Conference Glasgow 2017 :

The Wind Turbine "Noise" Problem - Is it Infrasound, Low Frequency Noise, or Amplitude Modulation?

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INTRODUCTION

I should run through the letters so that you know where I'm coming from.
Acoustic Impedance of liquid He3.
I have over 50 years experience and I've been working exclusively on wind turbine noise most of this decade.
That's enough about me.
So why am I am giving this presentation here in the city of Glasgow tonight when I hail from the Isle of Wight? Well it's partly due to a particularly contentious planning application by SSE to extend by a further two years their consent for "testing" of three obsolete offshore turbines at SSE's "National Offshore Wind Turbine Test Facility". Only one tubine is operational at present, a 7MW Mitsubishi "Sea Angel" (devil…), but by itself it is already seriously affecting the health of some local residents, including several who live over 3 km from the turbines. The number of complainants is 17 and rising; two of them are young children.
Their symptoms are…………nausea, headaches, vertigo, high volume nosebleeds, loss of balance, coordination problems, bedwetting and bed soiling in previously clean children, epilepsy.
Melvin is sensitive, I'm not.
The answer to the question in the title is probably all three. I have concentrated on the infrasound because I believe it is the easier one to prove, because it is the cause of the most serious symptoms, and because the wind industry have been determined to deny the existence of infrasound, let alone its effects. The harmful noise seems to be roughly in the frequency range 0.3 Hz to 30 Hz
Whats a Hz? c/s s/c. I'll explain dBs a bit later on.

2

INFRASOUND YOU CAN SEE

Would you like to see some infrasound? UCL physicist Helen Czerski has done a superb programme for the BBC, with much of it on infrasound. It's still available on BBC iplayer.
The candle flames illustrate very nicely how the air moves, by a cm or so, at the 20 Hz frequency the loud speaker is driven. The lack of sound is a plus, because the loudspeaker is banging from one end of its travel to the other and can clearly be heard doing so, because of the audible harmonics it produces. I imagine Helen's eardrums were quite uncomfortable.
The frequencies we need to consider for wind turbines are from 0.2 Hz – in pre-1960 speak that's 0.2 cycles per second, or 5 seconds per cycle. The ear defenders probably didn't give much protection at 20 Hz, as I expect Mariana will explain later.

3

IT'S HARD TO ADMIT TO SERIOUS ERRORS…(6)

- Asbestos
- Radium Girls
- Tobacco
- Thalidomide
- Primodos
- Wind turbines

Infrasound and Low Frequency Noise from wind turbines inflict serious adverse health effects on a significant minority of wind farm neighbours.

Dr Leventhall:

"I can state quite categorically that there is no significant infrasound from current designs of wind turbines. To say that there is an infrasound problem is one of the hares which objectors to wind farms like to run."

Dr Yelland:

"I firmly believe that the primary cause of the more severe symptoms of Wind Turbine Syndrome is the very high levels of infrasound and low frequency noise energy emitted by wind turbines."

Going back to Melvin's last slide, there are many hard working, honest, intelligent people in the wind industry – and there are some very clever, and well educated, scientists and engineers there too.
In four of the six cases Melvin listed there have been guilty parties in government as well as the industries, particularly in unelected government. A lack of technical competence in elected government, both local and national, is also a problem.
Big business, huge industries, immense profits.

The reason for listing wind turbine ILFN along with all these other catastrophes was not because it has maimed or killed anyone yet, although of course it has killed animals. It is because, in all the cases listed the victims have had to fight a very unequal battle against big business, and in most of them, including the wind energy case, against their own Governments too.

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THE INDUSTRY'S "ENHANCED ANNOYANCE" THEORY: DR LEVENTHALL SAYS IT'S ALL YOUR OWN FAULT

