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A system for measuring wind turbine infrasound emissions

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Summary

Utility scale wind turbines are capable of emitting sound over a broad range of frequencies, including infrasound (below 20 Hz). Though it is desirable to assess the infrasound in contexts such as magnitudes reaching unhealthy levels, often the available instrumentation, filtering techniques to distinguish signals from local noise (wind), and signal analysis methods are inadequate at producing accurate results. This paper describes progress towards the development of an infrasound measurement system that addresses and aims at eliminating such issues.

The system aims at addressing several issues in measuring wind turbine infrasound emissions: that of selection of appropriate instrumentation, data logging hardware, signal processing technique and wind filtering apparatus. This is done by identifying the limitations and shortcomings of standard infrasound monitoring systems and improving upon the individual components of the system to enhance robustness, portability, and cost.

The instrumentation selected for the system includes multiple Paroscientific Model 6000-16B nano-resolution barometers configured for infrasound measurement. These have been shown in previous research to be capable of infrasound detection, including microbaroms, distant tornadoes, and wind turbine emissions. For portability, the barometers were transported and could be operated from inside a standard size briefcase. In the field, the barometers were powered by battery inside the briefcase and connected to a laptop running Paroscientific INC. Digiquartz Interactive 2.0 pressure-logging software. Future improvements to the logging equipment will include the use of an Adafruit Raspberry Pi micro-computer running custom logging software for time-synchronized multi-barometer sampling.

Due to the fact that wind noise is generally strong during wind turbine operation, techniques are needed for its reduction. Techniques explored in this study include spatial filters comprised of microporous “soaker” hoses and PVC pipe, as well as a Paroscientiic Digiport high performance pressure port designed to eliminate effects of dynamic pressure gradients on barometric pressure measurements. Analysis techniques incorporate plots of raw data, spectra, cross correlation and coherence diagrams, among others to ascertain periodic signals that characterize the emissions of a wind turbine in operation. Infrasound spectral patterns are

correlated with factors such as topography, local vegetation, and proximity to other sources of infrasound and noise in order to determine the best deployment locations.

Results demonstrate the ability of the infrasound measurement system to isolate wind turbine infrasound from the signals of other sources of infrasound such as microbaroms, airplanes, urban noise, as well as ever present local wind noise. The system will be deployed in the future as part of an effort to better characterize the nature of the emissions with respect to factors such as human health and magnitude levels.

1. Introduction

Wind turbines are on the forefront of the world's renewable energy sources and are proving to be dependable, efficient, and manageable with respect to continued improvements in infrastructure and maintenance (Pacific Hydro, 2010). However, there has been controversy involving the broad range of sounds that wind turbines are capable of producing. Many people, most of whom dwell within the immediate vicinity of turbines report that they experience unfavourable encounters including adverse health effects due to wind turbine sound, or more popularly, wind turbine noise. Infrasound, one of the forms of wind turbine noise, is produced by the wind turbine blade passing the tower on the downwards portion of rotation and is identified as a possible cause of these adverse health effects.

Research by Salt and Kaltenbach (2011) suggests that although sensory cells responsible for hearing are not especially sensitive to infrasound, other sensory cells are significantly sensitive to the pressure fluctuations from wind turbines. Therefore, infrasound may interact with the brain through subconscious pathways and cause various sensations of disturbance. Although there have been reports of wind turbines having negative effects on people living in the vicinity of turbines (Ingielewicz, Zagubien 2014), there have been numerous studies stating that there is no conclusive evidence of wind turbines producing infrasound or other sounds that reach magnitudes that correspond to unhealthy levels (Ellenbogen et al. 2012).

The proposed negative consequences due to wind turbine infrasound nonetheless hinder further deployment of industrial scale wind turbines, turbines that help to reduce both the dependency on non-renewable energy sources such as fossil fuels and consequentially resulting greenhouse gases, among other pollutants. Therefore it is necessary to be able to accurately measure and analyse the infrasound emissions of similar industrial scale wind turbines in order to correlate the levels of such emissions with levels that are described to have negative impacts on human bodily systems. This will help inform the debate over if and how industrial scale wind turbines might be deployed in the vicinity of populated areas.

Wind turbine infrasound monitoring has been done using a variety of instruments and systems including low-frequency microphones and microbarographs. Ingielewicz and Zagubien (2014) implement a microphone to demonstrate infrasound levels from wind turbines and compare them to levels from common sources found in the environment. For the experiments in this report, micro-barometers manufactured by Paroscientific INC. are used. These were chosen for their compactness, robustness, and ease of operation and data collection. Previous work has demonstrated their ability for infrasound detection, including microbaroms, tornadoes, and wind turbine emissions (Subramanian, Muschinski 2011; Pepyne et al., 2012).

In order for a wind turbine to produce substantial magnitudes of infrasound, the rotation of the blades and therefore the wind speed must be significant. Previous studies suggest that monitoring infrasound, especially that produced by a wind turbine, is hindered by local wind noise deriving from significant wind speeds, which distorts the signal of interest (Carman, Amato 2013). This signal due to wind noise is often much stronger than the signal from the turbine and the resulting noise spectrum becomes totally dominated by the wind noise. In a search for a reliable way to remove this corrupting wind noise, this study investigates a number of wind-filtering methodologies ranging from physical apparatus attached to the infrasound sensors to signal processing methods.

Experiments measuring infrasound emissions from wind turbines in various locations of Massachusetts, United States demonstrate the effectiveness and appropriateness of various

system designs and deployments. This is done in terms of their ability to monitor wind turbine infrasound emissions at various locations subject to different weather and terrain conditions.

