

Figure 5. Plots showing the ratio of side-facing ports to upward-facing port: a) port away from flow, b) port parallel to flow, and c) port toward flow. 5

Figure 6. Plots showing the ratio of the roughness treatments to the upward facing port: a) 50 grit, b) 100 grit, and c) dimpled. 6

Figure 7. Plots showing the ratio of the porous treatments to the upward facing port: a) foam, b) sintered metal, and c) cloth. 7

Figure 8. Plot comparing all WNR treatments at 5.35 m/s with the a) upward facing bare and b) bare B&K. 7

List of Tables

Table 1. Averaged wind speeds and their respective segment IDs used in the analysis of the WNR treatments. 5

1. Introduction

As acoustic sensing moves toward self-contained, dispersed multimodal systems or lightweight mobile platforms, the resources defined for use by the acoustic system necessarily decrease to either 1) balance the computational needs of all sensors in the former, or 2) minimize the sensing system's impact on the overall performance of the latter. Beyond the regular computational needs of an acoustic sensing system to detect, localize, and classify a target of interest, there are necessary requirements to reduce wind noise on the acoustic sensors and weather effects on the microphone. This is especially true for acoustics sensors incorporated into unattended ground sensors (UGS).

In UGS, the object is to create a widely dispersed set of sensors with a long operational lifetime—greater than several days. UGS increasingly incorporate radios, GPS antennas, and limited processing power. The long operational lifetime and need for a radio necessitate that any algorithms operating on the sensors must be extremely well-managed such that their required computational cycles are at a minimum. Thus, potential algorithmic solutions for mitigating wind noise are infeasible and passive, mechanical wind noise reduction (WNR) solutions must be explored.

This report details the methods and analysis used to reach an inexpensive, passive, mechanical WNR solution for a resource-constrained system. Section 2 discusses the experimental configuration and methods used to arrive at a passive WNR solution, Section 3 discusses the procedures used to analyze the data collected during the experiment, and Section 4 offers concluding remarks and recommendations for WNR solutions.

2. Experimental Configuration and Methods

A standardized enclosure was required to test various WNR treatments. A small, commercially available plastic enclosure measuring 65 × 65 × 41 mm was used to maintain a regular form factor that could contain a microphone, battery, and DC–DC converter (Figure 1a). A commercially available analog microelectromechanical system (MEMS) microphone was used to mimic typical sensors and placements. Specifically, the SparkFun BOB-19389 analog MEMS microphone breakout board was used (Figure 1b). This printed circuit board (PCB) operates on 3.3 V and delivers analog signals from a Knowles SPH8878LR5H-1 analog MEMS microphone. The SparkFun PCB incorporates an approximate 64 times gain, resulting in a sensitivity of approximately 282 mV/Pa.

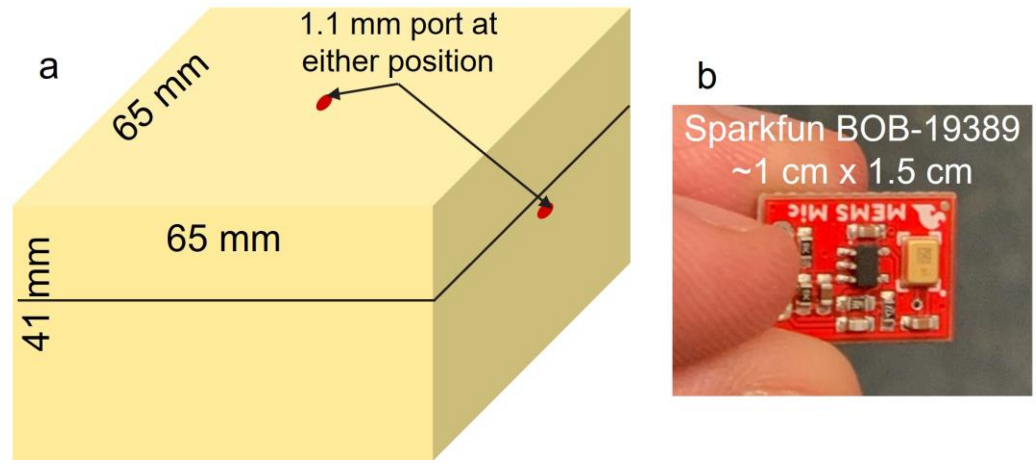

Figure 1. a) Drawing of enclosure used during the experiment and b) photograph of SparkFun microphone board showing the rear of the microphone (tan rectangle at the right of the chip).

