SIMULTANEOUS COMPARISON OF THREE CO-LOCATED PIPE SYSTEMS FOR WIND-NOISE REDUCTION FOR USE WITH MODEL #4 CHAPARRAL INFRASONIC MICROPHONES AT FAIRBANKS, ALASKA

John V. Olson and Charles R. Wilson, Geophysical Institute, University of Alaska
Fairbanks, Alaska, USA

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ABSTRACT

Three identical Chaparral Model No. 4 microphones were used for the simultaneous testing of three different co-located wind-noise reduction pipe systems in a forested area in Fairbanks, Alaska. The first pipe system was a standard 305 meter long Daniels tapered steel pipe that is vented with a hypodermic needle every 1.5 meters. The second noise reduction system tested was the Los Alamos National Laboratory/Comprehensive Nuclear-Test-Ban-Treaty (LANL/CTBT) prototype system consisting of twelve radial porous hoses, each with a length of 15 meters to give a total aperture of 30 meters for the array. The third system was suggested by Doug Christie of the Provisional Technical Secretariat (CTBTO) at the Infrasonic Workshop at Bruyeres-Le-Chatel, France, in July 1998. This third system is a hexagonal array of six 30-meter long linear sections of 2-inch diameter rigid pipe. The six chords of the hexagon array are vented every 1.5 meters with a hypodermic needle and are separately connected to the microphone, at their centers, by _-inch diameter rigid pipe. The total aperture of the hexagonal array is 70 meters. Located at a common site in a wooded area near the University of Alaska, the microphone outputs are digitized at a 100-hertz rate using a 24-bit digitizer and transmitted using a spread-spectrum radio link back to the Geophysical Institute. There the data are logged to a network accessible computer disk in files that contain 10-minute segments of the data. Daily plots of the rms levels from each microphone are produced on a regular basis. Detailed analysis of the microphone responses is performed using power spectral density estimates based upon the Welch method. In general, it is found that during almost all wind conditions the hexagonal array achieved the lowest noise power. The LANL/CTBT array noise levels were usually the highest and the Daniels pipe produced intermediate levels of noise reduction.

Key Words: infrasonic wind noise reduction

OBJECTIVE

One of the four primary sensor systems identified as part of the Comprehensive Nuclear-Test-Ban-Treaty (CTBT) program is a worldwide array of infrasonic detection systems. Each infrasonic system is based upon an array of at least four microphones, including noise-reducing arrays, arranged in an isosceles triangle with 1-3 km sides with one sensor in the center. It is well known that the primary source of pressure fluctuations near the ground is produced by wind-generated turbulence. In order to reduce the background levels of this wind noise, arrays of pipes are often used in an attempt to average the wind turbulence over some area near the microphone. The pipe systems are vented to the atmosphere at regular intervals and connected to each microphone.

Several pipe configurations for wind-noise reduction have been proposed. The objective of this study is to test three commonly used noise-reducing arrays under arctic conditions using co-located microphones. Through these tests we will be able to identify the noise-reducing array that is the most efficient in reducing wind noise. We will also be able to describe the performance of each system over a variety of climatic conditions ranging from warm, calm intervals through rain and frost conditions and, finally, to the frigid arctic conditions with an accompanying snow pack covering the array. The three noise reduction arrays that we have chosen to study include: 1) a 305 meter long Daniels tapered steel pipe that is vented with hypodermic needles every 1.5 meters; 2) a system of twelve radial porous "soaker" hoses, each with a length of 15 meters; 3) a hexagonal array of six 30-meter long sections of 2-inch diameter rigid pipe.

Once we have identified the most efficient of the noise-reduction systems we plan to deploy the microphones in the standard CTBT geometry in order to test the array itself under arctic conditions at a high-latitude site. In time we plan to add a fifth microphone placed several kilometers from the central array in order to estimate the coherence length of the various infrasound signals. A wealth of natural infrasound is present in the interior of Alaska that includes microbaroms, mountain associated waves, auroral infrasound, earthquakes and volcanic eruptions. A review of these signals and their analysis is given at our home page: http://maxwell.gi.alaska.edu/~crw.

RESEARCH ACCOMPLISHED

While our research encompasses a sequence of ongoing tasks and goals we have begun to gather data on microphone and noise-reduction array performance during summer conditions. After acquiring and deploying the microphones and data-logging equipment we began to collect data in early May, 1999. Our data is sampled at a rate of 100 samples per second giving a 50 hertz Nyquist frequency. Upon analysis the data are low-pass filtered and decimated by a factor of 5 to give a 10 hertz Nyquist frequency. In the first phase of microphone comparison we have collected data continuously in order to compare the microphone responses to a variety of signals and weather conditions.

