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Why is wind turbine noise noisier than other noise?

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ABSTRACT

For residents near modern wind farms wind turbine noise is more annoying than other important noise sources, when comparing equal sound levels.
Acoustically this may be due to the diurnal course of the noise and the rapid fluctuation in level related to the rotation, which are not usual features of most transportation and industrial noise sources. It can also be a result of non-acoustic factors such as visual intrusion and the perceived distribution of benefits and adverse effects. In this paper the pros and cons of these possible causes will be discussed based on measurement results and surveys, and on comparisons to other industrial and transportation noise sources.

1. INTRODUCTION

It was shown some years ago that the vertical wind gradient used in wind turbine noise assessments is valid for a 'standard' or neutral atmosphere but often is not a realistic description of the real atmosphere, especially at evening and night (or rather: between sunset and sunrise).[1] Since then a number of publications have supported this view, some of which are referenced in [2]. As a result in some countries (legal) guidelines to assess wind turbine sound levels are now about to change, based on more realistic atmospheric conditions. *E.g.* the Netherlands will adopt a new sound power assessment procedure leading to an average exposure level L_{den} determined from actual hub height wind speeds; in the appropriate New Zealand standard the assessment of turbine sound power and background sound pressure levels will be related to hub height instead of near-ground wind speeds; a similar approach is used for the new assessment procedure in New South Wales, Australia; in the UK a group of consultants have proposed determining sound power levels from realistic hub height wind speeds, though oddly still using the standard wind speed gradient to relate this to background sound levels.[3]
The growing acceptance that night time conditions were not adequately addressed in wind turbine noise assessments applies to the sound power level only, not to the character of the sound. There has been a general agreement that wind turbine noise can be tonal (because for older turbines tonal gear noise was louder and the tonal character often clearly audible). In

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contrast, there is no agreement that turbine noise could display other characteristics such as impulsivity or amplitude modulation; also there are no accepted methods to determine these characteristics, although many countries in principle apply a penalty for perceptible impulsivity and sometimes for regular amplitude modulations (as well as for tonality, for which measurement methods do exist).

This paper reviews the evidence that is available on the character of wind turbine sound, especially with regard to a beating character or, phrased technically, audible amplitude modulation.

2. MEASUREMENTS AND OBSERVATIONS

2A. Measured amplitude modulation

In an article dedicated to the beating character of wind turbine sound I have shown that the sound from a wind farm varied in level in the rhythm of the blade passing frequency where the variations varied up to 5-6 dB for a single, and up to 9 dB for multiple turbines.[4] The variations occur downwind from single wind turbines and wind farms and can be observed at distances up to approximately one km and perhaps more. Spectral analysis of the variations in the sound level at dwellings due to a single or to multiple wind turbines show that the variations occur in frequency bands from 100 to 2000 Hz, but are strongest at 500 to 1000 Hz.[4,5] The dominant source at these frequencies is turbulence at the trailing edge of the blades. Di Napoli found similar variations at a position 530 m downwind from for a single wind turbine.[6]

Hayes investigated the low-frequency character of wind turbine sound as a possible cause of increased annoyance at three wind farms, but concluded that the regular variations of the sound level were a more likely cause.[7] He showed that the variations in broad-band A-weighted sound level (approximately 2 dB) were less pronounced than the variations in the 250, 315 and 400 Hz 1/3 octave band level (approximately 8 dB), with a modulation frequency equal to the blade passing frequency. Variations in other 1/3 octave bands were less strong.

2B. Perception of modulation

There are numerous individuals and organizations, especially those that oppose wind energy or live not far from a wind farm, who give descriptions of wind turbine sound that show that the variation in sound level (swishing, beating, thumping, etc.) apparently is an important characteristic of wind turbine noise. Several publications list a number of such cases. [5,8,9] It can be shown that a modulation depth of at least 3 dB at a modulation frequency of approximately 1 Hz can be easily picked up by human listeners, possibly because it is not unlike modulation in speech. A similar modulation is used in warning signals (beeps from trucks in reverse gear, alarm clock) and in musical rhythm.