The Knowles microphone is a bottom-port MEMS microphone with a flat frequency response from roughly 7 Hz to 19 kHz. It senses pressure variations through a 1-mm-diameter through-hole in the PCB. To approximate how a MEMS microphone might sense through an enclosure, a 1.1-mm-diameter hole was drilled in the enclosure and the microphone PCB was glued into the enclosure such that the microphone port was aligned with the through-hole and spaced approximately 3 mm away from the enclosure wall.

Typical WNR treatments used for atmospheric acoustics are polyurethane open-cell foam spheres or other porous foam material. On some outdoor microphone emplacements, however, large porous spheres are impractical (e.g., the microphone on a cell phone cannot easily be covered by a porous material and still maintain its ergonomic functionality). Noting that many Army systems might be similarly restrained, a series of WNR treatments was considered to passively attempt to reduce wind noise. These treatments include roughness, porous materials, and a combination of both (Figure 2).

In each of the enclosures and WNR treatments shown in Figure 2, the 1.1-mm port through the side is visible on the top or side of each box, with the exception of Figures 2g and 2h, where the hole was opened to 1.91 cm to allow the insertion of a 60-µm pore-size sintered metal disc and an open-cell foam disc, respectively. Figure 2 shows eight photographs of the ten WNR treatments and configurations that were tested in the experiment described herein.

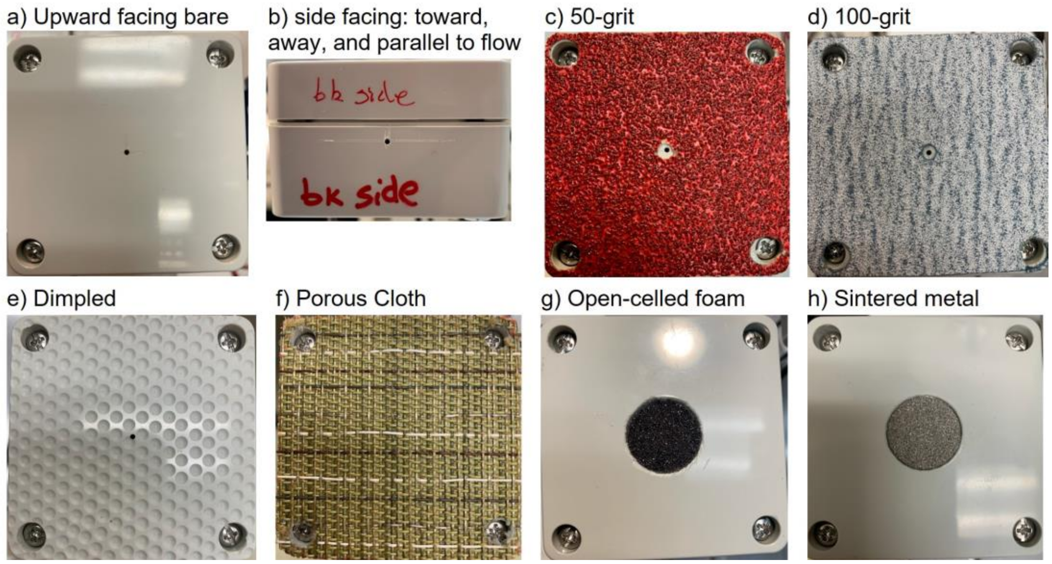

Figure 2. The enclosures: a) upward-facing bare, b) side-facing, c) 50 grit, d) 100 grit, e) dimpled, f) porous cloth, g) open-cell foam, and h) sintered metal.

To collect wind noise data, each enclosure was placed at a height of 10 cm above an aluminum bar (Figure 3). Enclosures were separated by 60 cm to minimize effects of wake from one enclosure impinging on another. The 10 enclosures were placed on two separate bars in a field (Figure 3) and then place in a line with Brüel and Kjær (B&K) microphones, a 3D R.M. Young 81000 ultrasonic anemometer, and a 2D Airmar weather station. The horizontal line of enclosures, microphones, and anemometers was placed at an angle roughly perpendicular to the prevailing wind direction. All sensors were mounted to be 1.5 m above ground level.