The wind industry now accepts that people living close to turbines are "more annoyed" by turbine noise than by other noise sources at similar levels, but explains this by stating that those who complain have some other reason to dislike turbines. The industry has borrowed a medical-sounding phrase for this – the "nocebo effect", which rhymes with (and means the opposite to) the placebo effect. The wind industry claim that weak-minded wind farm neighbours listen to rabble-rousers like me and Melvin, and by some strange psychosomatic process their dislike of the appearance of turbines makes you more annoyed than you ought to be about the noise they make. That's the *"enhanced annoyance"* theory. Or maybe you worry about your property values. Or even better, you are *climate change denialists* – and that's a powerful put-down, because it rhymes with holocaust denialists.
Unbelievably this slide is not taken from a children's comic; it opens a conference paper presented by Leventhall at the major biennial European wind turbine noise conference, WTN2017.
In truth of course the problem is not "enhanced annoyance"; it is serious harm to human health. The symptoms are variable from person to person, but include motion sickness (but without the motion), nausea, sleep deprivation, headaches, nosebleeds, dizziness, and bedwetting and bed soiling by previously clean children, etc. etc.
The wind industry has built a huge library of pseudo-scientific papers, "peer-reviewing" each others papers and declaring, in front of wind farm noise victims like you, and in their "expert witness" statements at planning appeals that there is *"no reliable evidence of any adverse health effects."* This assumes that everyone who reports WTS symptoms is either lying or imagining them. Amazing coincidence that all round planet earth, all different countries and languages, they all imagine the same symptoms.
Leventhall is right in one respect though – people made ill by wind turbine noise do understandably become very annoyed. But not for the reasons given by the wind **industry's *** psychobabble**. Having made numerous complaints about serious adverse health effects dismissed and ignored over several years by developers, local government and central government alike, and eventually having to abandon the family home, is rather annoying. Probably far more annoying than amplitude modulation.
But is it remotely credible that high volume nosebleeds, bed-wetting, bed soiling, vertigo, a sensation of "thumping" in the head or chest, extreme hypertension (hence the nose bleeds) could all be caused by a dislike of turbines? And is it any more credible that young but previously clean children suffering from bed-wetting and bed-soiling would hold politically incorrect opinions about **wind energy? *****

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ABORTED MINK PUPS IN A FREEZER

Does anyone recognise the picture? Kaj Ohlsen's mink farm in Denmark, a few hundred metres from a wind farm, suffered as soon as the turbines started generating the mink started fighting - to death. He persuaded the wind farm operator to switch off the turbines, whereupon the fighting immediately ceased. The wind farm operator sought advice, and was told that it couldn't possibly be the the turbines that caused the fighting. And the turbines were turned on again. The fighting immediately resumed. Proof by temporal **temporal coincidence that it was the turbines.** Kai has moved his farm; he had already had to move his family further from the turbines. But when the sows gave birth the abortion rate rose from the normal 5% up to 30%. This brought turbine building in Denmark almost to a halt for a year.

A Lincolnshire farmer used to graze his sheep close to the Bicker Fen turbines in Lincolnshire. He found that his ewes' abortion rate went up from the usual 5% to 10% up to 30%. The next year he grazed the same sheep elsewhere, away from any turbines, and the next lambing went back to the usual 5% miscarriage rate.

Were any of these animals annoyed by the turbine noise, and if so did they allow their denialist views on climate change to enhance their annoyance? I don't think so, but I do I think their health was seriously affected, and in some cases terminally affected, by wind turbines. Why should we – or Governments, or developers – assume our own species has a unique immunity to wind turbine ILFN, when there is plenty of anecdotal evidence that other species are harmed by it. The industry claim that the evidence is "anecdotal", so can be ignored. The precautionary principle however would dictates otherwise. Furthermore the AHEs suffered by three of the species listed on the slide have been the subject of scholarly papers in peer-reviewed academic journals.

The evidence of harm to non-human species * clearly demolishes the wind industry's "enhanced annoyance" theory.**

The human evidence, as reported by Hunterston victims, is impressive. The industry call such evidence anecdotal, which is deeply insulting to the victims.

When Rita or Denise are inside their houses they know when the SSE 7MW Mitsubishi offshore turbine is operating, even though they can neither see nor hear it at 3.3 km away. When they move away for respite – which they often do – their symptoms subside.

My next topics are the measurement of infrasound and how wind turbines generate it. We now have the funding to purchase two measuring systems based on class 1 calibrated and certified measurement microphones, and unlike the wind industry in general, and SSE in particular, we will be very happy to share our data, not just with the residents of the homes that host the equipment (WHICH SSE HAVE JUST REFUSED HAVING AGREED TO SUPPLY THE DATA PRIOR TO THE MEASUREMENTS.)

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A, C , G , Z WEIGHTING

But first it's how you don't measure it. For the Government and the wind industry, A-weighting rules for wind turbine noise measurements and noise limits. It should not, as it was designed to replicate the variation in the sensitivity of the human ear to low levels of sound. C-weighting is little better as it still ignores infrasound; like A-weighting, it is intended to replicate the response of the human ear, but to higher levels of sound. G-weighting is intended to replicate the varying response of the human ear to frequencies from 1 to 10 Hz, for no particular purpose that I'm aware of. It is intended to replicate the human ears **relative** response to infrasound, but drops of so rapidly, particularly below 1 Hz, which therefore understates any blade pass or blade stall events, which occur at less than 1 Hz.

