EAM. What is it?
Explanation of noise emissions from wind turbines.

The noise people living near wind turbines often hear noise often described as 'thumping and swishing'. It is likened to the sound of an 'aircraft that never go away' or 'a tumble drier with shoes in it'. These sounds are collectively and frequently described as Excessive Amplitude Modulation or EAM.

Frequency.

Let us start at the beginning. Noise is caused by something which, by moving in the air, generates pressure waves. (e.g. An electric motor in a food processor, baby crying, car engine, radio, wind turbine, etc.) The more energy used the more powerful the pressure wave. These pressure waves move away from the source like ripples on a pond when a stone is thrown in it. These pressure waves vibrate the human (and animal) ear drums and this minute movement is amplified and 'processed' by the brain producing what we know as noise. The human ear is very sensitive to both frequency and noise 'loudness'.

The speed at which these pressure waves are generated dictate the audio frequency of the noise our ears hear as sound. The greater number of cycles (Hertz: Hz) per second the higher the pitch of the audible sound we experience. Commentary from Wikipedia states.

> An **audible frequency** is characterized as a periodic vibration whose frequency is audible to the average human. The SI unit of audio frequency is the hertz (Hz). It is the property of sound that most determines pitch.
> The generally accepted standard range of audible frequencies is 20 to 20,000 Hz, although the range of frequencies individuals hear is greatly influenced by environmental factors. Frequencies below 20 Hz are generally felt rather than heard, assuming the amplitude of the vibration is great enough. Frequencies above 20,000 Hz can sometimes be sensed by young people. High frequencies are the first to be affected by hearing loss due to age and/or prolonged exposure to very loud noises.

Frequencies and descriptions

Frequency (Hz)	Octave	Description
16 to 32	1st	The lower human threshold of hearing, and the lowest pedal notes of a pipe organ.
32 to 512	2nd to 5th	Rhythm frequencies, where the lower and upper bass notes lie.
512 to 2048	6th to 7th	Defines human speech intelligibility, gives a horn-like or tinny quality to sound.
2048 to 8192	8th to 9th	Gives presence to speech, where labial and fricative sounds lie.
8192 to 16384	10th	Brilliance, the sounds of bells and the ringing of cymbals and sibilance in speech.
16384 to 32768	11th	Beyond Brilliance, nebulous sounds approaching and just passing the upper human threshold of hearing

Important Note 1

It is to be noted sound also occurs above and below the range of human hearing. Also the threshold and range of hearing varies from one person to another.

It is generally accepted Low Frequency Noise (LFN) is defined as being from 160Hz down to 20Hz.

At frequencies below 20Hz are known as 'Infra sound'.

Volume of Noise. (Amplitude Modulation)

Now we come to the next part of the noise story, the loudness of the noise. (Measured as decibels or Db). This is where the loudness of the noise we hear comes from. The more energy put into the pressure wave the greater the volume. For example the time 'pips' on the Radio are 1000Hz/sec (1KHz). If we turn up the volume on the radio we hear the pips much louder, but the frequency stays the same at 1KHz. However the dB level has increased making the sound more powerful or 'louder'. See Figs 1 & 2

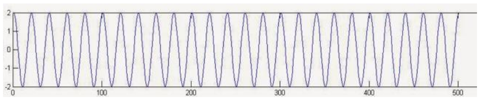


Fig 1

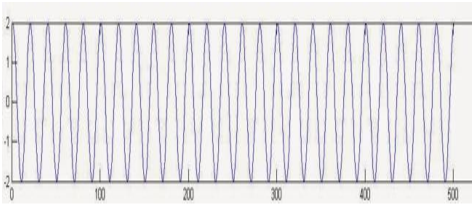


Fig 2

The volume of noise, measured in dB, has considerable effect on the hearing of people. This is why it is important to know why we need to know the range of the volume. This is done by measuring the frequency of the sound wave (or sine wave) from its peak (or top) to the trough (or bottom) of the sound wave. (P2T) The greater the distance from P2T the louder the sound. <u>This is Amplitude Modulation or AM.</u> At lower frequencies the high and low amplitude modulation are discernible to the human ear. The wind turbine blade rotation with about 60 blade passes per minute with creates low and high noise peaks and troughs and are discernible to people nearby.