Figure 3. The experimental setup. Inserts at top show closer images of the enclosures and mounting bars.

All microphones were simultaneously sampled at 10 kHz by a National Instruments CompactRIO data acquisition system with GPS synchronization to coordinated universal time. The Airmar was recorded by a laptop computer and the R.M. Young anemometer, sampling at 32 Hz, was recorded by a GPS-timed U.S. Army Combat Capabilities Development Command Army Research Laboratory–built serial data acquisition system.

3. Analysis

What follows is a description of the procedures that were used to compare the effects of wind on the various WNR treatments. First, the time domain recordings of the MEMS microphones were observed to determine times when the recordings could undergo further analysis. As shown in Figure 4a, the recordings from the bare MEMS microphones were clipped above certain wind speeds. This is attributed to the high gain of the SparkFun board. Therefore, continuous times when the bare microphone records were not clipped were visually chosen and then cross-referenced with the Airmar recordings to determine the wind speed during the unclipped times. This procedure resulted in 11 contiguous time segments totaling roughly 15 min of wind noise data. Table 1 gives the average wind speeds for each segment and associated segment identifiers (IDs). The segment IDs are listed to give an indication of relative timing; lower numbers occurred earlier in the experiment. For each time segment, the power spectral density (PSD) of the MEMS microphone was computed. The PSD was converted from the frequency domain to wavenumber space. This is done to follow the framework for wind noise studies introduced by Raspet et al. (2006), which lays out an analysis method that allows for comparison of WNR treatments across different experimental conditions. The wavenumber PSD for each WNR treatment was then divided by the upward-facing bare-box wavenumber PSD to obtain a ratio for each WNR treatment. Throughout Figure 5–8, each wind speed is given a separate color and style combination to enable the reader to extract the most information from each plot. The order shown in Table 1 has been followed in Figures 5–8 to illuminate possible systematic changes in WNR behavior due to increasing wind speed.

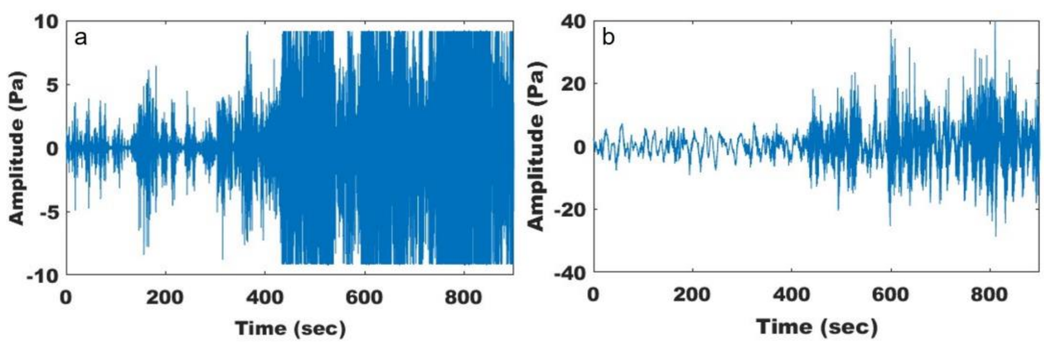

Figure 4. Time series plots of the a) upward-facing bare and b) bare B&K microphones.

Table 1. Averaged wind speeds and their respective segment IDs used in the analysis of the WNR treatments.

Segment ID	Avg speed (m/s)	Segment ID	Avg speed (m/s)	Segment ID	Avg speed (m/s)	Segment ID	Avg speed (m/s)
03c	0.6943	00	1.448	03aa	3.0595	03ab	4.0649
01d	1.0712	01a	1.5794	01b	3.2048	04	5.3552
01c	1.4228	03b	2.8731	02	3.8804		

Figure 5 depicts the ratio of the side-mounted ports to the upward-facing bare port. Figure 5a shows the ratio of the side port facing away from the wind direction to the bare upward-facing microphone, Figure 5b shows the ratio of the side port facing parallel to the wind direction to the upward-facing bare microphone, and Figure 5c shows the ratio of the side port facing into the wind to the upward facing bare microphone. There is no systematic change in the ratio with increasing wind speed in any of the cases shown in Figure 5. Being an outdoor experiment, it is reasonable to expect variations in the wind direction, especially at low wind speeds. This may contribute to the variability in the plots as changes in wind direction may increase or decrease the flow and the noise at the microphone port. Regardless, the port facing parallel to the wind direction (Figure 5b) does appear to have reduced wind noise over that of the other cases.