2. Experimental design

The collective infrasound monitoring system design consists of 4 sub-systems: the infrasound sensors, the wind filtering apparatus, the data logging equipment, and the signal processing techniques employed. For our experiments, criteria for subsystem selection were portability, effectiveness, and performance reliability.

2.1 Infrasound Sensors

The infrasound sensor selected for our experiments is the Paroscientific, Inc. Model 6000-16B nano-resolution barometer. This barometer, shown in Fig. 2.1, is a self-contained, compact sensor the size of a human fist. The sensor works by converting the frequency of vibration of a pressure sensitive quartz crystal into a high-precision ASCII digital barometric pressure output. A temperature sensor provides thermally compensated, accurate barometric pressure measurements over a broad range of temperatures. A nano-resolution mode allows one to sample the digital output to resolutions of 10-7 Pascal at sample rates in excess of 20Hz. A configurable analog low-pass filter internal to the barometer eliminates the aliasing of barometric pressure variations exceeding the Nyquist associated with the chosen sample rate. Prior work at the University of Massachusetts, Amherst has demonstrated the capability of the Model 6000-16B to detect infrasound signals, including microbaroms (Subramanian, Muschinski 2011), tornadoes (Pepyne, 2012), and industrial scale wind turbine emissions (Pepyne, 2012).

Figure 2.1 Paroscientific Series 6000 Intelligent Pressure Tansmitter

There are two logging software programs used in the experiments of this report. Digiquartz Interactive 2.0, distributed by Paroscientific INC is a software that enables the user to alter barometer baud rate, identification number, and sampling frequency. Digiquartz also provides a GUI layout, which plots the raw pressure in the time domain prior to logging the data. This capability allows the user to visually spot a possible incoming infrasound signal before storing the data.

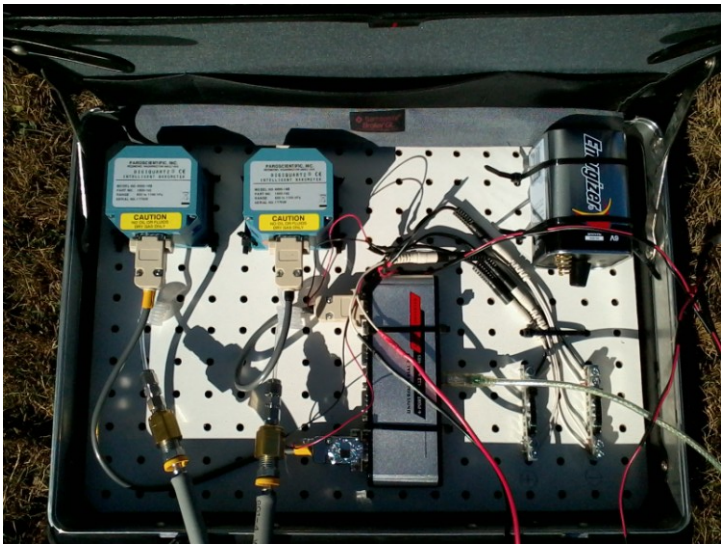

Figure 2.2 The “Infrasound Briefcase” containing barometers, serial-USB converter, battery, and required cables

The second software program is custom software that has been developed at the University of Massachusetts Amherst for time-synchronized multi-barometer sampling. This custom software has been deployed in various studies in infrasound monitoring, including severe weather (Pepyne 2012). Multi-barometer sampling is enabled by a 4-port RS 485/422 serial-to-USB converter which enables the simultaneous logging of up to 4 barometers.

The converter is connected to a Lenovo laptop which logs and stores the data as a text file. The text file contains column vectors of the time stamp, elapsed time of test, and measured pressure values. Data logging on the Lenovo laptop also accommodates devices with large storage capabilities including external hard drives, and the logging laptop itself. Providing electricity to the low-power barometers is a 6v battery. The collective system makes it very compact and portable, allowing all of the components to be stored inside a handheld briefcase (Figure 2.2).

2.2 Wind Filtering Apparatus

To reduce or eliminate the effects of local wind noise on incoming wind turbine infrasound emissions, various wind filtering techniques have been considered. These include placing the infrasound sensors inside buildings and covering the sensor input with foam wind screens. The state-of-the-art wind filtering technique employed worldwide by institutions such as the Comprehensive Nuclear-Test ban Treaty Organization (CTBTO) (Evers 2005) to monitor infrasound from clandestine nuclear tests involves the use of arrays of porous hoses or pipes to allow for pressure sampling over a widespread area rather than at a single point. The infrasound wave-fronts propagating from wind turbines remain well correlated over many meters, whereas wind noise becomes uncorrelated over a few meters. Therefore, by combining the pressure fluctuations at multiple pores spread over a wide physical area and summing them at a central manifold results in a constructive summing of the correlated infrasound wavefronts and destructive summing of the uncorrelated wind noise contributions for a resulting increase in signal-to-noise ratio. Circular symmetry of the spatial wind filter makes the wind filter capabilities independent of wind direction.

Figure 2.3 The spatial array wind filter

The spatial wind filters used by the CTBTO are constructed with heavy, rigid, and expensive materials. The spatial wind filter used in this study is similar in design to the CTBTO design, but uses of relatively inexpensive porous soaker hoses and a summing manifold composed of half-inch PVC pipe and brass barbed hose fittings (see Fig. 2.3). This makes our spatial wind filter inexpensive, portable, and able to be quickly set up and torn down.