Psychoacoustic characteristics of wind turbine sound have been investigated by Persson-Waye and Öhrström in a laboratory setting with naive listeners (students not used to wind turbine sound). Of sounds recorded from five different turbines, the most annoying sound was described as ‘swishing’, ‘lapping’ and ‘whistling’, the least annoying as ‘grinding’ and ‘low frequency’.[10] People living close to wind turbines, interviewed by Pedersen et al [10], felt irritated because of the intrusion of the wind turbines in their homes and gardens, especially the swishing sound, the blinking shadows and constant rotation. The study showed that annoyance with wind turbine sound was correlated with descriptions of the sound characteristics; most strongly to swishing with a correlation coefficient of 0.72. [11]

Legarth played recordings from a number of wind turbines in different conditions to listeners in a ‘home like’ laboratory room.[12] The fluctuation strength (determined by the modulation depth) was determined for the frequency band 350 – 700 Hz where the fluctuation was strongest. This fluctuation strength correlated very well with the swishing character perceived by the listeners. Lee et al found in laboratory listening tests that a sound with a higher modulation depth and at blade passing modulation frequency was considered more annoying by listeners than sound with less modulation.[13]

In a recent survey in the Netherlands residents living within 2.5 km of a wind farm were asked to describe the sound made by the wind turbines.[14] Several possible descriptions were given (and the possibility of giving another, personal description which was hardly used), shown in figure 1. A large proportion of respondents found 'swishing' or 'lashing' a proper description, regardless of whether they found the sound annoying or not. Rustling also appears to be a description shared by residents irrespective of their being annoyed or not, though it is mentioned rather less often. Other descriptions apply to fewer respondents and are not shared by those who were or were not annoyed.

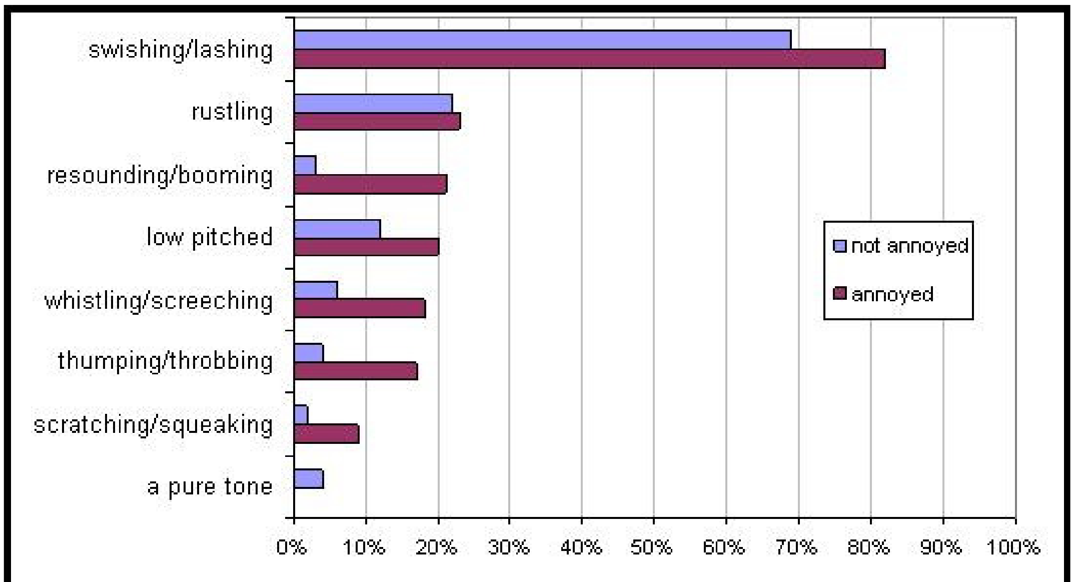

Figure 1: percentage of respondents that think the description fits the wind turbine sound they hear at home (based on [11])