Important Note 2

AM occurs at all frequencies, including LFN and Infrasound levels.

Because we cannot hear it, it does not mean it does not have an effect on our bodies and be the possible cause of health problems to sensitive people.

Important Note 3

The increase of sound volume is based on the logarithmic scale. For every 10dB of sound increase (i.e. from 20dB to 30dB) is <u>doubling the volume experienced by the ear.</u> Increasing to 40dB doubles the volume yet again.

It can be seen increasing the volume can have an effect on peoples hearing experience. It is not dependent on the frequency of sound directly[1] but on the energy used in generating the sound.

So, what is EAM.

EAM was coined to describe noise levels in access of 3dB P2T sound volume coming from wind turbines as experienced by near neighbours in their homes and gardens. Therefore noise levels exceeding the 3dB P2T levels are known as being 'Excessive', hence the abbreviation EAM.

Is EAM a constant noise?

No it is not. It is, like all noise, a mixture of a lot of frequencies and often when these frequencies are 'mixed up' we often get pulses of sound. See fig 3. This is very common with multiple turbines forming a wind farm. See fig 7 later.

[1] However some frequencies can affect some people. Like the inadvertent scratching of a blackboard with a finger nail.

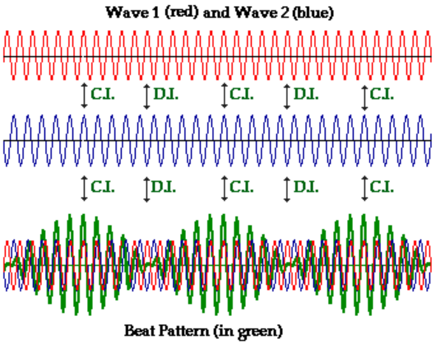


Fig 3

Add to this mix the variations of the wind turbines particular pattern of behaviour (often described as noise signature) with respect to noise generation and several factors can be identified.

First of all turbine noise is not a 'natural' sound in the countryside. It is also a very large piece of rotating machinery and out of proportion, in height and dimension to most of noise making sources in the landscape.

There are a number of other noise events that occur and these include roads with traffic noise, helicopters and other aircraft, farm machinery, trains, etc. Let's deal with these first.
Traffic noise is usually a constant and regular sound at relatively low frequencies. People get used to the regularity of the sound. It does not 'pulse'. At night the sound is, usually, much reduced.
Aircraft. Annoying for some but again the noise is fairly constant and of short duration.
Farm machinery. Seasonal especially at harvest time but a common noise of the countryside and not continuous.
Trains, again occasional rarely variable and short lived. Infrequent during the night.

Turbine Noise
What produces the sound signature of a wind turbine?
Let us look at a typical turbine.

This diagram clearly identifies all the areas of potential noise in the nacelle.