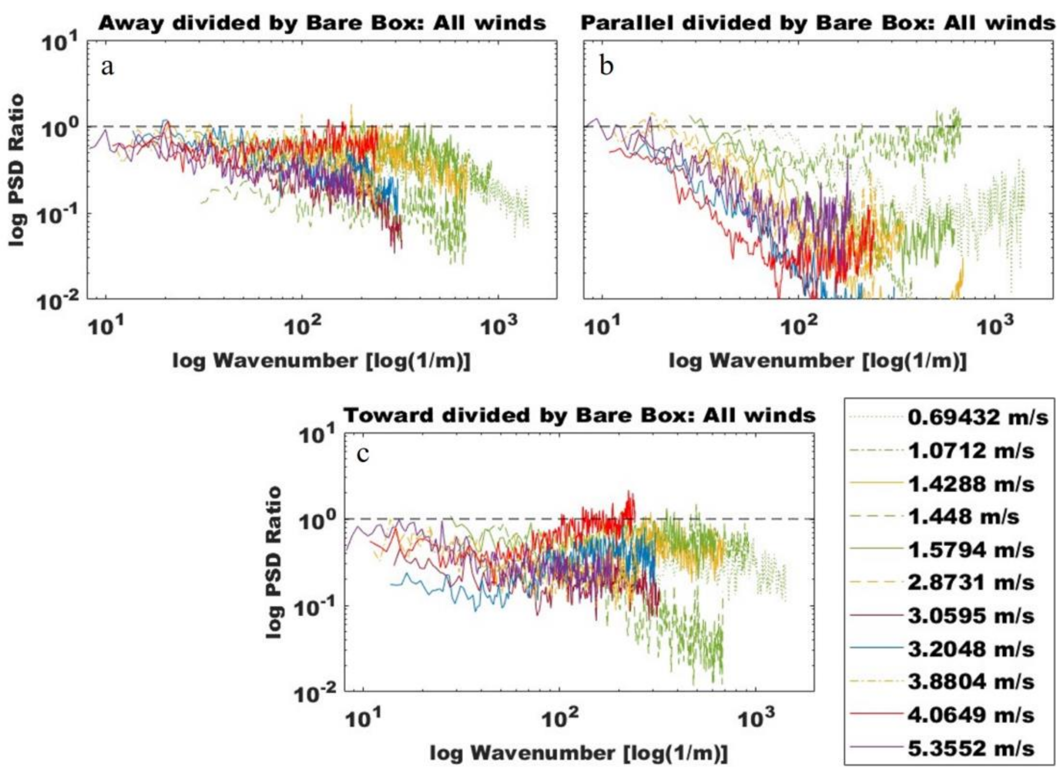

Figure 5. Plots showing the ratio of side-facing ports to upward-facing port: a) port away from flow, b) port parallel to flow, and c) port toward flow.

Figure 6 shows the impact of roughness as a passive WNR treatment. Figure 6a shows the ratio of the 50-grit sandpaper to the upward-facing bare microphone, Figure 6b shows the 100-grit sandpaper, and Figure 6c shows the dimpled case. In all cases depicted in Figure 6, the effect of roughness is to make wind noise worse.