As a follow-up of Hayes' results that at three wind farms amplitude modulation was perceptible and could be a cause of (stronger) disturbance, a further study investigated whether this phenomenon could be established at other wind farms.[15] Environmental health officers (EHOs) at local authorities in the UK were sent a questionnaire in which a detailed description of noise complaints, if any, was sought with a description of the sound. It was concluded that in four cases AM (amplitude modulation) appeared to be a factor in the complaints, in fourteen it was not, and in eight it was considered 'marginal'. In several cases the sound was described as swishing, beating, throbbing, pulsating, wooshing and/or lapping, but for unknown reasons the conclusion was that AM was not a factor in the complaints. In the appendix an overview of results is given, indicating that in 13 out of 14 completed questionnaires, where one or more words could be ticked to describe the sound, the description was of a (regular) variation in sound level (swish, swoosh, wooh wooh, beating, throbbing, thudding, thumping, pulsating, wooshing, rhythmical beat and/or lapping). In some cases a description was also given which did not, or less clearly, allude to a variation in sound level (helicopter, train, ghostly, grinding, rumbling, motions, whistling). In 13 further cases (out of the 27 returned questionnaires) no descriptions were ticked, although in some of these in the complaints themselves the sound was described as tonal/buzzing, wind noise, and drone/audible inside. In eleven cases the EHO had

heard the sound. Although in all cases complaints were received, according to EHOs there was no statutory nuisance in sixteen cases, and in eight cases this was doubtful or not resolved.
My conclusion from this survey is that in 13 out of 27 cases where complaints had been lodged, the sound was described with one or more words indicating a (regular) variation in level or AM. In one case only, the descriptions did not fit AM. In the remaining 13 cases the question was not resolved as no description was given.

3. CAUSES OF AMPLITUDE MODULATION IN WIND TURBINE SOUND

3A. Swishing near a wind turbine

When standing close to a wind turbine one can hear the typical swishing that is caused by the downward moving blades, which has been shown to be caused by the directivity of the blade as a sound source (more sound radiated in the forward direction) and of Doppler amplification (the blade tip moves at ~ Mach 0.2).[16] This explanation also holds at increasing distance from a wind turbine, but only for sideway positions, *i.e.* close to the plane in which the blades move.[17] Richarz et al[18] included diffraction, a third cause for AM: for an observer downwind from a turbine the blade sound is (partly) blocked when the blade passes the mast, resulting in a sudden, small decrease of sound level. Including al three causes he also showed that in upwind and downwind positions AM is weak.
Thus, the explanation based on sound directivity and Doppler amplification (and on diffraction) does not hold for a distant observer upwind or downwind from a turbine as the blades then have no significant changing velocity component in the direction of the observer.

3B. Thumping at some distance from a wind turbine or wind farm

From section 2 it is clear that amplitude modulation can occur at considerable distances from a wind turbine. This often or perhaps always seems to occur after sundown. An explanation for this phenomenon can be based on the changes in wind speed over the rotor area due to changes in the vertical wind profile associated with the change of the atmosphere from an unstable or neutral to a stable state.[4,5] In daytime, in an unstable atmosphere, the change in wind speed over the rotor area is small, but in a stable atmosphere the variation can be substantial. As an example for an 80 m diameter rotor at 80 m hub height and a 10-m wind speed of 8 m/s, with a shear exponent of 0.1 (unstable) the change in wind speed over the rotor area is 0.9 m/s, with a shear exponent of 0.45 (stable) this is 3.8 m/s. As a result the angle of incidence of the incoming air in daytime varies over 0.9º, increasing to 3.8º at night time. As the production of trailing edge sound in a first approximation varies linearly with the angle of incidence ($SPL \propto 1.5\alpha$),[4,5] the variation in sound level is stronger in a stable atmosphere. The predicted variation or modulation depth, using the numbers given above, is just over 1 dB in daytime and close to 5 dB in night time, in agreement with measured results.

Other circumstances can cause changes in wind speed over a rotor area, e.g. when one turbine is in the wake of another turbine, an obstacle or ridge.

The modulations in the sounds of two or several turbines are in phase when the modulations arrive at the same time at the ear of the listener. A doubling or tripling of sound energy, due to two or three pulse trains arriving simultaneously will add 3 or 5 dB respectively. This phenomenon will occur at night as it probably needs an atmosphere with little or no (large scale) turbulence, in which case turbines are driven by a much more constant wind. In practice, when turbines rotate at nearly but not quite the same speed, one can hear them come into phase, with the subsequent variations readily discernible, then go out of phase again and no separate beats can be heard.