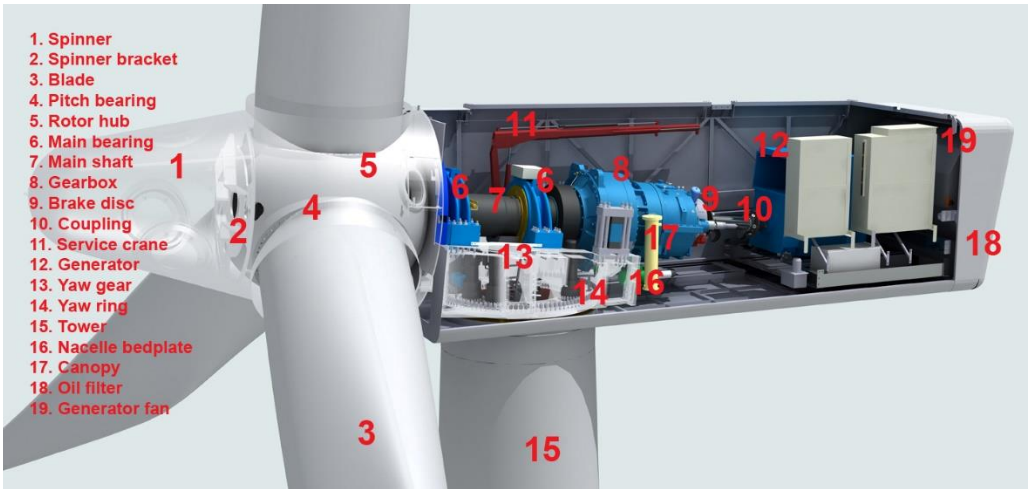


Fig 4

The areas that can produce individual noise signatures are 6. Main bearing; 8. Main gear box; 9. Brake; 12. Generator; 13 & 14. Yaw mechanism and 19. Generator fan and 3, the rotating blades.

It is the combination of these separate noise signatures from these individual sources that produce a specific level of noises from the turbine which defines the base noise. This is what raises the background noise levels of the local area by approx. 8dB to 10db.[2] The original background noise levels, especially in more tranquil areas, change all the time, day time is, for example, higher (noisier) than night time. This change is also seasonal. Adding turbine base noise levels, of approximately 35dB to 38dB, will dominate the background noise day and night for a large distance from the turbines. This could be up to 2KM[3].

[2] Actual depends on the distance of homes from turbines, the number of turbines and the turbine manufacturer, turbine size and model, etc.
[3] Dependant on height of turbine, length of the blades, terrain, wind speed and direction, etc. LFN noise will travel a lot further..

An example of how turbine noise changes the background noise levels can be seen in fig 5.

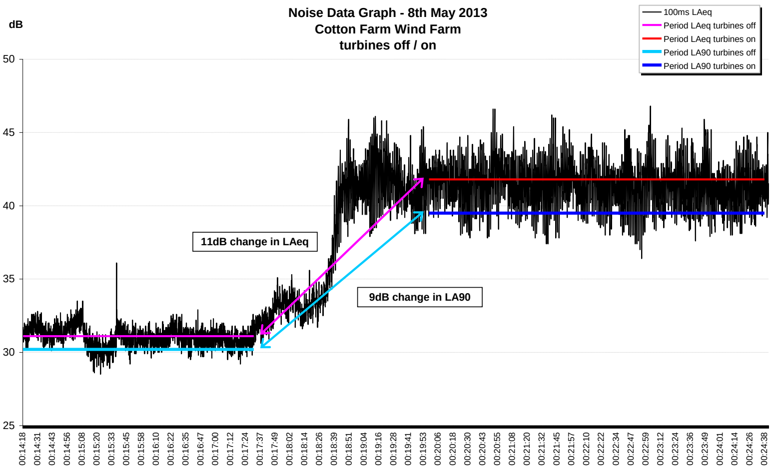


Fig 5

The red line shows the average noise of the background level being about 32dB. When the turbines start up this average rises to about 43dB. This is a <u>doubling</u> of the background noise levels.

Rotor Blade Noise

Let us now consider the AM noise from a turbine which causes the greatest anger and distress to local communities. This is relatively low frequency noises generated by the rotating turbine blades. There is a lot of confusion on how the AM noise is generated by the acoustic experts and there are claims and counter claims. As far as the community is concerned there is a noise and it is very intrusive. It is also variable. It can be experienced from most wind directions and, because of the mixed up low frequency noises, it is very intrusive in a variety of ways.

The wind industry has accepted noises over 3dB P2T are intrusive. Measurements at many, if not most wind farms show the dB level is very often over 6dB. Up to 15dB has been recorded at Cotton farm in ‘up wind’ conditions. Look again at fig 5, above and the level of P2T on the 43 dB average level ranges the P2T levels even though the 10 minute record in Fig 5 are compressed the P2T levels can be seen to be high at about 6dB to 8dB. Compare this with earlier pre turbine start up record when the natural dB P2T is seen to be much lower at about 2dB average. This also proves the turbines do generate the AM beat from the blades and the nacelle noise more than doubles the natural background noise.