Three microphones with three different noise-reducing arrays were installed side-by-side at the Ballaine Lake site near the University of Alaska. The first noise-reduction array is a 305 meter long Daniels tapered steel pipe that is vented with a hypodermic needle every 1.5 meters. The pipe axis lies roughly east-west. The second array is the Los Alamos National Laboratory/Comprehensive Nuclear-Test-Ban Treaty (LANL/CTBT) prototype. This array consists of twelve radial porous "soaker" hoses, each 15 meters in length giving a total aperture of 30 meters. The third system is a hexagonal array of six 30 meter long linear sections of 2 inch diameter rigid pipe. The six chords of the hexagon are vented every 1.5 meters with a hypodermic needle and each chord is separately connected to the microphone by a 3/4 inch diameter rigid pipe from the center of the chord. The total aperture of the array is 70 meters.

Figure 1 shows a typical 24 hour segment of data in which the rms variation is computed over 10 minute segments from each microphone.

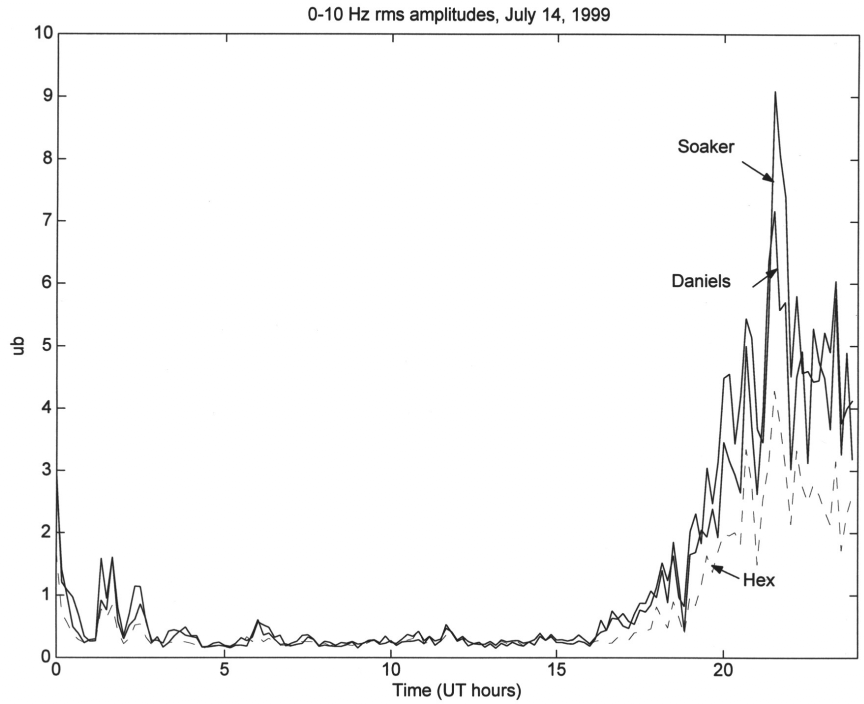

Figure 1. Rms signal levels computed from 10 minute segments for July 14, 1999. 0000 UT is 1600 local time. Typical of the data observed, the quietest intervals occur after midnight and the largest during the afternoons, local time. Note that through all wind conditions the hex array is the most effective noise reducer.

In this figure it can be seen that there is a diurnal variation in the rms signal level from each sensor. It should be noted that 0000 UT is 1600 local time. Generally speaking, the quietest intervals occur after midnight near 1200 UT and the noisiest during the windiest portion of the day which is usually the local afternoon. Figure 1 shows a consistent pattern found for all times and wind conditions and that is the relative efficiency in reducing the noise by each array. Almost always we have found that the hexagonal array is the most efficient in cancelling wind noise, followed by the Daniels array with the LANL “soaker” array the least efficient.

In order to evaluate the relative effectiveness of each of the noise-reducing arrays in more detail, we operated for a period with one of the three microphones open to the atmosphere with no noise-reducing array attached. This allowed us to compare the effectiveness of two of the noise-reducing arrays directly against an open microphone. Through the period the various arrays were swapped to give relative comparisons of all arrays against eachother and an open microphone. This procedure was necessitated since we have only three microphones. If a fourth microphone were available we could operate all three noise reducers simultaneously in comparison with an open microphone. Figure 2 shows a spectrum taken on July 7, 1999 at 0000 UT during which time one microphone was open to the atmosphere with only a 2-meter section of hose between the manifold and the outside atmosphere. The other two microphones were attached to the Daniels and hexagonal arrays. The wind conditions were moderate and the rms signal levels from the microphones ranged from 5 to 10 microbars.