The only weighting suitable for investigating AHEs from turbines is no weighting, usually called Z or zero weighting. This is because we are no longer talking about audible noise. (ETSU takes care of that, and offers reasonable protection to WFNs if the WF is genuinely ETSU compliant, albeit with little margin.) Not only is turbine infrasound essentially inaudible because of its low frequency; the pathways for its AHE's are not confined to the auditory system. The vestibular system is affected, and body cavity resonances occur. The human auditory system copes with a huge dynamic range of sound pressure, by an effective automatic volume control, formed by the ossicles of the middle ear, with the highest levels clamped by the stapedius muscle. There is no such protection from high levels of infrasound; what matters therefore is the power level of the pressure wave.

For non-specialists, if you've done arithmetic and geometric series in your school maths, then an arithmetic series use normal counting, whereas a geometric series use logarithmic counting. Every 10 dB (=1 Bel, but Bels are never used) means a factor of 10, so 20 dB means a factor of 100. The 120 dB range of my chart, for example, is a ratio of 1,000,000,000,000. The unit isn't specified, as the chart shows weighting factors. But 10 dB more than a banana is 10 bananas, and 20 dB more than a banana is 100 bananas, etc. And the -40 dB of G-weighting between 1Hz and 10Hz is a factor of 10,000.

My next topic is the wind turbine noise spectrum.

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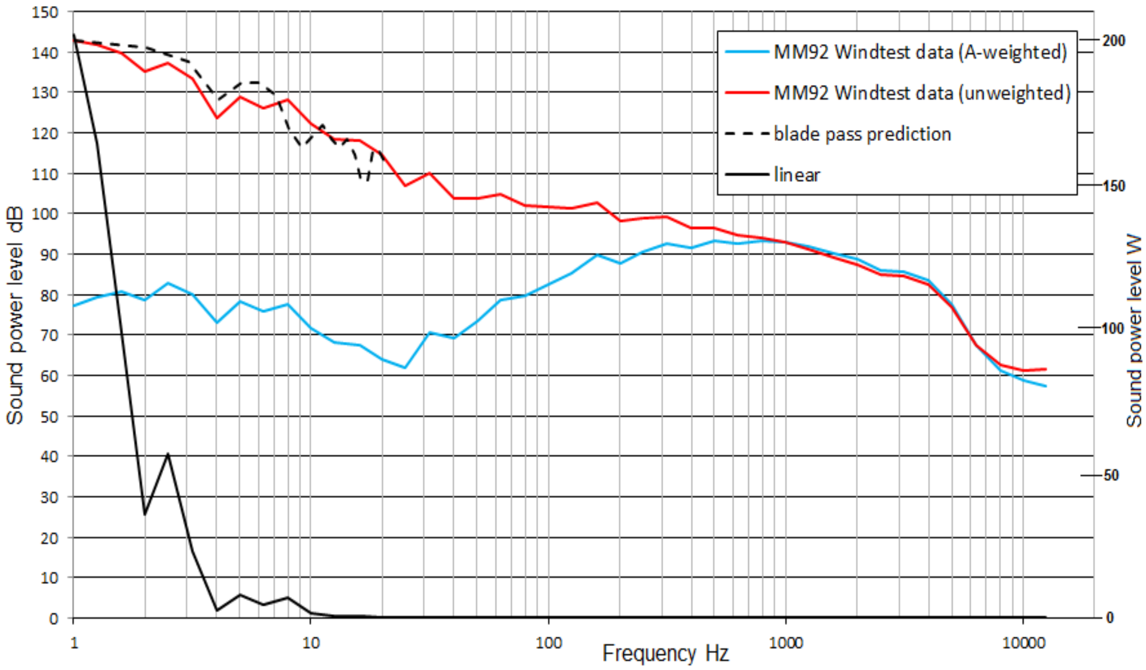
SENVION MM92 TEST DATA

This chart was plotted from measurements by Windtest GmbH for the turbine's manufacturer, RePower, now Senvion. The MM92 is a popular 2 MW turbine.