3. ANNOYANCE FROM WIND TURBINE SOUND

3A. Night time exposure

At the rotor height of modern, tall wind turbines the wind in the temperate climate zone does not abate at night as it often does closer to the ground. As a result sound levels near a modern wind turbine are not lower at night. In fact, at 100 m hub height the long-term average sound power level is 0.5 dB higher at night than it is in daytime,[19] in most cases adding to the already higher contrast with the lower ambient levels at night due to less wind, less traffic and less human activity. This is supported by the response to one of the questions in a Dutch survey, probing the circumstances for increased audibility of wind farm sound.[14] In figure 2 the results are shown: as expected more respondents find the wind farm more audible when the wind blows from the wind farm towards the dwelling or when the wind is stronger. In contrast to what many would expect a minority of respondents (22%) find it less audible at night: according to 40% the wind farm sound is louder at night and for another 38% there is no clear difference between night and day in this respect.

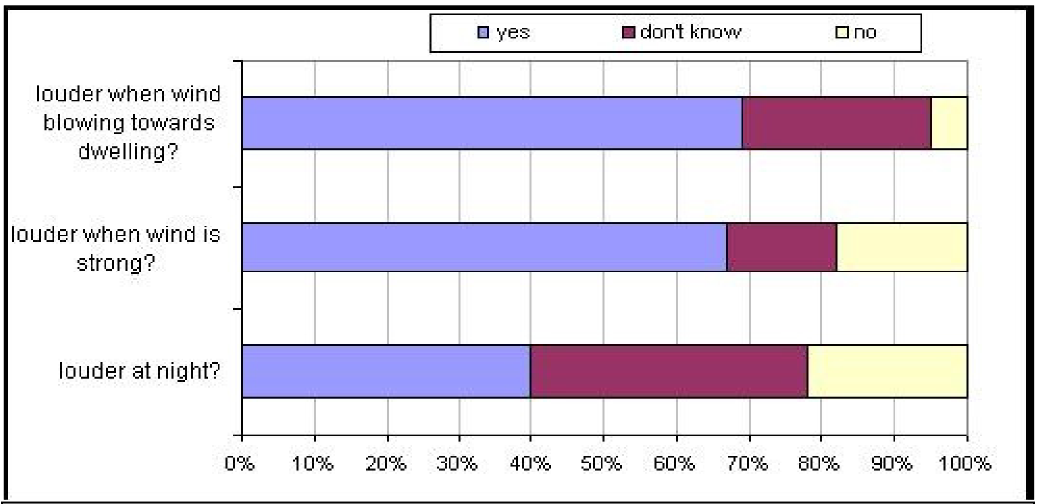

Figure 2: opinions on conditions when wind farms are perceived as being louder or less loud (based on [11])

Another important result of recent studies is that wind turbine sound appears to be annoying and is associated with sleep disturbance at relatively low sound levels, when compared to major sound sources such as transportation or industrial sound. In figure 3 the results are given from the Dutch survey,[14] showing that wind turbines are more annoying than other major sources and in this respect comparable to shunting yards. The similarity with shunting yards may be because of the type of noise (the clanking of shunting cars and the thumping of wind turbines), or the fact that both noise sources are often active at night in contrast to most other sources.

Dose-effect relationships based on all relevant surveys of wind turbine noise have been determined in a more recent study and will be presented in another Euronoise2009 paper.[20]

3B. Non-acoustic factors

The Dutch survey showed that very few people among those who benefited economically from wind energy reported annoyance with sound from wind turbines. This contrasts sharply with the result that for those who did not benefit economically, wind turbines are more annoying than other major noise sources. Despite this clear difference in annoyance between the two groups, there was no difference in the ability to hear the sound between respondents that benefited economically from wind turbines and those who did not. In fact, those benefiting were on average exposed to higher sound levels. They were also relatively young, well educated,