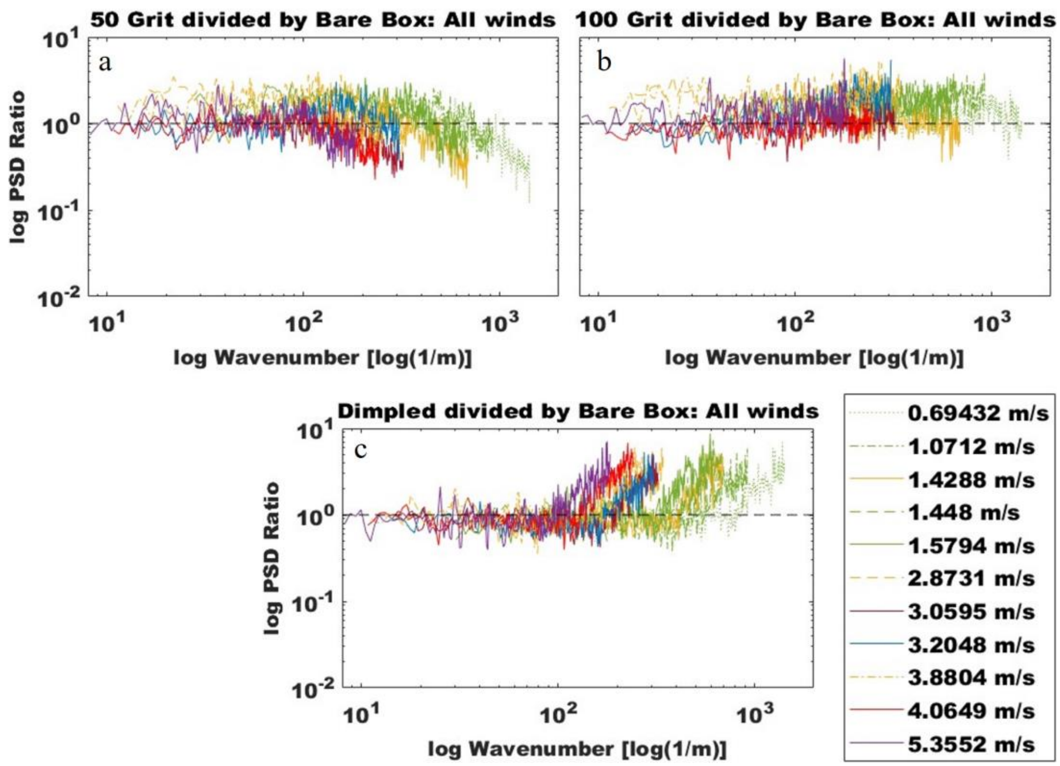

Figure 6. Plots showing the ratio of the roughness treatments to the upward facing port: a) 50 grit, b) 100 grit, and c) dimpled.

Figure 7 depicts the effects of porous materials on the measured wind noise. Figure 7a shows the ratio of the foam-covered microphone to the upward-facing bare microphone, Figure 7b shows the sintered metal versus the upward-facing bare microphone, and Figure 7c shows the ratio of the cloth-covered microphone to the upward-facing bare microphone. As might be expected, porous materials are largely successful in passively reducing the wind noise. Inconsistencies are observed with the cloth covering. These variations may be due to the coupled porous and rough nature of the cloth. Both the foam and sintered metal windscreens significantly reduce the wind noise, with the sintered metal performing slightly better across all wavenumbers and wind speeds.