In addition to filtering the wind, a spatial wind filter also prevents signal contamination due to the dynamic pressure of the wind. Different from infrasound wind noise, which is a static pressure phenomena due to turbulent eddies in the boundary layer between the atmosphere and the ground, dynamic pressure is due to the wind blowing directly onto the infrasound sensing element. There has been a recent evolution of high-performance static pressure ports that are small, compact, robust, and extremely portable. One such static pressure port is the Paroscientific Digiport (Fig. 2.4). The DigiPort is an omnidirectional static head designed to eliminate the effects of dynamic pressure gradients on barometric pressure measurements. The Digiport's small size and sturdy construction make it ideal from the point of view of portability, which prompted us to explore its use in conjunction with the cross-correlation noise reduction techniques.

Figure 2.4 Paroscientific Digiport High Performance Pressure Port

2.3 Data Logging Software

There are two logging software programs used in the experiments of this report. Digiquartz Interactive 2.0, distributed by Paroscientific INC is a software that enables the user to alter barometer baud rate, identification number, and sampling frequency. The Digiquartz software also provides a GUI, which plots the raw pressure in the time domain prior to logging the data. This capability allows the user to visually spot a possible incoming infrasound signal before storing the data. The second data logging program is custom software developed at the

University of Massachusetts Amherst for time-synchronized multi-barometer sampling. This software has been deployed in various studies in infrasound monitoring, including severe weather (Pepyne, 2012). Multi-barometer sampling is enabled by a 4-port RS 485/422 serial-to-USB converter which enables the simultaneous logging of up to 4 barometers. Both data logging programs store the data in human readable text files in a column format with columns for the data, elapsed time of test, and measured pressure values.

2.4 Signal Processing Methods

Many systems that monitor infrasound utilize intricate measurement amplifiers, digital data recorders, and analysers to record and analyse the pressure measurements sampled by one or more barometers. This equipment is often bulky, expensive, and required to be housed inside a dwelling for protection against weather elements. Alternatively, with the pressure sample data logged and stored on a computer or drive, the file can be accessed at a later time for analysis. The experiments in this study use MATLAB computing software to load the stored data file and compute plots of raw pressure data, band-pass filtered data, and spectrograms. Data pre-processing includes mean subtraction to remove the mean barometric pressure from the data and high-pass filtering to remove the very low frequency trends due to changes in barometric pressure during the period of data collection. Spectral analysis involving Hamming windows and Welch averaging is used to detect and characterize any wind turbine infrasound signals that might be present in the data.

2.5 Portable Infrasound Measurement System

Our selection of infrasound sensor was key to obtaining a compact portable infrasound measurement system that fits inside a standard briefcase (Fig. 2.2). As shown in the figure, two Paroscientific barometers were mounted inside a briefcase along with a battery to power them in the field. Pressure hoses connected the barometers to the wind filtering apparatus or DigiPort static heads. RS485 cables connected the barometers to a 4 port serial-to-USB multiplexer. A USB cable connects the multiplexer to a laptop data logging and analysis computer.

3. Test Site Results and Discussion

Infrasound measurements were taken at three wind turbine sites, one in Oklahoma and two in Massachusetts. The resulting infrasound detections from each site are evaluated with respect to the wind filter used, the terrain, the weather, and the location of the infrasound equipment relative to the wind turbines.

3.1. Blue Canyon Wind Farm, Oklahoma

In spring 2011, two infrasound monitoring stations were deployed as a part of a Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) experiment to research the applications of infrasound for increased public warning times of tornadoes and other severe storms (Pepyne et al. 2012). Both stations were collocated with CASA weather radars in Cyril and Rush Springs, Oklahoma (Figure 3.1). Blue Canyon Wind Farm (BCWF), the largest wind farm in Oklahoma and consisting of approximately 200 turbines amounting to 350 MW of power production, is located 30 km west of Cyril and 60 km west of Rush Springs.

The experimental set-up consisted of four Paroscientific barometers at each station, arranged in a square topology, with 50 meter spacing in between barometers. Each barometer was connected to a 50 foot diameter micro-porous spatial wind-filter, with data cables running from each barometer to a central USB hub connected to a data logger computer. A total of 71 days of pressure data was collected from April 18 to June 27, 2011 at a sample rate of 20Hz.

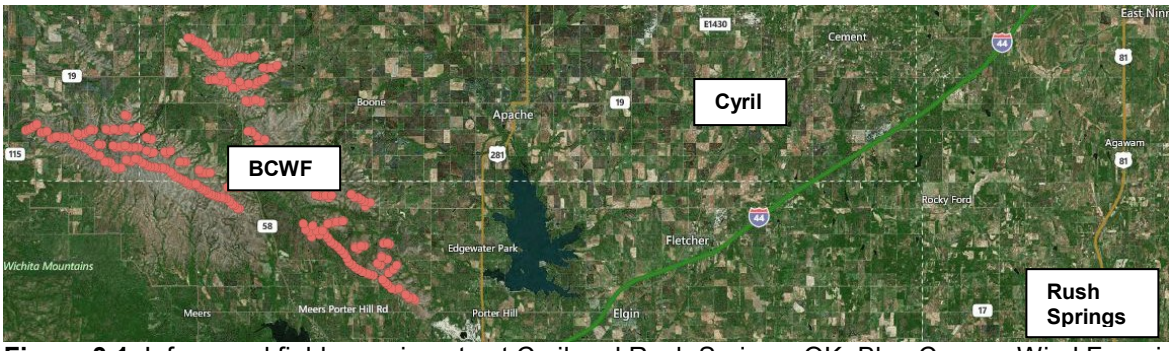

Figure 3.1. Infrasound field experiments at Cyril and Rush Springs, OK. Blue Canyon Wind Farm is approximately 30 km west of Cyril and 60 km west of Rush Springs.