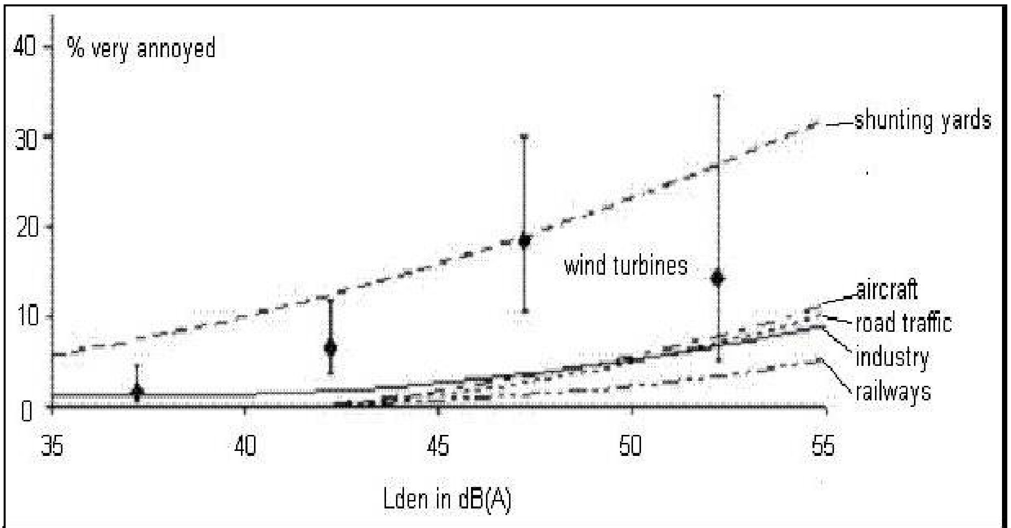

Figure 3: severe annoyance in relation to the Lden wind turbine sound level, compared to severe annoyance from other noise sources

worked at home and/or were self-employed. Also, they were healthier (less often exhibiting high blood pressure, cardiovascular disease or migraine), and they had less difficulty in falling asleep. In short, they could be typified as 'healthy farmers' and/or entrepreneurs who have to earn their living by making use of the land. This may help to explain the different opinions on wind farms, arising from different views on landscape utility and use. Another reason for the low prevalence of annoyance amongst respondents with an economical benefit may be that they usually have more control: most or all of them have taken part in the decision to put up the turbines and they can stop them if they want.

Respondents that could see at least one wind turbine from their dwelling were more likely to be annoyed by the sound than those who did not see any wind turbines. When respondents did not see wind turbines, the turbines were either relatively small, i.e. distant, or respondents lived in built-up areas. When the sight of the wind farm was blocked, then the sound could be (partly) blocked too, leading to lower sound levels, which could explain the lower levels of annoyance. However, the enhanced annoyance if the wind turbines were visible could also be due to a multimodal effect: the rotating blades of a wind turbine attracting attention could increase the awareness of the sound and hence also the possibility of noise annoyance.

4. CONCLUSION: DIFFERENT PERSPECTIVES ON NOISE

According to the British Wind Energy Association

> "well designed wind turbines are generally quiet in operation, and compared to the noise of road traffic, trains, aircraft and construction activities, to name but a few, the noise from wind turbines is very low. Outside the nearest houses, which are at least 300 metres away, and more often further, the sound of a wind turbine generating electricity is likely to be about the same level as noise from a flowing stream about 50-100 metres away or the noise of leaves rustling in a gentle breeze"

Critic Pierpont states that

> "the noise produced by wind turbines has a thumping, pulsing character, especially at night, when it is more audible. The noise is louder at night because of the contrast between the still, cool air at ground level and the steady stream of wind at the level of the turbine hubs. This night time noise travels a long distance. It has been

documented to be disturbing to residents 1.2 miles away from wind turbines in regular rolling terrain, and 1.5 miles away in Appalachian valleys".

The different notions are, in part, a result of the perspective of an individual or an organization. The recent WINDFARMperception study has shown that annoyance from the sound of wind turbines is related to attitudes towards wind energy and/or wind turbines in the landscape, and to the visibility of a wind farm. residents who had economic benefits from wind turbines were hardly or not annoyed, whilst for residents without such benefits the sound from wind turbines is more annoying than sound at the same level from major noise sources such as road, rail or air traffic and industry. Thus, both quotes can be correct, but the proponent mentions a typical daytime situation, the opponent a situation more typical for the night. The different perspectives on noise thus arise from different attitudes and from different physical conditions.