The purpose of the chart is to show (a) how the removal of A-weighting drastically affects the noise power vs frequency plot and (b) how plotting on a linear instead of a log scale shows how much of the noise power is concentrated in the Iow infrasound region. And this chart doesn't even go below 1 Hz; the power would still be increasing if it did.

Important – this chart is from working daytime measurements, certainly no **EAM and probably not much AM**. [explain]



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WIND SHEAR

Next topic wind shear.

Vertical wind shear is always present and often significant; it is simply the variation in windspeed with height above ground. It is site dependent, and shows a marked diurnal variation. At night, or more precisely between sunset and sunrise, the wind shear is greater than it is between sunrise and sunset. This is because when the sun heats the ground the ground heats the air just above it, which becomes less dense than the air further above, so rises up, to be replaced by colder air, etc. Think of a kettle with the element at the bottom; that stirs the water in a similar way, so it all gets heated. With the element at the top the water below it would be heated only by conduction, with no convection.

At night, the ground is no longer heated by the sun, but instead loses heat by IR radiation. So it cools the air closest to it, which becomes denser, and stay there. So there is none of the vertical turbulence that occurs during daylight hours. This greatly reduces the vertical viscosity of the air; think of it as being in layers with lubrication between them at night but mixed together by vertical turbulence at night. So the wind shear is greater at night. So what?

(Stubby tower effect)

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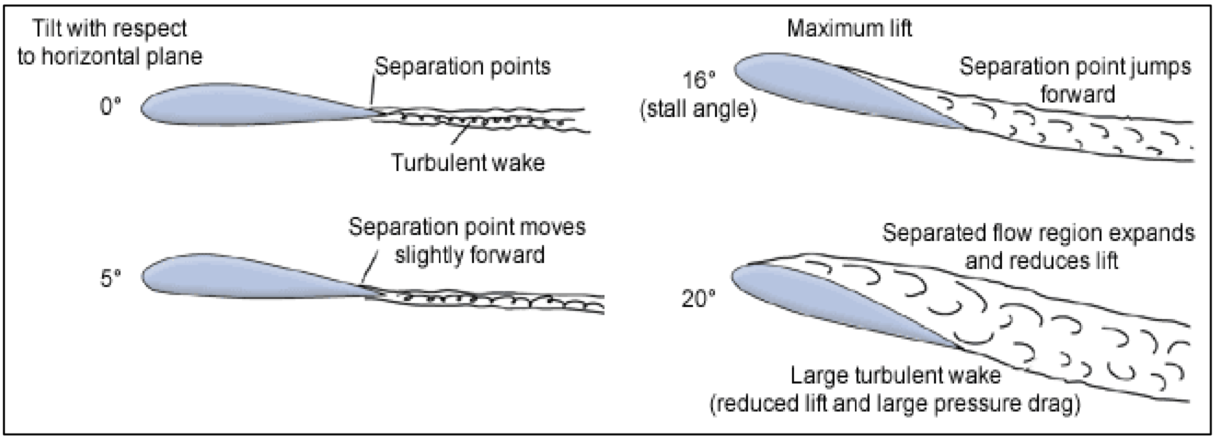
AEROFOIL ATTACK ANGLE

Now for some simple aerodynamics. Think initially in terms of aeroplanes, then wind turbines. The angle of attack is how far from parallel the wing is to the airflow. At 0º there is little noise, mostly from the trailing edge, and no lift. A degree or would do to maintain height at constant speed. In a WT this is equivalent to driving the turbine off the grid just enough to "keep up with" the wind. At 16º there is maximum lift (assuming no stall) and maximum noise. This would be climbing at maximum rate after takeoff. In the turbine case, having reached maximum turbine power, the angle of attack is then decreased to avoid exceeding maximum power, and indeed feathered completely at 25 m/s windspeed. The blade angle is of course adjustable, but it cannot be adjusted quickly enough for within-cycle variation. It is therefore optimised to be correct around hub height, but will be

higher than optimum at blade zenith (tip up) and lower than optimum at blade nadir (tip down). At night, when wind shear is high, the blade may not "keep up with" the wind enough to avoid stall.
Oerlemans



Aerofoils at increasing angles of attack (credit: NASA).