The data yielded banded spectrogram data at approximately 0.8 Hz and at ½ octave intervals as shown in Figure 3.2, frequencies typically associated with wind turbine blade rotational frequency and infrasound. Since the pressure data from each barometer was time synchronized, phase shifts in the infrasound wavefronts arriving at the array of 4 barometers allowed a bearing angle analysis to be performed to decipher the direction of arrival of the banded signals.

Both bearing angle analyses (Figure 3.3) and spectrograms reveal a western approach of the signal, and that the signal was stronger at the Cyril site. The persistence of the signal ruled out weather patterns as the possible source. The vast span of the Blue Canyon Wind Farm as compared to the distances between the farm and both the Cyril and Rush Spring sites, the bearing angle analysis, and the lack of any other significant sources of infrasound near both test sites, the source of the banded infrasound signal was concluded to be the Blue Canyon Wind Farm.

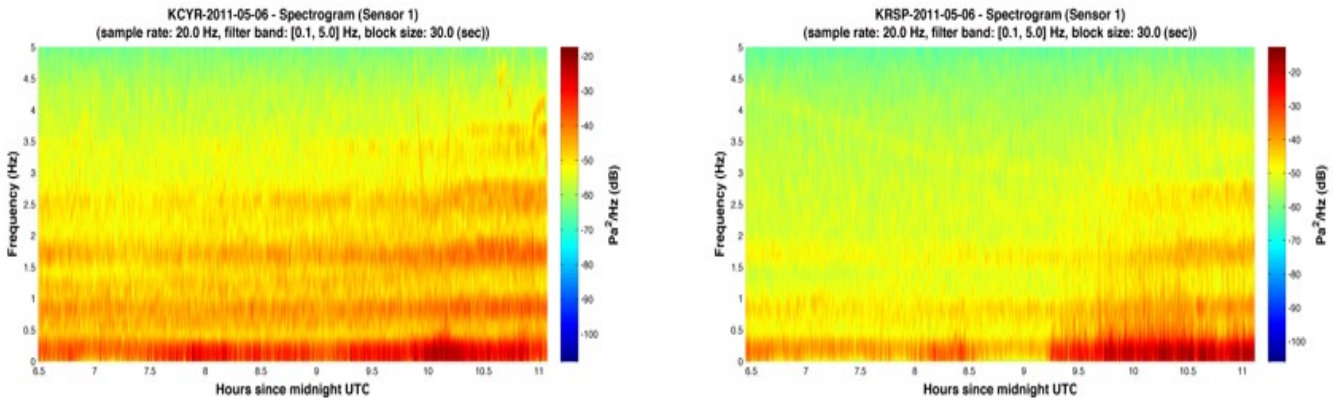

Figure 3.2. Spectrograms of Cyril Site (left) and Rush Springs (right).

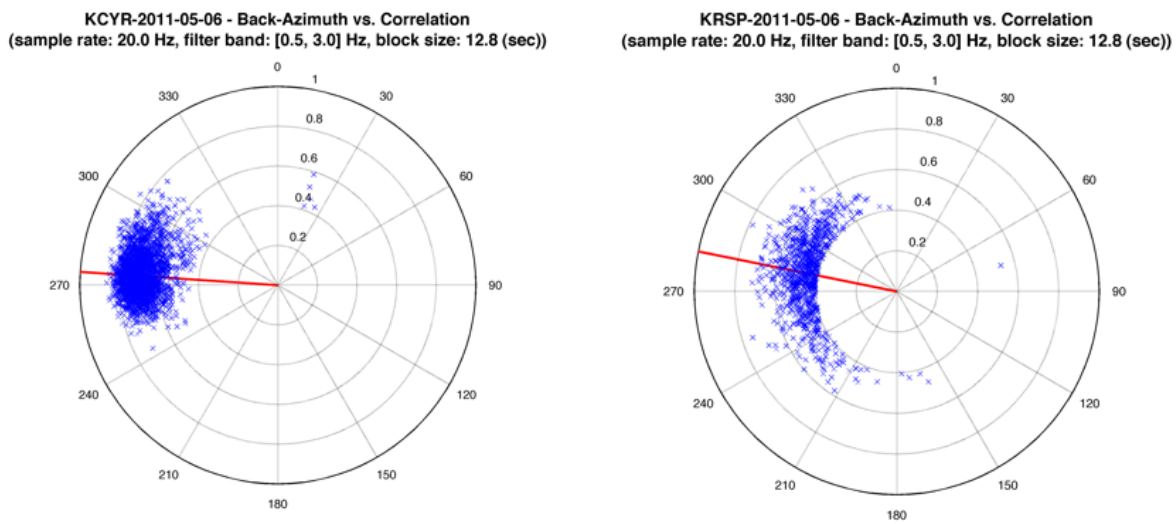

Figure 3.3. Bearing Angle Analysis for determining the direction of the banded signal of Cyril (left) and Rush Springs (right)

In geographic locations of heavy forestry or vegetation and rapid change in elevation, an infrasound signal may attenuate within hundreds of meters. The flat terrain between the Blue Canyon Wind Farm and both test sites suggest that the 60 and 30 km propagation distances are not unexpected, especially considering the lack of vegetation and intervening hills that would increase the attenuation rate of the signal (deGroot-Hedlin et al. 2010). The results of the Oklahoma tests clearly demonstrated the capability of a combination Paroscientific barometer and microporous soaker hose spatial wind filter to detect the infrasound emissions from industrial scale wind turbines. A desire to study these infrasound emissions from distances consistent with reported health effects, catalysed further studies to collect infrasound emissions from wind turbines at other sites.