REFERENCES

1. G.P. van den Berg, "Effects of the wind profile at night on wind turbine sound", *J Sound Vib* **277** (4-5), pp. 955-970 (2004)
2. G.P. van den Berg, "Wind turbine power and sound in relation to atmospheric stability", *Wind Energy*, **11** (2), pp. 151-169 (2008)
3. K. D. Bowdler, A. Bullmore, B. Davis, M. Hayes, M. Jiggins, G. Leventhall, A. McKenzie, "Prediction and assessment of wind turbine noise", in *Acoustics Bulletin*, pp. 35-37 (2009)
4. GP van den Berg, "The beat is getting stronger. the effect of atmospheric stability on low frequency modulated sound of wind turbines", *J Low Freq Noise Vib Active Control* **24** (1), pp. 1-24 (2005)
5. GP van den Berg, "The sounds of high winds" (doctoral thesis), University of Groningen (2006)
6. C. Di Napoli, "Case study: Wind turbine noise in a small and quiet community in Finland, *proc.3rd Int. Meeting on Wind Turbine Noise*, Ålborg (2009)
7. Hayes Mckenzie, "The measurement of low frequency noise at three UK wind farms", Hayes Mckenzie Partnership Ltd, report to the Department of Trade and Industry (2006)
8. B.J. Frey, P.J. Hadden, "Noise radiation from wind turbines installed near homes: effects on health", www.windturbinenoisehealthhumanrights.com (2007)
9. N. Pieront, "Wind turbine syndrome", www.windturbinesyndrome.com (2009)
10. K. Persson Waye, E. Öhström, "Psycho-acoustic characters of relevance for annoyance of wind turbine noise", *J Sound Vib* **250** (1), pp. 65-73 (2002)
11. S.V. Legarth, "Auralization and assessments of annoyance from wind turbines", *proc. 2nd Int. Meeting on Wind Turbine Noise*, Lyon (2007)
12. S. Lee, K. Kim, S. Lee, H. Kim, S. Lee, " An estimation method of the amplitude modulation in wind turbine noise for community response assessment", *proc.3rd Int. Meeting on Wind Turbine Noise*, Ålborg (2009)
13. E. Pedersen, K. Persson Waye, "Perception and annoyance due to wind turbine noise – a dose-response relationship", *J Ac Soc Am* **116** (6), pp. 3460-3470 (2004)
14. F. van den Berg, E. Pedersen, R. Bakker, J. Bouma: "Project WINDFARMperception – Visual and acoustic impact of wind turbine farms on residents", University of Groningen, UMCG and Universiteit Göteborg (2008)
15. A. Moorhouse, M. Hayes, S. von Hünerbein, B. Piper, M. Adams, "Research into Aerodynamic Modulation of Wind Turbine Noise", University of Salford en Department for Business, Enterprise & Regulatory Reform, UK (2007)`
16. S. Oerlemans, M. Fisher, T. Maeder, K. Kögler , "Reduction of wind turbine noise using optimized airfoils and trailing-edge serrations", *proc. 29th AIAA Aeroacoustics Conference*, Vancouver BC (2008)
17. S. Oerlemans, G. Schepers, "Prediction of wind turbine noise directivity and swish", *proc.3rd Int. Meeting on Wind Turbine Noise*, Ålborg (2009)
18. W. Richarz, H. Richarz, "Wind turbine noise diagnostics", *proc.3rd Int. Meeting on Wind Turbine Noise*, Ålborg (2009)
19. F. van den Berg, "Criteria for wind farm noise: Lmax and Lden", *proc. Acoustics08*, Paris (2008)
20. S. Jansen, "Exposure-response relationships for annoyance by wind turbine noise", *proc. Euronoise2009*, Edinburgh (2009)

APPENDIX: REVIEW OF UNIVERSITY OF SALFORD REPORT

The University of Salford has published the report “Research into Aerodynamic Modulation of Wind Turbine Noise” commissioned by the British Department of Business, Enterprise & Regulatory Reform (now the Department for Business, Innovation and Skills) [see ref. 15 above] with the aim of determining whether amplitude modulation (AM) in sound from wind farms is a significant effect. In the report complaints about wind farm noise were investigated by analyzing questionnaires sent to Environmental Health Officers (EHOs) working for local authorities with one or more wind farms in their district. The conclusion was that “the low incidence of AM and the low numbers of people adversely affected make it difficult to justify further research funding in preference to other more widespread noise issues. On the other hand, since AM cannot be fully predicted at present, and its causes are not fully understood we consider that it might be prudent to carry out further research to improve understanding in this area.” This is a somewhat surprising conclusion; as will be shown below other conclusions are possible. The authors state that industrial noise affects many more people than wind turbines do, but the relevance of this statement is not clear. Is a noise source a smaller problem when it affects fewer people (though perhaps more severely)? Was it a minor problem because early wind farms were less noisy (smaller turbines) and probably more often in relatively remote places? Will wind farm noise remain a minor problem in a future with more wind farms?