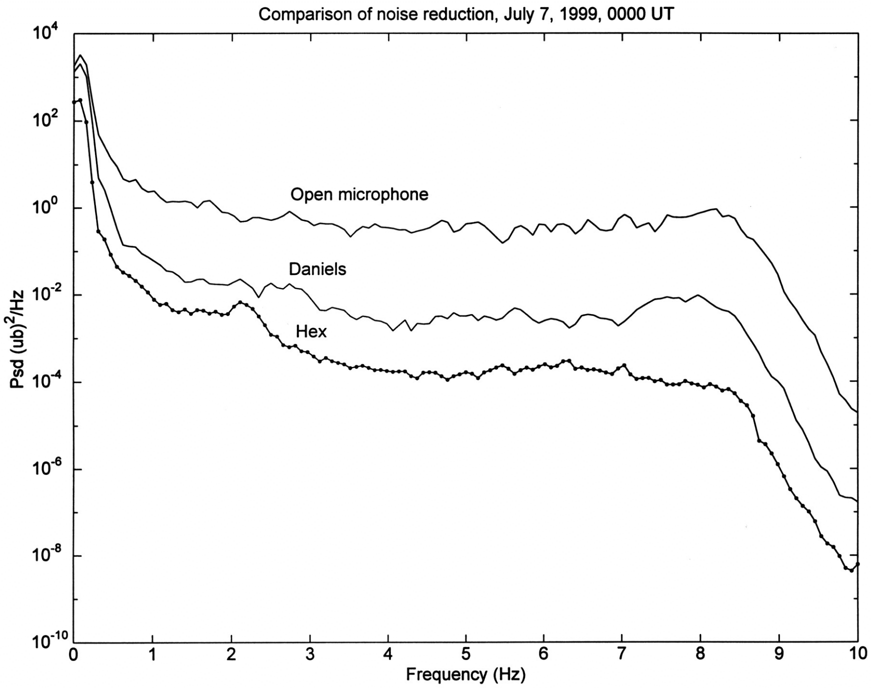

Figure 2. This figure shows power spectral density estimates of wind noise taken at 0000 UT on 7 July 1999. Noise levels produced by the Daniels and hexagonal noise-reducing arrays can be compared to the noise from an open microphone. It can be seen that the hex array is more effective than the Daniels array across the entire 0-10 hertz spectrum.

As can be seen the spectrum is dominated by variations at very low frequencies. While both noise-reducers are effective it can be seen that at all frequencies across the band from 0 to 10 hertz the hexagonal array is the most efficient in reducing the wind noise reaching levels a full order of magnitude less than the Daniels. Note the small increase near 2 hertz in the hexagonal response. This is characteristic of the hex array itself. The presence of resonances in the spectrum of the response of various acoustic filters was shown by Alcoverro, 1998.

Figures 3 and 4 show spectra with the other two possible combinations of microphones compared to an open microphone. Figure 3 shows a spectrum taken on June 29, 1999 at 0000 UT during which time the hexagon and "soaker" arrays were connected to microphones. Again, moderate winds of a few miles per hour were present. Again the hexagonal array is more efficient in reducing the wind noise at all frequencies between 0 and 10 hertz. Note also the continued presence of the resonance near 2 hertz. Figure 4 shows a spectrum taken on July 12, 1999 at 0000 UT. In this case the Daniels and "soaker" arrays were connected to microphones. In this case the responses are similar with the Daniels showing increased rejection of wind noise near 4 hertz.