3.2 Hoosac Wind Farm, Monroe, Massachusetts

On 21 July, 2014, two experiments were performed in an attempt to capture and characterize infrasound from the Hoosac Wind Farm of north-western Massachusetts. This wind farm consists of 19, 1.5 MW monopole wind turbines in two separate sub-sites. The infrasound measurement equipment was set up in a field approximate 2.4km east of sub-site 1 (10 turbines) and 2.5km north of sub-site 2 (9 turbines), see Fig. 3.4. The measurement location was suitable because of similarity in elevation between test site and turbines. Similar elevation helps reduce the effects of propagation-bending and refracting caused by uneven wind and temperature gradients as well as local vegetation.

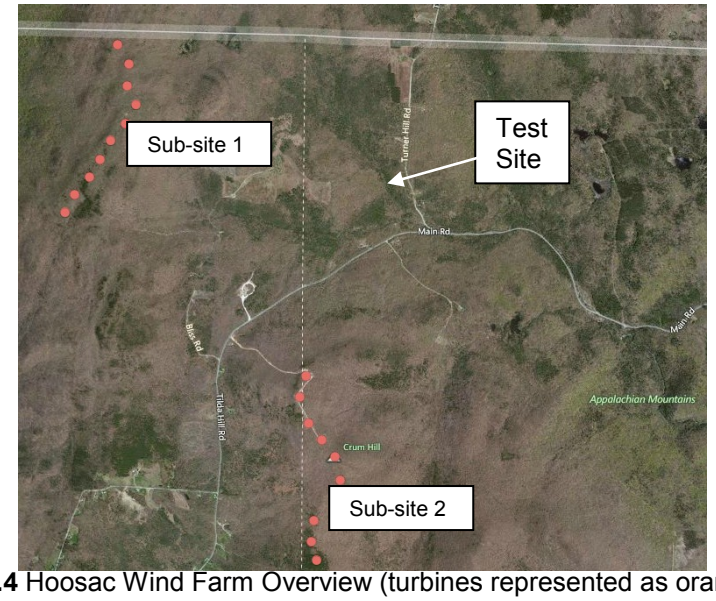

Figure 3.4 Hoosac Wind Farm Overview (turbines represented as orange dots)

The surrounding area included very few homes, and no other obvious sources of infrasound such as over-flying airplanes were present during the experiment, giving sufficient evidence that any infrasound signal from the wind turbines would be isolated and distorted only by local wind noise. Two experiments were conducted at the wind turbine site, each experiment consisting of one “bare” barometer having no connection to a wind filtering device and one barometer connected to a wind filtering device. The experiments were performed one right after the other. Comparisons between the two data sets were hypothesized to reveal the effects of different wind filtering devices on reducing local wind noise distortion and increasing the infrasound signal to noise ratio. The data logging software used was Digiquartz Interactive 2.0, the sample rate was 10Hz, and the data was stored on a Lenovo laptop

Figure 3.5 Overview of Hoosac test site. On left, the open infrasound briefcase contains barometers, battery cell, serial hub converter, necessary cables, and logging computer inside. The white ½ inch PVC pipe summing manifold can be seen to the right of the briefcase. On the right, the view of Sub-site 2 from the test site. The turbines can be seen above the tree line. Sub site 1 to the west cannot be seen from the test site due to blockage from trees outlining the field.

For the first experiment, the set-up contained one barometer with bare input (Barometer 1) and one barometer connected to a micro-porous hose spatial wind filter (Barometer 2) as displayed in Figure 3.5. The two barometers sampled pressure for 27 minutes between 18:18 and 18:45. No exact measurements were made of wind speed at the time of testing, but there was a slight breeze and both the National Weather Service and Weather Channel websites estimated the wind at 5 m/s in the southwest direction. Although these wind speeds are significantly slower than the average wind speed suitable for continuous operation of wind turbines, these wind speeds have been shown to significantly distort an infrasound signal (Pepyne et al. 2012).