The table below gives an overview of the survey results; it is based on the original, completed forms that were released after the Renewable Energy Foundation’s (REF) request under the Freedom of Information Act. The table should give the same data as presented in table 2 of the report of the University of Salford.
To interpret the table in terms of the sound character (Amplitude Modulation or AM) the descriptions have been divided into three categories according to whether the words indicate a repetition of a sound or a surge in sound level (where a repetition is implied, as swishing is a repeated swish). This categorization addresses the sound character, not the annoyance caused by the AM. Any sound character, including tonality and impulsivity, can increase nuisance for some, but it also may be considered irrelevant or even positive by others. Close to almost any noise source there are always people who are annoyed and people who are not; the latter are no reason to deny the annoyance experienced by the former.
As the sound power of a wind turbine is considered to be constant when the wind is constant, a repetition of a change in sound level at the rate of the passing blades must be a modulation of sound level, *i.e.* AM. Thus the descriptions swish, swoosh, wooh wooh, beating, throbbing, thudding, thumping, pulsating, wooshing, rhythmical beat and lapping indicate that AM was perceptible, whereas the descriptions ghostly, grinding, rumbling, motions and whistling are not an indication for AM; grinding and rumbling may imply a change in sound level, but in an erratic way, or could imply a (non-periodic) change in pitch. The descriptions helicopter and train are ambiguous as they could signify an enduring sound (hovering helicopter, long passage of train) but also periodic sound variations (chopping sound, clanking of wheels).

The final question in the survey concerned the EHO’s opinion of the AM character. The question was: “This project is about Amplitude Modulation of Aerodynamic Noise (AM) which can be described as ‘Wind turbine blade noise which is modulated at blade passage frequency (typically once per second) with a sharper attack and a more clearly defined character than usual blade swoosh. It is sometimes described as being like a distant train or distant piling operations’. Does the noise from this wind farm conform to this description?”

The results can be summarized as follows:

- *Presence of AM:*
    - in 13 cases one or more descriptions indicating AM were ticked positively; in 5 of these also other (non AM) characteristics were ticked; in no case was another characteristic ticked without an AM description as well
    - in 1 case only all excepting two descriptions were ticked as negative.

- in 13 cases no descriptions were ticked at all (although, in 5 cases descriptions were given elsewhere on the form, but it is not clear whether they represented all perceptions).

- *Heard by EHO:* in 11 cases the EHO had heard the sound, although it is not clear whether this applies to the wind turbine(s) as such or the sound at a time it caused complaints; in 3 cases the EHO did not know whether he/she had heard the sound, in 10 cases the EHO had not heard the wind turbines, and in 3 cases no answer was given.
- *Nuisance judgment:* in none of the cases was "the wind farm judged to be causing a noise nuisance" in the opinion of the EHO; in 8 cases the EHO did not know (in 4 of which the descriptions indicated AM), and in 16 cases the farm was not deemed a noise nuisance (in 10 of which the descriptions indicated AM).
- *AM or not?:* in 3 cases the EHO considered the noise to be AM, in 7 cases he/she did not think so, in 14 cases he/she did not know. In 3 out of the 7 cases where the EHO did not consider the sound as AM, a description (one in each case only) had been ticked indicating AM, in the other 4 cases no such description had been ticked. In 7 out of the 14 cases where the EHO did not know, several words had been ticked which indicated AM.