LFN and Infrasound Noise.

Rotor blade noise is also a source of LFN to very low frequencies down into the infra sound range. The blade passing frequency at about 1 to 2hz. The blade, at the very top of its travel, often loses its ‘lift’ and flaps generating its own noise signatures. The blade also generates a pulse of sound as it passes the tower at the bottom of its travel. In essence the rotating blades generate a spiral of complex sound pulses that radiate from the turbine source in all directions. This causes the lower frequency pulses we hear as swishing and thumping covering a wide range of generated sounds. This mix of different frequencies can be confused to the person experiencing it. Some of the noise can be heard and some can be felt as a sensation. If a person seems to experience the noise as a sensation they are being subjected to LFN or infrasound. The turbine generates powerful pressure waves and this can cause a physical experience like headaches or ‘queasy’ symptoms similar to travel sickness. It affects some people more than others. The wind industry does not want to recognise these affects or the urgent need to research these phenomena’s.

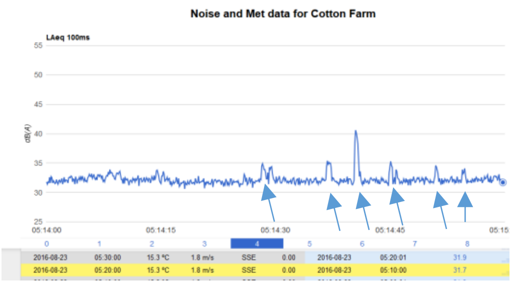
What does the Graveley monitor show us?

When one understands background noise is a mixed up cocktail of sounds of different frequencies and volumes of sound. Against this sound level, which does fluctuate, we can identify sounds which are not ‘normal’ and stand out. Sitting in the garden, for example, one can hear the sudden ‘mew’ of a buzzard call, or a short eared owl waking up in the early evening and calling to other owls. We hear changes to the noise spectrum and react to it. A baby crying on waking up, a car back firing in the street cause automatic physical reaction by an individual.

The monitor records these ‘sudden’ sounds too. It is important to hear these sounds to allow one to hear how and when the turbine sounds dominate the normal noise spectrum in relative terms. The addition of 8 to 10dB nacelle generated noise onto our normal background levels can be seen as an increase to a new 'normal' of 38dB to 40dB. At night the background noise, without turbines is much less than day time noise at about 25dB to 30dB but, with turbines operating, the background noise level is maintained 38dB to 40dB in low to medium wind speeds at ground level. This is way over the WHO[4] recommendations and the new regulations proposed for other countries at night[5]. However, the blades swish and thumping noises are not 'normal' and are constantly triggering awareness in the brain as does a baby crying, a slamming door or fast running footsteps in the road at two o'clock in the morning. The monitor shows us, in its visual mode, these actual noise signatures on the trace. These are visually different. A crow cawing and a pigeon cooing are obvious bird signatures on the trace. When this is coupled with the audio record our brains, being very clever, can hear the obvious difference and learn the visual differences.

It is by having all sounds recorded we can now see how the turbine blade noises can, and do, interplay with natural sounds and totally dominate the background noise under certain conditions. Having the met data as well (Wind speed and direction especially) the recordings can make total sense. The two 'snap shots' below illustrate the point

Let us look at Fig 6.
Wind direction is from the SSE at an average of 1.8m/sec. The time very early morning at 5:15AM. The mean dB level is about 32dB. There is very little turbine movement, it is quite tranquil for Graveley. On the trace we can see several peaks. The nature of these indicated peaks (arrowed) are singular and sharp. From the audio one can hear crow calls from several birds in variable distances. Often one can here bird calls from great distances proving the sensitivity of the equipment and the ability of human hearing.