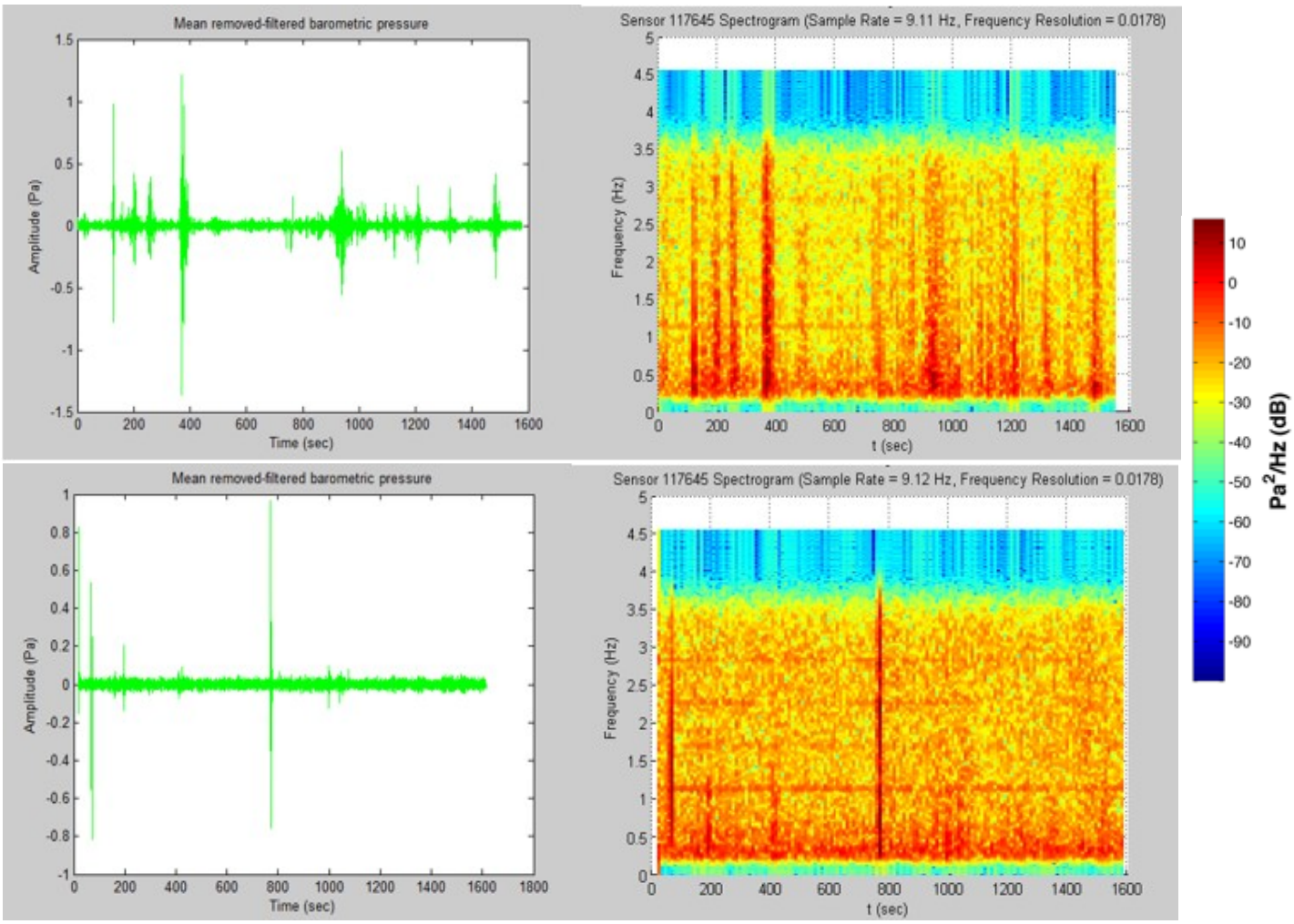

Figure 3.6 Filtered pressure and spectrograms of Experiment 1 (Barometer 1 top, Barometer 2 bottom)

The infrasound signals and spectrogram data from Experiment 1 are shown in Figure 3.6, the data from Barometer 1 (bare) in the top pair of plots and the data from Barometer 2 (spatial wind filter) in the bottom pair of plots. Though the spectrograms for both barometers show the horizontal bands associated with wind turbine infrasound, the bare barometer shows significantly more burstiness in the time-domain plots and vertical banding in the spectral plots. This vertical banding in the spectral plot is characteristic of wind noise. These results verify the effectiveness of the micro-porous hose spatial wind filter.

Experiment 2 used a similar set-up to Experiment 1, with Barometer 1 as bare input and Barometer 2 connected to the Paroscientific Digiport high performance pressure port. The test collected approximately 17 minutes of infrasound data between 18:48 and 19:05. The wind was noticeably stronger than in Experiment 1 and was expected to cause significant increase in wind noise distortion of the spectral plots. The respective infrasound data and spectrograms for the two barometers are plotted in Figure 3.7. From the plots, it is does appear that the DigiPort is able to reduce the effects of local wind noise, although not as dramatically as the spatial wind filter. This may have been due to the increase in noise intensity for Experiment 2.

Overall, the results of the two tests provide preliminary evidence that it may be not be necessary to use a spatial wind filter and that it may be possible to perform infrasound monitoring using the much more compact DigiPort static head to isolate the barometer from the effects of dynamic pressure and to some degree wind noise as well.