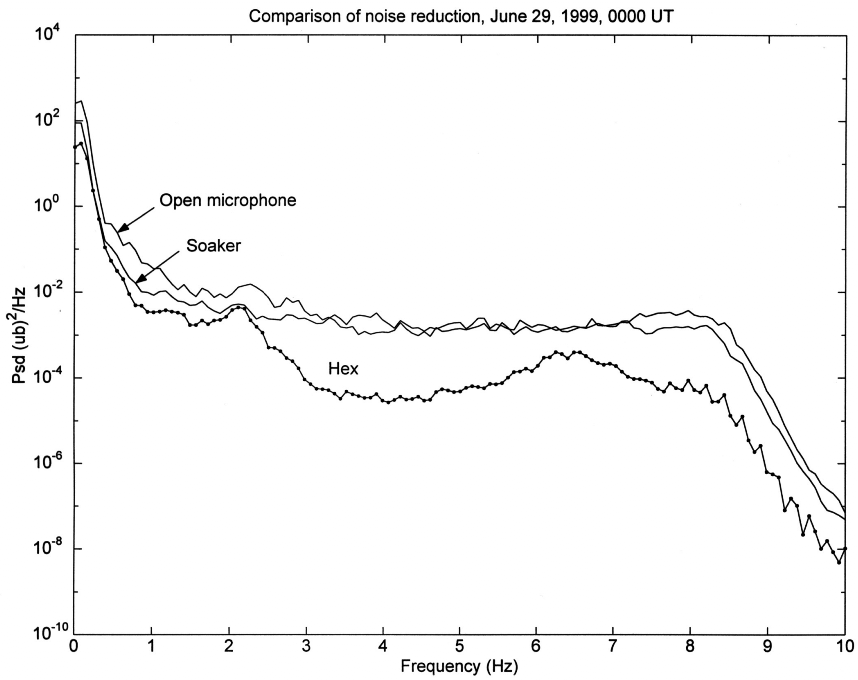

Figure 3. This figure shows power spectral density estimates of wind noise taken at 0000 UT on 29 June 1999. Noise levels produced by the LANL prototype ("soaker") and hexagonal noise-reducing arrays can be compared to the noise from an open microphone. It can be seen that the hex array is more effective than the "soaker" array across the entire 0-10 hertz spectrum. Note the spectral increase near 2 and 6 hertz in the hexagonal array. These are probably due to resonances in the array.

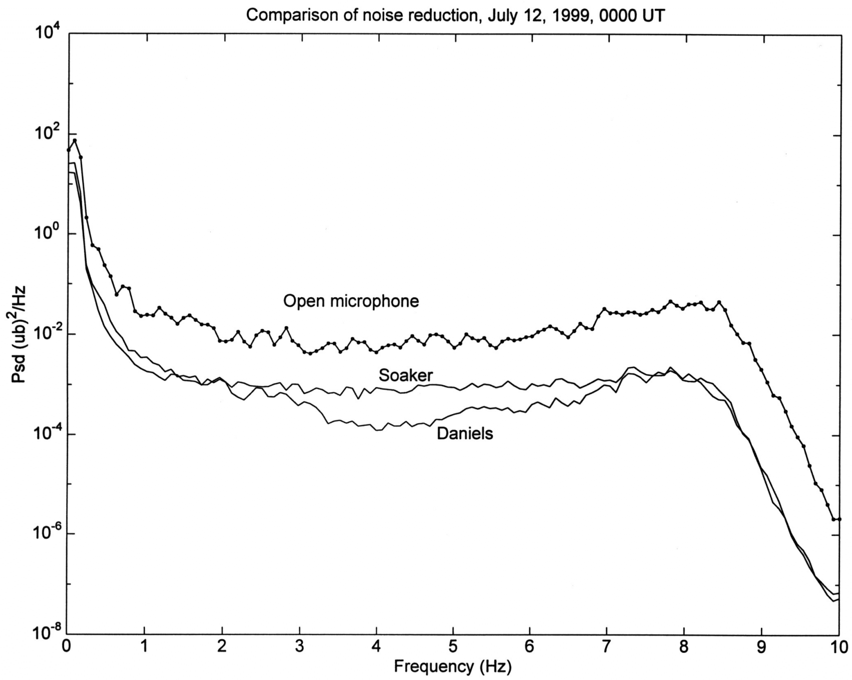

Figure 3. This figure shows power spectral density estimates of wind noise taken at 0000 UT on 12 July 1999. Noise levels produced by the Daniels and LANL prototype ("soaker") noise-reducing arrays can be compared to the noise from an open microphone. It can be seen that the Daniels array is more effective than the "soaker" array across the entire 0-10 hertz spectrum.

CONCLUSIONS AND RECOMMENDATIONS

The examples given above show a consistent result: the hexagonal array is the most efficient in reducing wind noise when compared to a linear Daniels pipe or the LANL/CTBT array of "soaker" hoses. Under most conditions data from the hexagonal array show power spectral density levels that are generally two orders of magnitude lower than those from an open microphone and usually an order of magnitude below those shown by the Daniels and LANL/CTBT "soaker" arrays.

With these data in hand we intend to proceed to the second phase of our research program that includes installing four microphones in a triangular array with one microphone at the center of the triangle as prescribed by CTBT specifications. It is our intention to install the hexagonal noise reducing array at each of the microphone sites.

REFERENCES

Alcoverro, B., Acoustic Filters Design and Experimental Results, Proceedings of the Informal Workshop on Infrasounds held in Bruyeres-le-Chatel, France, Published by Department Analyse et Surveillance de L'Environment, July 1998.