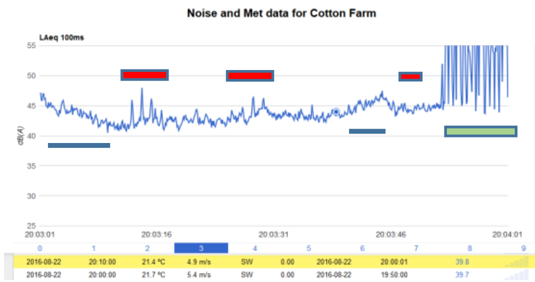


Fig 6 05:14 to 05:15 23rd Aug 2016 Fig 7 20:03 to 20:04 22nd Aug 2016.

Now for Fig 7. This recording is 9 hours earlier than Fig 6.
Wind direction from SW at and average4.9m/sec in the mid evening at 8:10 M. The average dB level is much higher at about 41dB from minute 03 for about 40 secs where there is no significant other noise.
The beginning of the trace shows a reducing noise trace. This a vehicle that has passed the monitor and travels further away from it. The other blue line, at minute 03:40secs is a small vehicle passing the opposite direction.
The red lines, shows the turbine EAM in pulses. The largest P2T is about 7dB. In audio they dominate.
The green line shows bird song very close by. The trace is indicative of a pigeon and the audio investigation proves it.

A comparison of the graphs show the near natural noise background of about 32dB in Fig 6 whereas, earlier with different conditions and the turbines powering away, the average noise level is much higher at 43dB in Fig 7. This is a rise of 11dB, doubling the average background sound level, as heard at the monitor. This shows how the turbine noise impacts the local area noise levels. A concurrence of the earlier Fig 5.

The two graphs in Figs 6 & 7 provide a wealth of information visually, and when coupled with the audio trace, the amount of detailed information is valuable evidence. This can be seen in extreme cases of EAM when the turbine

[4] World Health Organisation.
[5] Japan are to use 35dB max LAeq (33dB LA90). UK is 43dB LA90. Canada are looking a similar regulation.

dominates and crowds out all other noise signatures. This can be seen in the next graph, Fig 8. There many hundreds of similar (and worse) recordings like this from Cotton Farm

Archive of EAM 17th May 2015. See Fig 8 below.

Showing up to 10db P2T. In audio there is a lot of blade thrashing and nacelle noise which is irregular and unpredictable. The IoA AM proposal would probably eliminate this and consider it to be 'compliant' because the noise profile is not regular.

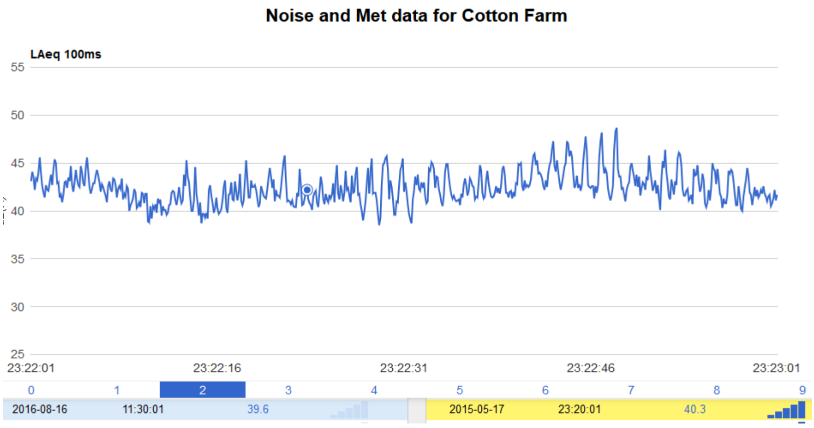


Fig 8

The monitor, when using its data correctly can, with a little experience, give a huge amount of information for communities and authorities to work with. The raw data can be used to prove (or not) all other standards and specifications.

Conclusion

This is the information, and the methodology of collecting the data to provide the evidence, the Wind Industry does not want the public, their MP's and councillors and council officers to see and use for protecting the locally affected populations.

All wind farms should be monitored permanently by law and the individual turbine own data (SCADA) and met mast data should be immediately available for assessment in cases of complaint and checks of compliance to the current regulations, including ETSU.