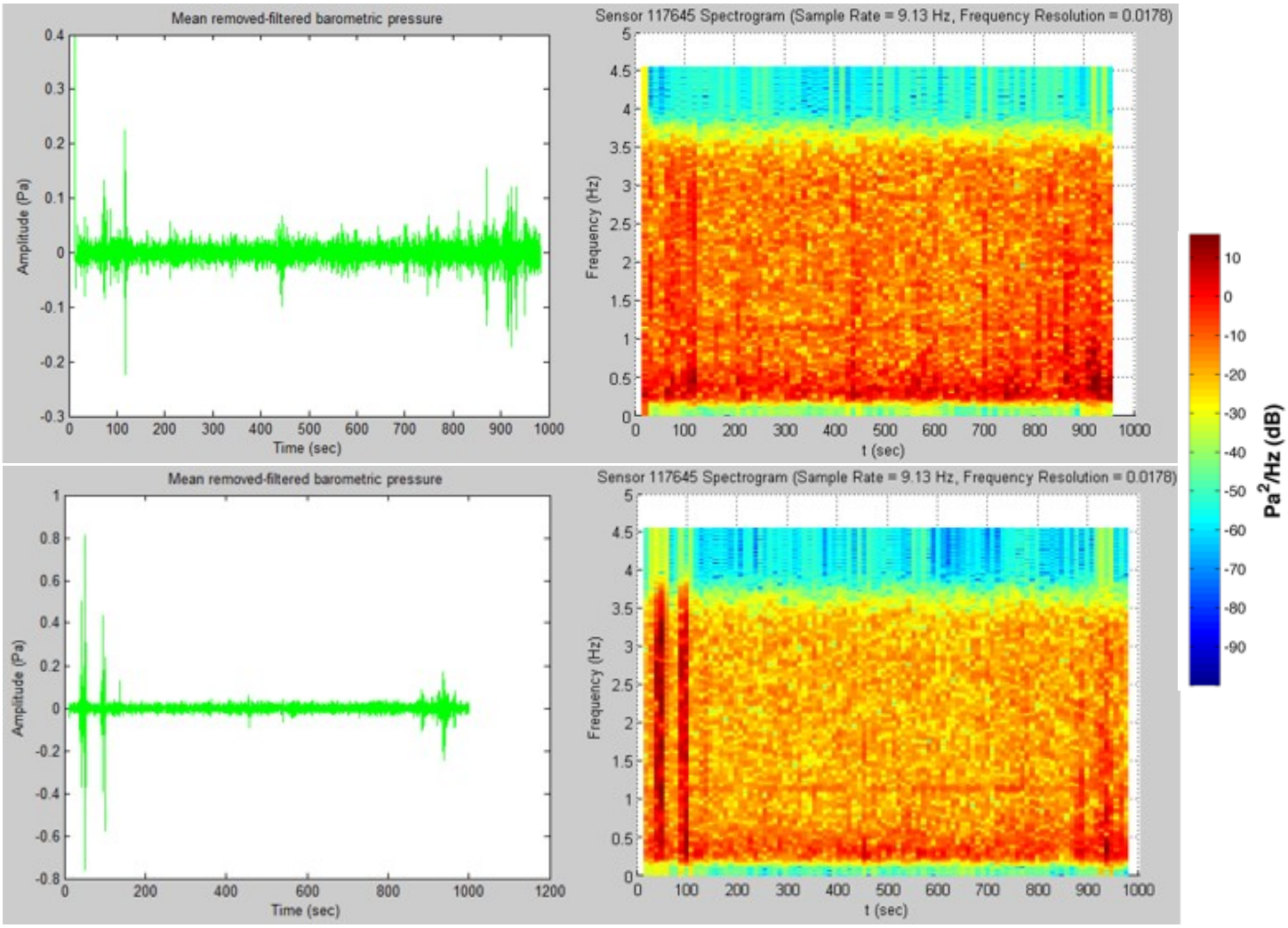

Figure 3.7 Filtered pressure and spectrograms of Experiment 2 (Barometer 1 top, Barometer 2 bottom)

3.3 Hull Municipal Light Wind Turbine, Hull, Massachusetts

On the eastern coast of Massachusetts in the peninsula town of Hull are two wind industrial scale wind turbines owned by Hull Municipal Light Company, Hull Wind 1 and Hull Wind 2, with respective capacities of 0.66 MW and1.8 MW. Hull Wind 1 is located at the Northwest tip of the peninsula (Pemberton, Figure 3.8), approximately 150 m from the local High School, and Hull Wind 2 at the base of the peninsula to the southeast (Rockaway, Figure 3.8). Hull is an urban setting and serves as a basis to test the infrasound monitoring system's capabilities for urban deployment.

Two experiments were conducted on 16 January, 2015 within immediate vicinity of Hull Wind 1. Experiment 1 was taken at a public parking lot within 100 m of the Hull Wind 1 turbine and the high school. Results will emulate those that would be found in the vicinity of the recreational fields, which are within 50 m of the turbine as well.

Experiment 1 sampled pressure for 1 hour in between 13:09 and 14:09, using Digiquartz Interactive 2.0 software and a 10Hz sample rate. The infrasound briefcase was placed on top of a car, and the data cable run through the open window to the car interior to protect the laptop from the snow which was falling and the high winds that were occurring on the test day. The wind speed was estimated at 13.5 m/s east towards the high school, however, the short distance between Test site 1 and Hull Wind 1 is expected to mitigate any attenuation and propagation effects from the wind. No wind filter was deployed in this experiment, due to the physical limitations posed by the test site.

Figure 3.8 Overview of Hull Wind 1 test sites. The high school is located to the northwest of Test site 2 and the wind turbine is directly north of the Test site 1. The recreational fields are located in the middle of the three. Test site 2 is located 600 m directly east of the turbine.

Experiment 2 was performed at a recreational field east of and outside the immediate area of Hull Wind 1 and the high school. The purpose of this test was to examine the wind noise reduction capability of the Digiport high performance pressure port wind filter for winds much stronger than those experienced in the Hoosac experiments. Due to the strong easterly wind occurring during the experiment and the significant distance between Test site 2 and turbine, the wind turbine signal can be expected to refract towards the earth in the eastern direction, theoretically making the signal stronger near the earth's surface at the measurement location than it would be for other wind directions.

The infrasound briefcase was placed on a bench overlooking the field and the turbine to the west, sampling pressure for 7 minutes, from 15:24 to 15:21 also using Digiquartz Interactive 2.0 and 10Hz sample rate. Due to the placement of the briefcase, the logging laptop was not protected from the elements and effectively shut off after 7 minutes due to thermal sensitivity of the battery. The spectral results of both experiments can be viewed in Figure 3.9.