Thus, in 13 out of 14 cases AM apparently did occur, based on descriptions ticked by the EHO, and in 13 more cases this was not resolved. In 3 cases where AM did occur the EHO considered the sound to be AM, but in 3 further cases he/she did not and for the remaining 7 he/she did not know. So, when descriptions fitted AM EHOs denied the description or were in doubt. This discrepancy has not been clarified by the authors. It could be that EHOs were aware of (regular) variations in sound level and therefore ticked descriptions related to AM, but were unsure whether the explanation about AM did apply. After all, what does a "sharper attack" or "a more clearly defined character" mean, especially when compared to "usual (!) blade swoosh" that by implication is not AM? It may also be relevant that proponents of wind energy –individuals, authorities and companies- can be expected to deny the existence of distant (far from the turbine) AM, and in my experience most of them usually do so, as it would complicate licensing wind farms. In this they may feel supported by the UK Guidelines for wind turbine noise (the ETSU-R-97 report), in which the existence of blade swish is acknowledged, but for increasing distance "the rhythmic swishing becomes less pronounced". Moreover, the limits for the "noise level recommended in this report take into account the character of noise described as blade swish" (recommendation 27 in ETSU-R-97 summary).

The question as to whether the sound was considered a nuisance is thus rather ambiguous. The fact that it did attract complaints shows that at least one person thought it was. It is probable that EHOs responding to this question thought of a nuisance in official or legal terms, in the UK meaning that it did not comply with the ETSU guidelines. Thus, an EHO acknowledging AM as an added nuisance would find little support for this in Government guidance (and he/she may be aware a firm stand on this issue could be against political and economic interests). It is likely this ambiguity also shows up in the completed forms.

			descriptions relating to AM?	yes											?		no					# of descriptions indicating								
	# complaints	year	description in texts about complaints	swish	swoosh	wooh wooh	beating	throbbing	thudding	thumping	pulsating	wooshing	rhytm. Beat	lapping	helicopter	train	ghostly	grinding	rumbling	motion s	whistling	other descriptions	AM	not clear	not to AM		did EHO hear sound?	was sound considered nuisance?	did EHO consider it AM?	other remarks
A	3	2005; 2006	aircraft, throbbing, whooshing, rhytmical jet engine	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	jet plane	3	1	1		1	?	?	dwellings shelterd below hill
AA	4	2005, 2006	whomping		1																	washing machine	1	0	0		1	0	0	depending on wind direction
B	10	2005	swishing, throbbing	1	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	?	7	0	0		0	0	?	
E	4	2003, 2005		0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	loud bass	3	0	0		1	?	?	not upwind, officers did not notice
J		2005, 2006		1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	mechanical	4	0	1		1	?	?	wind towards dwelling
K	7	2006	swooshing, swishing, aeroplane	1	1		1					1	1									roar	5	0	0		1	0	?	strong wind towards dweling
M	4	1997; 1998; 2004; 2005		1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	8	0	0		1	0	1	
N	2	2002, 2006	whining	0	0		0	0	0	0	0	0	0	0	0	0	0	0		0	0	whine	0	0	0		1	0	0	
O	1	2007		1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	8	0	0		1	0	?	day, moderate wind downwind
Q	many	2001, 2002, 2003, 2004		0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	washing machine	2	1	0		1	0	1	
U	1	2006	monotonous, swoosh, whine	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	whine, drone	1	0	0		0	0	0	low wind speed
V	1	2004		0	0	0	1	0	0	0	0						0			0			1	0	0		0	0	0	
X	2	2006, 2007	whoosh, LF	1	1	1	1	1	0	0	1	1	0	0	1	0	0	1	1	0	0	hum	7	1	2		1	?	1	
Z	2	2000, 2001	whine, thrashing thumping, LF whooshing	0	0	0	0	0	0	1	0	1	0	0	0	0	1			0	0		2	0	1		0	0	?	
C	1	1994																									0	0	?	
D																														
F	2	1996, 1998	tonal, buzzing																			buzzing					1	?	0	
G	4	2000, 2002, 2005, 2006	tonal, buzzing																								?	?	0	
H	1	2005	wind noise																								?	?	?	
I	1	…, 2003	wind noise																								?	?	?	
L	2	2004, 2005	drone, audible inside																								0	0	0	
P	many	1993, 1994, 1995, 1996																									0	0	?	
R	> 10	1992, 1993																									0	0	?	
S	2	< 1997																									0	0	?	
T	no info																													
W	2	2007																									0	0	?	
Y	ong ago																													
		totals	# of times mentioned	7	7	2	6	3	2	5	6	10	3	1	2	1	1	3	1	0	0		51	3	5					

0 = no, 1 = yes, ? = don’t know, empty = no answer given or not ticked