COMMENTS ON RECENTLY PUBLISHED ARTICLE, "CONCERNS ABOUT INFRASOUND FROM WIND TURBINES"

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The July, 2013, paper in *Acoustics Today* entitled "Concerns about Infrasound from Wind Turbine Noise" by Geoff Leventhall [Volume 9, Issue 3, pp. 30-38] seems to be centered on proof by assertion. The argument appears to be an assertion that infrasound from wind turbines cannot possibly affect people because (1) infrasonic body-generated sound is 20 dB or more greater than the measured levels from wind turbines and (2) that atmospheric noise in the wind turbine infrasonic frequency range is on the order of or greater than wind turbine noise.

This process can be thought of as something like how heated air will travel from a supply duct on the floor of a room to a ceiling return air duct and thereby fill the room with heat.

Regarding the first assertion, it is true that environmental infrasound is of the same order or greater, or sometimes less, than the infrasonic emissions of wind turbines. The second assertion is a half-truth. The signals impinging on the inner ear are 20 dB greater but this energy does not readily couple to the inner ear because its entry point is right next to the round window. Sound, including wind turbine sound, enters through the outer ear, and travels to and through the middle ear which matches the impedance of an acoustic wave in air to the impedance of an acoustic wave in the fluid-filled inner ear, preventing what would otherwise be a 29 dB loss. The wave travels through the inner ear from the oval window to the round window, which provides a compliance that permits the fluid in the inner ear to oscillate up and back in sync with the infrasonic acoustic pressures. This process can be thought of as something like how heated air will travel from a supply duct on the floor of a room to a ceiling return air duct and thereby fill the room with heat. In contrast, the body-generated sound entry point is right next to the round window which is something like having an HVAC supply duct entry point right next to the return-air grill; the in-room flow is short-circuited and the room is difficult to heat.

The point is that the acoustic pressures (applied via the stapes) from the wind turbine may be as great, or greater than the body-generated pressures that reach the whole of the inner ear. Professor Leventhall then goes on to assert that because the noise levels are greater than the signal, the signal won't be registered in the inner ear. These assertions, of course, are not necessarily true.

Seasickness symptoms are one set of symptoms exhibited by persons affected by wind turbine noise, and there is evidence that symptoms occur more strongly when there is just one or two nearby turbines so that one or two infrasonic "tones" are present. In contrast, if there are several nearby asynchronous turbines, then there are typically no clear tones—just random noise, and the problems with the seasickness symptoms near to wind farms appear to be less. This finding relates directly to Leventhall's assertion that atmosphere infrasound, which is random, masks wind turbine-generated infrasound. A tonal signal with an amplitude that is of the same order as the noise can easily be detected in the presence of that random noise via autocorrelation methods, or via a tuned circuit, etc.

There is evidence that the seasickness response of the body to the sensing of accelerations is tuned to the fundamental frequencies generated by large contemporary wind turbines. Figure 1 shows what has been termed the nauseogenic region, developed by the Navy to better understand and deal with seasickness (Kennedy *et al.*, 1987). It relates linear acceleration levels (amplitudes) and frequencies to the time it takes for 50% of test subjects (upper curve) or 10 % of test subjects (lower curve) to vomit. For example in Figure 1, at 0.63 Hz it takes about 3.5 m/s^2 acceleration to be on the "8 hour" curve. Newer wind turbines have fundamental rotational speeds of around 0.2 Hz and, being three-bladed, their blade passage frequencies are three times the fundamentals, so their frequencies are well into the nauseogenic region shown in Figure 1. Taking Figure 1 to be a tuned circuit, it does not represent a high Q but it provides at least a little selectivity; certainly enough to not reject the possibility or probability of detecting a tone in this frequency range when the levels of the tone(s) and the noise are by the same order.

But the Navy's seasickness study is for acceleration; the wind farm emissions are pressures. It is the otoliths in the inner ear that sense horizontal and vertical acceleration, so a natural question is whether or not there is a relation between the seasickness symptoms generated by acceleration at say 0.63 Hz and the symptoms generated by acoustic pressures emitted at 0.63 Hz. Part of the answer relates to whether the otoliths directly measure acceleration or if they measure force generated by the inertia of a mass. The answer is that both otoliths measure force generated by an inertial mass (Grant and Best, 1987), and that the utricular otolith which measures primarily horizontal acceleration responds to the force generated by an inertial mass virtually identically to the way it would respond when immersed in acoustic pressure. As recent research has shown (Uzun-Coruhlu *et al.* 2007), this result occurs because, the utricular otolith is only "hinged" to the temporal bone, whereas the saccular otolith and the classical model for both otoliths has their whole base firmly attached to the temporal bone (Grant and Best). In the classical model, the base contains the hair cells which extend into a gel region that sits above the base. Above the gel region is a region filled with calcium carbonate crystals called otoconia, such that this layer has about double the density of the gel layer and the fluids that fill the inner ear. So acceleration of this mass creates shear forces in the gel layer and these forces cause the hair cells to generate signals. But in the utricular otolith variations in the outer surface properties will result in localized stretching either as a result of the inertial mass or its being "immersed" in a pressure field.