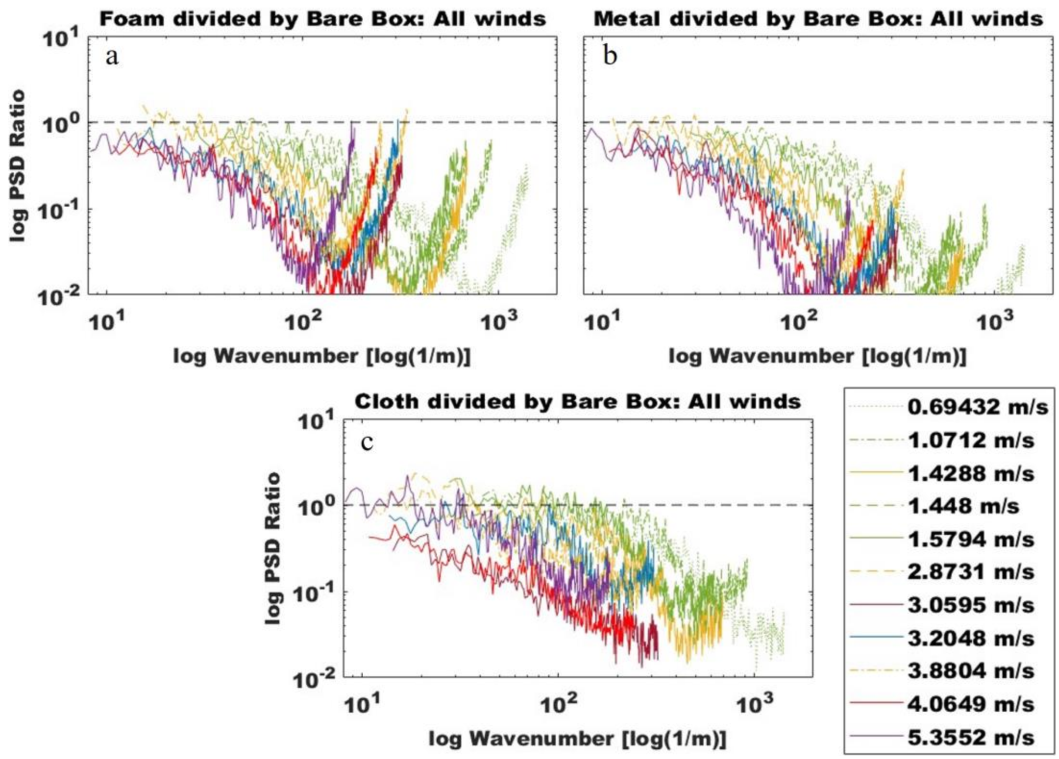

Figure 7. Plots showing the ratio of the porous treatments to the upward facing port: a) foam, b) sintered metal, and c) cloth.

As a comparison of all the WNR treatments, Figure 8 shows each of the treatments divided by either the upward-facing bare microphone or a 0.5-inch bare B&K microphone at the single highest windspeed during the experiment, 5.35 m/s. Of note in both Figures 8a and 8b is the reduction in wind noise as the WNR treatments progress from rough to porous. Both figures serve to reinforce that porous materials are the most effective at reducing wind noise on microphones behind ports and that, in the case discussed here, roughness serves to make the wind noise worse over broad wavenumber ranges.

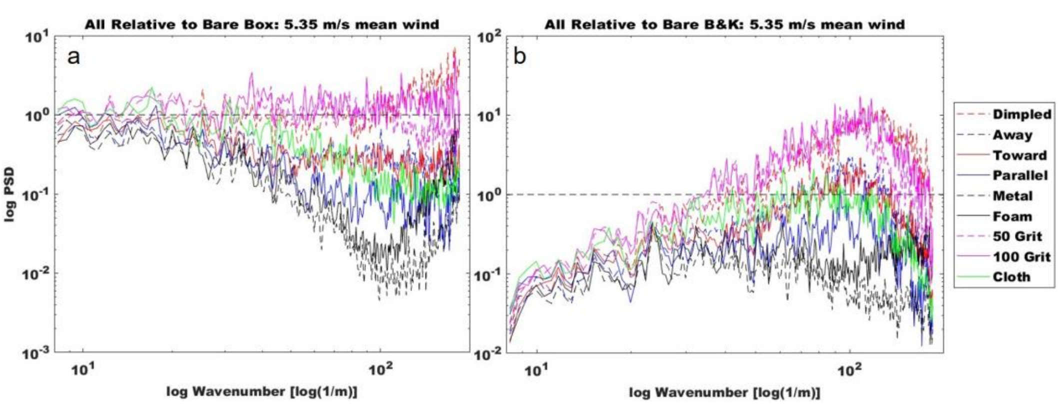

Figure 8. Plot comparing all WNR treatments at 5.35 m/s with the a) upward facing bare and b) bare B&K.

4. Conclusion

This experimental study of WNR treatments for microphones within ported enclosures has determined that bare ports in different orientations relative to the flow might offer some noise reduction. While this does not have implications for small ground-emplaced sensors, further study is required to determine if this observation can be exploited for emplacing acoustic sensors on platforms with well-defined flow characteristics.

As might be expected, porous WNR treatments such as the cloth covering, the 1.91-cm open-celled foam disc, and the 1.91-cm, 60-µm sintered metal disc were shown to create significant WNR over all wavenumbers. Based on the results demonstrated here, it is recommended to use sintered metal discs in place of small ports to reduce wind noise.

5. References

Raspet R, Webster J, Dillion K. Framework for wind noise studies. J Acoust Soc Am. 2006;119:834–843. https://doi.org/10.1121/1.2146113

List of Symbols, Abbreviations, and Acronyms

2/3D	two-/three-dimensional
B&K	Brüel and Kjær
DC	direct current
GPS	global positioning system
ID	identifier
MEMS	microelectromechanical system
PCB	printed circuit board
PSD	power spectral density
UGS	unattended ground sensors
WNR	wind noise reduction

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