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The 2013 RenewablesUK report on amplitude modulation is something of a curate's egg, as it has some pretty bad science in it. But the first paper in the report, by Siemens Wind Turbine Engineer Stefan Oerlemans, gives a good explanation of "blade stall at zenith". Oerlemans shows, using long established and well proven aerofoil model (the BPM model), how wind shear causes blade stall, and calculates the increase in noise level and the decrease in noise frequency
Oerlemans model does correctly predict a 6 dB (total) modulation height when in stall, and I agree with his analysis. His approach proposes a simple theory based on well established aerodynamic theory and practice, and his theory predicts the lower levels of EAM often observed. He is a wind industry engineer (Siemens), but I would still call his theory credible rather than just plausible. However he consider only what happens to the air around a blade when it stall; he doesn't consider what happens to the blade itself.

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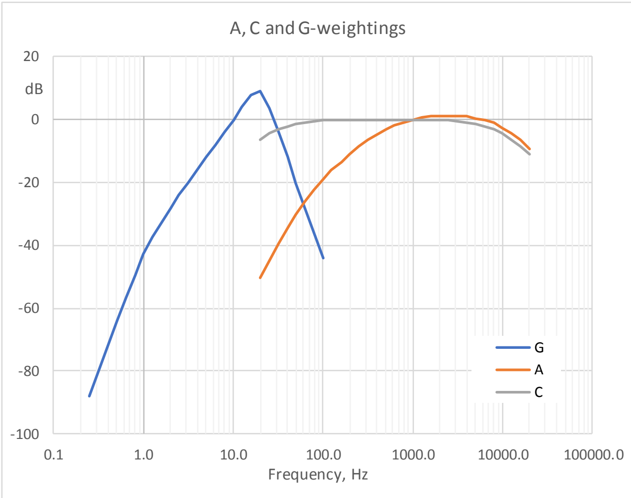
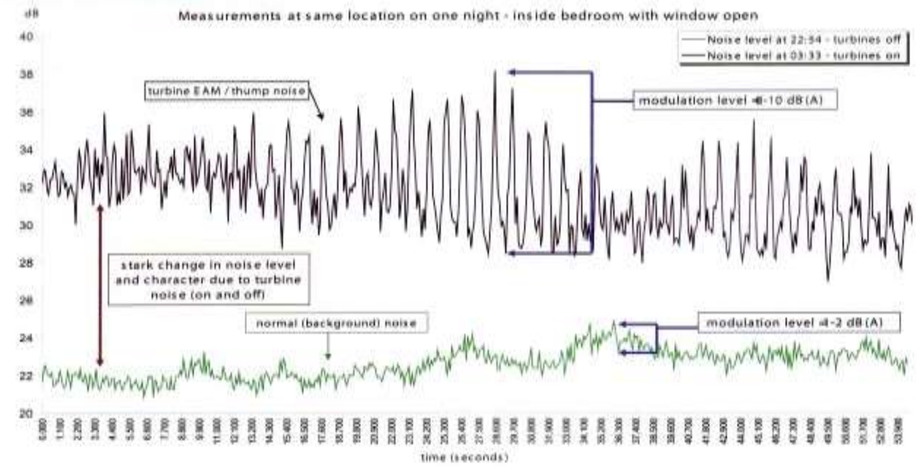
EXCESSIVE AMPLITUDE MODULATION
Amplitude modulation of wind turbine noise is easily explained. If you are fairly close to a turbine then a blade moving towards you will produce more audible noise than when it moves away, and the average frequency will increase too. It's a "Doppler effect" on both frequency and amplitude, like a non-stop express going through a station. Applying physics to it gives the observed results; an amplitude variation of about 2-3 dB. Amplitude just means how loud it is, and dBs are just a measure of the amplitude variation (about which I will have more to say later). This is all rather well explained by Oerlemans in the first paper in the notorious RenewableUK "Research" report. He goes on to explain how "blade stall at zenith" could increase the modulation height, and observes that stall is most likely to occur at night, when wind shear is higher. (just believe me, it's certainly true). He even does some credible sums to show that this could account quantitatively for the observed night time values of EAM, up to 6 dB or so, and quite accurately predicts the frequency increase on the "downsweep" of a blade.



Unfortunately Oerleman's paper is spoilt a bit because he does some entirely appropriate calculations which show that blade stall increases the modulation from 3 dB to 6 dB, yet concludes at the end *"However, if local* *stall occurs, the resulting noise characteristics can be very similar to the EAM characteristics mentioned above, depending on the size of the stall region. Thus, it can be concluded that local stall is a plausible explanation for EAM."* Yet modulations heights much greater than 6 dB have been measured, more even than the 10 dB seen in Mike Stigwood's chart here.