One can show that the force generated on the otolith is roughly identical between an acoustic pressure of 70 dB at 0.6 Hz and an acceleration of 2 m/s^2 at 0.6 Hz. So we have the following facts: (1) The otoliths sense acceleration in the region of about 10 Hz and below, (2) Accelerations of about 2 m/s^2 generate about the same force on the otoliths as do acoustic pressures of about 70 dB, (3) The utricular otolith senses force in about the same way for both acceleration and pressure and (4) There is evidence of a tuned response to accelerations that relate to seasickness. Therefore we come to two questions. The first question is, if the otoliths sense force generated by acceleration of a mass virtually identically to how they sense the force generated by acoustic pressures, and the force generated is essentially the same between moderate wind turbine pressures and moderate accelerations, how does the ear sense these accelerations if it cannot sense acoustic pressures that create the same force; both in the presence of the same atmospheric noise? The second question is to what extent does signal processing in the ear and/or in the brain play in the detection of these signals? From the ability of the utricular otolith to sense the force resulting from acceleration in the presence of random acoustic noise, one would expect the same signal processing to detect signals generated by the same otolith in the same way by an acoustic tone in the presence of the same random acoustic noise. Moreover, as Figure 1 shows, current wind turbine frequencies are well into the frequency range of what can be thought of as a tuned filter that affects the prevalence of seasickness.

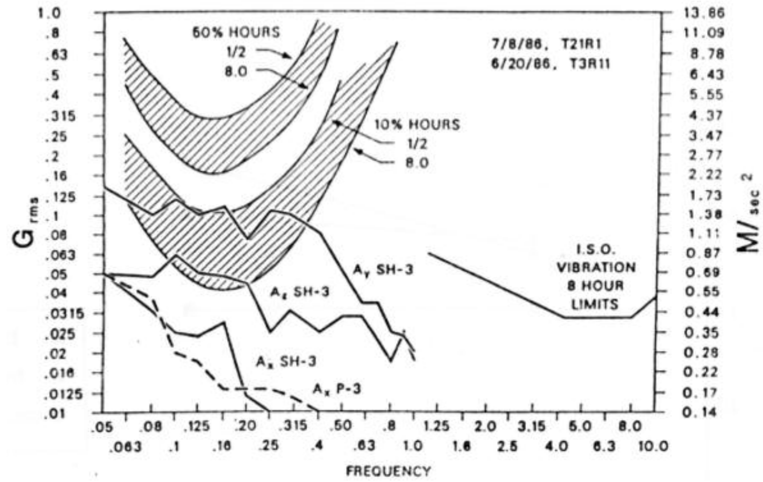

Figure 1. The Navy's nauseogenic region (after Kennedy et al., *1987)*

In terms of the ear/brain signal processing capability, the entire inner ear occupies 1 to 2 cubic centimeters and essentially performs a Fourier transform of audio signals, senses linear acceleration in three directions in addition to the acceleration due to gravity, senses angular acceleration on three orthogonal axes, and for noise immunity the sensing of angular acceleration and horizontal acceleration operate push-pull between the two ears. So the assertion that the ear detects signals in the presence of noise with no tuned circuit or "smart" signal processing is a questionable assertion.

The second assertion is that internal body-generated infrasound is in the same frequency range as is the wind turbine infrasound, and is higher in level by 20 dB or more. As noted, these signals enter the inner ear right next to the round window and couple only a fraction of their available energies to the full space of the inner ear. And again, the assertion is that it is a "dumb ear" and a "dumb brain", both using just the levels of the signal (wind-turbine-generated acoustic pressures) and the level of the noise, both without any signal processing. But in this case, unlike the random atmospheric noise case, the body generates the heartbeat and regulates respiration; the brain knows when these signals are occurring. Professor Leventhall's assertion, with absolute certainty, is that the brain doesn't use this information.

Professor Leventhall goes on to assert with absolute certainty that no problems are generated by low frequency sound whatsoever, and rather that all of the public outcries result from people being told that they have a problem. He decries people who have spoken out that there is a problem, but says nothing of the wind developers that have told the public that the sound is "less than a quiet refrigerator." The point is that for every extreme individual opposed to wind farms there are equal actions by proponents of wind farms. The proponents use what can only be termed "scientific spin" with such slogans as "If you can't hear it, it can't hurt you." As if, if you can't hear ultrasonic noises, they can't hurt you, or if you can't see infrared or X-rays, they can't hurt you. The situation is rapidly becoming airport-esque. Soon the siting of every new wind farm will be a battle like the siting of a new airport or even just a new runway. The answer is there is truth on all sides. Certainly some people are influenced by what they read and hear and their response is partially or even fully based on non-acoustic factors. But the assertion that every single person world-wide is being affected only by non-acoustic factors in totally unfounded.

The solution can only come from a broad research program participated in and guided by all parties with a material interest. Professor Leventhall, although his proof was mere assertion, says, "Whilst there are instances of genuine noise problems from wind turbines, the emphasis on infrasound and its supposed effects on health, distracts attention from solving these." He categorically rules out research in the infrasonic region; that research is unacceptable to him. Around the world there are people who report that they can sense the turning on and off of the wind turbines without any visual or audible clue. It would be very easy to test the veracity of these statements if a wind farm would cooperate in the testing by turning on and off the wind turbines in a double blind test. Duke Energy was asked to turn on and off their wind turbines for a small research project funded by the state of Wisconsin. But Duke Energy, the world's largest energy provider, said they could not participate because of the lost revenue from the eight turbines that make up this small farm. If one assumes 10 cents per kilowatt hour, a figure that seems quite high for electricity at the source, then 8, 1.5 Megawatt turbines all together (all 8) earn a total of $1200 in revenues per hour. I say again, the solution can only come from a broad research program participated in and guided by all parties with a material interest.

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