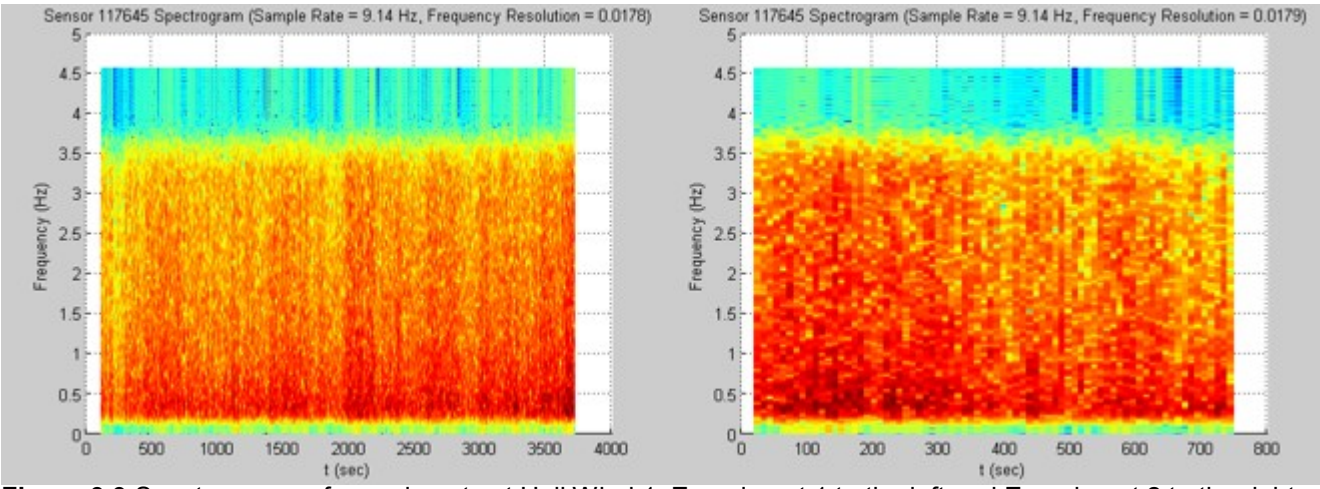

Figure 3.9 Spectrograms of experiments at Hull Wind 1, Experiment 1 to the left and Experiment 2 to the right.

From the spectrograms of the two experiments in Figure 3.9, there can be no infrasound signal distinguished in either spectrogram, both data sets being completely dominated by vertical bands of wind noise. Experiment 1 data yields insufficient evidence to conclude that an infrasound signal was present at the high school. It can be concluded from experiment 1 that the 13.5 m/s wind speed effectively drowned out any infrasound signal from Hull Wind 1. Experiment 2 data shows that the high performance pressure port was unable to filter out the wind noise at the appreciable wind speeds, and the easterly winds cannot be concluded to help propagate the signal to ground level.

4.0 Conclusions

The experiments aforementioned in this study reveal the necessary characteristics of a proper infrasound monitoring system. From the Oklahoma study, the results indicate that for rural deployment of an infrasound monitoring system in moderate wind speeds, multi-barometer sampling and the use of spatial array wind filters was sufficient to capture the infrasound emissions of a large-scale wind farm, with minimal physical obstructions to attenuate the signal. The large distances between the test sites and the wind farm provided incentive to test the infrasound monitoring system's capabilities for other rural and urban settings at shorter distances between test site and site of wind turbine(s).

The experiments at the Hoosac Wind Farm exhibit the capabilities of a portable infrasound system complete with multi-barometer sampling and wind filter. The portable and compact system was able to monitor the atmosphere for wind turbine emissions under conditions of moderate wind speeds, warm weather, and for rural deployment with minimal residences encompassing the turbines at short distances. Both the spatial array wind filter and the Digiport high performance pressure port were effective at increasing the infrasound signal-to-noise ratio and hindering the effects of wind noise on distorting the signal as displayed by spectrograms of both experiments. Although a bare barometer was able to capture the infrasound from the wind farm, the increase in signal clarity from the barometers connected to the spatial wind filter and pressure port suggest that for higher wind speeds, a bare barometer may not be adequate. The results also suggest that a Digiport pressure port, given its performance, robustness, and portability, may be ideal for infrasound monitoring in an urban setting.

The Hull Wind experiments reveal that a bare barometer was unable to pick up any infrasound signal from the Hull Wind 1 turbine, even for the short distance between barometer and turbine, due to the high speed winds and corresponding noise. For an urban setting deployment, the spatial array is limited by the physical constraints of the test area. The Digiport was unable to effectively reduce the effects of wind noise on any infrasound signal from the single wind turbine under conditions of strong wind. There is insufficient evidence to conclude the capabilities of the Digiport High Performance Pressure Head for urban deployment during conditions of low temperatures and high wind speed.

The results of the system in cold weather and urban setting catalyse further research of the high performance pressure head and spatial array in urban settings, as well as other wind filtering methods, including a signal analysis spectral cross-correlation method (Pepyne 2014) using multiple barometers. The results of the study also suggest that a micro-computer based logging system may be suitable for colder temperatures and increased robustness of the system. Such a device may prove to be a micro-computer or similar device, which has capabilities of logging barometer data using the custom software for multi-barometer sampling. Further research will have the overall objective of being able to monitor infrasound emissions from industrial scale wind turbines in various rural and urban settings and various temperature ranges, in order to make further valid assessments of how to correctly monitor wind turbine infrasound emissions. An ultimate goal of this research may be to associate the emissions with sound levels in order to characterize the levels in the contexts of human exposure and health.

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