In §3.3.2 of his paper Oerlemans cites three reported measurements of increase in AM due to stall as "somewhat lower than 10 dB, up to 20 dB (light stall) or 30 dB (deep stall) which he sets a target of 10 dB for his model to predict. That's a bit low in my opinion. The he states that *"7 dB is added … in order to obtain the desired 10 dB overall noise increase."*

Proposing a model for 10 dB of measured EAM, finding that the model predicts only 3 dB of extra modulation height **[explain]** on stall, then adding another 7 dB to get right answer, then calling your model is *"plausible*"………isn't really very plausible at all.

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AUDIBLE NOISE AND FLAPPING BLADES

Some nice work by Oerlemans of Siemens Wind Turbine division. He used a microphone array to map the audible noise from a modern turbine. [explain] Doppler + directional. Note that minor things happen at blade up and blade down positions, even though the wind shear regime is daytime, not night time Upwind/downwind. The remarkable difference between blade ascent and blade descent is due to the directionality of trailing edge noise, which is the dominant noise source for todays large modern turbine. The slight offset at blade zenith may be due to the hysteresis of the aerofoil attack angle.

Move to slide 23?

It is well known that early, and therefore relatively small, turbines, such as the 50 kW Endurance E-3120, were remarkably noisy for their size, simply because they were downwind turbines; like a child's windmill on the beach, they relied on the wind itself to maintain their back-to-the-wind orientation. The blade, when tip down, passed through the wind shadow of the tower. This had two drawbacks; the flip of the blade produced both audible and infrasound noise, and the power generation was reduced. But the oft repeated wind industry claim that the infrasound problem with downwind turbines disappeared with the change to upwind turbines is manifestly wrong. Todays much larger turbines produces 50 times the power of the E-3120, so it is most unlikely that they would produce less ILFN than the E3120. The blade passing through the tower wind shadow

13

BLADE FLEXIBILITY AND ELASTICITY

This is a triple exposure of a blade undergoing a static deflection test.

Perhaps the most important slide of all. Think what a blade was doing prior to stall; it was providing about a third (in fact a little more…) of the torque applied to the generator. So there was a huge amount of elastic energy stored in that wind-driven blade. This is an entire Vestas rotor in China; the Chinese have a much more exciting way of delivering them than we do.

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The point of the picture is, again, how thin and flexible the blades are.
That's what happens when the blade stalls at zenith.

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ANIMATED FLOPPY BLADES

As described on the page start 1:52
1/8th slow motion
Observe the blade passing tower event
Note the weather; this is daytime, not night time wind shear, so EAM is unlikely.
This is where I need my toy turbine (1/100 scale) to demonstrate blade stall at zenith.

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VICTORIAN TEHATRICS

Thunder – Storm

17

FLOPPY TOWERS (VORTEX SHEDDING)

Vortex shedding is another source of infrasound, but probably less important than blade shudder at zenith. Infrasound from turbine towers by this means has been recorded and clearly identified by my fellow acoustician Les Huson.

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IT IS THE POWER AND THE ENERGY THAT MATTERS

So what else could be happening to explain the missing 7 dB? Remember that the trace you see on the chart is just the integrated noise level, and contains no frequency information at all. That is the problem with using an SLM (Sound Level Meter); it destroys the frequency information. It's the wrong tool to investigate wind turbine noise, but the right tool to use if you want to hide infrasound.

- The wind industry claim there is no infrasound from modern turbines. Remember slide 9?
- Competent independent acousticians know that most of the energy in wind turbine acoustic emissions is concentrated below 20 Hz. See slide 13.
- So why has the wind industry not measured infrasound levels down to 0.2 Hz to prove that they are right and we are wrong?
- They have, at least once. Remember slide 13 (MM92 test data)? But not quite low enough in frequency.

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IN SUMMARY

1. Only the inclusion of infrasound can explain the severe AHEs suffered by many wind farm neighbours; it is notable that the wind industry do not publish unweighted noise measurements at infrasound frequencies.
2. The "enhanced annoyance" theory now promulgated by the wind industry is demonstrable nonsense, but for those want to believe it we must gather formal evidence of serious harm to non-human species.
3. We need to create an international independent noise working group comprising (i) specialists in the physics, acoustics and medical aspects of WTN and WTS, and (ii) proven WTN victims and their GPs
4. The group will require funding to procure the measuring equipment necessary the demonstrate the true ILFN outputs of wind turbines.
5. Governments must be enlightened in such a way that they cease their blind support of the wind industry and cease to ignore the evidence.